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Evaluation of Rapeseed-mustard Genotypes and Their Genetic Variabilities in Different Sowing Dates

Md. Habibul Islam[A], Muhammad Salim[A], Ahmed Khairul Hasan[A], Rehenuma Tabassum[B], Farhana Khatun Ousro[A], Ishak Hosen[A], Mst Maiful Akter Dina[C] and Fakhrul Islam Monshi[C]*

[A] Department of Agronomy, Faculty of Agriculture, Bangladesh Agricultural University, Mymensingh, Bangladesh
[B] Department of Crop Botany and Tea Production Technology, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh
[C] Department of Genetics and Plant Breeding, Faculty of Agriculture, Sylhet Agricultural University, Sylhet, Bangladesh

*Corresponding author; e-mail: monshifi.gpb@sau.ac.bd

Abstract

Rapeseed-mustard is an important oilseed species with high nutritional and economic values, and it's popularity increases due to its diverse uses. Ten genotypes of rapeseed-mustard and two sowing dates were evaluated in a split plot design with three replications. Our study demonstrated that sowing dates and genotypes greatly influenced the growth parameters, yield, and it contributing characters. BARI sarisha-16 had the highest yield (1613 kg.ha^{-1}) whereas Binasarisha-9 yielded the lowest yield (840 kg.ha^{-1}). All the yield contributing characters was superior in the earlier (10 November, S_1) sowing date than the 24 November (S_2), demonstrated by the highest grain yield (1120 kg.ha^{-1}) which was 10 % higher than the seed sown on 24th November (S_2) (1025 kg.ha^{-1}), and better higher vegetative growth. These results affirmed that the yield contributing traits resulted the higher seed yield. In most of the studied characters, the higher phenotypic variances were observed than that of its genotypic variances. The significant positive correlation with grain yield were found in plant height, number of primary branches/ plants, number of siliqua/plants, siliquae length, number of seed per siliquae, days of 50% flowering to maturity and 1000 seed weight. Therefore, based on the yield and the related traits, BARI sarisha-16 can be used for further utilization.

Keywords: Rapeseed-mustard, genetic variability, growth parameter, yield contributing character, correlation.

Introduction

Rapeseed-mustard, a well-known oil crop in Bangladesh, plays a significant role in the national economy by providing edible oils, vegetables, condiments and animal feed (Chand et al., 2021). It ranks first among all oil crops in Bangladesh in terms of cultivation area (64.64%) and oilseed output (36.8%). In Bangladesh, 309,253 ha of land was under rapeseed and mustard cultivation during 2019-2020 which produced about 358,240 ton of seed and average yield of 1.15 t.ha^{-1} (BBS, 2020). Among the sources of edible oils in the world, rapeseed-mustard occupied third position after palm and soybean (Dina et al., 2019). Rapeseed oil is high in energy, vitamins A, D, E, and minerals K, Ca and Mn (Filho et al., 2018). Thus, its cultivation has risen significantly in most parts of the world over the last few decades (Filipova et al., 2017).

Cultivation of low yielding local varieties and late sowing are the major causes for poor yield of rapeseed-mustard in Bangladesh (Malek et al., 2012; Sharif et al., 2016). Sowing at proper time allows sufficient growth and development of a crop to obtain a satisfactory yield (Ali et al., 2016; Sarker et al., 2021; Yesmin et al., 2022). Major cropping pattern in Bangladesh is *T Aman-Fallow-Boro* rice which occupies more than 45% area (Hossain et al., 2009; Khatun et al., 2019). Usually, farmers keep their land fallow rather than cultivation of rapeseed-mustard after harvest of *T Aman* to avoid the risk of delaying cultivation of *Boro* rice. The turn-around date between *T Aman* and *Boro* is about 80-85 days. This stipulated date may be utilized through cultivation of short duration high yielding varieties of rapeseed-mustard in between *T Aman* and *Boro* rice (Talukder et al., 2020); will increase cropping intensity simultaneously as well as accelerating the oil seed production in Bangladesh. Therefore, development of short duration high yielding rapeseed-mustard variety is essential to fulfill the edible oil demand in Bangladesh.

Suitable sowing date is very crucial for optimal agronomic performance of rapeseed-mustard (Alam et al., 2015; Hashim and Mahmood, 2021). Sowing in the correct time help the crops to survive in the diverse environmental condition which ensure proper growth and development and yield stability (Biswas et al., 2019; Hossain et al., 2017; Tabassum et al., 2021). In Bangladesh, rapeseed mustards are usually sown by the end of September to mid of October (Ferdous et al., 2017; Monshi and Malek, 2013). However, with the development of new varieties of rapeseed-mustard and adoption of multiple cropping systems, it has become essential to extend their sowing from late October to mid of November, or even later. However, delayed sowing would adversely affect the crop performance due to changes in abiotic and biotic environmental conditions (Bikshapathi et al., 2021; Sarker et al., 2016; Tabassum et al., 2015). So, emphasis should be given to develop environmentally suited rapeseed-mustard varieties to strengthen its productivity.

Seed yield is one of the complicated characters that can be determined by a genotypic factor which could have positive or negative impacts on these characters (Kayacetin, 2019; Saroj et al., 2021). Determination of correlation coefficients is important to evaluate breeding programs for high yield, as well as to examine direct and indirect contributions to yield variables (Chandra et al., 2018; Parvin et al., 2020). The present study was undertaken with the following objectives (i) to identify the suitable rapeseed and mustard genotype, (ii) to assess the effect of sowing date on growth, yield contributing characters and yield of rapeseed-mustard and (iii) to analyze the genotypic variability of rapeseed-mustard for growth, yield contributing characters and yield.

Materials and Methods

Soil and Climate of the Experimental Site

The experimental site is located at 24°25”N latitude and 90°50”E longitude. The experimental field was medium high land with silty clay loam soil having pH value of 6.50. Soil contains 1.67% organic matter, 0.10% total nitrogen, 26 ppm available phosphorus, 13.90 ppm available Sulphur, and 0.14 ppm exchangeable potassium. The climate of the experimental area is sub-tropical which is characterized by high temperature and heavy rainfall during *kharif* season (April to September) and scanty rainfall associated with moderately low temperature but high light intensity during October to March (*rabi season*) (Table 1). In Bangladesh, usually in the 1st week of November, the temperature, rainfall, relative humidity and sunshine starts to become lower up to the end of January (Table 1), which hamper the proper plant growth. Therefore, the present study was conducted at the location of Agronomy Field, Bangladesh Agricultural University, Mymensingh, Bangladesh, to determine if two sowing dates affect seed yields.

Experimental Materials

The experiment was conducted to evaluate the 10 rapeseed-mustard genotypes grown in the two different sowing dates, and to characterize their genetic variability. Seven genotypes (Tori-7, Sompo, BARI sarisha-9, BARI sarisha-12, BARI sarisha-14, BARI sarisha-15 and BARI sarisha-16) were collected from Bangladesh Agricultural Research Institute (BARI), two advanced lines (BAU Advanced line 1 and BAU Advanced line 2) from Bangladesh Agricultural University (BAU), and Binasarisha-9 from Bangladesh Institute of Nuclear Agriculture (BINA), Bangladesh.

Experimental Design

Two factorial (sowing date and genotypes) experiments were laid out in a split plot design with three replications where sowing date was assigned in the main plot and genotype was assigned in the sub-plot. Total experimental area was 60 x 5= 350m^2. Each plot size was 5 m^2 (2.5 m x 2 m) and the distance between replications was 1 m. The spacing between rows was 30 cm. Seeds were sown in line in the experimental plots on 10 November and 24 November 2019 (as two different sowing dates). The crop was fertilized as the rate of 10 tons.ha^{-1} of cow dung, urea 250 kg.ha^{-1}, triple super phosphate (TSP) 170 kg.ha^{-1}, muriate of potash (MoP) 85 kg.ha^{-1}, gypsum 150 kg.ha^{-1}, and boric acid 10 kg.ha^{-1}. Irrigation, weeding, thinning, and pest management were conducted uniformly as per the requirement.

Collection of Experimental Data

The crop was harvested when 80% had reached maturity. Harvesting was started on 2nd February to 15th February for 10 November (S_1) sowing date, and 20th to 28th February 2020 depending upon the maturity. Five plants were randomly selected from 10 genotypes in each replication. The data on morphological parameters include plant height (cm), no. of primary branches per plant, days to flowering, no. of siliqua per plant, siliqua length (cm), no. of seeds per siliqua, 1000-seed weight (g) and grain yield (kg.ha^{-1}) were collected from the five selected plants. The leaf area index (LAI) and crop growth ratio (CGR) were analyzed using Hunt (1978) formula:

Leaf area index (LAI) = $\frac{LA}{P}$

where
LA = Total leaf area of the leaves of all sampled plants (cm^2)
P = Area of the ground surface covered by the plant (cm^2)

growth rate (CGR): CGR =$\frac{W2-W1}{T2-T1} \times \frac{1}{GA} gm^{-2}d^{-1}$

where
W_1 =Dry weight at first harvest (gm^{-2})
W_2 =Dry weight at second harvest (gm^{-2})
GA =Ground area
T_1 and T_2 =Intervals of time

Five plants were randomly taken from the outside of harvest area at 20, 40, 60 DAS (days after sowing) to determine the total dry matter (DM) which were dried in the oven at $85+50^0$C for 72 hours.

Statistical Analysis

The data were analysed using R-Studio statistical software; differences among the treatment means were compared by Duncan's New Multiple Range Test (Gomez and Gomez, 1984) at the 5% significance level.

Estimation of Genetic Parameters

Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variance was estimated according to the formula by Johnson *et al.* (1955).

Genotypic variance, $\sigma^2{}_g = \frac{\text{GMS}-\text{EMS}}{\text{r}}$

where
GMS= genotypic mean square
EMS= error mean square
r= number of replication

Phenotypic variance, $\sigma^2{}_p = \sigma^2{}_g + \text{EMS}$

Where
$\sigma^2{}_g$ = genotypic variance
EMS= error mean square

Genotypic and phenotypic co-efficient of variation were determined using the formula by Burton (1952).

GCV= $\frac{\delta_{g\,x\,100}}{x}$

PCV= $\frac{\delta_{p\,x\,100}}{x}$

where,

GCV = genotypic co-efficient of variation
PCV = phenotypic co-efficient of variation
δ_g = genotypic standard deviation
δ_p = = phenotypic standard deviation
$\bar{x}$= population mean

Estimation of heritability

Heritability in broad sense was estimated according to Singh and Chaudhary (1985).

$h^2{}_b(\%)= \frac{\delta^2{}_g}{\delta^2{}_p}$ x100

where, $h^2{}_b$= heritability in broad sense
$\delta^2{}_g$=genotypic variance
$\delta^2{}_p$=phenotypic variance

Estimation of genetic advance

Expected genetic advance for different characters were measured by Allard (1960).

GA= $\frac{\delta^2{}_g}{\delta^2{}_p} K.\delta^2{}_p$

where
GA=genetic advance
$\delta^2{}_g$=genotypic variance
$\delta^2{}_p$=phenotypic variance
K = selection differential which is equal to 2.06 at 5% selection intensity.

Estimation of genetic advance in percentage of mean

The percentage of mean of genetic advance was calculated by Comsiock and Robinson (1952).

Genetic advance = $\frac{\text{Percentage of mean of genetic advance}}{\bar{x}}$ x100

Estimation of genotypic and phenotypic correlation coefficient

The genotypic and phenotypic correlation coefficient for all possible combinations were adopted by Johnson et al. (1955).

Genotypic correlation (r_{gxy}) =$\frac{\sigma^2{}_{gxy}}{\sqrt{(\sigma^2{}_{gx} \times \sigma^2{}_{gy})}}$

where
$\sigma^2{}_{gxy}$ = genotypic covariance between the traits x and y
$\sigma^2{}_{gx}$ = genotypic variance of the trait x
$\sigma^2{}_{gy}$= genotypic variance of the trait y

Phenotypic correlation (r_{pxy}) =$\frac{\sigma^2{}_{pxy}}{\sqrt{(\sigma^2{}_{px} \times \sigma^2{}_{py})}}$

where
$\sigma^2{}_{pxy}$ = phenotypic covariance between the traits x and y
$\sigma^2{}_{px}$ = phenotypic variance of the trait x
$\sigma^2{}_{py}$ = phenotypic variance of the trait y

Results and Discussion

There were significant differences among the mustard-rapeseed genotypes in the two sowing dates. In the 1st sowing date (10th November), all the plants had a better vegetative as well as reproductive growth, which enhanced the yield attributing traits than those planted on the 2nd sowing date (24th November). However, in the 1st sowing date, the genotypes had a wider maturity duration of 13 days (86-99 days) whereas in the 2nd sowing dated genotypes was 7 days (91-98 days). Rapeseed genotypes sown on the 2nd sowing date had poorer vegetative growth compared to those sown on the 1st sowing date, resulting the lower yield and yield attributing traits.

Leaf Area Index (LAI)

Leaf area index of rapeseed-mustard was affected by different sowing time and genotypes. The highest leaf area Index (2.89) at 40 DAS was found in the 10 November sowing and the lowest (0.46) was in the 24 November sowing at 20 DAS (Figure 1). This result indicated that LAI become higher when sown early; similar results were reported by Sharif et al. (2016). After sowing, LAI was continuously risen until 40 DAS and then started declining (Figure 1). The difference in LAI may be due to the variation in leaves number, their expansion and abscission. This result is consistent with the result found by Banerjee et al. (2017) and Hashim and Mahmood (2021). Leaf area index variation occurred due to variation of genotypes. The highest leaf area index was found from BARI sarisha-16 (4.5) at 40 and the lowest was observed from BAU Advanced line 1 (0.49) at 20 DAS (Figure 1).

Total Dry Matter/Plant

Different sowing dates had significant effect on the above ground dry matter (Table 2); the total dry matter (TDM) was continuously increased until maturity, and risen to highest at 60 DAS. Similar results were obtained in the studied genotypes of mustard-rapeseed by Ahmed et al. (2019) and Kumar et al. (2022). Total dry matter accumulation is higher for 1st sowing than 2nd sowing, so early sowing of mustard can be suggested. The total dry matter per plant had significant differences due to variation of genotypes.

Crop Growth Rate (CGR)

At primary stages of growth, the crop growth rate was slow (0.011 at 20-40 DAS) because in that time the plant coverage was low, and the plants can absorb a part limited of solar radiation. But as plant grows, LAI become higher and crop growth increased quickly and reached its peak (0.08) (Table 2). Kumar et al. (2018) and Ray et al. (2014) stated that late sowing caused a slow growth rate due to insufficient vegetation cover, low amount of sunlight absorption and heat during end of the growing season.

Days to Emergence

Days to emergence of mustard was significantly affected by sowing date. It took 4 days and 6 days to emergence of mustard seed in the 1st sowing and 2nd sowing date, respectively (Table 3). There were no significance differences between genotypes, that means all genotypes had a similar time to emergence (Table 3). Malek et al. (2012) and Sharif et al. (2016) found the similar results in which all the seeds in their studied mustard-rapeseed genotypes emerged at the same time.

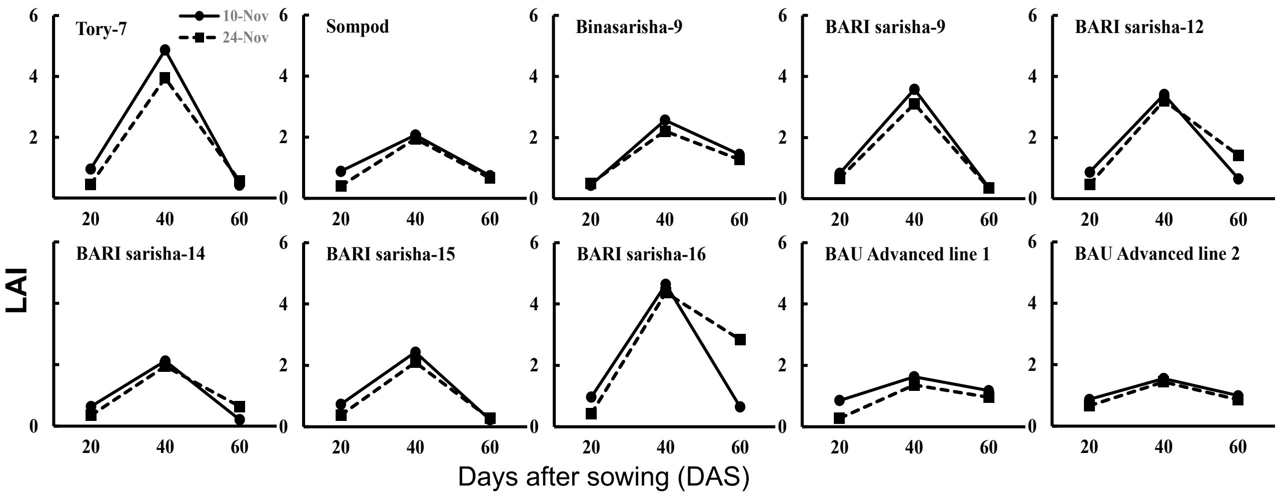

Figure 1. Leaf area index of rapeseed-mustard at different days after sowing as influenced by sowing dates (November 10 and November 24) and genotypes.

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Table 1. Monthly average air temperature, rainfall, relative humidity and day light duration at the experimental site during November 2019 to February 2020

Time	Air temperature (^{0}C)			Rainfall (mm)	Relative humidity (%)	Day light duration (hours)
	Maximum	Minimum	Average			
November 2019	29.50	18.10	23.40	1.00	81.00	204.8
December 2019	27.50	14.60	21.10	0.00	81.40	180.30
January 2020	25.08	12.85	19.40	0.00	76.74	168.90
February 2020	28.30	15.81	22.08	0.20	74.71	157.20

Source: Weather Yard, Department of Irrigation and Water Management, Bangladesh Agricultural University, Mymensingh, Bangladesh

Table 2. Summary of the analysis of variance (mean square) for dry matter (g) and crop growth rate (CGR) of 10 rapeseed-mustard cultivars in two sowing dates, 2020.

Source of variation	df	Dry matter (g)			Crop growth rate (CGR)	
		20	40	60	20-40	40-60
Replication	2	0.012	0.005	0.214	0.00001	0.000
Sowing date (A)	1	0.011^{ns}	0.370^{*}	2.869^{*}	0.00063^{ns}	0.001^{ns}
Genotype (B)	9	0.023^{**}	4.807^{**}	37.252^{**}	0.01130^{**}	0.081^{**}
A x B	9	0.001^{ns}	0.003^{ns}	0.071^{ns}	0.00001^{ns}	0.000^{ns}
Residual	36	0.003	0.013	0.369	0.00010	0.001
Mean		0.44	3.02	11.36	0.13	0.42
CV (%)		12.58	3.82	4.39	7.49	7.54

Notes: ** = significant at 1% level of probability, *= significant at 5% level of probability, ns= non-significant

Days to Emergence to 50% flowering

Sowing date significantly affected days to emergence to 50% flowering (P=0.01, Table 3). The minimum days required for emergence to 50% flowering was from 10 November (Table 3). Akhter et al. (2016) and Kumar et al. (2022) stated that the difference in seeding date positively influenced the flowering time and delayed sowing can lessen the flowering time. The minimum and maximum days required for emergence to 50% flowering was recorded from Tori-7 (32.0) and BARI sarisha-16 (43.5), respectively (Table 3). This variation among genotypes were due to the genetical as well as environmental effects.

Days to 50% Flowering to Maturity (days)

Sowing date significantly affected days to 50% flowering to maturity (P<0.01,Table 3). By comparing the data from Table 3, it was clear that days required from 50% flowering to maturity was more in case of early sowing than delayed sowing. The minimum and maximum days required for 50% flowering to maturity was recorded from Tori-7 (44 days) and BARI sarisha-12 (53 days) (Table 3). Interaction effect of genotype and sowing date showed statistically significant on 50% flowering to maturity (Table 3). These findings are corroborated with the findings of Alam et al. (2015) and Jiotode et al. (2017).

Plant Height

Plant height of rapeseed-mustard was significantly influenced by sowing dates (P=<0.01). The taller plant was recorded from plants sown on the 10 November (92.71 cm) compared to those sown in 24 November (86.53 cm, Table 4). Thermal and photosensitivity of oil seed crop can hamper the sowing period; delayed sowing changes the physiological mechanisms upon retarding the cell division and enlargement due to chilling temperature. The present results were corroborated with the results of Azam et al. (2018), Nazeri et al. (2018) and Singh et al. (2017) who reported that too early or too delayed sowing can decrease the plant height. The tallest plant was recorded in BARI sarisha-16 (157.6 cm) (Table 4).

Number of Primary Branches/Plant

Different sowing dates significantly affectedthe number of primary branch/plant (P<0.01). The highest number of primary branch/plant was recorded in 10 November (5.31) and lowest was from 24 November (3.99) (Table 4). This could happened due to prolonged vegetative growth period with favorable

Table 3. Effect of sowing date, genotype and their interaction on emergence, 50% flowering, maturity and total growth (days) of rapeseed-mustard

Genotype	Sowing date							
	Nov 10th	Nov 24th	Nov 10th	Nov 24th	Nov 10th	Nov 24th	Nov 10th	Nov 24th
	Emergence (days)		50% Flowering (days)		Maturity (days)		Total growth (days)	
Tori-7	4.0	6.0	32.0	35.0	46.0ef	44.0g	82.0	85.0
Sompod	4.0	6.0	34.0	36.0	47.0de	45.0fg	85.0	87.0
Binasarisha-9	4.0	6.0	34.0	36.0	46.0ef	45.0fg	84.0	87.0
BARI sarisha-9	4.0	6.0	34.0	36.0	49.0c	46.0ef	87.0	88.0
BARI sarisha-12	4.0	6.0	40.0	43.0	53.0b	49.0c	97.0	98.0
BARI sarisha-14	4.0	6.0	34.0	35.0	48.0cd	45.0fg	86.0	86.0
BARI sarisha-15	4.0	6.0	34.0	35.0	49.0c	46.0ef	87.0	87.0
BARI sarisha-16	4.0	6.0	38.0	43.5	55.0a	49.0c	97.0	98.0
BAU Advanced line 1	4.0	6.0	34.0	36.0	47.0de	45.0fg	85.0	87.0
BAU Advanced line 2	4.0	6.0	34.0	36.0	47.0de	45.0fg	85.0	87.0
Error	0.05		1.12		0.82		1.85	
CV (%)	4.47		2.58		1.60		1.45	
$LSD_{0.05}$ G	0.26ns		1.23**		1.06**		1.59**	
$LSD_{0.05}$ S	0.25**		0.75**		0.50**		1.24*	
$LSD_{0.05}$ G×S	0.37 ns		1.74 ns		1.50**		2.24 ns	

Notes: ** = significant at 1% level of probability, *= significant at 5% level of probability, ns= non-significant

Table 4. Effect of sowing date on yield and yield contributing character of rapeseed-mustard

Factor	PH (cm)	PBPP (no.)	SL (cm)	SPP (no.)	SPS (no.)	TSW (g)	GY ($kg.ha^{-1}$)	SY ($kg.ha^{-1}$)	BY ($kg.ha^{-1}$)	HI (%)
Sowing dates										
1st sowing	92.71a	5.31a	4.36a	89.77a	21.83a	2.99a	1120a	3180b	4303a	26.01
2nd sowing	86.53b	3.99b	4.28b	85.35b	20.53b	2.88b	1025b	3002cd	4030b	25.49
$LSD_{0.05}$	3.44	0.29	0.07	0.55	0.65	0.10	0.04	0.19	0.16	1.78
Level of significance	**	**	*	**	**	*	**	NS	**	NS
CV (%)	3.45	5.69	1.46	0.57	2.78	3.05	2.94	5.51	3.48	6.24
Genotypes										
Tori-7	87.83b	4.998a	4.527b	88.25d	15.52g	3.230abc	908e	3283b	4192b	21.95e
Sompod	74.18ef	4.253d	4.475b	85.39e	16.62f	3.062c	1003d	3023cd	4026b-d	24.87cd
Binasarisha-9	82.58c	5.110a	4.20bc	72.2g	22.03cd	2.70de	848f	3135b-d	3982cd	21.28e
BARI sarisha-9	88.30b	4.832ab	4.02bc	93.62c	27.41b	3.170bc	1197b	3510a	4707a	25.42c
BARI sarisha-12	78.95d	4.155d	4.533b	103.1b	21.56d	3.307ab	1040d	3058cd	4098bc	25.36c
BARI sarisha-14	72.92f	4.620bc	3.510c	86.49de	30.51a	2.530ef	1160a	2807e	3967cd	29.23b
BARI sarisha-15	77.3de	5.177a	3.77bc	91.93c	15.57g	2.462f	916e	2983d	3899d	23.49d
BARI sarisha-16	157.6a	4.237d	5.397a	108.3a	22.81c	3.420a	1613a	3138b-d	4752a	33.91a
BAU Advanced line 1	87.18b	4.343cd	4.465b	71.11g	18.37e	2.668def	1002d	3198bc	4200b	23.85d
BAU Advanced line 2	89.26b	4.943ab	4.33bc	75.03f	21.42d	2.803d	1080c	2763e	3843d	28.11b
$LSD_{0.05}$	3.20	0.32	0.75	2.04	1.01	0.21	0.04	0.16	0.17	1.32
Level of significance	**	**	**	**	**	**	**	**	**	**
CV (%)	3.06	5.81	14.80	2.00	4.09	6.09	2.94	4.46	3.39	4.41

Notes: ** =Significant at 1% level of probability, *= significant at 5% level of probability, NS= Non-significant. PH =plant height (cm), PBPP= primary branch/plant, SL= siliqua length (cm), SPP= number of siliqua/plant, SPS= number of seeds/siliqua, TSW=1000-seed weight (g), GY= grain yield (t/ha), SY= straw yield (ton/ha), BY= Biological yield (ton.ha-1), HI=harvest index (%).

Table 4. Effect of sowing date on yield and yield contributing character of rapeseed-mustard (continued)

Factor		PH (cm)	PBPP (no.)	SL (cm)	SPP (no.)	SPS (no.)	TSW (g)	GY (kg.ha-1)	SY (kg.ha-1)	BY (kg.ha-1)	HI (%)
Genotypes x Sowing dates											
1st sowing	Tori-7	91.93	5.66a	4.55	90.60de	16.07	2.62	950hi	3620a	4570b	20.78
	Sompod	77.39	5.44ab	4.41	88.86ef	17.13	3.11	1060ef	3110cd	4170cd	25.42
	Binasarisha-9	83.78	5.55a	4.25	72.85ij	22.80	2.81	870jk	3220bc	4080cd-f	21.25
	BARI sarisha-9	94.67	4.66de	4.02	98.82c	28.52	3.18	1240c	3570a	4820ab	25.80
	BARI sarisha-12	82.67	5.44ab	4.58	107.1b	22.65	3.35	1080ef	3081cd	4170cd	26.04
	BARI sarisha-14	75.44	5.44ab	3.57	86.73f	31.00	3.13	1222c	2900def	4120c-e	29.72
	BARI sarisha-15	78.89	5.55a	3.79	93.33d	15.80	2.62	930hi	3033cde	3970d-g	23.53
	BARI sarisha-16	158.78	4.55de	5.56	110.6a	23.75	3.57	1710a	3171cd	4880a	35.07
	BAU Advanced line 1	90.68	5.22abc	4.59	72.13ij	18.64	2.72	1041fg	3220bc	4260c	24.37
	BAU Advanced line 2	92.86	5.50b	4.32	76.64h	21.95	2.83	1100de	2820ef	3925d-g	28.08
2nd sowing	Tori-7	83.73	4.33e	4.51	85.90f	14.97	2.44	865jk	2941def	3805g	23.11
	Sompod	70.96	3.06gh	4.54	81.93g	16.10	3.02	941hi	2931def	3880efg	24.32
	Binasarisha-9	81.38	4.66de	4.16	71.68ij	21.27	2.61	840k	3053cde	3871efg	21.31
	BARI sarisha-9	81.93	5.00bcd	3.98	88.41ef	26.30	3.16	1151d	3440ab	4590b	25.04
	BARI sarisha-12	75.23	2.86h	4.49	99.15c	20.46	3.27	990gh	3035cde	4022c-g	24.69
	BARI sarisha-14	70.40	3.80f	3.45	86.25 f	30.03	3.33	1105ef	2710f	3805g	28.73
	BARI sarisha-15	75.87	4.80cde	3.76	90.5 de	15.33	2.30	893ij	2934def	3820fg	23.46
	BARI sarisha-16	156.42	3.52fg	5.23	106.1b	21.87	3.27	1512b	3102cd	4621b	32.76
	BAU Advanced line 1	83.67	3.46fg	4.34	70.09j	18.10	2.61	966h	3171cd	4130cde	23.33
	BAU Advanced line 2	85.67	4.33e	4.35	73.42i	20.88	2.78	1065ef	2703f	3765g	28.15
$LSD_{0.05}$		4.53	0.45	1.06	2.88	1.43	0.30	0.05	0.23	0.23	1.87
Sx		5.42	0.20	0.11	2.78	1.09	0.08	0.05	0.06	0.08	0.84
Level of significance		NS	**	NS	**	NS	NS	*	**	**	NS
CV (%)		3.06	5.81	14.80	2.00	4.09	6.09	2.94	4.46	3.39	4.41

Notes: ** =Significant at 1% level of probability, *= significant at 5% level of probability, NS= Non-significant. PH =plant height (cm), PBPP= primary branch/plant, SL= siliqua length (cm), SPP= number of siliqua/plant, SPS= number of seeds/siliqua, TSW=1000-seed weight (g), GY= grain yield (t/ha), SY= straw yield (ton/ha), BY= Biological yield (ton.ha^{-1}), HI=harvest index (%).

environmental conditions; early sowing ensures the rapid cell division in the meristematic tissues of crop which helps its proper growth and development. These results are compatible with the findings of Jiotode et al. (2017), Kumar et al. (2018) and Singh et al. (2017) who reported the reduced branch/plant in mustard in delayed sowing. The highest number of primary branch/plant was recorded in BARI sarisha-15 (5.17) and the lowest were recorded in BARI sarisha-12 (4.15;Table 4).

Siliqua Length (cm)

Siliqua length significantly varied in the different dates of sowing which showed decreasing tendency with delayed sowing. Akhter et al. (2016) found significant variations in siliqua length in mustard due to planting time. Effect of genotype on siliqua length was significant ($P<0.01$); the highest siliqua length was recorded from BARI sarisha-16 (5.39) and lowest from BARI sarisha-9 (4.01; Table 4). Interaction effect of genotype and sowing date on siliqua length of rapeseed-mustard was non-significant (Table 4).

Number of Siliqua/Plant

Different sowing date was statistically significant at 1% level of significance for the number of siliqua/ plant of mustard (Table 4). In the flowering time, high temperature can lower the pollination facilities, flower abortion and shedding if mustard plant delayed seeding. Meanwhile, the plant produced higher number of quality flower in optimum planting date which ultimately increased the siliqua number. Akhter et al. (2016) and Tabassum et al. (2021) reported that the number of siliqua/plant greatly reduced for each week delay after 2 November sowing. The maximum number of siliqua/plant was recorded in BARI sarisha-16 (108.3) and minimum was recorded in BAU Advanced line 1 (71.11) which was similar to Binasarisha-9 (72.27; Table 4). Different varieties showed different number of siliqua per plant.

Number of Seeds/Siliqua

Number of seeds/siliqua showed statistically significant variation due to different genotype of mustard (Table 4). The maximum number of seeds/ siliqua (21.83) was from the 10 November sowing date (Table 4). This result of the present investigation agreed with the findings of Azam et al. (2018), Akhter et al. (2016) and Malek and Monshi (2009a).

1000-seed weight (g)

There was significant variation in seed weight ($P=<0.05$) between the sowing dates. A greater 1000 seed weight (2.99 g) was obtained from the 10 November, and the 24 November had 2.88 g (Table 4). This may be due to variation in predominant environmental condition. During vegetative growth, normal sowing crop get favorable soil moisture condition and relatively warmer temperature whereas reproductive stage like proper flowering and pod formation occurred in the favorable temperature which boosting the siliqua formation, accelerating the seed weight. The results of current research had agreements with the findings of Akhter et al. (2016), Malek and Monshi (2009b). and Sharif et al. (2016) who reported that 1000-seed weight showed gradual reduction with the delayed planting date, and 1000-seed weight showed statistically significant due to effect of genotypes. The highest 1000-seed weight was recorded from BARI sarisha-16 (3.42 g). Dinda et al. (2015), and Monshi and Malek (2013) stated that varieties showed significant influence in weight of thousand seeds.

Grain Yield

The highest (1120 $kg.ha^{-1}$) and the lowest (1030 $kg.ha^{-1}$) seed yield was produced by 10 November and 24 November, respectively (Table 4). Mustard seed sown on 10 November (S_1) produced 10% more seed than the seed sown on 24 November. Kumar et al. (2022) reported that the highest yield may be attributed due to better source sink relationship. Grain yield of mustard varied for different varieties, and this might be due to genetical and environmental effect among the studied genotypes. Nazeri et al. (2018) stated that seed yield and other yield contributing characters significantly varied among the varieties. The maximum grain yield was found from BARI sarisha-16 (1710 $kg.ha^{-1}$) at S_1 (Table 4).

Straw Yield

Sowing date had non-significant effect on straw yield (Table 4). Kumar et al. (2022) and Monshi and Malek (2013) reported that straw yield was decreased due to delayed sowing. Straw yield ($kg.ha^{-1}$) showed statistically significant due to effect of genotypes ($P<0.01$). The highest straw yield was recorded from BARI sarisha-9 (3500 $kg.ha^{-1}$) and the lowest straw yield was recorded from BAU Advanced line 2 (2700 $kg.ha^{-1}$, Table 4).

Biological Yield

Sowing date had significant effect on biological yield of mustard ($P<0.01$). The 10 November sowing produced significantly the highest yield (4290 $kg.ha^{-1}$) and the lowest one (4150 $kg.ha^{-1}$) was produced by 24 November (Table 4). Saroj et al. (2021) recorded the highest biological yield (65.23 q.ha^{-1}) was obtained in case of early sown crops. Genotype had significant effect on biological yield of mustard. The highest and lowest biological yield was recorded from BARI sarisha-16 (4750 kg.ha^{-1}) and BAU Advanced line 1 (3800 kg.ha^{-1}) respectively.

Harvest Index (%)

Sowing date had non-significant effect on harvest index. Harvest index was statistically significant variation due to different genotype of mustard at 1% level of significance. The maximum and minimum harvest index was observed from BARI sarisha-16 (33.91%) and Binasarisha-9 (21.28%) respectively (Table 4). Interaction effect of genotype and sowing date was found statistically non-significant on harvest index of rapeseed-mustard (Table 4).

Variability in Rapeseed-mustard Genotypes

Analysis of variance of ten varieties of rapeseed-mustard in different yield contributing characters were summarized in Table 5 which showed the values of genetic advance and heritability. The significant variation was observed among the studied genotypes which indicates the wide scope for selection of traits. Genotypic and phenotypic variance for days to 50% flowering was found as 15.461% and 14.344% indicating moderate environmental influence on their phenotypic expression for the trait of the genotypes (Table 5). The value of the PCV (10.94) closer to GCV (10.54), respectively indicating low variability due to influence of genotypes and environment both for the character. Jahan et al. (2014) mentioned the high genotypic and phenotypic coefficient of variation for days to 50% flowering. It exhibited high heritability (92.78%), moderate genetic advance (7.51) and genetic advance in percentage of mean (20.91%; Table 5), indicated that the character is governed by additive genes and selection for this character will be effective.

In days to 50% flowering to maturity, the phenotypic coefficient of variation (7.23%) was higher than the genotypic coefficient of variation (6.97%; Table 5), which indicating the variability for the character is influenced by genotypes and environment both. Jahan et al. (2014) reported high genotypic and phenotypic coefficient of variation for days to 50% maturity. Genotypic and phenotypic variances for plant height were 1211.44 and 1218.97, respectively. The phenotypic variance was higher than the genotypic variance, suggesting the influence not only

Table 5. Estimation of genetic parameters for morphological characters of rapeseed-mustard genotypes.

Characters	Phenotypic variation (δ^2p)	Genotypic variation (δ^2g)	PCV (%)	GCV (%)	Heritability (%)	GA	GA%	CV (%)	SE
Plant height (cm)	1218.97	1211.44	38.96	38.84	98.01	71.48	79.76	3.06	7.79
Primary branch/plant	0.41	0.33	13.70	12.40	81.98	1.07	23.13	5.82	0.13
Number of siliqua/plant	312.68	309.62	20.20	20.10	99.02	36.07	41.20	2.00	3.94
Number of seeds/siliqua	49.79	49.04	33.31	33.06	98.49	14.32	67.59	4.09	1.57
Siliqua length (cm)	0.80	0.39	20.66	14.42	48.73	0.90	20.74	14.80	0.16
Days of emergence to 50% flowering	15.461	14.344	10.94	10.54	92.78	7.51	20.90	2.94	0.86
Days to 50% flowering to maturity	11.68	10.86	7.23	6.97	92.96	6.55	13.84	1.92	0.75
1000-seed weight (g)	0.26	0.23	17.27	16.16	87.55	0.91	31.14	6.12	0.11
Grain yield (kg.ha^{-1})	0.096	0.095	28.72	28.57	98.95	0.63	58.55	3.54	0.07

Notes: PCV=phenotypic coefficient of variation (%); GCV= genotypic coefficient of varietion (%); GA= genetic advance; CV = coefficient of variation; SE = standard error.

genotypes but also its environmental effects on the expression of the genes controlling these traits (Table 5).

The highest phenotypic variance (312.68) was found in number of siliqua/plants with the highest genotypic variance (309.62), indicating the large environmental influence over genotypes (Table 5). The value of GCV and PCV for number of seeds/siliquae were 22.96% and 21.75%, respectively for number of seeds/ siliquae which indicate that a very little variation exists among different genotypes (Table 5). Similar variability was also recorded by Atikunnaher et al. (2017) and Chandra et al. (2018). Selection based on these characters will be rewarding for future breeding program.

1000-seed weight showed low genotypic (0.23) and phenotypic (0.26) variance with little differences indicating that they were low in response to the environmental factors (Table 5). The PCV and GCV for grain yield were 28.72% and 28.57% respectively (Table 5). Heritability for this trait was higher (98.95) with moderate genetic advance (0.63) and moderate genetic advance in percentage (58.55%) indicating that this trait was governed by both genetic and phenotypic characters. The high heritability along with considerable genetic advance in percentage of mean was reported by Pradhan et al. (2021) and Singh et al. (2017).

Coefficient of Correlation

Correlation coefficients depict the relationships among independent traits and the degree of linear relation between these characteristics. Genotypic and phenotypic correlation coefficients of the characters of the studied ten varieties of rapeseed-mustard are presented in Table 6 and Table 7, respectively. The phenotypic coefficient of correlation was lower than the genotypic's, indicating.

Days to emergence and days to 50% flowering was positively and highly significantly ($p \leq 0.01$) correlated with days of 50% flowering to maturity (r_g=0.940**, r_p=0.916**) whereas insignificant correlation with 1000-seed weight (r_g=0.606, r_p=0.591) and grain yield (r_g=0.517, r_p=0.512) (Table 6 and Table 7). The insignificant association of these traits indicated that the association between these traits was largely influenced by environments. Nasim et al. (2013) observed negative correlation with 1000 seed weight.

Days to 50% flowering to maturity showed the positive correlation with 1000-seed weight (r_g=0.549, r_p=0.539) and positively significant with grain yield (r_g=0.634*, r_p=0.625) (Table 6 and Table 7). It seems that if the days to 50% flowering to maturity days increases the 1000 seed weight and grain yield also increase. Kayacetin (2019) reported that days to maturity had positive interaction with yield per plant.

In case of plant height, it showed positive and significant correlation with siliqua length (r_g=0.818**, r_p=0.725*), 50% flowering to maturity (r_g=0.635*, r_p=0.627) and grain yield (r_g=0.917**, r_p=0.914**) followed by positive correlation was found with number of siliqua/plant (r_g=0.503, r_p=0.501), number of seeds/siliqua (r_g=0.101, r_p=0.100 and 1000-seed weight (r_g=0.546, r_p=0.531) (Table 6 and Table 7). Similar significant correlation of plant height with number of siliqua/plant and seed yield/plant was reported by Pradhan et al. (2021).

Positive and significant correlation of number of primary branch/plant was observed with number of seeds/siliqua (r_g=0.392**, r_p=0.374**), number of siliqua/plant (r_g=0.462**, r_p=0.445**), grain yield (r_g=0.480**, r_p=0.462**) and 1000 seed weight (r_g=0.546, r_p=0.531). (Table 6 and Table 7). These suggesting if number of primary branches increases then yield/plant also increases.

Siliqua length showed highly significant and positive interaction with 1000-seed weight (r_g=0.800**, r_p=0.678*) and grain yield (r_g=0.824**, r_p=0.713*) indicated that if siliqua length increased then grain yield and 1000 seed weight is also increased. Supported results were found from the findings of Iqbal et al. (2019). It also showed insignificant and positive correlation with the days of emergence to 50% flowering (r_g=0.679, r_p=0.560), days of 50% flowering to maturity (r_g=0.564, r_p=0.475) (Table 6 and Table 7). Nasim et al. (2013) reported positive correlation between siliqua length and 1000- seed weight.

Highly significant positive correlation was found among siliqua/plant with the days of emergence to 50% flowering (r_g=0.701*, r_p=0.693*), days of 50% flowering to maturity (r_g=0.852**, r_p=0.841**), 1000-seed weight (r_g=0.654**, r_p=0.642**) and grain yield (r_g=0.642**, r_p=0.641**) (Table 6 and Table 7). It also showed insignificant and positive correlation with number of seeds/siliqua (r_g=0.114, r_p=0.114) and siliqua length (r_g=0.392, r_p=0.341. Jahan et al. (2014) reported positive correlation between siliqua/plant and seed yield.

Number of seeds/siliquae showed highly significant positive correlation with 1000 seed weight (r_g=0.661**, r_p=0.648**) and grain yield (r_g=0.685**, r_p=0.659**) (Table 6 and Table 7). So, if number of seeds/siliquae increased then grain yield also increased. Iqbal et al.

Table 6. Coefficients of genotypic correlation (r_g) among different yield components

Characters	PBPP	SPP	SPS	SL (cm)	DE-DF50% (days)	DF50%-DM (days)	TSW (g)	GY ($kg.ha^{-1}$)
PH (cm)	-0.431	0.503	0.101	0.818**	0.537	0.635*	0.546	0.917**
PBPP		0.662*	0.618*	0.611	-0.731*	-0.642*	0.536	0.702*
SPP			0.114	0.392	0.701*	0.852**	0.654*	0.642*
SPS				0.286	0.206	0.150	0.661*	0.685*
SL (cm)					0.679*	0.564	0.800**	0.824**
DE-DF50% (days)						0.940**	0.606	0.517
DF50%-DM (days)							0.549	0.634*
TSW (g)								0.755*

Notes: * and ** indicate significant at 5% and 1% levels of probability. PH =plant height (cm), PBPP= primary branch/plant, SL= siliqua length (cm), SPP= number of siliqua/plant, SPS= number of seeds/siliqua, DE-DF50%= days of emergence to 50% flowering, DF50%-DM= days to 50% flowering to maturity, TSW=1000-seed weight (g), GY= grain yield ($kg.ha^{-1}$).

Table 7. Coefficients of phenotypic correlation (r_p) among different yield components

Characters	PBPP (no.)	SPP (no.)	SPS (no.)	SL (cm)	DE-DF50% (days)	DF50%-DM (days)	TSW (g)	GY ($kg.ha^{-1}$)
PH (cm)	-0.414	0.501	0.100	0.725*	0.530	0.627	0.531	0.914**
PBPP (no.)		0.641*	0.611*	-0.542	-0.690*	-0.611*	-0.506	0.678*
SPP (no.)			0.114	0.341	0.693*	0.841**	0.642*	0.641*
SPS (no.)				0.257	0.204	0.146	0.648*	0.659*
SL (cm)					0.560	0.475	0.678*	0.713*
DE-DF50% (days)						0.916**	0.591	0.512
DF50%-DM (days)							0.539	0.625
TSW (g)								0.739*

Notes: * and ** indicate significant at 5% and 1% levels of probability. PH = plant height (cm), PBPP= primary branch/plant, SL= siliqua length (cm), SPP= number of siliqua/plant, SPS= number of seeds/siliqua, DE-DF50%= days of emergence to 50% flowering, DF50%-DM= days to 50% flowering to maturity, TSW=1000-seed weight (g), GY= grain yield ($kg.ha^{-1}$).

(2019) reported that number of seeds/siliquae had positively correlated with seed yield/plant. The data of 1000-seed weight exhibited highly significant positive correlation with grain yield (r_g=0.755*, r_p=0.739*) (Table 6 and Table 7). Similarly, Jahan et al. (2014) and Islam et al. (2020) reported positive significant relations between these traits.

Both significant and insignificant differences were observed in correlation coefficient values on the seed yield. As the genetic correlation coefficient value was yielded higher than that of phenotypic one, the association of two characters was likely caused by the genotypic traits.

Conclusion

Sowing rapeseed mustard on 10 November produced 10% higher yield and had superior yield contributing characters than sowing on 24 November. The performance of BARI sarisha-16 was the best among the tested genotypes. Farmers can increase yields by sowing at the right time, avoiding late sowing, and selecting high-yielding rapeseed and mustard varieties. Yield of the genotypes can be increased by improving yield contributing characters including number of seeds/siliquae, number of siliqua/plant, 1000-seed weight, and grain yield, as these traits showed higher heritability and genetic advance. Therefore, these traits can be explored in the future studies to get new high yielding mustard-rapeseed genotypes.

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No potential conflict of interest was reported by the authors.

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