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# GROWTH AND YIELD PERFORMANCE OF MUSTARD AND RAPESEED VARIETIES AS INFLUENCED BY DIFFERENT SOWING TECHNIQUES

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## Abstract

An experiment was conducted at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka, from November 2013 to February 2014 to investigate mustard and rapeseed varieties' growth and yield performances influenced by different sowing techniques. The experiment was laid out in a factorial randomized complete block design (RCBD) with three replications. The four varieties were BARI Sarisha-11, BARI Sarisha-13, BARI Sarisha-15, SAU Sarisha 2 ($V_1$, $V_2$, $V_3$, and $V_4$ respectively) and sowing techniques included broadcasting, line Sowing, raised bed, system of mustard intensification (SMI) ($S_1$, $S_2$, $S_3$, and $S_4$ respectively). Results showed that the highest plant height (143.58 cm) was achieved at the combination of BARI Sarisha-11 and the raised bed technique ($V_1S_3$) at harvest. Though the highest leaf number varied in different varieties, it was produced by the SMI technique. BARI Sarisha-15 and the SMI techniques produced the highest number of primary branches, though BARI Sarisha-11 produced the maximum secondary branches with the same technique. BARI Sarisha-11 performed best at all the DAS regarding dry matter accumulation (g) and the values resulting in 1.07, 11.44, 21.3, and 25.87g. SMI also proved to be the best, except for 30 DAS. The highest seed yield (3.74 t $ha^{-1}$ and 3.80 t $ha^{-1}$) was obtained using BARI Sarisha-11 and SMI techniques, respectively. The highest biological yields (12.80 t $ha^{-1}$ and 12.86 t $ha^{-1}$) were obtained by BARI Sarisha-11 and SMI technique, respectively. However, the maximum harvest index (34.84% and 32.45%) and highest oil percentages (40.65% and 41.38%) were obtained by BARI Sarisha-15 and line sowing, respectively. As such the var. BARI Sarisha-11 could be expected good yield following the SMI technique.

## Introduction

Bangladesh's primary edible oil source is the Brassica oil crop. It makes up 59.4% of the nation's total production of oil seeds (AIS, 2010). According to BBS (2010), these crops only comprise about 3% of Bangladesh's farmed land. The rapeseed and mustard crops occupy 2.42 lac hectares of total land and 2.22 lakh metric tons of yearly production. Seed yield and other yield-contributing characteristics considerably varied among the varieties of rapeseed and mustard (BARI, 2001). Uddin *et al.* (1987) reported a significant yield difference between the varieties of rapeseed and mustard of the same species. Singh *et al.* (1999) was found oil content variation due to different varieties and methods. They estimated the oil content of different varieties from different species and the highest oil content (44.3%) from variety PYS841 (*B. campestris*) and the lowest (40.8%) from Kranti (*B. juncea*) by the Soxhlet method. According to Hossain *et al.* (2013), the sowing techniques significantly impacted the seed yield. In his investigation, line sowing produced the most seed yield, and broadcasting produced the lowest seed yield. Several studies suggest that a higher number of siliqua $plant^{-1}$ has the greatest effect on the seed yield of rape and mustard (Thurling, 1974; Mendham *et al*., 1981; Rahman *et al*., 1988). Rahman *et al.* 2019 stated that the highest biological yield per hectare (5.08 tonnes) was obtained from the broadcast method with the BARI Sarisha-15 and Hossain *et al.* (2015) further supported the effectiveness of the broadcast method, particularly when combined with two irrigations. Bharat *et al*. (2022) found that early sowing

led to higher utilization and accumulation of various agromet indices and the planting geometry of 30 cm × 10 cm was found to increase yields. The mustard intensification (SMI) system allows farmers with limited resources to enhance crop yields by minimizing the use of water and seeds while also advocating for ecological and market-oriented principles (Lyu *et al*., 2021). Considering the valuable aspects, the study evaluates the impacts of varieties, sowing techniques and identifying the best outcome.

## Materials and Methods

The research was conducted at the Agronomy Department of Sher-e-Bangla Agricultural University, Dhaka, from November 2014 to February 2015. The field was located in the southeast part of the academic building, and the soil was from the agroecological zone of the Madhupur tract (AEZ 28). Soil samples were collected from 0-15 cm depths, mainly sandy to silty and loamy in texture. Soil Resources and Development Institute (SRDI) conducted soil analyses. The experimental area is in a sub-tropical climate, with heavy rainfall during the kharif season and less during Rabi.

The seeds were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh, with a germination percentage of 90%. The land was prepared by plowing and harrowing removing stubbles and weeds and divided into unit plots, spaded one day before planting and fertilized uniformly with sulfur (gypsum) and boron (boric powder) fertilizers. 1/3$^{rd}$ of the urea and full doses of other fertilizers were applied at the time of final land preparation. The remaining urea was top-dressed at 17 and 27 DAS. The rate applied in the field for N, $P_2O_5$, $K_2O$, and Zn was 115, 82, 51, and 7.8 Kg $ha^{-1}$ respectively.

The experiment was comprised with four mustard and rapeseed varieties and four sowing techniques viz. A. Varieties: $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2; B. Sowing techniques: $S_1$= Broadcasting, $S_2$= Line Sowing, = Raised Bed, $S_4$= System of Mustard Intensification (SMI). The experiment was laid out in factorial Randomized Complete Block Design (RCBD) with three replications and unit plot size 3 m × 3 m. The germination test was conducted using Petri dishes, each containing 25 seeds and data on emergence was collected on a percentage basis by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of seeds germinated}}{\text{Number of seeds taken for germination}} \times 100$$

Crop growth rate (CGR), Relative growth rate (RGR) and Harvest index were calculated by using the following standard formulas as shown below:

$$\text{Crop growth rate} = \frac{W_2 - W_1}{T_2 - T_1} \text{ g plant}^{-1} \text{ day}^{-1}$$

($W_1$= Total plant dry matter at time $T_1$, $W_2$ = Total plant dry matter at time $T_2$)

$$\text{Relative growth rate} = \frac{\text{Ln}W_2 - \text{Ln}W_1}{T_2 - T_1} \text{ g plant}^{-1} \text{ day}^{-1}$$

($W_1$ = Total plant dry matter at time $T_1$, $W_2$ = Total plant dry matter at time $T_2$, Ln = Natural logarithm)

$$\text{Harvest Index (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

The data was analyzed using CROPSTAT, a computer program from IRRI, Philippines, to determine the significance level and compare mean differences with a 5% level of significance.

## Results and Discussion

**Effect of varieties and sowing techniques on plant height**

Different varieties significantly influenced mustard and rapeseed plant height (cm) throughout the growing period (Fig. 1).

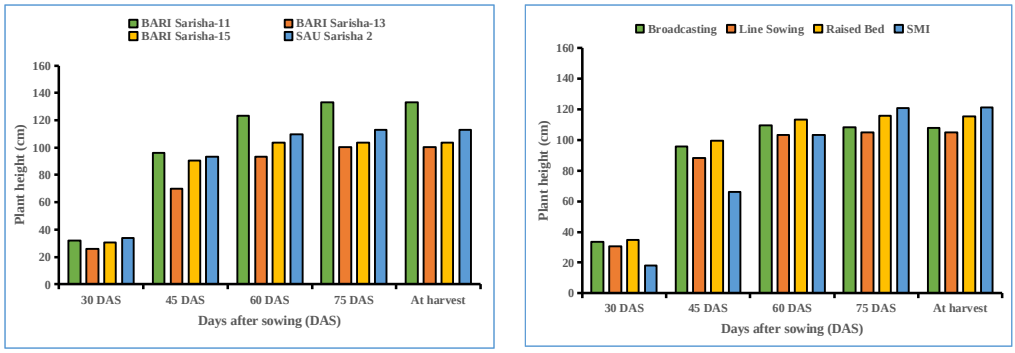


Fig. 1. Effect of varieties and sowing techniques on plant height of mustard and rapeseed plants at different DAS.

According to findings, BARI Sarisha-11 ($V_1$) showed the highest plant height, which were 96.28, 123.38, 133.03, and 132.88 cm at 45, 60, 75 DAS, and at harvest, respectively. Though SAU Sarisha 2 ($V_4$) was slightly taller than BARI Sarisha-11 at 30 DAS, the difference is insignificant. The var. BARI Sarisha-13 was the smallest. It also varied significantly due to different sowing techniques (Fig. 1). At 30, 45, and 60 DAS, the raised bed performed well, producing the tallest plants, which were 34.86, 99.64, and 113.49 cm respectively. However, SMI performed well at 75 DAS and at harvest, producing 120.88 and 121.31 cm.

**Combined effect of varieties and sowing techniques on plant height**

Plant height was not significantly affected by the combination of variety and sowing techniques at 30, 60, and 75 DAS and at harvest but significantly affected at 45 DAS, as shown in Table 1.

Table 1. Combined effect of varieties and sowing techniques on plant height (cm)

| Treatments | 30 DAS | 45 DAS | 60 DAS | 75 DAS | At harvest |
|---|---|---|---|---|---|
| $V_1S_1$ | 42.11 a | 107.33 ab | 126.08 ab | 123.34 b | 123.02 b |
| $V_1S_2$ | 31.56 b-e | 101.00 b-d | 120.17 a-c | 123.00 b | 122.82 b |
| $V_1S_3$ | 37.45 a-c | 113.00 a | 136.26 a | 144.11 a | 143.58 a |
| $V_1S_4$ | 16.89 g | 63.78 g | 111.02 b-e | 141.67 a | 142.10 a |
| $V_2S_1$ | 34.11 a-d | 82.22 e | 98.83 de | 96.56 de | 96.25 cd |
| $V_2S_2$ | 23.22 e-g | 65.11f g | 80.58 f | 87.56 e | 87.31 d |
| $V_2S_3$ | 27.55 d-f | 86.11 e | 98.42 de | 99.45 de | 99.21 cd |
| $V_2S_4$ | 18.00 g | 46.33 h | 95.08 ef | 118.33 bc | 118.97 b |
| $V_3S_1$ | 36.33 a-d | 96.89 d | 102.81 c-e | 102.33 c-e | 102.10 cd |
| $V_3S_2$ | 29.66 c-f | 87.55 e | 99.81 de | 99.22 de | 98.80 cd |
| $V_3S_3$ | 35.22 a-d | 94.89 d | 100.7 de | 100.22 de | 99.98 cd |
| $V_3S_4$ | 21.11 f | 82.22 e | 110.68 b-e | 112.40 b-d | 112.69 bc |
| $V_4S_1$ | 40.78 a | 96.44 d | 110.49 b-e | 111.00 b-d | 110.50 bc |
| $V_4S_2$ | 37.55 a-c | 100-00 cd | 112.87 b-d | 110.67 b-d | 110.55 bc |
| $V_4S_3$ | 39.22 ab | 104.55 bc | 118.57 bc | 119.66 b | 119.35 b |
| $V_4S_4$ | 17.00 g | 71.67 f | 96.18 d-f | 111.11 b-d | 111.47 bc |
| CV (%) | 17.4 | 4.9 | 9.8 | 8.9 | 8.9 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

At 30 DAS, the highest plant height (42.11 cm) was recorded from the combination of BARI Sarisha-11 and broadcasting technique ($V_1S_1$), which was statistically similar with $V_1S_3$, $V_2S_1$, $V_3S_1$, $V_3S_3$, $V_4S_1$, $V_4S_2$, and $V_4S_3$. A combination of BARI Sarisha-11 and raised bed technique ($V_1S_3$) scored the highest plant height (113 cm) at 45 DAS, statistically similar to $V_1S_1$. However, the combination of BARI Sarisha-11 and the raised bed technique ($V_1S_3$) performed best at all the other DASs.

**Effect of varieties and sowing techniques on leaf number**

Leaf number was significantly affected at 45, 60, and 75 DAS and at harvest but not at 30 DAS (Fig. 2). At 30, 45, and 75 DAS, the maximum leaf numbers (7.36, 61.75, and 94.11) were recorded at SAU Sarisha-2. At 60 DAS, the maximum leaf number (96.36) was observed at BARI Sarisha-15.

However, it was not significantly affected by sowing techniques at 30 DAS (Fig. 2). SMI showed the best results (59.25, 142.17, 201.81, and 78.58) at every DAS except 30 DAS.

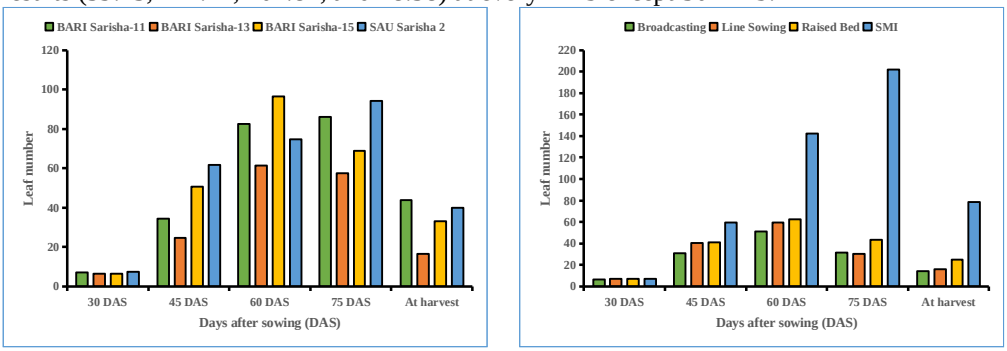


Fig. 2. Effect of varieties and sowing techniques on leaf number of mustard and rapeseed plants at different DAS.

**Combined effect of varieties and sowing techniques on leaf number**

Leaf number was not significantly affected by the combination of variety and sowing technique at 30 DAS but significantly affected at 45, 60, and 75 DAS and at harvest (Table 2).

Table 2. Combined effect of variety and sowing technique on leaf number at 30, 45, 60, and 75 DAS, and at harvest

| Treatments | 30 DAS | 45 DAS | 60 DAS | 75 DAS | At harvest |
|---|---|---|---|---|---|
| $V_1S_1$ | 6.78 ab | 31.67 f | 73.44 f | 59.22 d | 21.67 gh |
| $V_1S_2$ | 8.00 a | 25.56 g | 61.89 g | 33.33 f-h | 18.00 hi |
| $V_1S_3$ | 7.11 ab | 28.33 fg | 62.78 g | 43.89 e | 23.33 fg |
| $V_1S_4$ | 6.56 ab | 52.67 cd | 132.33 c | 208.00 b | 112.67 a |
| $V_2S_1$ | 6.00 b | 10.78 i | 26.44 k | 8.11 j | 3.00 k |
| $V_2S_2$ | 6.33 ab | 18.67 h | 48.00 i | 23.44 i | 8.00 j |
| $V_2S_3$ | 6.67 ab | 24.56 g | 54.00 hi | 30.22 g-i | 13.67 i |
| $V_2S_4$ | 6.89 ab | 44.11 e | 117.22 d | 168.00 c | 41.00 d |
| $V_3S_1$ | 6.22 ab | 30.56 f | 63.11 g | 25.44 hi | 13.33 i |
| $V_3S_2$ | 6.33 ab | 43.22 e | 71.33 f | 28.11 g-i | 17.67 hi |
| $V_3S_3$ | 6.33 ab | 56.33 c | 83.33 e | 59.11 d | 35.00 e |
| $V_3S_4$ | 7.00 ab | 72.56 a | 167.67 a | 162.33 c | 66.33 c |
| $V_4S_1$ | 7.56 ab | 51.22 d | 41.00 j | 32.11 f-i | 18.00 hi |
| $V_4S_2$ | 7.56 ab | 73.33 a | 57.33 gh | 35.11 e-g | 19.67 gh |
| $V_4S_3$ | 7.67 ab | 54.78 cd | 48.56 i | 40.33 ef | 27.33 f |
| $V_4S_4$ | 6.67 ab | 67.67 b | 151.44 b | 268.89 a | 94.33 b |
| CV (%) | 15.7 | 5.4 | 5.2 | 7.2 | 8.9 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

At 30 DAS, maximum leaf number (8) was recorded at the combination of BARI Sarisha-11 and line sowing technique ($V_1S_2$), which was statistically similar to other combinations except $V_2S_1$. At 45, 60, and 75 DAS and at harvest, $V_4S_2$, $V_3S_4$, $V_4S_4$, and $V_1S_4$ performed best respectively.

**Effect of varieties and sowing techniques on the number of primary branches**

Throughout the life cycle, variation had a major impact on the number of primary branches (Fig. 3).

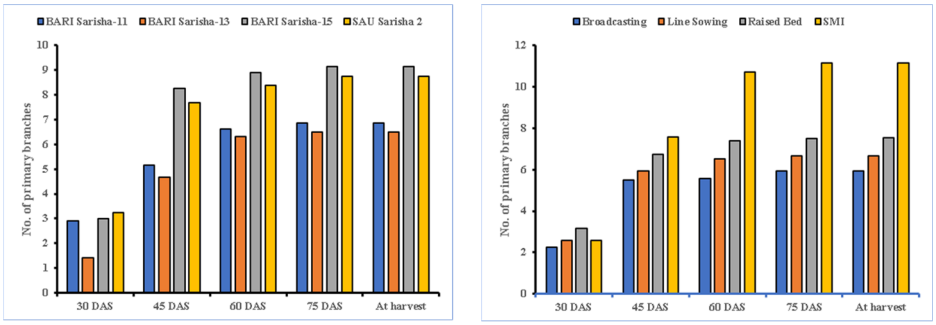


Fig. 3. Effect of varieties and sowing techniques on the number of primary branches of mustard and rapeseed plants at different DAS.

At 30 DAS, the maximum number of primary branches (3) were recorded at SAU Sarisha-2, which was statistically similar to BARI Sarisha-11 (3) and BARI Sarisha-15 (3). However, BARI Sarisha-15 proved the best in terms of no. of primary branches at all the other DAS and at harvest respectively. At 30 DAS, the sowing strategy had no discernible effect on the number of primary branches; however, at 45, 60, and 75 DAS and during harvest, it did (Fig. 3). At 30 DAS, the maximum number of primary branches (3) were recorded using the raised bed technique, which was statistically similar to line sowing and the SMI technique. On the other hand, the SMI technique proved the best in terms of no. of primary branches at all the other DAS and at harvest, resulting in 8, 11, 11, and 11 respectively. Additionally, Hossain *et al.* (2013) found that the seeding technique significantly affected the number of total branches produced per plant.

**Combined effect of varieties and sowing techniques on the number of primary branches**

The number of primary branches in a plant was not significantly affected by the combination of variety and sowing technique at 30 and 45 DAS and at harvest (Table 3).

Table 3. Combined effect of varieties and sowing techniques on the number of primary branches

| Treatments | 30 DAS | 45 DAS | 60 DAS | 75 DAS | At harvest |
|---|---|---|---|---|---|
| $V_1S_1$ | 2.33 b-e | 4.33 hi | 4.89 hi | 5.11 hi | 5.00 hi |
| $V_1S_2$ | 2.67 a-d | 4.67 g-i | 5.78 f-h | 5.67 g-i | 5.78 f-i |
| $V_1S_3$ | 3.33 ab | 5.00 f-i | 6.11 f-h | 6.33 f-h | 6.33 f-h |
| $V_1S_4$ | 3.33 ab | 6.67 c-f | 9.67 b-d | 10.33 bc | 10.33 ab |
| $V_2S_1$ | 1.67 c-e | 3.67 i | 3.45 i | 4.44 i | 4.33 i |
| $V_2S_2$ | 1.00 e | 3.67 i | 4.67 hi | 4.56 i | 4.67 hi |
| $V_2S_3$ | 1.67 c-e | 5.67 e-h | 5.44 gh | 5.67 g-i | 5.67 g-i |
| $V_2S_4$ | 1.33 de | 5.67 e-h | 11.67 a | 12.67 a | 11.33 a |
| $V_3S_1$ | 2.33 b-e | 7.67 a-d | 6.89 fg | 6.89 e-g | 7.22 d-g |
| $V_3S_2$ | 3.33 ab | 8.00 a-d | 8.44 de | 8.33 de | 8.67 b-e |
| $V_3S_3$ | 3.67 ab | 8.00 a-d | 9.22 cd | 9.00 cd | 9.00 b-d |
| $V_3S_4$ | 2.67 a-d | 9.33 a | 11.00 ab | 11.67 ab | 11.67 a |
| $V_4S_1$ | 2.67 a-d | 6.33 d-g | 7.11 ef | 7.22 ef | 7.11 e-g |
| $V_4S_2$ | 3.33 ab | 7.33 b-e | 7.22 ef | 8.11 de | 7.56 c-f |
| $V_4S_3$ | 4.00 a | 8.33 a-c | 8.78 d | 9.00 cd | 9.11 bc |
| $V_4S_4$ | 3.00 a-c | 8.67 ab | 10.45 a-c | 11.22 ab | 11.22 a |
| $LSD_{(0.05)}$ | 1.36 | 1.75 | 1.52 | 1.45 | 1.83 |
| CV (%) | 30.8 | 16.3 | 12.1 | 11.0 | 14.0 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

However, it was significant at 60 and 75 DAS. At 30 DAS, the maximum number of primary branches was recorded at the combination of SAU Sarisha-2 and raised bed technique ($V_4S_3$), while the minimum number at the combination of BARI Sarisha-13 and line sowing ($V_2S_2$). At 45 DAS, the maximum number of primary branches was at the combination of BARI Sarisha-15 and SMI technique ($V_3S_4$), while the minimum number was at the combination of BARI Sarisha-13 and broadcast sowing technique ($V_2S_1$). At 60 DAS, the maximum number of primary branches was at the combination of

BARI Sarisha-15 and SMI technique ($V_2S_4$), while at 75 DAS, the minimum number was at the combination of BARI Sarisha-13 and broadcast sowing technique ($V_2S_1$).

**Effect of varieties and sowing techniques on the number of secondary branches**

Number of secondary branches was significantly affected by variety throughout the life cycle (Fig. 4). At 45 DAS, the maximum number of secondary branches (8) was recorded at BARI Sarisha-11, and the minimum number of secondary branches (1) at BARI Sarisha-15. On 60 and 75 DAS and at harvest, the maximum number of secondary branches (23, 26, and 28) was recorded at BARI Sarisha-11 and the minimum number of secondary branches (13, 16, and 17) at BARI Sarisha-13.

The sowing techniques significantly affected the number of secondary branches throughout the life cycle (Fig. 4). At 45 DAS, the maximum number of primary branches (6) was recorded using the SMI technique and the minimum number of secondary branches (1) by broadcasting technique which was statistically similar to line sowing. At 60 and 75 DAS and at harvest, the maximum number of secondary branches (41, 47, and 51) was recorded at the SMI technique and the minimum number of secondary branches (8, 9, and 9) at the broadcast sowing technique.

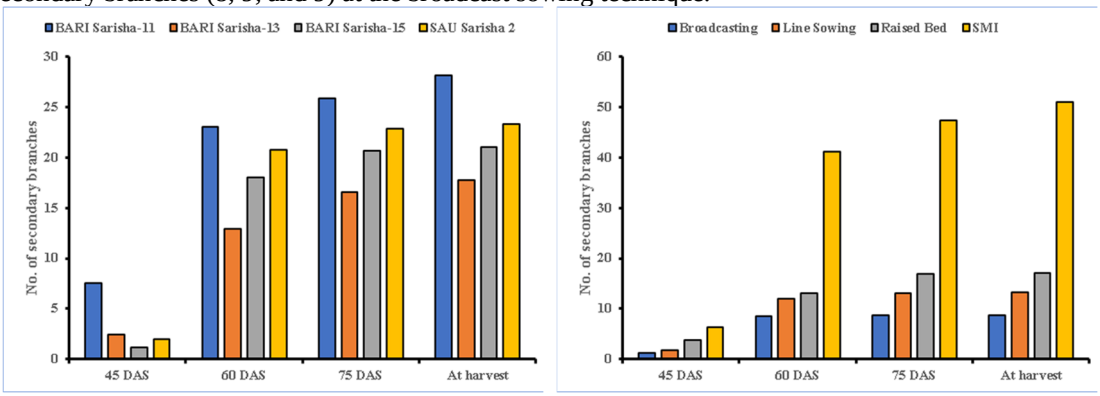


Fig. 4. Effect of varieties and sowing techniques on the number of secondary branches of mustard and rapeseed plants at different DAS.

**Combined effect of varieties and sowing techniques on the number of secondary branches**

The combination of variety and sowing technique throughout the life cycle significantly affected the number of secondary branches, as shown in Table 4. At 45 DAS, the maximum number of secondary branches (14) was recorded at the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$). The minimum number of secondary branches (0) was observed both at the combination of BARI Sarisha-15 and line sowing ($V_3S_2$) and BARI Sarisha-15 and raised bed technique ($V_3S_3$) which was statistically similar with $V_2S_1$, $V_3S_1$, $V_4S_1$, and $V_4S_2$. At 60 and 75 DAS and at harvest, the maximum number of secondary branches (52, 62, and 70) was recorded at the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$). The minimum number of secondary branches (2, 3, and 3) was observed at the combination of BARI Sarisha-13 and broadcast sowing technique ($V_2S_1$).

Table 4. Combined effect of varieties and sowing techniques on the number of primary branches

| Treatments | 45 DAS | 60 DAS | 75 DAS | At harvest |
|---|---|---|---|---|
| $V_1S_1$ | 2.89 de | 11.89 e-h | 12.00 e-g | 12.00 e-g |
| $V_1S_2$ | 4.45 c | 13.78 e-g | 14.00 ef | 14.11 d-g |
| $V_1S_3$ | 9.00 b | 14.56 ef | 15.67 de | 16.00 de |
| $V_1S_4$ | 13.89 a | 52.00 a | 62.00 a | 70.33 a |
| $V_2S_1$ | 0.56 h | 2.33 i | 2.78 h | 2.56 h |
| $V_2S_2$ | 1.67 fg | 8.78 h | 10.67 fg | 11.00 fg |
| $V_2S_3$ | 2.67 d-f | 9.55 gh | 15.00 de | 16.00 de |
| $V_2S_4$ | 4.89 c | 30.89 d | 37.78 c | 41.33 c |
| $V_3S_1$ | 0.44 h | 10.11 f-h | 10.33 fg | 10.33 fg |
| $V_3S_2$ | 0 h | 13.33 e-g | 15.00 de | 15.00 d-f |

| | | | | |
|---|---|---|---|---|
| $V_3S_3$ | 0 h | 12.56 e-h | 18.00 d | 18.00 d |
| $V_3S_4$ | 4.22 c | 36.00 c | 39.33 c | 40.67 c |
| $V_4S_1$ | 1.00 gh | 9.67 gh | 10.00 g | 10.00 g |
| $V_4S_2$ | 0.56 h | 12.33 e-h | 12.67 e-g | 12.67 e-g |
| $V_4S_3$ | 3.67 d | 15.45 e | 18.67 d | 18.67 d |
| $V_4S_4$ | 2.55 ef | 45.56 b | 50.11 b | 50.00 b |
| $LSD_{(0.05)}$ | 1.05 | 4.52 | 3.94 | 4.98 |
| CV (%) | 19.2 | 14.5 | 11 | 13.2 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

**Effect of varieties and sowing techniques on dry matter accumulation**

Variation significantly affected dry matter (g) production throughout the life cycle (Fig. 5). BARI Sarisha-11 performed well at all the DAS, resulting in 1.07, 11.44, 21.3, and 25.87 g. BARI Sarisha-13 holds the second position except at 30 DAS.

Dry matter (g) production was also significantly affected by the sowing techniques throughout the lifecycle (Fig. 5). SMI performed best at all the DASs except at 30 DAS, resulting in 14.85, 28.68, and 36.44 g. According to Sushma *et al.* (2023), transplanting seedlings that are 25 days old with a spacing of 30 cm × 30 cm under the System of Mustard Intensification led to increased dry matter production.

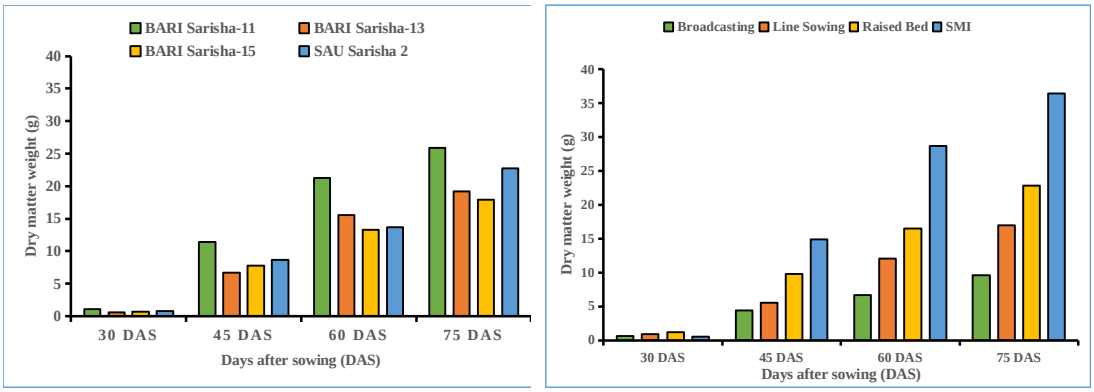


Fig. 5. Effect of varieties on dry matter accumulation of mustard and rapeseed plants at different DAS.

**Combined effect of varieties and sowing techniques on dry matter accumulation**

Dry matter accumulation (g) was significantly affected by the combination of variety and sowing technique at 30, 45, and 60 DAS but not significantly at 75 DAS (Table 5). At 30 DAS, maximum dry matter (1.7 g) accumulation was recorded at the combination of BARI Sarisha-11 and raised bed technique ($V_1S_3$) and minimum dry matter (0.45 g) accumulation was observed at the combination of BARI Sarisha-15 and SMI technique ($V_3S_4$) which was statistically similar with $V_1S_1$, $V_1S_4$, $V_2S_1$, $V_2S_2$, $V_2S_4$, $V_3S_1$, $V_3S_2$, and $V_4S_4$. On 45 DAS, maximum dry matter (19.2 g) production was recorded using the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$). At 60 DAS, maximum dry matter (35.12 g) production was recorded using the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$). At 75 DAS, maximum dry matter (39.93 g) production was recorded using the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$) which was statistically similar to $V_2S_4$ and $V_4S_4$.

Table 5. Combined effect of variety and sowing technique on dry matter accumulation (g) at 30, 45, 60, and 75 DAS.

| Treatments | 30 DAS | 45 DAS | 60 DAS | 75 DAS |
|---|---|---|---|---|
| $V_1S_1$ | 0.61 e-g | 5.25 hi | 6.96 ki | 11.53 gh |
| $V_1S_2$ | 1.41 b | 6.11 g | 20.12 e | 24.01 de |
| $V_1S_3$ | 1.70 a | 15.18 c | 23.00 d | 28.02 cd |

| | | | | |
|---|---|---|---|---|
| $V_1S_4$ | 0.57 fg | 19.20 a | 35.12 a | 39.93 a |
| $V_2S_1$ | 0.58 fg | 3.43 j | 6.42 l | 7.68 h |
| $V_2S_2$ | 0.61 e-g | 5.83 gh | 10.47 hi | 13.94 fg |
| $V_2S_3$ | 0.83 de | 6.27 g | 16.39 f | 20.61 e |
| $V_2S_4$ | 0.48 g | 11.24 e | 28.91 b | 34.52 ab |
| $V_3S_1$ | 0.48 g | 5.05 i | 6.81 l | 8.56 gh |
| $V_3S_2$ | 0.63 e-g | 5.23 hi | 8.47 jk | 11.18 gh |
| $V_3S_3$ | 1.24 bc | 7.78 f | 12.06 h | 18.56 ef |
| $V_3S_4$ | 0.45 g | 12.99 d | 25.96 c | 33.34 bc |
| $V_4S_1$ | 0.81 d-f | 3.93 j | 6.52 l | 10.45 gh |
| $V_4S_2$ | 0.83 de | 4.98 i | 9.02 ij | 18.57 ef |
| $V_4S_3$ | 1.05 cd | 9.94 e | 14.5 g | 24.02 de |
| $V_4S_4$ | 0.54 g | 15.98 b | 24.72 c | 37.98 ab |
| CV (%) | 18.3 | 4.4 | 6.1 | 15.4 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

**Effect of varieties and sowing techniques on crop growth rate**

Crop growth rate (CGR) is a measure of the increase in size, mass, or number of crops over a period of time (Fig. 6). CGR was significantly affected by varieties throughout the life cycle. At 30-45 DAS, the highest CGR (0.691 g plant$^{-1}$ day$^{-1}$) was recorded at BARI Sarisha-11 and the lowest CGR (0.405 g plant$^{-1}$ day$^{-1}$) at BARI Sarisha-13. On 45-60 DAS, the highest CGR (0.658 g plant$^{-1}$ day$^{-1}$) was recorded at BARI Sarisha-11 but at 60-75 DAS, the highest CGR (0.604 g plant$^{-1}$ day$^{-1}$) was recorded at SAU Sarisha-2.

Crop growth rate was significantly affected by the sowing technique throughout the life cycle (Fig. 6). At 30-45 DAS, the highest CGR (0.956 g plant$^{-1}$ day$^{-1}$) was recorded using the SMI technique, and the lowest CGR (0.253 g plant$^{-1}$ day$^{-1}$) at broadcast sowing technique. On 45-60 DAS and 60-75 DAS, the highest CGR (0.658 g plant$^{-1}$ day$^{-1}$ and 0.518 g plant$^{-1}$ day$^{-1}$) was recorded at SMI technique.

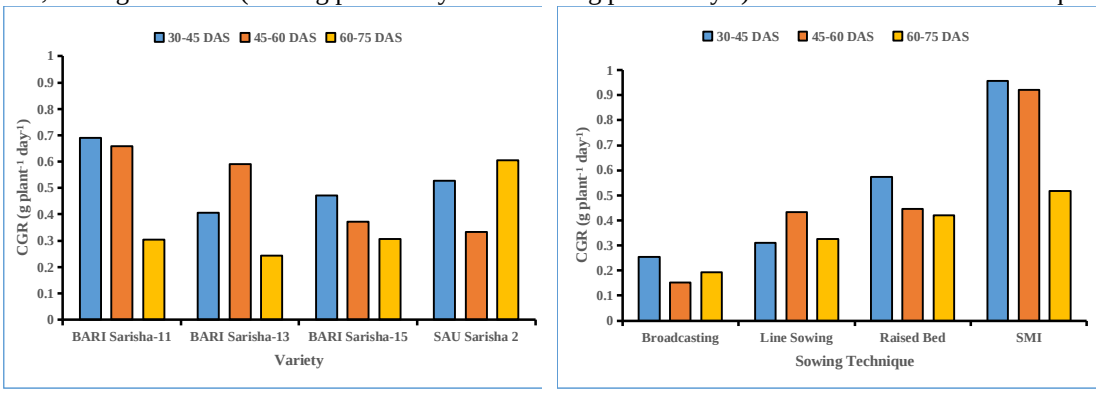


Fig. 6. Effect of varieties and sowing techniques on CGR of mustard and rapeseed plants at different DAS.

**Combined effect of varieties and sowing techniques on crop growth rate**

Crop growth rate was significantly affected by the combination of variety and sowing technique at 30-45 and 45-60 DAS but not significantly at 60-75 DAS, as shown in Table 6. At 30-45 DAS, highest CGR (1.242 g plant$^{-1}$ day$^{-1}$) was recorded at the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$) and lowest CGR (0.19 g plant$^{-1}$ day$^{-1}$) at the combination of BARI Sarisha-13 and broadcast sowing technique ($V_2S_1$) which was statistically similar (0.208 g plant$^{-1}$ day$^{-1}$) with $V_4S_1$ at 45-60 DAS. The highest CGR (1.178 g plant$^{-1}$ day$^{-1}$) was recorded at the combination of BARI Sarisha-13 and SMI technique ($V_2S_4$). At 60-75, the highest CGR (0.884 g plant$^{-1}$ day$^{-1}$) was recorded at the SAU Sarisha-2 and SMI technique ($V_4S_4$) combination.

Table 6. Combined effect of variety and sowing technique on CGR (g plant$^{-1}$ day$^{-1}$) at 30-45, 45-60 and 60-75 DAS

| Treatments | 30-45 DAS | 45-60 DAS | 60-75 DAS |
|---|---|---|---|
| $V_1S_1$ | 0.309 ij | 0.114 i | 0.305 b-e |
| $V_1S_2$ | 0.314 ij | 0.934 c | 0.259 c-e |
| $V_1S_3$ | 0.898 c | 0.522 e | 0.334 b-e |
| $V_1S_4$ | 1.242 a | 1.061 b | 0.321 b-e |
| $V_2S_1$ | 0.190 k | 0.199 g-i | 0.084 e |
| $V_2S_2$ | 0.348 hi | 0.309 f | 0.232 c-e |
| $V_2S_3$ | 0.362 h | 0.675 d | 0.282 c-e |
| $V_2S_4$ | 0.717 e | 1.178 ah | 0.374 b-e |
| $V_3S_1$ | 0.305 j | 0.117 i | 0.117 de |
| $V_3S_2$ | 0.306 ij | 0.216 f-i | 0.181 c-e |
| $V_3S_3$ | 0.436 g | 0.286 fg | 0.433 b-d |
| $V_3S_4$ | 0.836 d | 0.865 c | 0.492 bc |
| $V_4S_1$ | 0.208 k | 0.173 hi | 0.262 c-e |
| $V_4S_2$ | 0.276 j | 0.270 f-h | 0.637 ab |
| $V_4S_3$ | 0.593 f | 0.304 fg | 0.635 ab |
| $V_4S_4$ | 1.030 b | 0.582 de | 0.884 a |
| CV (%) | 4.8 | 13.2 | 55 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

**Effect of varieties and sowing techniques on relative growth rate**

Relative growth rate (RGR) is the increase of materials per unit of plant materials per unit of time. Relative growth rate was not significantly affected by variety at 30-45 DAS but was significant at 45-60 and 60-75 DAS (Fig. 7). At 30-45 DAS, the highest RGR (0.161 g $g^{-1}$ $day^{-1}$) was recorded at BARI Sarisha-15, and the lowest RGR (0.15 g $g^{-1}$ $day^{-1}$ was recorded at SAU Sarisha-2. On 45-60 DAS, the highest RGR (0.052 g $g^{-1}$ $day^{-1}$) was recorded at BARI Sarisha-13. At 60-75 DAS, the highest RGR (0.035 g $g^{-1}$ $day^{-1}$) was recorded at SAU Sarisha-2.

Relative growth rate was significantly affected by the sowing techniques at 30-45 and 45-60 DAS but not significant at 60-75 DAS (Fig. 7). At 30-45 DAS, the highest RGR (0.224 g $g^{-1}$ $day^{-1}$) was recorded both at the SMI technique, and the lowest RGR (0.132 g $g^{-1}$ $day^{-1}$) At both at broadcast and line sowing technique, which was statistically similar (0.138 g $g^{-1}$ $day^{-1}$) with raised bed technique. On 45-60 and 60-75 DAS, the highest RGR (0.048 g $g^{-1}$ $day^{-1}$, 0.024 g $g^{-1}$ $day^{-1}$) was recorded at line sowing.

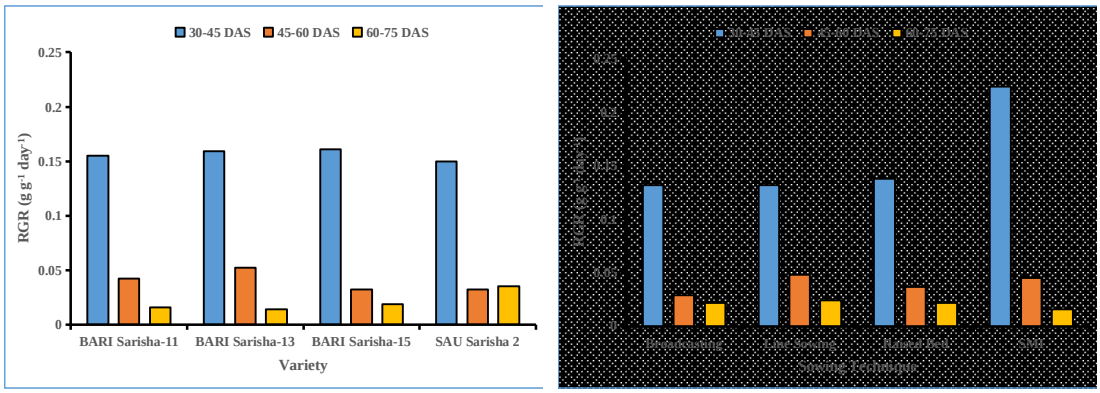


Fig. 7. Effect of varieties and sowing techniques on RGR of mustard and rapeseed plants at different DAS.

**Combined effect of varieties and sowing techniques on relative growth rate**

Relative growth rate was significantly affected at 30-45 and 45-60 DAS but not significantly at 60-75 DAS, as shown in Table 7.

Table 7. Combined effect of variety and sowing technique on relative growth rate (g $g^{-1}$ $day^{-1}$) at 30-45, 45-60 and 60-75 DAS

| Treatments | 30-45 DAS | 45-60 DAS | 60-75 DAS |
|---|---|---|---|
| $V_1S_1$ | 0.144 b-d | 0.019 g | 0.029 b-d |
| $V_1S_2$ | 0.098 f | 0.079 a | 0.012 d |
| $V_1S_3$ | 0.146 b-d | 0.028 fg | 0.013 cd |
| $V_1S_4$ | 0.234 a | 0.040 cd | 0.084 a |
| $V_2S_1$ | 0.121 d-f | 0.042 cd | 0.012 d |
| $V_2S_2$ | 0.170 b | 0.039 c-e | 0.019 cd |
| $V_2S_3$ | 0.135 c-e | 0.064 b | 0.015 cd |
| $V_2S_4$ | 0.210 a | 0.063 b | 0.012 d |
| $V_3S_1$ | 0.158 bc | 0.020 g | 0.015 cd |
| $V_3S_2$ | 0.140 b-d | 0.033 d-f | 0.018 cd |
| $V_3S_3$ | 0.123 d-f | 0.029 e-g | 0.027 b-d |
| $V_3S_4$ | 0.225 a | 0.046 c | 0.017 cd |
| $V_4S_1$ | 0.106 ef | 0.034 d-f | 0.032 b-d |
| $V_4S_2$ | 0.119 d-f | 0.039 c-e | 0.046 b |
| $V_4S_3$ | 0.150 b-d | 0.025 fg | 0.033 bc |
| $V_4S_4$ | 0.226 a | 0.029 e-g | 0.029 b-d |
| CV (%) | 12.4 | 14.5 | 56.3 |

Here, $V_1$= BARI Sarisha-11, $V_2$= BARI Sarisha-13, $V_3$= BARI Sarisha-15, $V_4$= SAU Sarisha-2, $S_1$= Broadcasting, $S_2$= Line Sowing, $S_3$= Raised Bed, $S_4$= SMI

At 30-45 DAS, the highest RGR (0.234 g $g^{-1}$ $day^{-1}$) was recorded at the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$) which was statistically similar to $V_2S_4$, $V_3S_4$, and $V_4S_4$. The lowest RGR (0.098 g $g^{-1}$ $day^{-1}$) was observed at the combination of BARI Sarisha-11 and line sowing ($V_1S_2$). At 45-60 DAS, the highest RGR (0.079 g $g^{-1}$ $day^{-1}$) was recorded at the combination of BARI Sarisha-11 and line sowing ($V_1S_2$). At 60-75 DAS. The highest RGR (0.084 g $g^{-1}$ $day^{-1}$) was recorded at the combination of BARI Sarisha-11 and SMI technique ($V_1S_4$) and the lowest RGR (0.012 g $g^{-1}$ $day^{-1}$) at the combination of BARI Sarisha-11 and broadcast technique ($V_1S_4$).

**Effect of varieties and sowing techniques on shell yield, stover yield, seed yield**

According to Fig. 8, all the yield parameters were affected significantly. The highest shell yield (2.62 t $ha^{-1}$) was obtained at BARI Sarisha-13, and the lowest shell yield (1.01 t $ha^{-1}$) at BARI Sarisha-15. The highest shell yield (2.44 t $ha^{-1}$) was obtained using SMI techniques, and the lowest shell yield (1.38 t $ha^{-1}$) by broadcast sowing techniques. Akhter (2005) also reported same result.The highest stover yield (6.95 t $ha^{-1}$) was obtained at BARI Sarisha-13, and the lowest stover yield (3.77 t $ha^{-1}$) at BARI Sarisha-15. The highest stover yield (6.62 t $ha^{-1}$) was obtained using the SMI technique, and the lowest stover yield (3.72 t $ha^{-1}$) was found using the broadcast sowing technique.

The highest seed yield (3.74 t $ha^{-1}$) was obtained at BARI Sarisha-11, and the lowest seed yield (2.54 t $ha^{-1}$) at BARI Sarisha-15. The highest seed yield (3.8 t $ha^{-1}$) was obtained using the SMI technique, and the lowest seed yield (2.11 t $ha^{-1}$) at broadcast sowing technique.

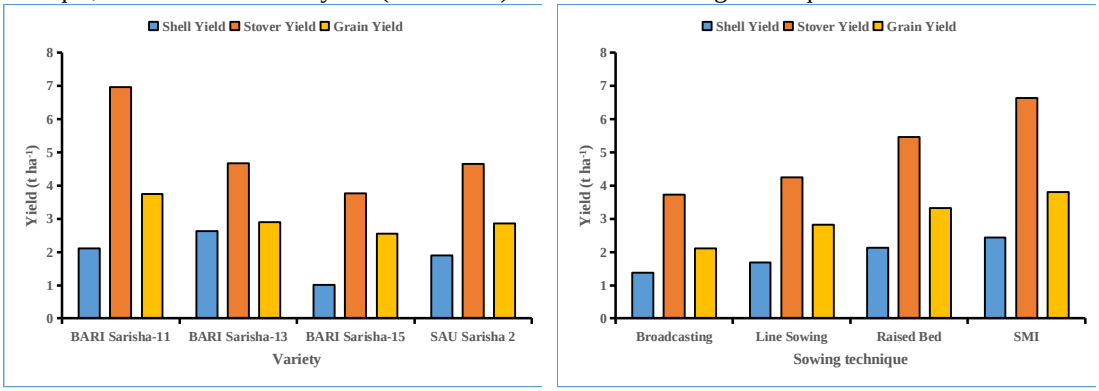


Fig. 8. Effect of varieties and sowing techniques on shell, stover, and grain yield of mustard and rapeseed plants.

**Effect of varieties and sowing techniques on biological yield**

According to Fig. 9, different varieties and sowing techniques significantly affected mustard and rapeseed plants' biological yield (t ha$^{-1}$). The highest biological yield (12.8 t ha$^{-1}$) was obtained at BARI Sarisha-11, and the lowest biological yield (7.32 t ha$^{-1}$) at BARI Sarisha-15. The highest biological yield (12.86 t ha$^{-1}$) was obtained using the SMI technique, and the lowest biological yield (7.21 t ha$^{-1}$) by broadcast sowing technique. Khan *et al*. (2000) also reported by different sowing methods with similar result.

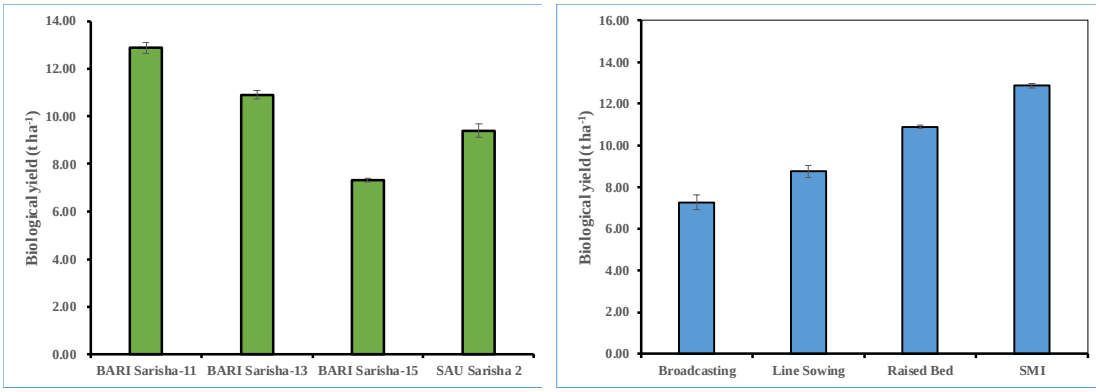


Fig. 9. Effect of varieties and sowing techniques on biological yield of mustard and rapeseed plants.

**Effect of varieties and sowing techniques on harvest index**

Different varieties and sowing techniques significantly affected the harvest index (%) of mustard and rapeseed plants (Fig. 10). The highest harvest index (34.84%) was observed at BARI Sarisha-15 and the lowest harvest index (28.04%) at BARI Sarisha-13. Islam *et al.* (1994) also reported that varieties significantly affected the harvest index (%) of mustard.

The highest harvest index (32.45%) was observed at line sowing and the lowest harvest index (29.43%) at broadcast sowing which was statistically similar (29.83%) to the SMI technique.

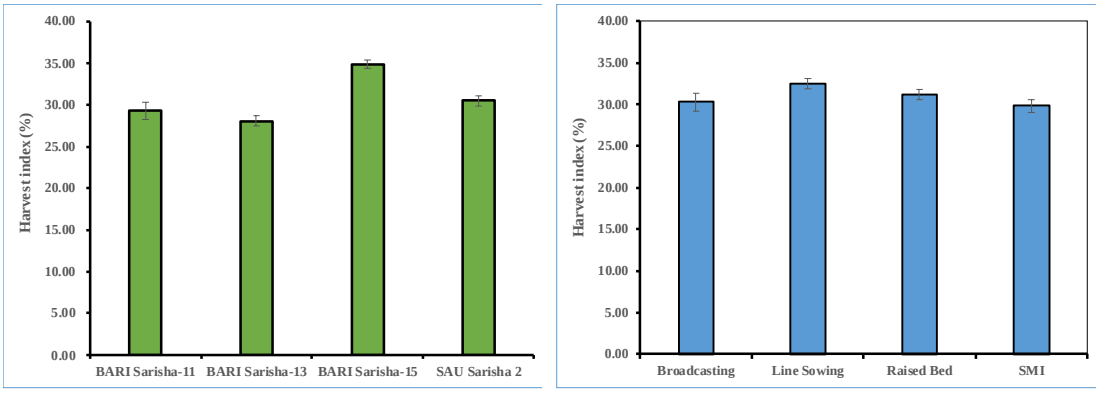


Fig. 10. Effect of varieties and sowing techniques on harvest index (%) of mustard and rapeseed plants.

**Effect of varieties and sowing techniques on oil percentage**

The oil percentage of mustard and rapeseed plant seeds was significantly affected by varieties and sowing techniques. The highest oil percentage (40.65%) was obtained at BARI Sarisha-15 and the lowest (39.17%) was recorded at BARI Sarisha-11.

The highest oil percentage (41.38%) was obtained at line sowing and the lowest (39.24%) at the raised bed technique. Singh *et al*. (1999) also found oil content variation due to different varieties and sowing methods.

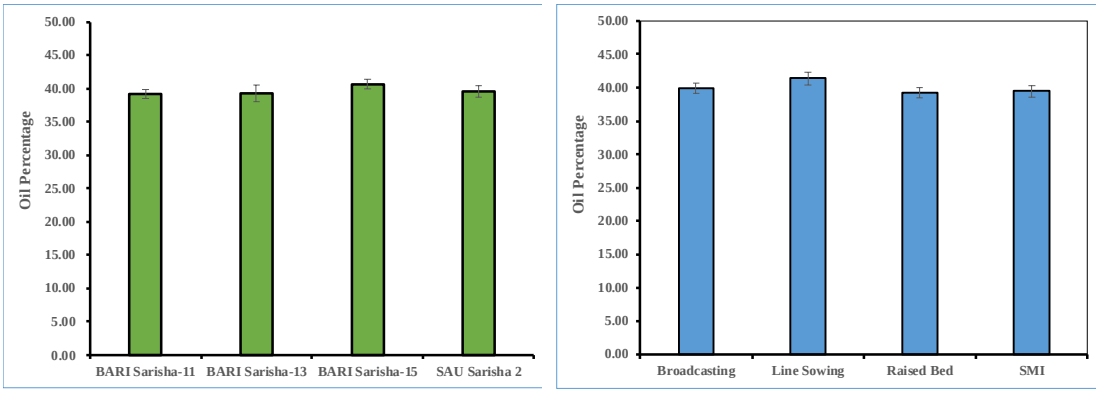


Fig. 11. Effect of varieties and sowing techniques on oil percentage (%) of mustard and rapeseed plants.

## Conclusion

The e life cycle of mustard var. BARI Sarisha-11 is longer, it showed better results in almost all the parameters. On the other hand, the System of Mustard Intensification (SMI, $S_4$) resulted in the best performance in almost every parameter followed by the raised bed ($S_3$) sowing technique. From the findings it can be concluded that mustard var. BARI Sarisha-11 in the SMI technique ($S_4$) may be feasible if labour is not a problem in the raised beds. However, more trials need to be performed in different locations in Bangladesh for better understanding and utilization.

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