



Morphological characterization of resynthesized *Brassica napus* L. lines giving priority to earliness

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ABSTRACT

The experiment was conducted to evaluate the performances of fifteen resynthesized *Brassica napus* L. lines along with one check variety (Binasarisha-4) based on some morphological, yield and yield attributes and also to estimate association among the traits. Randomized Completely Block Design (RCBD) with three replications was used for this experimentation. A wide range of variation was observed among the studied morphological traits which have a great interest for the *Brassica* breeders. Considering the two most important traits like early flowering and early maturity the RS lines RS-7, RS-2, RS-3, RS-5, RS-11, RS-14, and RS-15 performed best among the germplasms compared with check variety Binasarisha-4. All the studied traits except main leaf area showed high heritability. High heritability coupled with high genetic advance (>20%) was observed for plant height, flag leaf area, siliqua length, beak length, siliqua angle and yield/plant. This result suggested that these characters could be improved more easily through simple selection. Correlation analysis revealed a significant positive correlation of yield/plant with plant height and siliqua length. Days to first flowering and days to maturity were negatively correlated with plant height, siliqua length and beak length whereas a highly significant positive correlation existed between days to first flowering and days to maturity. Principal Component Analysis revealed the utmost suitable combination of the studied attributes and stated that the first four principal components (PC) explained 78.3% of the total data variation. These results provide a scope for selection of RS lines in regard to develop short duration varieties of *B. napus* with high yield potential.

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Introduction

Brassica is the most economically important genus in the Brassicaceae family (syn. Cruciferae) (Uddin *et al.* 2015). It is the world's third most important sources of edible vegetable oils after palm and soybean (FAO, 2017). Among the *Brassica* crops, oilseeds have the highest economic value (Cardoza and Stewart, 2004). Oilseed *Brassica* is commonly known as rapeseed and mustard. Among the oleiferous *Brassica* species, the varieties of *Brassica napus* and *Brassica rapa* are commonly known as rapeseed, while mustard includes *Brassica carinata*, *Brassica juncea* and *Brassica nigra* (Yarnell, 1956). Rapeseed mustard covers the major portions among the 67% of the total oilseed planted area in Bangladesh (BBS, 2017). Bangladesh ranked 19 among rapeseed producing countries in the world which covers 0.5% of total rapeseed production (FAOSTAT, 2016). In Bangladesh, the seed yield of rapeseed is about 920 kg ha⁻¹ which is very low in comparison to the average yield (2090 kg ha⁻¹) throughout the world (USDA, 2018). Bangladesh requires 0.30 million tons of oil equivalent to 0.85 million tons of oilseed for

nourishing her people but at present, 0.23 million tons of rapeseed are produced from 25 million hectares area (USDA, 2018). Thus Bangladesh is facing an acute shortage in edible oil. Bangladesh has one of the lowest per capita consumption of edible oil in the world (BBS, 2016; USDA, 2018). Considering the dominance of rice cultivation and space availability between T. aman and Boro, there should be an attempt to develop short duration and high yielding varieties of mustard with more oil percentage in seed, tolerant to biotic and abiotic stresses for fulfilling the edible oil requirements (Aktor *et al.*, 2019). In Bangladesh, local cultivars/varieties of *B. rapa* are widely grown and short duration variety Tori-7 of *B. rapa* is still popular in Bangladesh due to well fitness into the T. Aman-Mustard-Boro cropping pattern. However, most of the varieties of *B. napus* are not popular in Bangladesh, because of yield loss due to shattering and longer duration (Alam *et al.*, 2010). Besides, for being originated in temperate regions *B. napus* remains constantly in the vegetative stage resulting in too long maturity period. These obstacles make *B. napus* complicated for becoming an oil crop.

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So, it is necessary to develop short duration varieties of *B. napus* with high yield potential. Thus, resynthesis of *B. napus* may be a good approach to produce short duration high yielding cultivars in Bangladesh (Alam et al., 2010). *B. rapa* (AA, 2n = 20) and *B. oleracea* (CC, 2n = 18) naturally crossed and from which allotetraploid *B. napus* (AACC, 2n = 38) has been evolved (Malek et al., 2012). Resynthesized *B. napus* provides various gene sources from *B. rapa* and *B. oleracea* and also potential germplasm for utilization in rapeseed breeding (Kraling, 1987). Again the use of different parental combinations for synthesis of *B. napus* will enhance new variability in germplasm which could be exploited for crop improvement. A plant breeding program includes three steps like building up a gene pool of variable germplasm, selection of individual from the gene pool and utilization of selected individual to evolve a superior variety (Chauhan and Singh, 1985). The knowledge of genetic variability present in the population, heritability of economically important characters and correlation coefficients of those characters is very important before launching an effective breeding program. Therefore, the study was designated to evaluate the yield and yield contributing traits of resynthesized lines of *B. napus* giving emphasis on early maturity for finding out some novel genetic resources thus helping out to develop short duration *B. napus* varieties.

Materials and Methods

This experiment was performed during winter season (November 2018 to March 2019) using the experimental field of Department of Genetics and Plant Breeding (GPB), Bangladesh Agricultural University (BAU), Mymensingh. The experimental materials consisted of 15 resynthesized (RS) *Brassica napus* lines (RS-1 to RS-15) and one of the most popular varieties of *Brassica napus* (Binasharisha-4) as a check variety. Experimental materials were collected from GPB, BAU, Mymensingh (Table 1). In this experiment, Agrani, Binasharisha-6, Safal, Sampad, BARI Sarisha-15, BARI Sarisha-6, BARI Sarisha-9, BARI Sarisha-12 of *B. rapa* and Alboglabra-1 of *B. oleracea* var. “alboglabra” were used as parental genotypes for the development of interspecific hybrids. Interspecific hybrids were induced to double chromosome number for the development of synthetic *B. napus*. Seeds of all selected RS lines of *B. napus* along with the check variety were sown on the experimental plot to assess some morphological characters, seed yield and yield attributes. The experiment was conducted using Randomized Complete Block Design (RCBD). Each plot contained 5 rows with 12 plants in each row. Harvesting was done when 90% of the plant population of each plot reached to maturity. Data were recorded on three randomly chosen plants of each genotype for different characters, such as plant height, flag leaf area, and main leaf area, days to first

flowering, siliqua length, beak length, main stem length, siliqua angle, days to maturity, and seed yield/ plant.

Table 1. Name and sources of studied resynthesized *Brassica napus* lines and check variety

Designation	Populations
RS-1	Agrani × Alboglabra-1
RS-2	Binasharisha-6 × Alboglabra-1
RS-3	Safal × Alboglabra-1
RS-4	Sampad × Alboglabra-1
RS-5	BARI Sarisha-15 × Alboglabra-1
RS-6	BARI Sarisha-6 × Alboglabra-1
RS-7	BARI Sarisha-9 × Alboglabra-1
RS-8	BARI Sarisha-9 × Alboglabra-1
RS-9	BARI Sarisha-9 × Alboglabra-1
RS-10	Alboglabra-1 × BARI Sarisha-14
RS-11	BARI Sarisha-12 × Alboglabra-1
RS-12	BARI Sarisha-12 × Alboglabra-1
RS-13	BARI Sarisha-12 × Alboglabra-1
RS-14	Tori-7 × Alboglabra-1
RS-15	Tori-7 × Alboglabra-1
Check	Binasharisha-4

Statistical analyses of the recorded data for different characters were performed using MINITAB®17 statistical software packages (Minitab Inc., State College, Pennsylvania, NZ). Two-way Analysis of Variance (ANOVA) was executed for different yield and yield contributing traits following general linear model (GLM).

Principle Component Analysis (PCA) was carried out to investigate association between the traits of RS lines and check variety of *B. napus*. The principle component (PC) scores were stored and ANOVA of the PC scores was performed using the GLM procedure to explore the statistical significance between variety and replication. A correlation analysis was performed to explore relationship among the traits. Estimation of genotypic and phenotypic variances, heritability in broad sense (h^2_b) as well as categorization of h^2_b and genetic advance (GA) was done according to the formula given by Johnson et al. (1955) and Hanson et al. (1956). Genetic advance in percent of mean was calculated by the formula of Comstock and Robinson (1952). GA (%) was categorized as low (0-10%), moderate (10-20%) and high ($\geq 20\%$) as given by Johnson et al. (1955) and Falconer and Mackay (1996).

Genotypic Coefficient of Variation (GCV) and Phenotypic Coefficient of Variation (PCV) values were estimated according to the formula given by Burton (1952). GCV and PCV values were categorized as low ($< 10\%$), moderate (10-20%) and high ($> 20\%$) (Sivasubramanian and Madhavamenon, 1973).

Results

The analysis of variance for some morphological, yield and yield contributing components presented in the Table 2. In the present study, four RS lines RS-1, RS-2, RS-3 and RS-5 produced taller plants over check variety among which plant height of RS-1 was significantly

higher from check variety (Table 3). Most of the RS lines produced long siliqua compared to check variety (Table 3). Eight RS lines RS-1, RS-2, RS-4, RS-7, RS-9, RS-11, RS-14 and RS-15 showed higher length of siliqua compared to check variety among which siliqua length of RS-15 was significantly higher (Table 3).

Table 2. Genetic parameters for some morphological characters, seed yield and yield attributes of 15 resynthesized *B. napus* lines and 1 check variety (Binasarisha-4)

Characters	MS	σ^2_g	σ^2_p	h^2_b (%)	GA	GA (%)	GCV (%)	PCV(%)
Plh (cm)	1137.1***	365.38	406.33	89.92	37.33	43.40	22.22	23.43
FLA (cm ²)	1034.4***	296.54	441.33	67.19	29.07	110.60	65.50	79.90
MLA(cm ²)	4042.4***	883.07	2276.26	38.79	38.12	35.92	27.99	44.95
SiL (cm)	3.21***	1.05	1.12	93.75	2.04	67.45	33.81	34.92
BkL (cm)	0.77***	0.25	0.273	92.68	0.99	76.19	38.42	39.90
MSL (cm)	125.91***	31.96	61.99	51.55	8.36	15.20	10.27	14.31
SilAn (°)	353.57***	100.42	152.74	65.74	16.73	31.57	18.90	23.31
Y/P (g)	7.23***	2.41	2.42	99.58	3.19	95.84	46.62	46.72
DFF (days)	10.93***	3.41	4.10	83.29	3.47	12.89	6.85	7.51
DM (days)	170.94***	56.62	57.69	98.1488	15.35	18.15	8.89	8.97

Here, *** indicates significant at ≤ 0.1 % level of significance, MS = mean sum of square, σ^2_g = Genotypic variance, σ^2_p = Phenotypic variance, h^2_b = Broad sense heritability, GA= Genetic Advance, GA (%) = Genetic advance in percentage of mean, GCV= Genotypic Coefficient of Variation, PCV = Phenotypic Coefficient of Variation, Plh= Plant height; FLA= Flag leaf area; MLA= Main leaf area; SiL= Siliqua length; BkL= Beak length; MSL= Main stem length; SilAn= Siliqua angle; Y/P= Yield per plant; DFF= Days to first flowering; DM= Days to maturity.

Table 3. Mean performances of 15 resynthesized *B. napus* lines and 1 check variety (Binasarisha-4) for some yield and yield attributing traits

Genotype	Plh	FLA	MLA	SiL	BkL	MSL	SilAn	Y/P	DFF	DM
RS1	131.67a	54.2ab	167.2ab	3.26b	1.87ab	69.00a	46.67bc	6.67a	29.33a	87.67c
RS2	99.33bc	50.0abc	158.2ab	3.23b	1.48bc	60.67abc	45.00bc	3.46e	25de	79f
RS3	104.33b	17.46cd	110.0ab	1.73e	1.48fg	55.33abc	43.33bc	3.53e	25.01cde	73.67g
RS4	90.33bcd	36.17bcd	95.82ab	3.83b	1.13cde	65.67abc	81.67a	3.33e	27.33a-d	86cd
RS5	106.34b	22.16bcd	119.7ab	3.20bc	2.10a	53.00abc	51.67bc	4.70c	25.33cde	77.33f
RS6	92.33bcd	20.01bcd	92.0ab	3.00bcd	1.50bc	53.67abc	63.33ab	2.20b	28.67ab	83.67de
RS7	90.33bcd	8.640d	91.36ab	3.96b	1.33cd	50.00bc	45.00bc	4.53c	24.33e	83.33de
RS8	70.33e	27.86bcd	98.3ab	1.13e	0.40g	56.00abc	61.67ab	2.20f	29.33a	97.67a
RS9	76.00de	8.90d	100.9ab	3.63b	1.20cde	48.00c	48.33bc	3.43e	27.67abc	82.67e
RS10	47.33f	28.96bcd	58.33b	2.10cde	0.77efg	52.67abc	53.33bc	2.16f	29ab	97.33a
RS11	73.67de	13.55cd	66.2b	3.90b	1.23cd	47.00c	33.33c	3.37e	25.33cde	93.33b
RS12	69.33e	17.20cd	118.5ab	2.03de	1.26cd	55.33abc	51.67bc	4.03d	29.67a	91.67b
RS13	69.33e	13.04d	77.71ab	1.76e	0.90def	55.33abc	60.00ab	0.63g	28.67ab	85.67cde
RS14	82.00cde	15.50cd	96.08ab	3.43b	1.43bc	51.00bc	55.00bc	2.43f	25.67cde	77.33f
RS15	83.00cde	13.07d	63.13b	5.13a	1.53bc	46.00c	58.33b	2.50f	26.67b-e	73.67g
Check	90.67bcd	73.86a	184.7a	3.10bcd	2.27a	61.33abc	50.00bc	0.93g	24.67e	83.67de
Mean	86.02	26.29	106.14	3.02	1.31	55.00	53.02	3.32	26.958	84.60
SE	2.85	2.99	6.75	0.153	0.074	1.12	1.75	0.220	0.293	1.07
Sig. level	*	*	*	*	*	*	*	*	*	*

Here, * indicates significant at $\leq 5\%$ level of significance, Tukey's pairwise comparison is used for lettering, Plh= Plant height; FLA= Flag leaf area; MLA= Main leaf area; SiL= Siliqua length; BkL= Beak length; MSL= Main stem length; SilAn= Siliqua angle; Y/P= Yield per plant; DFF= Days to first flowering; DM= Days to maturity.

Table 4. Principal Components and their coefficients for morphological, yield and yield attributes of 15 resynthesized *B. napus* lines and 1 check variety (Binasarisha-4)

Variables	PC1	PC2	PC3	PC4
Plh	0.014	0.273	0.006	0.320
FLA	0.325	-0.402	-0.330	-0.088
MLA	0.386	-0.282	-0.164	-0.139
MSL	0.272	-0.500	-0.011	0.111
SiL	0.245	0.392	0.024	0.296
SilAn	-0.078	-0.244	0.022	0.865
BkL	0.402	0.145	-0.009	0.069
DFF	-0.261	-0.356	0.453	0.124
DM	-0.285	-0.385	0.109	-0.395
Y/P	0.252	0.026	0.756	-0.135
% Variation explained	32.7	22.5	12.4	10.7
ANOVA for PC Scores				
Genotype (<i>p</i> value)	<0.001	<0.001	<0.001	<0.001
Replication (<i>p</i> value)	0.073	0.749	0.256	0.879

Here, PC = Principal Component, *p* = Probability of statistical significance, Plh= Plant height; FLA= Flag leaf area; MLA= Main leaf area; SiL= Siliqua length; BkL= Beak length; MSL= Main stem length; SilAn= Siliqua angle; Y/P= Yield per plant; DFF= Days to first flowering; DM= Days to maturity.

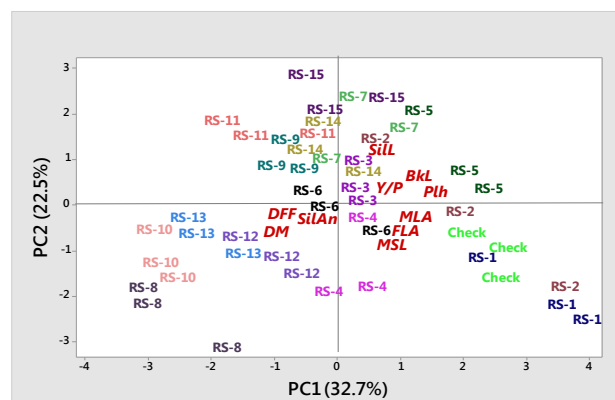


Fig. 1. Biplot of studied morphological, yield and yield attributing traits of 15 resynthesized *B. napus* lines and 1 check variety (Binasarisha-4)

Here, Plh= Plant height; FLA= Flag leaf area; MLA= Main leaf area; SiL= Siliqua length; BkL= Beak length; MSL= Main stem length; SilAn= Siliqua angle; Y/P= Yield per plant; DFF= Days to first flowering; DM= Days to maturity.

Among the RS lines, the RS-1, RS-2, RS-4 showed higher main stem length compared to check variety (Table 3). The RS-4 line produced significantly higher siliqua angle compared to the check variety (Table 3). RS-1 and RS-2 showed similar flag leaf area with check variety while flag leaf area of RS-7 and RS-9 were significantly lower than check variety (Table 3). Similarly, main leaf area of RS-1 and RS-2 showed similarity with those of check variety whereas RS-10, RS-11 and RS-15 produced significantly lower main leaf

area compared to check variety (Table 3). In case of beak length, RS-8 and RS-10 produced significantly lower beak length compared to check variety (Table 3). All the RS lines except RS-13 had significantly higher yield over check variety (Table 3).

In the present study RS-7 required the lowest days for first flowering. Besides, the RS lines RS-2, RS-3, RS-5, RS-11, RS-14 and RS-15 also found to be earliest to first flowering and in terms of maturity, RS-3, RS-15, RS-5, RS-14 and RS-2 matured earlier (Table 3). Phenotypic coefficient of variation (PCV) were higher than the genotypic coefficient of variation (GCV) for the traits flag leaf area, main leaf area, main fruiting axis length, siliqua angle (Table 2). Besides the differences between PCV and GCV were very low for the character plant height, siliqua length, beak length, yield/plant, days to first flowering, days to maturity. The higher estimates of PCV and GCV were observed for plant height, flag leaf area, main leaf area, siliqua length, beak length and yield/plant (Table 2). The present study revealed that estimates of broad sense heritability were high (>50%) for all the traits studied except main leaf area (Table 2). High genetic advance in per cent of mean (>20%) was recorded for plant height, flag leaf area, main leaf area, siliqua length, beak length, siliqua angle and yield/plant (Table 2). High heritability coupled with high genetic advance in per cent of mean was observed for plant height, flag leaf area, siliqua length, beak length, siliqua angle and yield/plant (Table 2).

The most appropriate combination of the studied attributes was obtained from the principal component analysis. Principal Component Analysis (PCA) revealed that the first four principal components (PC) explained 78.3% of the total data variation (Table 4). Separately PC1, PC2, PC3 and PC4 explained 32.7%, 22.5%, 12.4% and 10.7% data variation respectively (Table 4). Variation in PC1 is largely manifested by the positive coefficients of beak length, main leaf area and flag leaf area and the negative coefficient of days to maturity, days to first flowering and siliqua length (Table 4, Fig. 1). PC1 scores clearly divided RS-1, RS-2 and check variety from RS-8, RS-10, RS-13 and RS-12 (Fig. 1). For measuring the mutual relationship between different morphological, yield and yield contributing traits of resynthesized *Brassica napus* lines and check variety, correlation coefficient analysis was conducted (Table 5).

Discussion

Synthetic amphidiploids provide important genetic variability in the form of basic germplasm for further improvement in seed yield and yield contributing characters and quality traits (Prakash and Chopra, 1993). Significant difference among genotypes for all the characters revealed by the analysis of variance (Table 2) indicating the presence of adequate amount of genetic variability among the genotypes. The existence of genetic variability in the population provides ample

opportunities for selection being effective. Khan *et al.* (2006) studied variation for yield and yield contributing characters in rapeseed and reported significant variation for eleven accessions of *B. napus*. As like as the production of taller plants of RS-1, RS-2, RS-3 and RS-5 in the present study, taller plants were also found in synthetic hexaploid *Brassica sp.* (Meng *et al.* 1998). Malek *et al.* (2012) also found taller plants in resynthesized *B. napus* lines. Yingze *et al.* (2003) and Malek *et al.* (2012) also obtained long and high siliqua in synthetic *B. napus* lines which showed similarity to the findings of this study. Karim *et al.* (2014) showed that resynthesized *B. napus* lines produced 2.0-4.6 times higher yields as compared to short duration *Brassica napus*. Malek *et al.* (2012) also found that resynthesized

plants produced higher mean value of seed yield per plant. RS lines, RS-2, RS-3, RS-5, RS-11, RS-14 and RS-15 were found to be earliest to first flowering in this study. Yingze *et al.* (2003) also found that resynthesized *B. napus* required fewer days to produce flower. Higher PCV value for the traits over GCV indicated that they all interacted with the environment to some extent whereas very low difference between PCV and GCV of the traits indicated less environmental effects on those characters. These results of PCV and GCV in this study are in accordance with the reports of Akbar *et al.* (2003); Naazar *et al.* (2003); Khan *et al.* (2006) and Akbar *et al.* (2007).

Table 5. Correlation coefficient among some morphological characters, seed yield and yield attributes in 15 resynthesized *B. napus* L. lines and 1 check variety (Binasarisha-4)

	Plh	FLA	MLA	SilL	BkL	MSL	SilAn	Y/P	DFF	DM
Plh	1									
FLA	0.355*	1								
MLA	0.542***	0.631***	1							
SilL	0.240	-0.029	-0.011	1						
BkL	0.492***	0.365*	0.369**	0.527***	1					
MSL	0.450***	0.711***	0.523***	-0.158	0.099	1				
SilAn	-0.086	0.027	-0.039	-0.054	-0.137	0.266	1			
Y/P	0.619***	-0.032	0.156	0.217***	0.269	0.182	-0.156	1		
DFF	-0.300*	-0.109	-0.162	-0.410**	-0.282	0.093	0.330*	0.093	1	
DM	-0.503***	0.101	-0.130	-0.417**	-0.367**	0.122	0.031	0.091	0.557***	1

Here, *, **, *** indicates significant at $\leq 5\%$, $\leq 1\%$ and $\leq 0.1\%$ level of significance; Plh= Plant height; FLA= Flag leaf area; MLA= Main leaf area; SilL= Siliqua length; BkL= Beak length; MSL= Main stem length; SilAn= Siliqua angle; Y/P= Yield per plant; DFF= Days to first flowering; DM= Days to maturity.

Knowledge of heritability of a character is important as it indicates the possibility and extent to which improvement is possible through selection (Robinson *et al.*, 1949). In earlier studies, Marjanovic-Jeromela *et al.* (2007) and Sabaghnia *et al.* (2010) reported high heritability estimates for yield components of *Brassica napus*. Yadava and Yadav (2007) studied twelve genotypes of *B. napus* grown in 18 environments, where heritability estimates were high for plant height, number of days to first flowering and maturity. High values for heritability and genetic advance were also stated for seed yield of *B. juncea* (Akbar *et al.* 2003, 2007). High heritability estimates for days to flowering and maturity reported by Dhagate *et al.* (1972). Sandhu and Gupta (2000) reported high expected genetic advance and high heritability for plant height and seed yield/plant in 18 strains of *Brassica napus* indicating additive gene effects for these characters.

The result of PCA suggested that the traits i.e. beak length, main leaf area and flag leaf area, days to first flowering and days to maturity were responsible for the contrasting performances of RS-1, RS-2, check variety with RS-8, RS-10, RS-13 and RS-12. Highly significant positive associations between plant height and other characters indicated that the traits were governed by same gene and simultaneous improvement would be effective. These results are in conformity with the

findings of Musnicki (1974); Kumar and Yadava (1978); Verma and Sachan (2000), Akbar *et al.* (2003); Naazar *et al.* (2003) and Khayat *et al.* (2012). Negative and significant correlation between days to first flowering and plant height, was also found by Shekhawat *et al.* (2014). By contrast, Kumar *et al.* (1984) recorded positive and significant correlation between plant height and days to maturity.

Negative and significant relationship was examined between plant height and ripeness days by Siddique *et al.* (2017). The significant and positive association between the characters suggested additive genetic model thereby less affected by the environmental fluctuation. Su-qin and Xiang-tan (2006) observed that *B. napus* lines with the longest siliqua generally showed significantly higher correlation with seed yield which showed similarity to the present study. Significant and positive correlation with days to first flowering and siliqua angle suggested that an increase of days to first flowering may lead to the increase of the siliqua angle (Table 5). Highly significant and positive relation between days to first flowering and days to maturity indicated that if days to first flowering increased then days to maturity also increased (Table 5). There are several reports on correlation analysis in canola (Ali *et al.* 2003; Khan *et al.* 2008; Basalma, 2008).

Conclusion

The objective of this study was to evaluate some morphological, yield and yield contributing traits of resynthesized *B. napus* lines with a check variety giving priority to the character of earliness. The RS lines performed better for the traits plant height, siliqua length, main fruiting axis length, siliqua angle, seed yield/plant, days to first flowering and days to maturity over check variety. Considering the two most important traits like early flowering and early maturity to assess earliness, the RS lines RS-7, RS-2, RS-3, RS-5, RS-11, RS-14 and RS-15 performed best among the germplasms compared with check variety Binasharisha-4. However, it needs further screening and evaluation in the subsequent generations in respect of morphological, higher yield and yield contributing traits.

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