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SUITABILITY OF RAPESEED-MUSTARD VARIETIES AS A RELAY WITH T. AMAN RICE

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Abstract

A field experiment on T. Aman-mustard relay cropping was conducted at the Agronomy Research field of Sher-e-Bangla Agricultural University, Dhaka in 2023-2024 to identify the suitable short duration variety for relay with T. Aman. Ten varieties of rapeseed-mustard *viz*., BINA sharisha4, BINA sharisha9, BINA sharisha10, BINA sharisha11, BARI sharisha14, BARI sharisha15, BARI sharisha16, BARI sharisha17, BARI sharisha18, and BARI sharisha20 were evaluated as relay with T. Aman. The seeds of rapeseed-mustard were broadcasted in a standing T. Aman rice crop after the excess water drained out at 10 days before the rice harvest. The rice was harvested at 15 cm above the ground level. The experiment was conducted in a Randomized Complete Block Design with three replications. Results indicated that growth as well as yield contributing characteristics and seed yield of rapeseed-mustard were significantly varied among the varieties. The variety BARI sharisa16 produced the highest seed yield and followed a trend as BARI sharisha17 > BARI sharisa15 > BARI sharisa14 > BINA sharisha11. These varieties showed higher number of leaf plant^{-1}, leaf area, leaf area index, 1000-seed weight, siliqua plant^{-1}, and seeds siliquae^{-1}.and took minimum days to flower and mature. The seed yields of these varieties were significantly positively correlated with growth duration, and yield contributing attributes. Despite its high yield potential, farmers are not interested to cultivate mustard var. BARI sharisha16 as a relay crop with T. Aman rice due to its long growth duration. On the other hand, mustard var. BARI sharisha14, BARI sharisha15, BARI sharisha17, and BINA sharisha11 matured by 75-80 days, which were suitable as relay crop with T. Aman rice.

Keywords: Duration, Growth, Relay mustard, Variety, Yield.

Introduction

Rapeseed-mustard covering about 80% of the total oilseed area and contributing to more than 60% of the total oilseed production in Bangladesh (Rahman *et al*., 2022). The estimated total area and production of rapeseed-mustard was 1.04 million hectare

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and 1.35 million tons, respectively in Bangladesh during 2024-2025 (USDA FAS, 2025). The present average rapeseed-mustard seed yield (1.33 t ha^{-1}) is very low as compared to other oilseeds growing countries in the world. Recently many high yielding varieties of T. Aman rice has been released but due to long duration variety of rice, it is difficult to cultivate mustard timely. On the other hand, delay sowing of mustard results in poor growth, ultimately lower yield and difficult to fit in Boro rice season.

Relay cropping under zero tillage conditions is one of the cropping system where growing a crop few days before harvesting of another crop. In Bangladesh, many crops *viz*. lentil, grasspea, chickpea, field pea, maize, etc. are relayed with T. Aman rice (Islam *et al*., 2017; Roy *et al*., 2017; Mandal *et al*., 2015; Ali *et al*., 2018). This cropping system is generally adopted in areas where T. Aman harvesting delayed and/or land remains moist which takes few to more days to become optimum condition ('Zoe' condition) for land preparation. Under this situation, farmers can grow the crop in optimum time by adopting relay cropping. Moreover, this practice makes the best use of the residual moisture of T. Aman rice field. Relay mustard with T. Aman under zero tillage conditions has already received remarkable attention by the farmers mainly due to time, cost effectiveness and profitability (Rahman *et al*., 2022). In view of this, the present study was conducted to select the suitable varieties of mustard relay with T. Aman under zero tillage cultivation for increasing the cropping intensity and to increase the production of mustard.

Materials and Methods

The experiment was conducted at the Agronomy farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the 2023-2024. The short duration rice var. BRRI dhan75 was used in this study. Rice seedlings were transplanted in each thirty plots without any treatment variations and fertilized with recommended dose of fertilizers. Rice was transplanted maintaining 25 × 15 cm spacing with two seedlings $hill^{-1}$. Different intercultural operations were performed in each plot for maintaining proper growth and development of rice. Mustard/rapeseed varieties were collected from BARI and BINA and were relayed with T. aman rice under zero tillage conditions. The experiment was randomly arranged using a RCB design with three replicates and the total number of plot was thirty for ten mustard/rapeseed varieties.

Ten varieties of rapeseed-mustard, *viz*. BINA sharisha4, BINA sharisha9, BINA sharisha10, BINA sharisha11, BARI sharisha14, BARI sharisha15, BARI sharisha16, BARI sharisha17, BARI sharisha18 and BARI sharisha20 were included in this study. The varietal characteristics have been given in the Table 1. The seeds of mustard were broadcast in the standing rice crop after the excess water drained out i.e., 10 days before the rice harvest under a sufficient moisture conditions. The rice was harvested at 15 cm above the ground level and transferred from the field within three days. The seed rate of all mustard/rapeseed was used at the rate of 8 kg ha^{-1}. The mustard was fertilized with 120-36-80-20 kg ha^{-1} N-P-K-S as a urea, TSP, MoP and Gypsum, respectively (Ahamed *et al*., 2018). Half of the urea and the other fertilizers were broadcast in the standing T. Aman crop just three days before relay sowing of seeds. Rest of the urea was applied before flowering stage. Two hand weeding were done at 15 days after sowing (DAS) and 30 DAS manually.

Light irrigation was given at 40 DAS (at flowering stage). The crop was sprayed with Malathion 57 EC at recommended dose to control aphids at siliquae formation.

The growth parameters *viz*., plant height, number of branches plant^{-1}, number of leaves plant^{-1}, and fresh and dry weight of leaf, leaf area, leaf area index, specific leaf area, specific leaf weight, were measured at 40 and 70 DAS using three plants for every sampling from each plot. Plants were harvested depending on the maturity of variety. At maturity stage i.e. when 80% of the pod turned brown in colour, the crop was harvested from each plot in 4.5 m^2 area at ground level for seed yield. Prior to harvesting, three plants were randomly uprooted for yield attributes *viz*., number of siliqua plant^{-1}, number of seeds siliquae^{-1}, and weight of 1000-seeds. Seeds from harvested area collected and sun dried to obtain proper seed moisture content of 12% to get optimum seed weight. The straw was also dried in the sun and weighted. Both seed and straw yields were calculated and expressed as t ha^{-1}. Biological and harvest index were also calculated.

Table 1. Varietal characteristics of different rapeseed-mustard genotypes (Azad *et al.*, 2020)

Name	Types	Duration	Siliqua plant^{-1}	Seed siliquae^{-1}	1000-seed weight (g)	Seed yield (t ha^{-1})
BINA sharisha4	*Brassica napus*	85-88	60-85	24.32	3.6-4.0	1.8-2.4
BINA sharisha9	*Brassica napus*	80-84	75-90	25-28	3.5-4.0	1.7-2.0
BINA sharisha10	*Brassica campestris*	78-80	110-125	14-16	2.8-2.95	1.5-1.7
BINA sharisha11	*Brassica napus*	80-83	90-100	28-30	3.5-4.5	1.8-2.1
BARI sharisha14	*Brassica campestris*	75-80	80-100	22-26	3.5-3.8	1.4-1.6
BARI sharisha15	*Brassica campestris*	80-85	70-80	20-22	3.25-3.5	1.5-1.6
BARI sharisha16	*Brassica juncea*	105-115	180-200	9-11	4.7-4.9	2.0-2.5
BARI sharisha17	*Brassica rapa*	82-86	60-65	28-30	3.0-3.4	1.7-1.8
BARI sharisha18	*Brassica napus*	95-100	80-130	28-30	3.5-4.0	2.0-2.5
BARI sharisha20	*Brassica rapa*	80-85	50-55	28-34	3.5-3.8	1.7-2.0

Statistical analysis

All data were analyzed by using SPSS 20.0 for windows (SPSS Inc.). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 1% levels of probability.

Results and Discussion

Growth characteristics of different rapeseed-mustard

Plant height

The plant height was significantly different among the varieties at all growing stages (Figs. 1a and 1b). At 40 DAS, the maximum plant height was recorded in BARI sharisha14 (86.89 cm) which was at par with BARI sharisha15, BARI sharisha17, BARI sharisha20 and BINA sharisha11, and the lowest in BARI sharisha18 (42.68 cm). After 40 DAS, it increased sharply up to 70 DAS where maximum plant height was recorded in

BARI sharisha16 (164.84 cm) and the lowest in BARI sharisha14 (92.32 cm). The present study revealed that BARI sharisa14 and BARI sharisa15 produced the highest plant height at early stage and BARI sharisa16 at harvesting stage. It could be happened due to the genetic makeup of the variety. BARI sharisa14 and BARI sharisa15 are short duration variety whereas BARI sharisa16 completes its life cycle within 115 DAS. Therefore, BARI sharisa14 and BARI sharisa15 were grown quickly and BARI sharisa16 grown slowly at early stage. Helal *et al*., 2016; Rahman *et al*., 2022 was also corroborated the findings.

Number of leaves plant^{-1}

Number of leaves plant^{-1} at different days after sowing differed significantly at 40 and 70 DAS (Figs. 1c and 1d). Number of leaves plant^{-1} ranged from 7.66 to 32 at 40 DAS and increased in all varieties at 70 DAS, ranging from 13.44 to 34.67. The maximum number of leaves plant^{-1} was produced by the var. BARI sharisha15 at 40 and 60 DAS which was statistically similar to BARI sharisha14 and BARI sharisha17 and the minimum by the BINA sharisha9 which was at par with BINA sharisha4, BARI sharisha16 and BARI sharisha18. Rahman *et al*. (2022) reported the similar findings among the tested varieties of rapeseed-mustard and found the highest leaf number at 45 DAS in BARI sharisha14 (19.3±0.8) and BARI sharisha15 (18.0±0.5) and the highest leaf number at 60 DAS were recorded in BARI sharisha14 (27.3±0.8) and BARI sharisha15 (24.6±0.3). It was revealed that a good number of leaves remain upto harvesting may constitute to higher leaf area index and enhanced photosynthetic activity of plants which eventually contribute to higher yield.

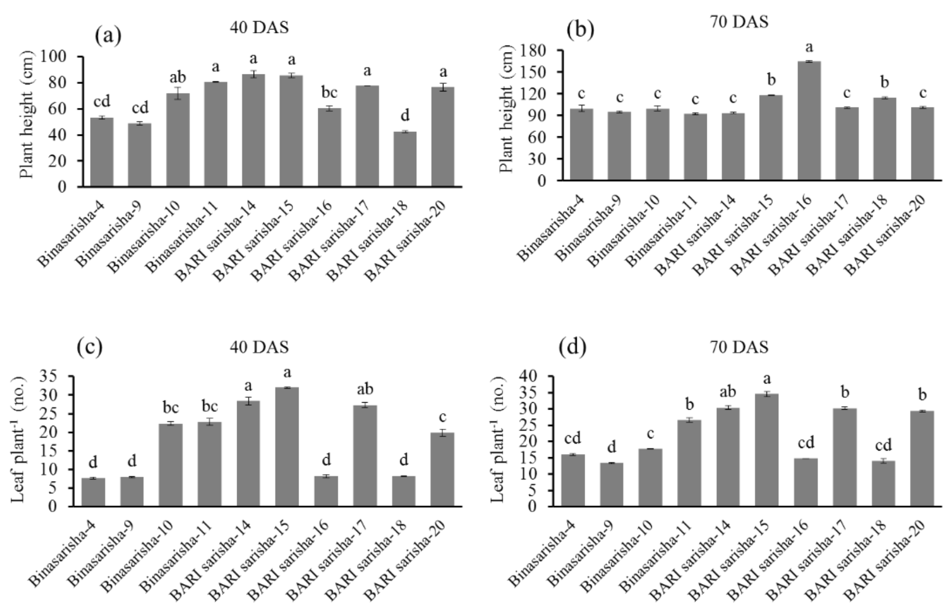

Fig. 1. Plant height and leaf number at different days after sowing (DAS) of different rapeseed-mustard varieties as relay cropping, (a) plant height at 40 DAS and (b) 70 DAS; (c) leaf number at 40 DAS, and (d) 70 DAS. Values labelled with different lower case letters are significantly different at $P < 0.01$.

Leaf area

Significant variation was observed in leaf area at 40 and 70 DAS (Figs. 2a and 2b). Leaf area ranged from 27.13 cm^2 to 80.01 cm^2 at 40 DAS and declined in all varieties at 70 DAS, ranging from 6.78 cm^2 to 65.74 cm^2. The maximum number of area was observed by the var. BARI sharisha16 which was statistically similar to BARI sharisha20 at 40 DAS and the minimum by the BINA sharisha11 which was at par with BARI sharisha15. At 70 DAS, the highest leaf area was found with BARI sharisha16 whereas the lowest with BARI sharisha14 which was at par with BARI sharisha15. The result revealed that leaf area decreased with increasing crop duration. Higher leaf area at vegetative stage contributes to develop deeper root system and helps to uptake more moisture and nutrient whereas the reduced leaf area at flowering and siliquae development stage contribute to reduce transpirational water resulting to enhancing tolerance against drought stress under relay cropping conditions (Chauhan *et al*., 2020). It was stated that leaf area constituted to higher leaf area index and increased photosynthetic activity of plants resulting in higher grain and stover yield.

Leaf area index

Leaf area index is a dimensionless quantity of plant that determined the plant canopy structure. It is used as a tool to predict the light interception, photosynthesis assimilation, and evapotranspiration and contribute to plant growth. Leaf area index varied significantly at 40 and 70 DAS (Figs. 2c and 2d). Leaf area index ranged from 0.69 to 4.55 at 40 DAS and decreased in all varieties at 70 DAS, ranging from 0.51 to 2.43. The maximum leaf area index was observed by the var. BARI sharisha14 which was statistically similar to BARI sharisha20 at 40 DAS and the minimum by the BINA sharisha4 which was statistically at par with BINA sharisha9, BINA sharisha11, BARI sharisha16 and BARI sharisha18. At 70 DAS, the highest leaf area index was found with BARI sharisha16 whereas the lowest with BARI sharisha14. The probable reason may be attributed to genetic characters of BARI sharisha14 at vegetative growth stage and BARI sharisha16 at harvesting stage which has higher capacity to utilized the photosynthetic more efficiently through maximum leaf area index and ultimately the dry matter production, the similar findings have been reported by Singh *et al*. (2017) and Chauhan *et al*. (2020) stated that higher leaf area index constituted to increase higher photosynthetic activity of plants resulting in higher grain and stover yield.

Specific leaf area

Specific leaf area (SLA) is a measure of the leaf area of the plant to leaf dry weight. Significant variation was observed in SLA at 40 and 70 DAS (Figs. 3a and 3b). SLA ranged from 67 cm^2 g^{-1} to 486.05 cm^2 g^{-1} at 40 DAS and decreased in all varieties at 70 DAS, ranging from 42.60 cm^2 g^{-1} to 118.60 cm^2 g^{-1}. The maximum SLA was observed by the var. BARI sharisha14 which was statistically similar to BARI sharisha20 at 40 DAS and the minimum by the BARI sharisha16 which was statistically at par with BINA sharisha4, BINA sharisha9, BINA sharisha11 and BARI sharisha18. At 70 DAS, the highest SLA was found with BINA sharisha10 whereas the lowest with BARI sharisha14, which was statistically at par with BINA sharisha11, BARI sharisha15, BARI sharisha16 and BARI sharisha18. The result revealed that SLA decreased with increasing crop duration.

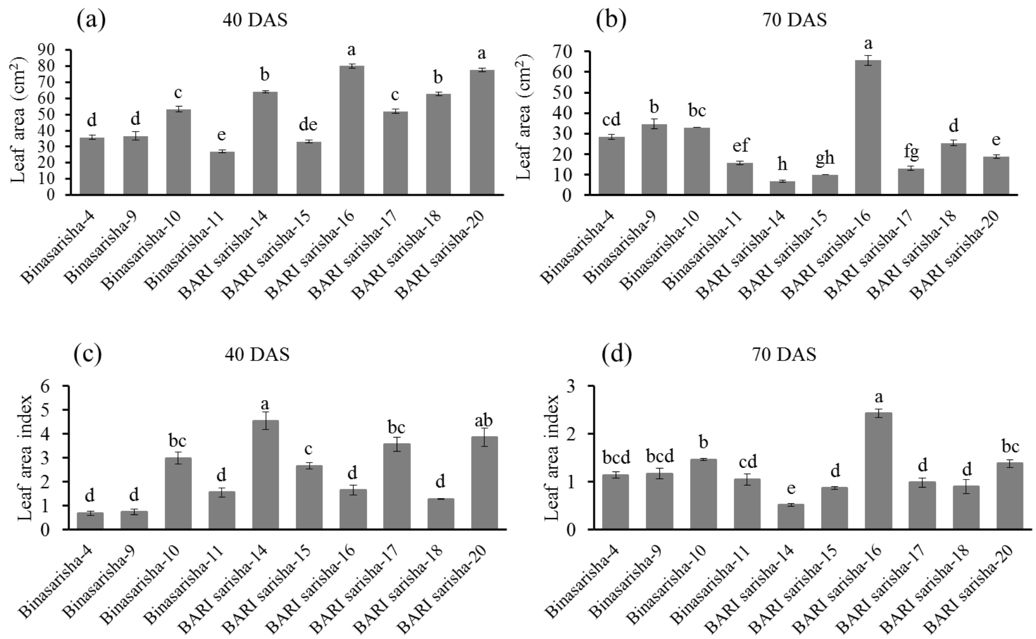

Fig. 2. Leaf area and leaf area index at different days after sowing (DAS) of different rapeseed-mustard varieties as relay cropping, (a) leaf area at 40 DAS and (b) 70 DAS; (c) leaf area index at 40 DAS, and (d) 70 DAS. Values labelled with different lower case letters are significantly different at $P < 0.01$.

Specific leaf weight

Specific leaf weight (SLW) is a measure of the leaf weight per unit leaf area. SLW varied significantly at 40 and 70 DAS (Figs. 3c and 3d). SLW ranged from 0.002 g cm^{-2} to 0.016 g cm^{-2} at 40 DAS and increased in all varieties at 70 DAS, ranging from 0.008 g cm^{-2} to 0.024 g cm^{-2}. The maximum SLW was observed by the variety BARI sharisha16 at 40 DAS and the minimum by the BARI sharisha14 which was statistically similar to BARI sharisha20, BARI sharisha17, BARI sharisha15, BINA sharisha10 and BINA sharisha4. At 70 DAS, the maximum SLW was found with BARI sharisha14 which was statistically at par with BARI sharisha15, BARI sharisha18 and BINA sharisha11 whereas the lowest with BINA sharisha10. The present study stated that SLW increased with increasing crop duration due to the significant reduction in leaf area. Similar result also observed by Akhter *et al.* (2014) and Singh *et al.* (2014) revealed that more SLW per unit leaf area indicated more production of biomass and constituted to increase grain and stover yield.

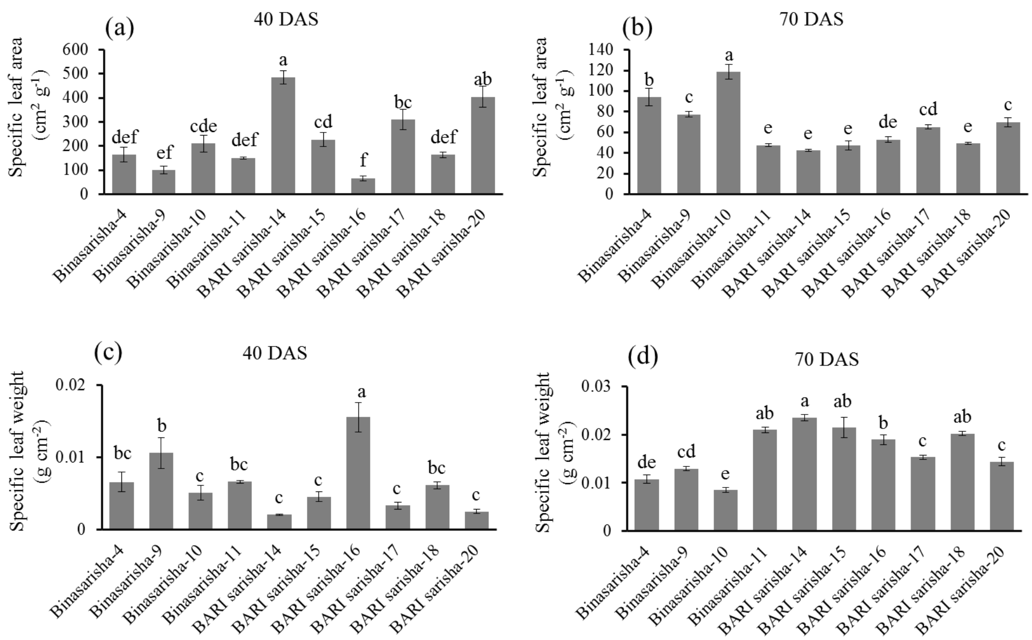

Fig. 3. Specific leaf area and specific leaf weight at different days after sowing (DAS) of different rapeseed-mustard varieties as relay cropping, (a) specific leaf area at 40 DAS and (b) 70 DAS; (c) specific leaf weight at 40 DAS, and (d) 70 DAS. Values labelled with different lower case letters are significantly different at $P < 0.01$.

Leaf fresh weight

Leaf fresh weight (LFW) varied significantly at 40 and 70 DAS (Figs. 4a and 4b). LFW ranged from 0.71 g $leaf^{-1}$ to 8.58 g $leaf^{-1}$ at 40 DAS and increased in all varieties at 70 DAS, ranging from 0.94 g $leaf^{-1}$ to 9.13 g $leaf^{-1}$. The maximum LFW was observed by the var. BARI sharisha16 at 40 DAS and the minimum by the BARI sharisha14 which was statistically similar to BARI sharisha15, BARI sharisha17, BINA sharisha11, BARI sharisha20, BINA sharisha10 and BINA sharisha4. At 70 DAS, the highest LFW was found with BARI sharisha-16 whereas the lowest with BARI sharisha14.

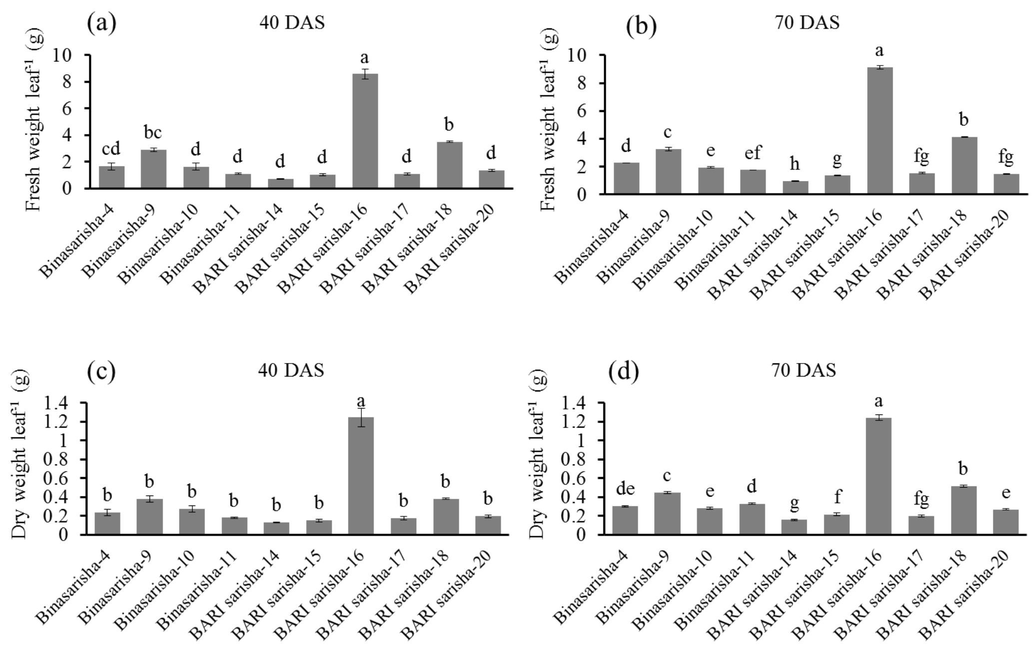

Fig. 4. Fresh weight of leaf area and dry weight of leaf at different days after sowing (DAS) of different rapeseed-mustard varieties as relay cropping, (a) fresh weight of leaf area at 40 DAS and (b) 70 DAS; (c) dry weight of leaf at 40 DAS, and (d) 70 DAS. Values labelled with different lower case letters are significantly different at $P < 0.01$.

Leaf dry weight

Leaf dry weight (LDW) varied significantly at 40 and 70 DAS (Figure 4c and 4d). LDW ranged from 0.13 g $leaf^{-1}$ to 1.24 g $leaf^{-1}$ at 40 DAS and increased in all varieties at 70 DAS, ranging from 0.16 to 1.25 g $leaf^{-1}$. The maximum LDW was observed by var. BARI sharisha16 at 40 DAS and the minimum by the BARI sharisha14 which was statistically similar to all other variety except BARI sharisha16. At 70 DAS, the highest LDW was found with BARI sharisha16 whereas the lowest with BARI sharisha14 which was statistically similar to BARI sharisha17.

Days to flower and growth duration

The days of flower and growth duration of rapeseed-mustard significantly differed among the varieties (Fig. 5). The flowering time ranged between 42-55 DAS and growth duration ranged between 75 DAS to 115 DAS. BARI sharisa14 took minimum days to flowering and mature. The variety BINA sharisha10 also took minimum days to flower and mature. On the other hand BARI sharisha16 and BARI sharisha18 took maximum days to flowering and mature.

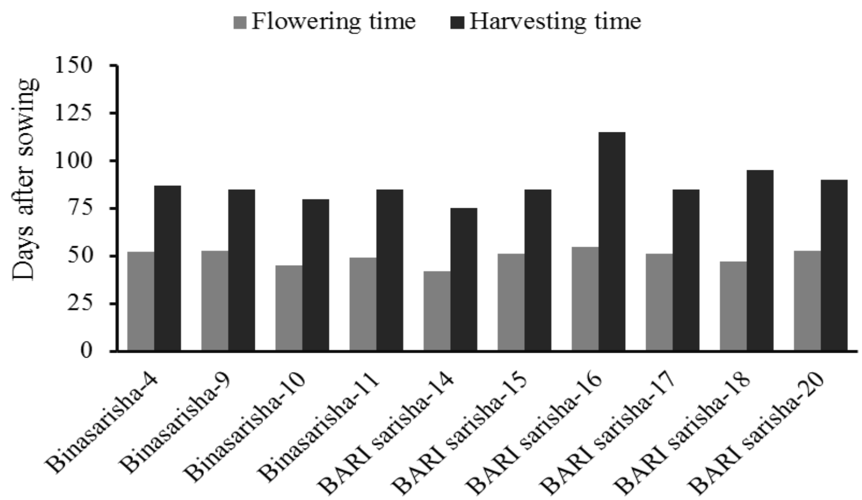

Fig. 5. Days to flower and growth duration of different rapeseed-mustard varieties as relay cropping. Data represent the mean values calculated from three replications of different varieties.

Yield contributing characteristics of rapeseed-mustard

Branch plant^{-1}

Significant variation was observed in number of branches plant^{-1} at harvesting time (Fig. 6a). The number of branches plant^{-1} ranged from 7.22 to 14.22. Improved BINA sharisha10 produced the maximum number of branches plant^{-1} and it was statistically similar to BARI sharisha15, BARI sharisha18, and BARI sharisha20 and BINA sharisha9. On the other hand the lowest branches plant^{-1} was observed from the BINA sharisha4 which was statistically at par with BINA sharisha11 and BARI sharisha17. The result was in agreement by Mamun *et al*., 2014 stated that BARI sharisha15 produced 7.45 branches plant^{-1}. It was also found that BINA sharisha10 produced maximum 6.60 branches plant^{-1} whereas minimum branches plant^{-1} produced by the variety of BINA sharisha4 (Sohel *et al*., 2024).

Siliqua plant^{-1}

Significant variation was found in the number of siliqua plant^{-1} among the varieties (Fig. 6b). The number of siliqua plant^{-1} ranged from 57.89 to 211.22. The maximum number of siliqua plant^{-1} was produced by the variety BARI sharisha16 followed by the variety BINA sharisha10 which was statistically similar to BARI sharisha18. On the other hand the lowest siliqua plant^{-1} was produced by the variety BARI sharisha17 and it was statistically similar to BARI sharisha20 and BARI sharisha15. Similar results were observed by Rahman *et al*. (2022). Laila (2014) also found the highest number of siliqua plant^{-1} produced by the var. BARI sharisha16 (143.7). Yadav *et al*. (2010) suggested that for ensuring high yields in *B. juncea* (BARI sharisha16), the plant type should have more number of siliqua plant^{-1} (100-125).

Seeds siliquae^{-1}

Significant variation was observed in terms of number of seeds siliquae^{-1} among all the varieties (Fig. 6c). The number of seeds siliquae^{-1} ranged from 14.13 to 34.73. The maximum number of seeds siliquae^{-1} was produced by the var. BINA sharisha11 (34.73) and it was statistically identical to the var. BINA sharisha4 (34.47) and BARI sharisha12 (30.87). The minimum number of seeds siliquae^{-1} was produced by the var. BARI sharisha16 (14.13) and it was statistically similar to the var. BINA sharisha10 (16.26).

1000-seed weight

In case of 1000-seed weight, a significant variation was found among all the varieties (Fig. 6d). The 1000-seed weight ranged from 3.58 g to 4.73 g. The maximum 1000-seed weight (4.73 g) was recorded in the var. BARI sharisha14 which was statistically similar to BARI sharisha20 (4.63), BARI sharisha16 (4.50) and BARI sharisha17 (4.47). The minimum 1000-seed weight was observed from the var. BINA sharisha4 (3.58) and it was statistically identical with BINA sharisha11 (3.87). Previous results observed that the maximum 1000-seeds weight was produced in BARI sharisha14 followed by BARI sharisha16, BARI sharisha17 and BARI sharisha20 among the other varieties. The present study is in agreement with previous results by Helal *et al*., (2016), Sohel *et al*., (2024) and Rahman *et al*. (2022).

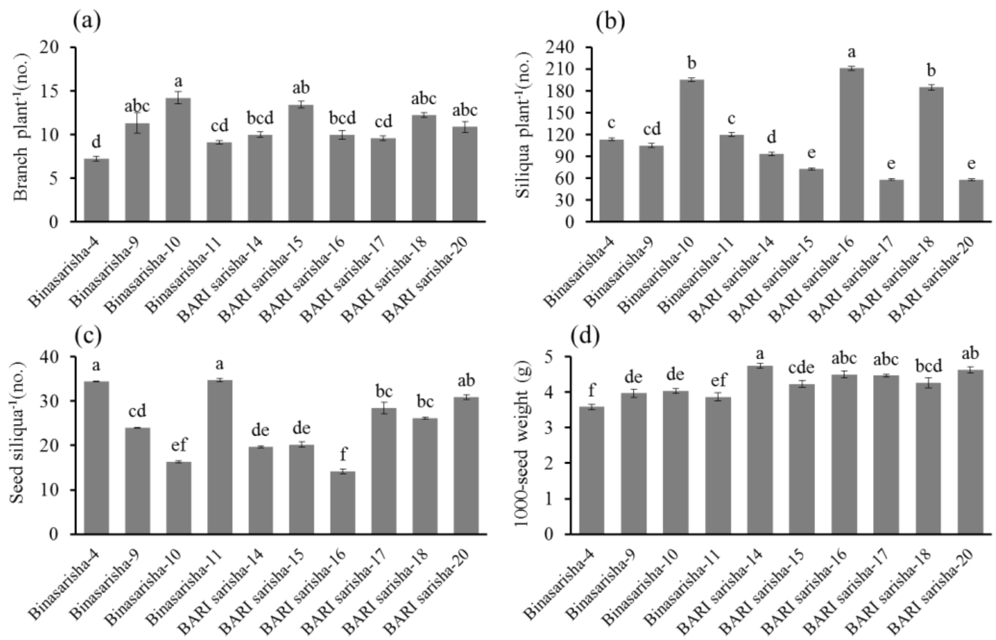

Fig. 6. Yield contributing characteristics of different rapeseed-mustard varieties as relay cropping, (a) number of branch plant^{-1}; (b) number of siliqua plant^{-1}; (c) number of seeds siliqua^{-1}; and (d) 1000-seed weight. Values labelled with different lower case letters are significantly different at $P < 0.01$.

Yield of rapeseed-mustard

Seed yield

The seed yield of rapeseed-mustard varieties was differed significantly as relay cropping (Fig. 7a). Seed yield was ranged from 0.61 t ha^{-1} to1.10 t ha^{-1}. The mustard var. BARI sharisha16 produced the maximum seed yield (1.10 t ha^{-1}) followed by BARI sharisha17 (0.90 t ha^{-1}) and BARI sharisha15 (0.85 t ha^{-1}). The lowest seed yield was observed from the var. BINA sharisha9 (0.61 t ha^{-1}) and it was statistically similar to BINA sharisha4 (0.62 t ha^{-1}) and BARI sharisha18 (0.62 t ha^{-1}).

Stover yield

The stover yield of rapeseed-mustard varieties was differed significantly as relay cropping (Fig. 7b). Stover yield ranged from 3.56 t ha^{-1} to 5.86 t ha^{-1}. The variety BARI sharisha16 produced the maximum seed yield (5.86 t ha^{-1}) followed by the variety BARI sharisha17 (5.28 t ha^{-1}) whereas lowest stover yield was found from BINA sharisha11 (3.56 t ha^{-1}).

Biological yield

The biological yield of rapeseed-mustard varieties was varied significantly as relay cropping (Fig. 7c). Biological yield ranged from 4.33 to 6.95 t ha^{-1}. The variety BARI sharisha16 produced the maximum seed yield (6.95 t ha^{-1}) followed by var. BARI sharisha17 (5.28 t ha^{-1}). The lowest stover yield was found from BINA sharisha11 (4.32 t ha^{-1}) and it was statistically at par to BINA sharisha10.

Harvest index

The harvest index (HI) of rapeseed-mustard varieties was varied significantly as relay cropping (Fig. 7d). HI ranged from 13.18% to 18.63%. The var. BINA sharisha11 produced the maximum HI (18.63%) and it was statistically similar to BARI sharisha14 (18.15%), BARI sharisha17 (17.63%), BARI sharisha20 (16.54%), BARI sharisha15 (16.33%) and BINA sharisha10 (16.15) followed by var. BARI sharisha17 (5.28 t ha^{-1}). The lowest HI was found from BINA sharisha4 (13.17%) and it was statistically similar to BINA sharisha9 (13.19%).

The present study indicated variation of production of seed and stover yield by different varieties. This might be due to the contribution of cumulative effects of the crop growth and yield contributing characteristics such as leaf number, leaf area index, number of branches $plant^{-1}$, siliquae $plant^{-1}$ and seeds $siliqua^{-1}$, 1000-seed weight, etc. In the study, the variety BARI sharisha16 produced the highest seed yield (1.10 t ha^{-1}) which might be due to the highest leaf area, leaf area index, leaf fresh and dry weight, leaf specific weight, siliqua $plant^{-1}$, and 1000-seed weight. The highest stover yield produced by BARI sharisha16 also influenced by the highest plant height, leaf area, leaf area index, leaf fresh and dry weight, and leaf specific weight. Similar higher seed and stover yield were reported by Rahman *et al*. (2022) and Sarker *et al.* (2018) in var. BARI sharisha16.

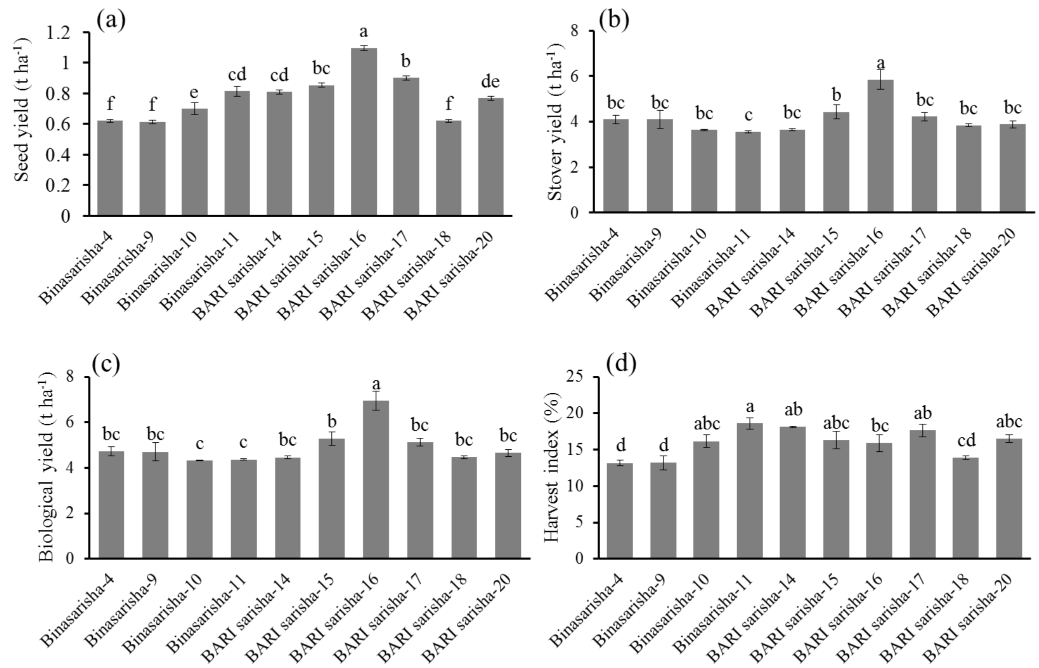

Fig. 7. Yield of different rapeseed-mustard varieties as relay cropping, (a) seed yield (t ha^{-1}); (b) stover yield (t ha^{-1}); (c) biological yield (t ha^{-1}); and (d) harvest index (%).Values labelled with different lower case letters are significantly different at $P < 0.01$.

Correlation between yield with growth and yield contributing characters

Correlation between seed yield and yield contributing attributes of different rapeseed-mustard varieties are presented in Table 2.It appears that seed yield was significantly and positively correlated with plant height, leaf number, leaf fresh and dry weight, leaf area, leaf area index, days to growth duration, 1000-seed weight and stover yield which indicated that seed yield would increase with the increase growth and yield attributes parameters. Stover yield was also significantly and positively correlated with plant height at 70 DAS, leaf fresh and dry weight, leaf area, leaf area index, specific leaf area, days to flowering and growth duration and seed yield which indicated that stover yield would increase with the increase of these growth and yield attributes. It was reported that seed and stover yield significantly and positively correlated with number of siliquae $plant^{-1}$, 1000-seed weight, stover yield, plant height, biological yield and harvest index as reported by Aytaç and Kınacı (2009), Akter *et al*. (2020) and Helal *et al*. (2022).

Table 2. Pearson's correlations between various growth, yield contributing and yield parameters of different mustard/rapeseed varieties under T. Aman-mustard relay cropping at a significance level less than ≤ 0.05.

Traits	PH70	LN40	LN70	LDW40	LDW70	LFW40	LFW70	LA40	LA70	LAI40	LAI70	SLA40	SLA70	SWL40	SWL70	BN	NS	SS	TSW	FT	HT	SY	StY	BY	HI
PH 40	-0.18	0.89	0.84	-0.35	-0.43	-0.45	-0.49	-0.03	-0.53	0.75	-0.24	0.57	-0.25	-0.46	0.32	0.08	-0.47	-0.09	0.38	-0.29	-0.42	0.44	-0.16	-0.07	0.72
PH70		-0.30	-0.26	0.86	0.87	0.86	0.87	0.50	0.71	-0.18	0.70	-0.42	-0.29	0.65	0.24	0.10	0.53	-0.52	0.27	0.45	0.88	0.66	0.76	0.79	-0.05
LN 40			0.87	-0.53	-0.60	-0.61	-0.64	-0.14	-0.70	0.78	-0.46	0.62	-0.22	-0.62	0.32	0.19	-0.52	-0.09	0.36	-0.42	-0.57	0.29	-0.27	-0.19	0.64
LN70				-0.53	-0.56	-0.59	-0.61	-0.09	-0.73	0.69	-0.42	0.67	-0.38	-0.63	0.40	0.02	-0.72	0.12	0.41	-0.18	-0.44	0.34	-0.19	-0.10	0.62
LDW40					0.96	0.98	0.95	0.48	0.87	-0.32	0.79	-0.56	-0.12	0.88	0.08	-0.06	0.64	-0.49	0.16	0.45	0.87	0.53	0.76	0.76	-0.18
LDW70						0.98	0.99	0.45	0.90	-0.41	0.82	-0.60	-0.17	0.85	0.11	-0.07	0.68	-0.41	0.11	0.49	0.93	0.51	0.71	0.72	-0.17
LFW40							0.98	0.49	0.89	-0.39	0.77	-0.60	-0.14	0.87	0.08	-0.03	0.68	-0.46	0.14	0.46	0.91	0.46	0.74	0.74	-0.25
LFW70								0.46	0.91	-0.44	0.79	-0.60	-0.14	0.82	0.07	-0.07	0.70	-0.43	0.10	0.47	0.92	0.46	0.72	0.72	-0.24
LA40									0.37	0.44	0.43	0.30	-0.13	0.07	0.08	0.05	0.27	-0.40	0.72	0.01	0.49	0.38	0.31	0.34	0.10
LA70										-0.48	0.90	-0.65	0.25	0.81	-0.30	-0.03	0.73	-0.41	-0.10	0.49	0.80	0.28	0.64	0.61	-0.36
LAI40											-0.25	0.85	-0.14	-0.61	0.20	0.13	-0.41	-0.22	0.70	-0.44	-0.39	0.31	-0.19	-0.11	0.58
LAI70												-0.48	0.25	0.66	-0.31	-0.04	0.55	-0.34	0.04	0.58	0.79	0.48	0.65	0.66	-0.13
SLA40													-0.13	-0.80	0.16	-0.06	-0.57	0.04	0.57	-0.47	-0.53	0.02	-0.37	-0.32	0.42
SLA70														-0.05	-0.95	0.08	0.20	-0.01	-0.44	0.01	-0.21	-0.45	-0.13	-0.20	-0.40
SWL40															-0.01	-0.05	0.56	-0.30	-0.18	0.52	0.71	0.29	0.65	0.62	-0.34
SWL70																0.00	-0.09	-0.12	0.44	-0.23	0.10	0.43	0.04	0.11	0.48
BN																	0.21	-0.49	0.09	-0.23	-0.10	-0.07	-0.08	-0.09	0.01
NS																		-0.47	-0.15	-0.12	0.52	0.06	0.26	0.24	-0.21
SS																			-0.37	0.18	-0.23	-0.40	-0.39	-0.41	-0.06
TSW																				-0.15	0.14	0.48	0.13	0.20	0.41
FT																					0.64	0.27	0.58	0.56	-0.30
HT																						0.51	0.75	0.75	-0.21
SY																							0.60	0.71	0.56
StY																								0.99	-0.33
BY																									-0.19

Red indicates negative correlation, and blue indicates positive correlation. Plant height (PH); Leaf number (LN); Leaf fresh weight (LFW); Leaf dry weight (LDW); Leaf area (LA); Chl (Chlorophyll SPAD value); Specific leaf area (SLA); Specific leaf weight (SLW); Branch number (BN); Number of siliqua (NS); Seed per siliquae (SS); Thousand seed weight (TSW); Flowering time (FT); Harvesting time (HT); Seed yield (SY); Straw yield (StY); Biological yield (BY) and Harvest index (HI).

Conclusion

The yield contributing characteristics and yield indicated that the mustard var. BARI sharisa16 performed the highest yield and followed a trend as var. BARI sharisha17>BARI sharisa15>BARI sharisa14>BINA sharisha11. These varieties showed higher number of leaf plant^{-1}, leaf area, leaf area index, 1000-seed weight, siliqua plant^{-1}, and seeds siliquae^{-1}. However, crop duration is an inevitable part of *Brassica* oilseed crop in Bangladesh. Generally short duration varieties are preferable to the farmers of Bangladesh as these can be fitted in rice-based cropping pattern. Although BARI sharisha16 has a high yield potential, farmers are hesitant to adopt it as a relay crop with T. Aman rice due to its long growth duration. In contrast, BARI sharisha14, BARI sharisha15, BARI sharisha17, and BINA sharisha11 mature within 75-80 days and could be potentially well-suited as relay cropping with the T. Aman. Considering overall yield and crop duration, the mustard varieties BARI sharisa14, BARI sharisha15, BARI sharisha17 and BINA sharisha11 are suited as relay cropping with T. Aman rice.

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Conflicts of interest

The authors declare no conflicts of interest regarding publication of this manuscript.

Authors' contribution

Conceptualization, Supervision, Writing-original draft: AAFB and MH, Data curation: MNS and FI; Formal analysis: MNS and MH; Funding acquisition: MH; Investigation: FA and MM; Methodology: MAB and SMM; Resources: FA, MAB and MMB; Validation: FI and SMM; Visualization: FI, MH; Review and editing: SMM, MAB, MH.

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