Analysis of relationship between yield and some yield contributing characters in few advanced lines of rapeseed (*Brassica rapa*) by using correlation and path analysis

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Abstract. The correlation co-efficient analysis and direct and indirect effect of eleven characters on yield per hectare was studied on eleven advanced lines and three popular check varieties of *Brassica rapa*. To study the interrelationships among the characters, the genotypic correlation co-efficient was done. It was found that yield per hectare was positively and highly significantly correlated with days to first flowering, days to 80% flowering and number of primary branches per plant which indicated that the yield would be higher by improving these characters while would be decreased with the increase of days to 50% flowering and length of siliquae as they were negatively correlated with yield. The interrelationship was clearly pictured through path co-efficient analysis. Plant height showed highest positive and highly significant direct association with the yield per hectare followed by number of primary branches per plant. Highest negative significant direct effect was found in number of siliquae per plant followed by days to maturity. The high direct effect gave the massage that selection of the traits might be effective for yield improvement. Low residual effect indicated that the considered traits of the study explained almost all the variability towards yield.

Key Words: inter-varietal crosses, genotypic correlation, direct and indirect effects, variability.

Introduction. *Brassica* sepecies under the family Brassicaceae, have been changed to meet up the demand of human being. The most important crops of the family Brassicaceae is oilseed crops. Among the oilseed crops *Brassica rapa*, *B. napus* and *B. juncea* is known as rapeseed, oilseed rape or canola (Khan et al 2008). *B. rapa* and *B. napus* is referred as rapeseed where the rest one is known as mustard.

Among the oil seed crops like mustard and rapeseed, soybean, groundnut, linseed, safflower, sunflower etc. the former one is in the third position after soybean and palm oil (FAO 2005). About 408,328.17 hectare area was used for 804,000 MT oil seed production in Bangladesh and among them 294,648.23 hectare was covered by rape and mustard seed during 2012-2013 (BBS 2013). Mustard is the source of 13.2% of the edible oil (Downey & Robbelen 1989).

It secures the top rank among the oil seed crops in Bangladesh and about 60% of the total acreage land is covered by it (BBS 2010). The utilization of oil seed in Bangladesh is 102.7 million ton where 44 million ton is imported (FAO 2013). *B. rapa* occupies first position in oil crops with cultivated area 252,238.13 ha which produced 0.246 million tons per seed and average yield was 0.997 t ha^{-1} during 2010-2011 (BBS 2011a) due to its low erucic acid and low glucosinolate. About 0.832 million tons of edible oil produced in the country that is very lower than the requirement (BBS 2011b). In spite of being a major oil producing crop, it has lower average yield than the other developing countries. There are two important reasons behind this.

First of all the yield potential of the commonly used *B. rapa* varieties are in stagnant position (Shathi et al 2012). The second one is that the farmers still use the low yielding varieties with the smaller seed size and weight (Farhana 2012). At present, the leading short duration variety of it is TORI-7 which has lower yield like 1.1-1.13 t ha^{-1} (Karim et al 2014). The total amount of land for mustard is reducing in increasing rate for using more land in Boro rice cultivation (BBS 2010). *B. rapa* is well suited in aman-mustard-boro cropping pattern where there is still lack of high yielding short durable variety of the crop.

Hence, the necessity of production of short durable and high yielding new varieties has aroused to solve the present problem of edible oil production in Bangladesh. That's why the study was come to concern. Study was therefore conducted to estimate the correlation and path analysis of fourteen genotypes of *B. rapa*. Here, the correlation is mostly occurred because of pleiotropic effects or linkages between the traits. Breeding value of correlation is more useful in crop improvement, especially for indirect selection which is advantageous over direct selection. To evaluate the genotypic relationship of different yield contributing characters towards the yield per hectare, the present study was conducted.

Material and Method. The experimental field of the Department of Genetics and Plant Breeding of Sher-e-Bangla Agricultural University was the experimental site of the research work. The experiment was conducted during Nov 2013 to Feb 2014. Fourteen genotypes were used as experimental materials in which eleven advanced lines and three popular check varieties of Bangladesh (BARI Sarisha-14, BARI Sarisha-15 and TORI-7) were taken. From six and more than six generations of inter-varietal crosses of *B. rapa*, the advanced lines were obtained that is listed below (Table 1).

Table 1

Name of the advanced lines with their abbreviated forms

Name of the lines	*Crosses*	
1. SAUSR 04	F_6 × BARI Shrisha-9	S_1
2. SAUSR 05	F_6 × BARI Sarisha-9	S_2
3. SAUSR 06	F_6 × BARI Sarisha-9	S_3
4. SAUSR 07	BARI Sarisha-6× Tori-7	S_1
5. SAUSR 08	BARI Sarisha-6× Tori-7	S_2
6. SAUSR 09	BARI Sarisha-9 × BARI Sarisha-6	S_1
7. SAUSR 10	BARI Sarisha-9 × BARI Sarisha-6	S_2
8. SAUSR 11	BARI Sarisha-9 × BARI Sarisha-6	S_3
9. SAUSR 12	SS_{75} × Tori-7	
10. SAUSR 13	BARI Sarisha-9 × F_6	
11. SAUSR 14	Tori-7× BARI Sarisha-9	

S1 - Line 1, S2 - Line 2, S3 - Line 3.

Three replications of the materials were used in the randomized complete block design (RCBD). The length of single row in each plot was 3 m and the spacing between the rows was 30 cm. Plant to plant distance was maintained 10 cm. 13 t ha^{-1} cowdung, 251:184:85:152:3:13 kg ha^{-1} urea : triple super phosphate (TSP) : muriate of potash (MoP) : gypsum : zinc sulphate : boric acid was used as fertilizers. Before the application of chemical fertilizers, cowdung was applied. 50% urea and whole TSP, MoP, gypsum, zinc sulphate, boric acid was used as basal dose and at the flower initiation stage the remaining 50% urea was used as top dressing. At 15 DAS (days after sowing) first weeding and thinning was done. Second weeding, thinning and top dressing were done at 25 DAS.

For data collection, 10 plants of each genotypes of each replication were taken. Data was recorded on days to first flowering, days to 50% flowering, days to 80% flowering, days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, length of siliquae, number of seeds per siliquae, yield per hectare and thousand seed weight. Genotypic correlation obtained by the formula that was suggested by Sing & Chaudhary (1985). Path co-efficient analysis was done by following the outlined method of Dewey & Lu (1959). A computer based software, MSTAT was used to accomplish all the statistical analysis

Results and Discussion

Correlations between yield per hectare and yield treating characters. Genotypic correlation coefficient between pairs of characters for advanced lines and check varieties of *B. rapa* are presented in Table 2. Highest highly significant positive correlation with yield per hectare was found in days to 80% flowering (0.74). However, the days to first flowering was positively and highly significantly correlated (0.54) with yield per hectare. Positive and significant correlation was found in number of primary branches per plant (0.45) and number of seeds per siliquae (0.41). Non-significant positive correlation was revealed in plant height and number of siliquae per plant.

On the other hand days to 80% maturity showed highest negative and significant correlation (-0.40). Days to 50% flowering and number of secondary branches per plant showed negatively significant correlation with the yield per hectare which was 0.47 and 0.42, respectively where negative but non-significant correlation was found in length of siliquae and thousand seed weight.

Yield per hectare will be increased if more duration is found for days to 1st flowering, days to 80% flowering, higher number of primary branches per plant, more number of siliquae per plant and seeds per siliquae with higher plant height.

Correlation among the yield contributing traits. Days to 1st flowering had highly significant and positive correlation with the days to 50% flowering, days to 80% flowering, plant height, number of secondary branches per plant, number of seeds per siliquae while negative and highly significant correlation with number of primary branches per plant, siliquae length and thousand seed weight. Days to 50% flowering was positively and highly significantly correlated with days to 80% flowering while positive significant correlation with the trait was found with days to maturity and number of secondary branches per plant. Days to maturity, plant height, number of secondary branches per plant and number of siliquae per plant were highly significantly and positively correlated with days to 80% flowering.

Days to 80% maturity had positive and significant correlation only with number of secondary branches per plant but negative and highly significant correlation with siliquae length. Negative significant correlation existed between days to maturity and number of primary branches per plant and number of seeds per siliquae.

Highly significant negative correlation was estimated between plant height and siliquae length and no positive significant correlation was found in case of plant height. It was revealed that positive highly significant and significant correlation with number of primary branches per plant was found in siliquae length and number of seeds per siliquae, respectively while negative but significant correlation existed between the former traits and number of secondary branches per plant.

Siliquae length had highly significant and positive correlation with number of secondary branches per plant but number of seeds per silique showed significant but negative correlation with the last mentioned trait. Number of siliquae per plant had highly significant positive correlation with siliquae length. Number of seeds per siliquae showed negative but highly significant correlation with siliquae length where siliquae length had highly significant and positive correlation with thousand seed weight.

Table 2

Genotypic (r_g) correlation among different yield and yield contributing characters of 14 genotypes of *Brassica rapa*

Characters	*DFiF*	*DEF*	*DM*	*PH (cm)*	*NPBP*	*NSBP*	*NSP*	*NSS*	*SL (cm)*	*TSW (g)*	*YH (kg)*
DFF	0.71**	0.75**	0.17*	0.34**	-0.62**	0.24**	-0.33**	0.64**	-0.56**	-0.20**	0.54**
DFiF		0.73**	0.44*	-0.37*	-0.48*	0.45*	-0.29	-0.45*	-0.50**	-0.34	-0.47*
DEF			0.24**	0.87**	-0.71**	0.28**	-0.34**	0.79**	-0.84**	-0.33**	0.74**
DM				-0.31	-0.41*	0.39*	-0.25	-0.38*	-0.35**	-0.29	-0.40*
PH (cm)					0.35	-0.32	0.21	0.32	-0.56**	0.24	0.34
NPBP						-0.43*	0.27	0.42*	0.26**	0.32	0.45*
NSBP							-0.25	-0.39*	0.19**	-0.29	-0.42*
NSP								0.25	0.68**	0.19	0.27
NSS									-0.61**	0.29	0.41*
SL (cm)										0.63**	-0.42
TSW (g)											-0.19

* - significant at 5% level of probability, ** - significant at 1% level of probability, DFF - days to 1st flowering, DFiF - days to 50% flowering, DEF - days to 80% flowering, PH - plant height, NPBP - number of primary branches per plant, NSBP - number of secondary branches per plant, DM - days to maturity, NSP - number of siliquae per plant, NSS - number of seeds per silique, SL - siliquae length, TSW - thousand seed weight, YH - yield per hectare.

Days to maturity could be reduced by increasing the number of primary branches per plant, number of seeds per siliquae and siliquae length as they were negatively and significantly correlated with the trait. Due to positive and highly significant correlation, the increase of the duration of the 80% flowering will be helpful for higher plant height, more number of secondary branches per plant and increased number of seeds per silique. Number of primary branches per plant, number of siliquae per plant and thousand seed weight will be decreased with the increase of duration of days to 1st flowering as they were negatively and highly significantly correlated. Number of siliquae per plant and siliquae length will be increase with the higher number of primary branches per plant. Increase of days to 80% maturity has a reverse effect on length of siliquae whereas the length will be increased if the siliquae number increases. When the length of siliquae will increase the thousand seed weight will be higher.

To get more yields per hectare, days to 1st flowering, days to 80% flowering, number of primary branches per plant and number of seeds per siliquae should be improved as there were significant positive correlation existed between them.

Path analysis. Seed yield is the ultimate product of several yield contributing characters. Simple correlation co-efficient are helpful to determine the association of characters which might not provide an clear picture of the relative importance of direct and indirect influence of each yield components on seed yield of the plant. For this reason, to establish the intensity of the effects of independent variables (causal variables) to dependent variables (resultant variables), genotypic correlation co-efficient were partitioned. Seed yield per hectare was considered as dependent variable while the rests were considered as independent variables. Estimation of direct and indirect effect of path co-efficient analysis for *B. rapa* is presented in Table 3. Residual effects of their independent variables, the environmental effect and sampling error which influenced on yield to a medium extent (0.25), have been denoted as 'R'.

It was revealed from the path analysis that plant height (0.96) showed highest positive and highly significant direct effect to seed yield per hectare where the correlation co-efficient was moderate. Positive and highly significant direct effects were also found in days to 50% flowering (0.39), days to 80% flowering (0.54), number of primary branches per plant (0.65), siliquae length (0.08) and thousand seed weight (0.55) while the days to 80% maturity (-1.03), number of siliquae per plant (-0.10) and number of seeds per siliquae (-1.88) showed negative but significant direct effect on yield per hectare.

There were no positive indirect effects on number of primary branches per plant. Days to 80% flowering and plant height had positive indirect effect on number of siliquae per plant and the other characters had negative effect. Number of siliquae per plant showed highest positive and plant height highest negative indirect effect on number of seeds per siliquae. In case of siliquae length, days to 80% maturity had highest negative indirect effect. All considered characters except days to 50% and 80% flowering had positive indirect effect on thousand seed weight which leads to positive direct effect of the character to yield per hectare in spite of negative correlation co-efficient. Days to 80% maturity showed highest positive indirect effect on thousand seed weight.

Table 3

Path co-efficient analysis showing direct and indirect effect of yield components on yield per hectare in 14 materials of *Brassica rapa*

Characters	*Days to 50% flowering*	*Days to 80% flowering*	*Days to 80% maturity*	*Plant height (cm)*	*No. of primary branches plant^{-1}*	*No. of silique plant^{-1}*	*No. of seeds per siliquae*	*Siliquae length (cm)*	*TSW (g)*	r_g
Days to 50% flowering	0.39**	0.39	-0.18	0.17	-0.29	-0.07	-0.95	-0.04	-0.07	-0.47
Days to 80% flowering		0.54**	-0.25	0.83	-0.46	0.04	-1.47	-0.06	-0.18	0.74
Days to 80% maturity			-1.03**	0.64	-0.03	-0.05	0.14	-0.03	0.37	-0.40
Plant height (cm)				0.96**	-0.21	0.03	-0.61	-0.04	0.24	0.34
No. of primary branches plant^{-1}					0.65**	-0.03	0.61	0.02	0.27	0.45
No. of siliqua plant^{-1}						-0.10**	1.14	0.05	0.32	0.28
No. of seeds siliquae^{-1}							-1.88*	-0.05	0.12	0.45
Siliquae length (cm)								0.08**	0.35	-0.42
TSW (g)									0.55**	-0.19

Residual effect, R = 0.25. The bold data indicates direct effect and the rests indirect effect. TSW - thousand seed weight.

Discussion. Determining the correlation between yield and yield contributing characters have great interest to plant breeder so that the important yield related characters are easy to identify to improve yield of plant. Genotypic correlations were discussed in this study. It was revealed that highly significant and positive correlation with yield per hectare were found with days to first flowering and days to 80% flowering when days to primary branches per plant and number of seeds per siliquae showed positive and significant correlation with yield per hectare. Negative significant correlations with yield were found in days to 50% flowering, days to maturity and number of secondary branches per plant.

Significant and positive correlation between number of primary branches per plant and seed yield per hectare was supported by Uddin et al (2013) while it was partially supported by Tahira et al (2011). Zahan (2006) observed highly positive association between yield per plant and seed per siliquae that supports the result of the present study. Positive and highly significant correlation between seeds per siliquae, days to maturity and seed yield was found by Hosen (2008). On the other hand Uddin et al (2013) reported positive but non-significant correlation between them. In contrast Zahan (2006) and Uddin et al (2013) reported that days to 50% flowering and days to maturity showed negative but insignificant association with seed yield. Naznin et al (2015) supported negative correlation between days to maturity and yield per plant while Akter (2010) opposed to it. Naznin (2013) and Islam et al (2015) found positive significant relation between secondary branches per plant and yield per plant while Akter (2010) found negative result.

Siddikee (2006) studied correlation analysis on *B. campestris* and found that yield per plant were positively and significantly correlated with number of siliquae per plant that partially supported the current study result. Positive and highly significant correlation was found between siliquae length and yield per plant which was partially supported by Ara et al (2013). Uddin et al (2013) and Ara et al (2013) found negative correlation between plant height and yield per plant that is opposite to our found result. On the other hand Naznin et al (2015) found positive and highly significant correlation between the two variables. The positive but non-significant correlations between the mentioned traits are supported by Musnicki (1974), Akbar et al (2003) and Naazar et al (2003). Non-significant and negative correlation between yield per plant and thousand seed weight was found from this study and that is similar to the findings of Uddin et al (2013) and Afrin et al (2011). However, Helal et al (2014) opposed the result as he found positive and significant correlation between that to characters.

The present study considered the genotypic path analysis. The current investigation found higher positive direct effect of plant height, number of siliquae per plant, thousand seed weight, days to 80% flowering and days to 50% flowering on yield per hectare. On the contrary, negative direct effect on yield per hectare was seen by number of siliquae per plant, days to maturity and number of seeds per siliquae.

Highest positive significant direct effect on yield per hectare was found in plant height that was supported by Marjanovic-Jeromela et al (2008) but Uddin et al (2013) reported the highest result for primary branches per plant and Ara et al (2013) found it to number of secondary branches per plant where Helal et al (2014) reported negative association between that, two characters. Ejaz-Ul-Hasan et al (2014) supported the result in case of days to 50% flowering. Belete (2011) and Tahira et al (2011) also found negative direct effect on yield per plant by number of seeds per siliquea that supported the present study.

Conclusions. Days to 80% flowering and number of primary branches per plant should be improved due to their positive and significant correlation and direct effect on yield to get higher production of the crop. Days to maturity should be reduced for crop improvement as it should negatively significant correlation and direct effect on yield per hectare of *B. rapa*.

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