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CORRELATION COEFFICIENT AND PATH COEFFICIENT ANALYSIS IN DIFFERENT *Brassica rapa* GENOTYPES

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ABSTRACT

A field experiment was conducted in the experimental field of Sher-e- Bangla Agricultural University, Dhaka, Bangladesh to study the correlation between pairs of different characters and the direct and indirect effect of different characters on seed yield plant^{-1} in seven selected genotypes of *Brassica rapa* L. to select the plants with higher yield potential. Yield plant^{-1} was highly significant and positively correlated with days to 50% flowering (r_g = 0.987** and r_p = 0.989**) and 80% maturity (r_g = 0.989** and r_p = 0.990**) at both genotypic and phenotypic level while the correlation was significant and positive with plant height (r_g = 0.802* and r_p = 0.812*) and thousand seed weight (r_g = 0.770* and r_p = 0.768*) indicating dependence of these characters on grain yield. Path coefficient analysis for yield plant^{-1} revealed that days to 80% maturity (7.9587) exerted the highest direct effect on the yield followed by days to 50% flowering (5.4155) and plant height (2.4601). The indirect contribution of component characters *viz.* days to 80% maturity was high indirect effect via days to 50% flowering (5.3693) followed by number of secondary branches plant^{-1} via days to 80% maturity (4.0874) towards seed yield plant^{-1}. Thus, the yield plant^{-1} in selected *B. rapa* genotypes could be improved by direct selection based on these traits.

Keywords: *Brassica rapa,* correlation coefficient, path coefficient analysis, residual effect.

INTRODUCTION

In Bangladesh total cultivated area under rapeseed and mustard cultivation is 0.522 million hectares which produces 0.683 million metric tons in 2018-19 (AIS, 2020). *B. rapa* is the main oil yielding species in Bangladesh and occupies the 1st position in respect of area and production (Naznin *et al.,* 2015). Other two major local cultivar*, B. juncea* and *B. napus* are high yielding but not short durable so comparatively low yielding *B. rapa* is widely grown in the country for their short duration and fulfills our requirement approximately 50% (Islam, 2015). Although short durable, low yielding and pest susceptible variety Tori-7 of *B. rapa* is popular in Bangladesh but there is still lack of improved short durable variety with higher yield. Therefore, oilseed research should be directed towards the minimization of yield gap through the development of the high yielding short duration varieties to fit into the profitable cropping patterns (T. Aman-Mustard-Boro) with higher adaptability and stability which will ultimately increase the oil production in the country. Increased yield and improved quality are generally confronted with laborious analyses and long term breeding programs. The inter relationship of quantitative characters with yield may determine the efficiency of breeding program. Phenotypic correlation reflects the observed relationship, while genotypic correlation underline the true relationship among characters. Selection procedures could be varied depending on the relative contribution of each. The association of a particular character in relation to other traits contributing to yield of a crop would be of great importance in planning a successful breeding program (Mary and Gopalan, 2006). Thus determination of correlation coefficients is an important statistical procedure to evaluate breeding programs for high yield, as well as to examine direct and indirect contributions to yield variables (Ali *et al.,* 2003). On the other hand the path analysis helps to determine the direct and indirect contribution of traits towards the yield which cannot be differentiated from correlation studies. Unlike the correlation coefficient path coefficient measures the magnitude of direct and indirect contribution of a component character to a complex character and it has been defined as a standardized regression coefficient which splits the correlation coefficient into direct and indirect effects and thus

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enable the breeders to judge about the important component characters during selection (Sabaghnia *et al.,* 2010). Therefore, correlation in combination with the path coefficient analysis quantifies the direct and indirect contribution of one character upon another (Dewey and Lu, 1959). Hence the present study was carried out to understand the correlation and the direct and indirect effect of different characters on yield as selection criteria which will help for launching an effective breeding program to meet the existing demand.

MATERIALS AND METHODS

Different *B. rapa* genotypes were collected from BARI (Bangladesh Agriculture Research Institute), BINA (Bangladesh Institute of Nuclear Agriculture) and SAU (Sher-e-Bangla Agricultural University). Selection was done on the basis of yield, duration and oil content of the collected genotypes. Then seven selected genotypes BARI Sar-6, BARI Sar-9 × BARI Sar-6 (F_{16}), Yellow Special, Tori-7, BARI Sar-14, BARI Sar-15 and BARI Sar-17 were grown on the experimental plot. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. Each plot was 2.5 m long with three rows. Distance between row- row 30 cm and plant-plant 10 cm and block-block 1 m were maintained. Recommended doses of fertilizers and standard cultural practices were carried out for better crop production. Data were recorded on days to flowering, days to maturity, plant height (cm), number of primary branches plant^{-1}, number of secondary branches plant^{-1}, number of siliqua plant^{-1}, siliqua length (cm), number of seeds siliqua^{-1}, 1000 seed weight (g) and seed yield plant^{-1} (g). The mean values of ten randomly selected plants were computed for each of ten traits for each genotype in each replication and were subjected to statistical analysis. Mean, range and co-efficient of variation (CV %) were estimated using MSTAT-C software program. Both genotypic and phenotypic coefficients of correlation between two characters were determined by using the variance and covariance components as suggested by Al-Jibouri *et al*. (1958) and path coefficient analysis was done following the method outlined by Dewey and Lu (1959) and categories were determined according to Lenka and Mishra (1973).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance was performed for ten quantitative characters including yield and yield attributing traits on seven genotypes of *B. rapa* (Table 1). From the analysis of variance it was observed that mean sum of squares due to genotypes were significant for all the studied traits, thus exhibiting the presence of considerable genetic variability. This finding was in confirmation with the findings of Singh *et al.* (2013), Tripathi *et al.* (2013) and Shekhawat *et al*. (2014).

Correlation analysis

The genotypic and phenotypic correlation coefficient for ten yield and related characters in seven selected genotypes of *B. rapa* was studied and presented in Table 2 and 3.

Days to 50% flowering

It showed high significant and positive correlation with seed yield plant^{-1} (r_g = 0.987** and r_p = 0.989**) and days to 80% maturity (r_g = 0.991** and r_p = 0.990**) at both genotypic and phenotypic levels, so any change or variation for this trait will have considerable effect on seed yield plant^{-1}. Hence, selection in the performance of one of the traits will result in the improvement of the other traits. The result was supported by Naznin *et al.* (2015), Jamali *et al.* (2016), and Siddique *et al.* (2017) while Zahan (2006) reported non-significant negative association of this trait with seed yield plant^{-1}. Kahrizi and Alaahvarand (2012), Halder *et al.* (2014) reported seed yield plant^{-1} had significant negative association with this trait. It presented significant and positive correlation with thousand seed weight (r_g = 0.840* and r_p = 0.795*) and plant height (r_g = 0.791* and r_p = 0.772*) at both genotypic and phenotypic levels while significant and negative correlation with number of siliqua plant^{-1} (r_p = -0.784*) at phenotypic levels only. It also showed non-significant and negative correlation with number of secondary branches plant^{-1} (r_g = -0.515 and r_p = -0.551) at both genotypic and phenotypic levels, siliqua length (r_p = -0.019) at phenotypic level and number of siliqua plant^{-1} (r_g = -0.381) at genotypic level only while non-significant and positive correlation with other remaining traits at both levels. Ejaz-Ul-Hasan *et al.* (2014) found a positive and high significant genetic relationship of days to 50% flowering with seeds siliqua^{-1}.

Table 1. Analysis of variance for seed yield and seed yield attributing traits in *Brassica rapa* genotypes

Source of variation	Df	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of siliqua plant^{-1}	Siliqua length (cm)	No. of seed siliqua^{-1}	1000 Seed Weight (g)	Seed yield plant^{-1} (g)
Genotype	6	235.11**	311.89**	2101.65**	2.24**	44.13**	7726.9**	0.88**	101.46**	1.35**	2.96**
Replication	2	26.09	20.67	1.15	0.66	0.69	404.7	0.02	1.18	0.02	0.58
Error	12	0.09	0.08	10.24	1.02	1.24	124.2	0.01	0.91	0.08	0.03
CV (%)		0.66	0.32	3.05	13.69	28.06	6.54	1.97	4.41	7.20	3.09
LSD		0.52	0.51	5.70	1.80	1.98	19.83	0.13	1.70	0.50	0.29

Here, Df = Degree of freedom, CV = Co-efficient of variation, LSD = Least Significant Difference, ** = Significant at 1%

Table 2. Genotypic correlation coefficients among different pairs of yield and yield contributing traits of selected *Brassica rapa* genotypes

Yield contributing traits	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of siliqua plant^{-1}	Siliqua length (cm)	No. of seeds siliqua^{-1}	1000 seed weight (g)
Days to 80% maturity	0.991**								
Plant height (cm)	0.791*	0.794*							
No. of primary branches plant^{-1}	0.195	0.215	0.801*						
No. of secondary branches plant^{-1}	-0.515	-0.513	-0.774*	-0.952**					
No. of siliqua plant^{-1}	-0.381	-0.239	-0.091	-0.186	0.775*				
Siliqua length (cm)	0.082	0.131	0.849*	0.470	-0.197	0.235			
No. of seeds siliqua^{-1}	0.560	0.469	0.219	0.095	-0.411	-0.775*	-0.034		
Thousand seed weight (g)	0.840*	0.843*	0.924**	0.799*	-0.871*	-0.348	0.780*	0.406	
Seed yield plant^{-1} (g)	0.987**	0.989**	0.802*	0.213	-0.593	-0.485	0.144	0.571	0.770*

Here, ** = Significant at 1%; * = Significant at 5%

Table 3. Phenotypic correlation coefficients among different pairs of yield and yield contributing traits of selected *Brassica rapa* genotypes

Yield contributing traits	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of siliqua plant^{-1}	Siliqua length (cm)	No. of seeds siliqua^{-1}	1000 seed weight (g)
Days to 80% maturity	0.990**								
Plant height (cm)	0.772*	0.771*							
No. of primary branches plant^{-1}	0.111	0.124	0.493						
No. of secondary branches plant^{-1}	-0.551	-0.548	-0.865*	-0.806*					
No. of siliqua plant^{-1}	-0.784*	-0.577	-0.566	-0.366	0.939**				
Siliqua length (cm)	-0.019	0.039	0.794*	0.321	-0.259	-0.073			
No. of seeds siliqua^{-1}	0.630	0.534	0.321	0.122	-0.404	-0.871*	0.047		
Thousand seed weight (g)	0.795*	0.801*	0.885**	0.524	-0.912**	-0.846*	0.575	0.477	
Seed yield plant^{-1} (g)	0.989**	0.990**	0.812*	0.116	-0.596	-0.781*	0.095	0.598	0.768*

Here, ** = Significant at 1%; * = Significant at 5%

Days to 80% maturity

Days to 80% maturity showed high significant and positive correlation with seed yield plant^{-1} (r_g = 0.989** and r_p = 0.990**) at both genotypic and phenotypic levels hence direct selection for this trait will be effective in improving the seed yield. Hosen (2008), Uddin *et al.* (2013) and Halder *et al.* (2014) also found high significant and positive correlation of seed yield plant^{-1} with days to maturity but Naznin *et al.* (2015) and Kumari *et al.* (2017) revealed non-significant and positive interaction with seed yield plant^{-1}. Zahan (2006) studied non-significant negative association with days to maturity. It also showed significant and positive correlation with thousand seed weight (r_g = 0.843* and r_p = 0.801*) and plant height (r_g = 0.794* and r_p = 0.771*) whereas non-significant negative correlation with number of secondary branches plant^{-1} (r_g =-0.513 and r_p = -0.548) and number of siliqua plant^{-1} (r_g =-0.239 and r_p =-0.577) at both genotypic and phenotypic levels while having non-significant positive correlation with remaining traits at genotypic and phenotypic levels. Ejaz-Ul-Hasan *et al.* (2014) found positive and highly significant genetic relationship of 80% maturity with thousand seed weight and seed siliqua^{-1}.

Plant height

Plant height showed high significant and positive correlation with thousand seed weight (r_g = 0.924** and r_p = 0.885**) while it showed significant and positive correlation with seed yield plant^{-1} (r_g = 0.802* and r_p = 0.812*) and siliqua length (r_g = 0.849* and r_p = 0.794*) at both genotypic and phenotypic levels and number of primary branches plant^{-1} (r_g = 0.801*) at genotypic level only hence direct selection for this trait will be effective in improving the associated traits. Genotypic correlation coefficients were generally higher than their corresponding phenotypic correlations indicated strong hereditary association and the masking effects of environment on these traits. Joya *et al.* (2016), Afrin *et al.* (2017) and Siddique *et al.* (2017) reported that seed yield plant^{-1} had high significant positive association with plant height. Parveen (2007) and Mekonnen *et al*. (2014) observed that seed yield plant^{-1} had non-significant positive association with plant height while Kumari *et al.* (2017) observed that seed yield plant^{-1} had non-significant negative association with plant height. It was significant and negatively associated with number of secondary branches plant^{-1} (r_g = - 0.774* and r_p = - 0.865*) at both genotypic and phenotypic level. Non-significant and negative association was observed for number of siliqua plant^{-1} (r_g = - 0.091 and r_p = - 0.566) while the correlation of plant height with other remaining traits were positive but not significant at both genotypic and phenotypic level. Mekonnen *et al*. (2014) studied strong and positive correlation with number of siliqua plant^{-1}. Ejaz-Ul-Hasan *et al.* (2014) found a positive and high significant genetic relationship of plant height with seeds siliqua^{-1} while Siddique *et al.* (2017) observed negative and significant relationship of this trait with seeds siliqua^{-1}.

Number of primary branches plant^{-1}

Number of primary branches plant^{-1} showed high significant and negative correlation with number of secondary branches plant^{-1} at genotypic level (r_g = -0.952**) but have significant and negative correlation at phenotypic level (r_p = -0.806*). It also showed significant and positive correlation with thousand seed weight (r_g = 0.799*) at genotypic level only. It had negative and non-significant interaction with number of siliqua plant^{-1} (r_g = -0.186 and r_p = -0.366) at both genotypic and phenotypic level but had positive non-significant interaction with other remaining traits at both genotypic and phenotypic levels hence selection for this trait would not effective. Naznin *et al.* (2015), Singh *et al.* (2017) and Rauf and Rahim (2018) reported that seed yield plant^{-1} had significant positive correlation with number of primary branches plant^{-1} while Kumari *et al.* (2017) observed that seed yield plant^{-1} had non-significant negative association with number of primary branches plant^{-1}.

Number of secondary branches plant^{-1}

The number of secondary branches plant^{-1} showed high significant and positive correlation with number of siliqua plant^{-1} at phenotypic level (r_p = 0.939**) but had significant and positive correlation at genotypic level (r_g = 0.775*) while it showed highly significant and negative correlation with thousand seed weight at phenotypic level (r_p = -0.912**) but had significant and negative correlation at genotypic level (r_g = -0.871*). The correlation of this trait with other remaining traits were negative and non-significant at both genotypic and phenotypic levels. Uddin *et al.* (2013), Halder *et al.* (2014), Naznin *et al.* (2015) and Afrin *et al.* (2017) observed high significant positive association of this trait with seed yield plant^{-1}. Parveen (2007) and Mekonnen *et al*. (2014) observed non-significant positive association of this trait with seed yield plant^{-1}.

Number of siliqua plant^{-1}

It showed significant and negative correlation with number of seeds siliqua^{-1} (r_g = -0.775* and r_p = -0.871*) at both genotypic and phenotypic level. It also showed significant and negative correlation with thousand seed weight (r_p = -0.846*) and seed yield plant^{-1} (r_p = -0.781*) at phenotypic level only and had positive and non-significant association with siliqua length at genotypic level while had negative and non-significant association with other remaining traits thus selection for this trait would not effective. Jamali *et al.* (2016), Afrin *et al.* (2017) and Siddique *et al.* (2017) revealed that it had significant positive association with seed yield plant^{-1}. Parveen (2007) observed non-significant positive association with yield plant^{-1}. Siddique *et al.* (2017) found significant negative association for this trait with seeds siliqua^{-1}.

Siliqua length

It had a significant and positive association with thousand seed weight (r_g = 0.780*) at genotypic level while had non-significant and positive association with seed yield plant^{-1} (r_g = 0.144 and r_p = 0.095) at both genotypic and phenotypic levels, number of seed siliqua^{-1} (r_p = 0.047) and thousand seed weight (r_p = 0.575) at phenotypic level only but non-significant and negative correlation with number of seeds siliqua^{-1} (r_g = -0.034) at genotypic level only. The result was supported by Parveen (2007) and Kumari *et al.* (2017) where they observed seed yield plant^{-1} had non-significant positive association with it but Singh *et al.* (2017) and Rauf and Rahim (2018) reported that seed yield plant^{-1} had high significant positive association with this trait. Halder *et al.* (2014) reported seed yield plant^{-1} had high significant negative association with siliqua length. Ejaz-Ul-Hasan *et al.* (2014) found positive and high significant genetic relationship between siliqua length and seeds siliqua^{-1}.

Number of seeds siliqua^{-1}

It showed non-significant positive interaction with thousand seed weight (r_g = 0.406 and r_p = 0.477) and seed yield plant^{-1} (r_g = 0.571 and r_p = 0.598) at both genotypic and phenotypic levels. Non-significant association of these traits indicated large influences of environmental factors. The result was supported by Parveen (2007) and Kumari *et al.* (2017) while Jamali *et al.* (2016) and Rauf and Rahim (2018) observed positive and high significant association of this trait with seed yield plant^{-1} at both genotypic and phenotypic levels.

Thousand seed weight (g)

It had significant and positive interaction with seed yield plant^{-1} (r_g = 0.770* and r_p = 0.768*) at both genotypic and phenotypic levels (Table 2 and 3), hence direct selection for this trait will be effective in improving the seed yield. Genotypic correlation coefficients were generally higher than their corresponding phenotypic correlations indicated strong hereditary association among the traits due to genetic factors such as linkage and/or pleiotropic effect enabling consistent performance and the masking effects of environment on these traits. The result was supported by Maurya *et al.* (2012), Hussain *et al.* (2014), Joya *et al.* (2016), Afrin *et al.* (2017) and Rauf and Rahim (2018) while Naznin *et al.* (2015) and Kumari *et al.* (2017), reported that it had non-significant positive interaction with seed yield plant^{-1}. Yadava *et al.* (2011) and Kumari *et al*. (2017) found positive significant correlation of thousand seed weight with siliqua length and number of seeds siliqua^{-1}.

Days to 50% flowering and 80% maturity showed high significant and positive correlation with seed yield plant^{-1} at both genotypic and phenotypic level while plant height and thousand seed weight showed significant and positive correlation with yield plant^{-1} at both genotypic and phenotypic level indicated yield plant^{-1} would be increased if these associated traits increase, hence direct selection for these traits will be effective in improving the seed yield. Number of primary branches plant$^{-1,}$ siliqua length, Number of seeds siliqua^{-1} showed non-significant and positive correlation with yield plant^{-1} at both genotypic and phenotypic level while number of secondary branches plant^{-1} showed non-significant and negative correlation at both genotypic and phenotypic level. Number of siliqua plant^{-1} showed non-significant and negative correlation at genotypic level and significant negative correlation at phenotypic level with yield plant^{-1}. Non-significant association of these traits indicated large influences of environmental factors and therefore, selection for these traits would not be effective. However, such traits need further study on their direct and indirect effect on the grain yield plant^{-1} by path coefficient analysis to remark as selection criteria for grain yield improvement programs.

Path Coefficient Analysis

Path coefficient analysis was carried out in the present study (Table 4) considering yield plant^{-1} as dependent character and its attributes as independent characters. Each component has two path actions *viz.* direct effect on yield and indirect effect through components which are not revealed by correlation studies.

Table 4. Partitioning of genotypic correlations into direct (bold) and indirect effects of yield and yield related characters by path coefficient analysis in *Brassica rapa* genotypes

Traits	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches plant^{-1}	No. of secondary branches plant^{-1}	No. of siliqua plant^{-1}	Siliqua length (cm)	No. of seed siliqua^{-1}	Thousand seed weight (g)	Genotypic correlation with yield
Days to 50% flowering	**5.4155**	-7.8909	-1.6033	-0.0211	0.9094	-0.2589	0.1365	-0.6117	-0.6571	0.987**
Days to 80% maturity	5.3693	**7.9587**	-1.7086	-0.0232	0.9062	-0.2203	0.2189	-0.5130	-0.6597	0.989**
Plant height (cm)	3.5295	-5.5276	**2.4601**	-0.0758	1.1725	-0.0838	1.2449	-0.2401	-0.8204	0.802*
No. of primary branches plant^{-1}	1.0602	-1.7129	-1.7249	**-0.1081**	1.5037	-0.1713	0.7814	-0.1046	-0.6202	0.213
No. of secondary branches plant^{-1}	-2.7909	4.0874	1.6346	0.0921	**-1.7646**	0.6213	-0.3284	0.4495	0.7731	-0.593
No. of siliqua plant^{-1}	-1.5246	1.9063	0.2241	0.0201	-1.1920	**0.9197**	0.3909	0.7377	0.3089	-0.485
Siliqua length (cm)	0.4453	-1.0493	-1.8441	-0.0508	0.3490	0.2165	**1.6608**	0.0380	-0.4439	0.144
No. of seeds siliqua^{-1}	3.0338	-3.7393	-0.5411	-0.0103	0.7264	-0.6214	-0.0579	**-1.0919**	-0.3602	0.571
Thousand seed weight (g)	4.0119	-5.9191	-2.2754	-0.0756	1.5380	-0.3203	0.8310	-0.4434	**-0.8871**	0.770*

Here, Residual effect = 0.094, ** = Significant at 1%,* = Significant at 5%

Days to 50% flowering

It showed very high positive direct effect (5.4155) towards yield plant^{-1}. This result was supported by Uddin *et al.* (2013), Ejaz-Ul-Hasan *et al.* (2014) and Rashid *et al.* (2015) but Islam *et al.* (2016) and Rauf and Rahim (2018) who found that it had the negative direct effect on yield plant^{-1}. Kumari *et al.* (2017) showed that it exerted negative indirect effect on seed yield but showed very high negative indirect effect towards yield plant^{-1} via days to 80% maturity (-7.8909) and plant height (-1.6033) while negligible negative indirect effect via number of primary branches plant^{-1} (-0.0211). It also showed highly positive indirect effect towards yield plant^{-1} via number of secondary branches plant^{-1} (0.9094) while high negative indirect effect via number of seeds siliqua^{-1} (-0.6117) and thousand seed weight (-0.6571). However, moderate negative indirect effect was recorded towards yield plant^{-1} via number of siliqua plant^{-1} (-0.2589) and low positive indirect effect via siliqua length (0.1365). It had positive and high significant genotypic correlation (0.987**) with yield plant^{-1}.

Days to 80% maturity

It showed very high positive direct effect (7.9587) towards yield plant^{-1}. Ejaz-Ul-Hasan *et al.* (2014), Mekonnen *et al.* (2014), Naznin *et al.* (2015), Rashid *et al.* (2015) and Rauf and Rahim (2018) also found positive direct effect towards yield plant^{-1} but Hussain *et al.* (2014) and Halder *et al.* (2016) reported direct negative association with yield plant^{-1}. Further, it recorded high negative indirect effect towards yield plant^{-1} via thousand seed weight (-0.6597) and plant height (-1.7086), negligible negative indirect effect via number of primary branches plant^{-1} (-0.0232), moderate negative indirect effect via siliqua plant^{-1} (-0.2203) and moderate positive indirect effect via siliqua length (0.2189). However, high negative indirect effect towards yield plant^{-1} via number of seeds siliqua^{-1} (-0.5130) and number of secondary branches plant^{-1} (0.9062) and very high positive indirect effect via days to 50% flowering (5.3693). It showed positive and high significant genotypic correlation (0.989**) with yield plant^{-1}.

Plant height (cm)

It exhibited very high positive direct effect (2.4601) towards yield plant^{-1}. The result matched with Halder *et al.* (2016), Islam *et al*. (2016), Afrin *et al.* (2017), Karmokar (2018) and Rauf and Rahim (2018) while in the contrast, Uddin *et al.* (2013) and Rashid *et al.* (2015) found negative direct effect on yield plant^{-1}. Here the genotypic correlation was positive and significant (0.802*) with yield plant^{-1} (Table 4). Further, very high positive indirect effect towards yield plant^{-1} via days to 50% flowering (3.5295), siliqua length (1.2449) and number of secondary branches plant^{-1} (1.1725) while very high negative indirect effect via days to 80% maturity (-5.5276) was recorded. Naznin *et al.* (2015) observed positive indirect effect on seed yield plant^{-1} through siliqua length. It also showed high negative indirect effect towards yield plant^{-1} via thousand seed weight (-0.8204). However, it was found negligible negative indirect effect towards yield plant^{-1} via siliqua plant^{-1} (-0.0838) and number of primary branches plant^{-1} (-0.0758). It showed moderate negative indirect effect towards yield plant^{-1} via seeds siliqua^{-1} (-0.2401).

Number of primary branches plant^{-1}

It had low negative direct effect (-0.1081) towards yield plant^{-1}. Alam (2010) and Islam *et al.* (2016) also recorded negative direct effect on yield plant^{-1} but Halder *et al.* (2016), Afrin *et al.* (2017) and Rauf and Rahim (2018) reported that it had strong positive direct effect on seed yield. Further, it was recorded high positive indirect effect towards yield plant^{-1} via days to 50% flowering (1.0602) and number of secondary branches plant^{-1} (1.5037) while very high negative indirect effect via plant height (-1.7249) and days to 80% maturity (-1.7129). However, low negative indirect effect towards yield plant^{-1} was recorded via seeds siliqua^{-1} (-0.1046) and siliqua plant^{-1} (-0.1713). It showed highly positive indirect effect towards yield plant^{-1} via siliqua length (0.7814) and highly negative indirect effect via thousand seed weight (-0.6202). Here the correlation was non-significant and positive (0.213) with yield plant^{-1}.

Number of secondary branches plant^{-1}

It showed very high negative direct effect (-1.7646) towards yield plant^{-1}. Hussain *et al.* (2014), Islam *et al*. (2016) and Rauf and Rahim (2018) also found similar result but Naznin *et al.* (2015) and Rashid *et al.*(2015) reported that it had strong positive direct effect on seed yield. It also recorded high positive indirect effects to yield plant^{-1} via seeds siliqua^{-1} (0.4495), siliqua plant^{-1} (0.6213) and thousand seed weight (0.7731) but had high negative indirect effect via siliqua length (-0.3284). However, it had very high positive indirect effect towards yield plant^{-1} through days to 80% maturity (4.0874) and plant height (1.6346) while it had very high negative indirect effect via days to 50% flowering (-2.7909). It also showed negligible positive indirect effect towards yield via number of primary branches plant^{-1} (0.0921). The genotypic correlation of this trait with yield plant^{-1} (-0.593) was negative and non-significant.

Number of siliqua plant^{-1}

It exhibited high positive direct effect (0.9197) towards yield plant^{-1}. This result was supported by Naznin *et al.* (2015), Rashid *et al.* (2015), Islam *et al*. (2016), Afrin *et al.* (2017) and Rauf and Rahim (2018) but Halder *et al.* (2016) reported that it had the greater negative direct effect on seed yield plant^{-1}. Though it showed high positive direct effect on yield, but its correlation with yield was significant and negative at phenotypic level only. However, it showed highly positive indirect effect towards yield plant^{-1} via siliqua length (0.3909), seeds siliqua^{-1} (0.7377) and thousand seed weight (0.3089) while it had very high negative indirect effect via number of secondary branches plant^{-1} (-1.1920) and days to 50% flowering (-1.5246). It also showed very high and moderate positive indirect effect towards yield plant^{-1} via days to 80% maturity (1.9063) and plant height (0.2241) respectively but showed moderate positive indirect effect via number of primary branches plant^{-1} (0.0201) (Table 4). The genotypic correlation of this trait with yield plant^{-1} (-0.485) was negative and non-significant.

Siliqua length

It showed very high positive direct effect (1.6608) towards yield plant^{-1}. Hussain *et al.* (2014), Islam *et al*. (2016) and Rauf and Rahim (2018) also found positive direct effect but Rashid *et al.*(2015) and Kumari *et al.* (2017) found negative direct effect of it towards yield plant^{-1}. High negative indirect effect towards yield plant^{-1} via thousand seed weight (-0.4439) and high positive indirect effect via number of secondary branches plant^{-1} (0.3490) and days to 50% flowering (0.4453) while, very high negative indirect effects to yield plant^{-1} via days to 80 % maturity (-1.0493) and plant height (-1.8441) was recorded. It also showed negligible positive and negative indirect effect via seeds siliqua^{-1} (0.0380) and number of primary branches plant^{-1} (-0.0508), respectively towards yield plant^{-1} and moderate positive indirect effect via number of siliqua plant^{-1} (0.2165) (Table 4). The genotypic correlation of siliqua length with yield plant^{-1} (0.144) was positive and non-significant.

Number of seeds siliqua^{-1}

It showed very high negative direct effect (-1.0919) towards yield plant^{-1}. Hussain *et al.* (2014) and Rashid *et al.* (2015) also found similar result but Afrin *et al.* (2017) and Rauf and Rahim (2018) revealed greater direct positive contribution of it on seed yield. Further, it was recorded very high positive indirect effect towards yield plant^{-1} via days to 50% flowering (3.0338) while very high negative indirect effect via days to 80% maturity (-3.7393). It also showed high negative indirect effect via thousand seed weight (-0.3602), plant height (-0.5411) and number of siliqua plant^{-1} (-0.6214) while negligible negative indirect effect via number of primary branches plant^{-1} (-0.0103) and siliqua length (-0.0579) towards yield plant^{-1} while highly positive indirect effect towards yield plant^{-1} via number of secondary branches plant^{-1} (0.7264). It had non-significant and positive genotypic correlation (0.571) with yield plant^{-1}.

Thousand seed weight

It showed high negative direct effect (-0.8871) towards yield plant^{-1}. Alam (2010), Rashid *et al.* (2015) and Islam *et al*. (2016) also found negative direct effect of this trait towards yield plant^{-1} while, Joya *et al.* (2016), Afrin *et al.* (2017) and Rauf and Rahim (2018) revealed the maximum direct positive effect towards yield plant^{-1}. Naznin *et al.* (2015) found negative indirect effect for thousand seed weight towards yield plant^{-1}. However, it showed high negative direct effect on yield but its correlation with yield was significant and positive (0.770*). Further, it was recorded very high positive indirect effect towards yield plant^{-1} via number of secondary branches plant^{-1} (1.5380), siliqua length (0.8310) and days to 50% flowering (4.0119) while very high negative indirect effect via days to 80 % maturity (-5.9191) and plant height (-2.2754) but had high negative indirect effect via seeds siliqua^{-1} (-0.4434) and number of siliqua plant^{-1} (-0.3203) but negligible negative indirect effect via number of primary branches plant^{-1} (-0.0756) towards yield plant^{-1}.

Residual effect

The magnitude of residual effect (0.094) indicated that traits included in the path analysis explained about 90.6% of the variation in yield. However, the remaining variation in yield (9.4%) can be attained by incorporating other yield related traits in the path analysis as far as studies involving association of traits is concerned. Karmokar (2018) also found residual effect 0.091 while Naznin *et al.* (2015) found 0.450, Islam *et al.* (2016) found 0.430 and Ullah (2018) found 0.570 in case of yield plant^{-1}.

Days to 50% flowering and 80% maturity, plant height, number of siliqua plant^{-1}, siliqua length showed very high positive direct effect towards yield plant^{-1} while thousand seed weight, number of primary and secondary branches plant^{-1} and number of seeds siliqua^{-1} had high positive indirect effect towards yield plant^{-1} hence all the traits were the most important contributors to seed yield plant^{-1} which could be taken in consideration for future hybridization program. Strong direct effect indicate selection of the traits might be effective for yield improvement. Low residual effect indicated respective traits of the study explained almost all the variability towards yield.

CONCLUSION

Correlation analysis revealed that days to 50% flowering and 80% maturity, plant height and thousand seed weight had positive significant correlation with seed yield plant^{-1} and path coefficient analysis indicated that days to 50% flowering and 80% maturity, plant height, number of siliqua plant^{-1} and siliqua length showed very high positive direct effect towards yield plant^{-1}, hence direct selection for such traits will be effective in improving the seed yield in *B. rapa*. The strong positive association among the traits indicated that simultaneous selection for these characters would result in improvement of high yielding varieties.

REFERENCES

Afrin, F., Mahmud, F. and Islam, M.S. 2017. Genetic variability and character association in BC_1F_6 population of *Brassica napus* L. MS. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

AIS. 2020. Agricultural Information Service. Krishi Diary (In Bangla). Khamarbari, Farmgate, Dhaka, Bangladesh, 16 pp.

Alam, M.F. 2010. Variability studies in F_4 progenies of *Brassica rapa* obtained through inter-varietal crosses. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Ali, N., Javidfar, F., Elmira, J.Y. and Mirza, M.Y. 2003. Relationship among yield components and selection criteria for yield improvement in winter rapeseed (*Brassica napus* L.). *Pakistan J. Bot.,* 35 (2): 167-174.

Al-Jibouri, H., Miller, P.A. and Robinson, H.F. 1958. Genotypic and environmental variances and co-variances in an upland cotton cross of interspecific origin. *Agron. J.,* 50 (10): 633-636.

Dewey, D.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.,* 51: 515-518.

Ejaz-Ul-Hasan, Mustafa, H.S.B., Bibi, T. and Mahmood, T. 2014. Genetic variability, correlation and path analysis in advanced lines of rapeseed (*Brassica napus* L) for yield components. *Cercetări Agron.,* 1 (157): 71-79.

Halder, T., Bhuiyan, M.S.R. and Islam, M.S. 2014. Variability and correlation study of some advanced lines of *Brassica rapa*. *Bangladesh J. Pl. Breed. Genet.,* 27 (1): 25-36.

Halder, T., Bhuiyan, M.S.R., Islam, M.S. and Hossain, J. 2016. Analysis of relationship between yield and some yield contributing characters in few advanced lines of rapeseed (*Brassica rapa* L.) by using correlation and path analysis. *Adv. Agric. Bot*., 8 (1): 32-42.

Hosen, M. 2008. Variability, correlation and path analysis in F_3 materials of *Brassica rapa* L. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Hussain, M.A., Hossain, M.S. and Bhuiyan, M.S.R. 2014. Genetic variability and character association of advanced lines in *Brassica rapa*. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Islam, M.S., Haque, M.M., Bhuiyan, M.S.R. and Hossain, M.S. 2015. Estimation of genotypic and phenotypic coefficient variation of yield and its contributing characters of *Brassica rapa* L. *American- Eruasian J. Agril. Environ. Sci.,* 15 (10): 2029-2034.

Islam, M.S., Haque, M.M., Bhuiyan, M.S.R. and Hossain, M.S. 2016. Path coefficient analysis and correlation coefficients effects of different characters on yield of *Brassica rapa* L. Plant. 4 (6): 51-55.

Jamali, K.H., Mari, S.N., Soomro, Z.A., Soomro, S. and Khanzada, A. 2016. Correlation study on yield and yield contributing traits in *Brassica compestris* L. *Int. J. Life Sci.,* 10 (1): 1-7.

Joya, S., Shamsuddin, A.K.M. and Nath, U.K. 2016. Genetic variability, heritability and characters associations in rapeseed (*Brassica napus* L.). *Bangladesh J. Pl. Breed. Genet*., 29 (2): 11-16.

Kahrizi, D. and Alaahvarand, T. 2012. Estimation and interrelationships of genetic variability parameters of some morpho-phenological traits in spring rapeseed (*Brassica napus* L.). *Asian J. Biol. Sci.,* 5: 358-364.

Karmokar, D. 2018. Genetic study on the yield and quality traits of advanced breeding populations in *Brassica rapa* L. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Kumari, S., Kumar, K. and Kumari, K. 2017. Study on correlation among different character pairs and path coefficient analysis in yellow sarson (*Brassica rapa*. Var. Yellow Sarson). Prog. Agric. 17 (1): 1-20.

Lenka, D. and Mishra, B. 1973. Path coefficient analysis of yield in rice varieties. *Indian J. Agril. Sci*., 43: 376-379.

Mary, S.S. and Gopalan, A. 2006. Dissection of genetic attributes yield traits of fodder cowpea in F_3 and F_4. *J Appl. Sci. Res.,* 2: 805-808.

Maurya, N., Singh, A.K. and Singh, S.K. 2012. Inter-relationship analysis of yield and yield components in Indian mustard, *Brassica juncea* L. *Indian J. Pl. Sci*. 1 (23): 90-92.

Mekonnen, T.W., Wakjira, A. and Genet, T. 2014. Correlation and path coefficient analysis among yield component traits of Ethiopian mustard (*Brassica carinata*). *Ethiopian J. Pl. Sci*. 2 (2): 89-96.

Naznin, S., Kawochar, M.A., Sultana, S. and Bhuiyan, M.S.R. 2015. Genetic variability, character association and path analysis in *Brassica rapa* L. Genotypes. *Bangladesh J. Agril. Res.,* 40 (2): 305-323.

Parveen, S. 2007. Variability study in F_2 progenies of inter-varietal crosses of *Brassica rapa* L. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Rashid, M.H.U., Parveen, S. and Bhuiyan, M.S.R. 2015. Morphological attributes species identification of oleiferous *Brassica* species and better parents selection criteria for *Brassica juncea*. *Int. J. Cur. Res*., 7 (9): 19847-19854.

Rauf, M.A. and Rahim, M.A. 2018. Genetic variability studies among yield and its contributing traits in mustard (*Brassica napus* L.). Adv. Zool. Bot., 6 (4): 101-108.

Sabaghnia, N., Dehghani, H., Alizadeh, B. and Mohghaddam, M. 2010. Interrelationships between seed yield and 20 related traits of 49 canola (*Brassica napus* L.) genotypes in non-stressed and water-stressed environments. *Spanish J. Agric. Res.,* 8: 356-370.

Shekhawat, G., Jadeja C., Singh, J. and Shekhawat, R.S. 2014. Character association studies among yield and its component characters in Indian mustard (*Brassica juncea* L. Czern and Coss). The Biosean, 9 (2): 685-688.

Siddique, D.M., Chandio, S.A., Ahmed, N.S., Karloo, W.M., Pathan, K.A., Meghwar, L.B. and Laghari, M.A. 2017. Character association of *Brassica campestries* L. *J. Agril. Res*., 55 (2): 249-265.

Singh, P., Chauhan, V.V., Meena, J.S. and Mishra, D.C. 2013. Correlation and path coefficient analysis for yield and yield components in early generation lines of Indian mustard (*Brassica juncea* L.). Curr. Adv. Agril. Sci., 5 (1):37- 40.

Singh, A.P.K., Verma, O.P. and Kumar, K. 2017. Estimates of genetic variability parameters and interrelationships of morpho-physiological traits in yellow sarson (*Brassica rapa* L. var. yellow sarson). *Elect. J. Pl. Breed*., 8 (2): 629 -635.

Tripathi, N., Kumar, K. and Verma, O.P. 2013. Genetic variability, heritability and genetic advance in Indian mustard (*Brassica juncea* L. Czern and Coss) for seed yield and it's contributing attributes under normal and saline/alkaline condition. *Int. J. of sci. Res.*, 6: 6-14.

Uddin, M.S., Bhuiyan, M.S.R., Kabir, K., Shahjahan, M. and Rahaman, M.S. 2013. Variability study in F_2 progenies of *Brassica rapa. Int. J. Agric. Crop Sci*., 6 (11): 676-683.

Yadava, D.K., Giri, S.C., Vignesh, M., Vasudev, S., Yadav, A.K., Das, B., Singh, R., Singh, N., Mohapatra, T. and Prabhu, K.V. 2011. Genetic variability and trait association studies in Indian mustard (*Brassica juncea*). *Indian J. Agril. Sci*., 81 (8): 712–716.

Zahan, M.I. 2006. Morphological characterization and genetic diversity in oleiferous *Brassica* species. M.S. Thesis, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.