COMPARATIVE AND GENETIC STUDY OF THE ADVANCED POPULATIONS OF *Brassica rapa* L.

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CERTIFICATE

*This is to certify that thesis entitled, **"COMPARATIVE AND GENETIC STUDY OF THE ADVANCED POPULATIONS OF Brassica rapa L."** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS AND PLANT BREEDING,** embodies the result of a piece of bona fide research work carried out by **SURAIYA SHARMIN**, Registration No. **08-02740** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated: June, 2016
Place: Dhaka, Bangladesh

(Dr. Md. Shahidur Rashid Bhuiyan)
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

An experiment was conducted by using seventeen F_{14} generation of *Brassica rapa* obtained through advancing generation of different inter-varietal crosses and one check variety in Randomized Complete Block Design with three replications at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka during November 2015 to February 2016 growing season to compare the various populations and to study the variability, heritability, genetic advance, correlation and direct and indirect effect of different characters on seed yield. The characters showed significant variations among the genotypes. Phenotypic variance was higher than the genotypic variance for every character. Minimum difference between phenotypic and genotypic variance was seen in number of primary branches per plant, number of secondary branches per plant, siliqua length, number of seeds per siliquae, days to 50% flowering, days to 80% flowering, days to 80% maturity, thousand seed weight and seed yield per plant. Moderate heritability with low genetic advance and high genetic advance in percentage of mean was found in number of secondary branches per plant while high heritability with moderately high genetic advance in percentage of mean was observed in number of primary branches per plant, number of siliqua per plant and seed yield per plant. Significant positive association with seed yield per plant was observed in number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and thousand seed weight. On the other hand significant negative correlation was found in number of seeds per siliquae, days to 50% flowering, days to 80% flowering and days to 80% maturity. Path co-efficient analysis revealed that all the characters had positive direct effect on seed yield per plant except plant height and days to 80% flowering. From this comparative study two advanced populations G16 and G17 were selected based on their better performances over the check variety and other advanced populations in respect of days to maturity, number of primary branches per plant, number of siliqua per plant, thousand seed weight and seed yield per plant to release as a new variety.

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SOME COMMONLY USED ABBREVIATIONS

FULL WORD	ABBREVIATION
Agro-Ecological Zone	AEZ
Agricultural	*Agril.*
And others	*et al.*
Agronomy	*Agron.*
Analysis of variance	ANOVA
At the rate	@
Bangladesh Bureau of Statistics	BBS
Biological	*Biol.*
Centimeter	Cm
Co-efficient of Variation	CV
Degree Celsius	°C
Degree of Freedom	D.F.
Etcetera	etc.
Environmental variance	δ^2_e
Fourth generation of a cross between two dissimilar homozygous parent	F_4
Fourteen generation of a cross between two dissimilar homozygous parent	F_{14}
Food and Agricultural Organization	FAO
Genotype	G
Genetic Advance	GA
Genotypic Co-efficient of Variation	GCV
Genotypic Variance	δ^2_g
Gram	G
Hectare	H
Heritability in broad sense	h^2b
Hydrogen ion potentiality	pH
Journal	*J.*
Kilogram	Kg
Least Significant Difference	LSD
Meter	m
Mean Sum of Square	MS
Millimeter	Mm
Mill equivalent	meq
Muriate of Potash	MP
Number	No.
Per	/
Percent	%
Phenotypic Co-efficient of Variation	PCV
Phenotypic variance	δ^2_p
Randomized Complete Block Design	RCBD
Replication	R
Research	*Res.*
Science	*Sci.*
Sher-e-Bangla Agricultural University	SAU
Triple Super Phosphate	TSP

CHAPTER I

INTRODUCTION

Brassica is a cross-pollinated oil crops belonging to the family Brassicaceae. *Brassica rapa* L. commonly known as field mustard or turnip mustard is widely cultivated as an oil seed. The primary centre of origin for *Brassica rapa* L. is near the Himalayan region and the secondary centre of origin is located in the European mediterranean area and Asia (Downey and Robbelen, 1989). Major producing regions of this crop are china, Canada and northern Europe and the Indian subcontinent (Ram and Hari, 1998). The genus *Brassica* has generally been divided into three groups namely rapeseed, mustard and cole. The rapeseed group includes the diploid *Brassica rapa*, turnip rape (AA, 2n = 20) and amphidiploid *Brassica napus* (AACC, 2n =38) (Yarnell *et al*., 1956).

Brassica have great economic and commercial value and play a major role in our daily diet. In a balanced diet 20-25% of calories should come from fats and oils and the average need of fats and oils in about 37 g/day (Rahman, 1981). The seeds of *Brassica rapa* contain 42% oil, 25% protein (Khaleque, 1985).

It is used as a condiment, salad, green, organic manure and fodder crop and as a leaf and stem vegetable in various mustard growing countries of the world. Rapeseed is grown for the production of animal feed, vegetable oil for human consumption, and biodiesel.

Rapeseed is the second largest oilseed crop in the world providing 13% of the world's edible oil after soybean. In 2012-2013, the edible oil production from major oilseeds crops in the world was 497.9 million tons where rapeseed contributed 64.3 million tons (FAO, 2014). During 2014, rapeseed were globally grown on area of 36.5 million hectare with the total production of 72.7 million metric tons having average yield of 1991.0 kg/ ha (FAO, 2014).

In Bangladesh *Brassica rapa* is the main oil yielding species of *Brassica* and it occupies the 1st position in respect of area and production among the oil crops grown in Bangladesh that covers about 60% of the total acreage land (BBS , 2015a). Though the local cultivars of *Brassica juncea* and *Brassica napus* are high yielding, they are not short durable. That's why *Brassica rapa* is grown widely throughout the country. In Bangladesh, 252238.13 ha of land was under rapeseed cultivation which produced about 246494 tons of seed and average yield was 0.977 ton per ha during 2014-2015 (BBS, 2015a).

Bangladesh has been facing acute shortage of edible oil for the last several decades. The utilization of oil seed in Bangladesh is 1.8 million tons where 1.6 million tons is imported (FAO, 2013). Our internal production can meet only about 21% of our consumption. The rest 79 % is met from the import (BBS, 2015a).

Though Bangladesh is an agricultural country is facing increasing deficiency in oil seed production and consequently import cost is increasing. About 0.832638 million tons of edible oil produced in Bangladesh which is very low against the requirement (BBS, 2015b). To fulfill this lacking the country imported 0.89970 million tons of mustard oil that cost 371.8457000 million Tk. (BBS, 2015 c).

The yield of rapeseed and mustard is generally low in Bangladesh as compared with the world average. The present seed yield per hectare of mustard in Bangladesh is far below the level attained in the developed countries of the world. The major reasons for such poor yield in Bangladesh may be attributed due to pressure of other crops, lack of improved varieties and poor management practices.

In Bangladesh there is limited scope to increase acreage for oilseed due to pressure of other crops. The total amount of land for mustard and rapeseed was decreased due to increasing Boro rice cultivation. The area for rapeseed and mustard is reduced from 0.784730 million acres to 0.5780208 million acres in 2001 to 2009. But the area and production has been increased in 2012-2013 to 2013-2014 as the production was 1.10 ton per hectare in 0.518 million hectare in 2012-2013 and 1.12 ton per hectare in 0.532 million hectare in 2013-2014 due to high yielding varieties of mustard (MOA, 2014).

There is limited scope to increase yield because farmers usually cultivate the existing low yielding varieties with low input and management. Short duration variety is still popular in Bangladesh because it can fit well into the T. Aman – Mustard–Boro rice cropping pattern. There is few improved short duration variety of *Brassica rapa* is available to replace the existing Tori -7.

The above scenario indicated that 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 stress to fulfill the requirement of edible oil of the country. The improved variety also should well fit into T. Aman– Mustard–Boro cropping pattern.

Thus, seventeen advanced populations were produced through advancing generations and the present study was conducted to compare among the different populations and to study the variability, character association and the direct and indirect effect of different characters on yield per plant which will give an opportunity to select the desired plant types to meet the existing demand.

Objectives:

1. To compare among the advanced populations and to analyze the genetic variability of the genotypes for the selection of desired populations,
2. To find out the relationship among the different traits and their contribution to the yield and
3. To select promising genotypes considering early maturity and high yielding plants to release as a new variety.

CHAPTER II

REVIEW OF LITERATURE

Brassica species is the most important oil seed crops in Bangladesh and also holds a strong position in worldwide edible oil supply. Researchers feel much interest in the species on various aspect of its production and utilization. A great number of studies on variability, heritability, genetic advance, interrelationship, path co-efficient analysis have been carried out in Bangladesh as well as in many other countries of the world. Concerning the studies, the review of literature is presented under the following mentioned heads:

- Variability, heritability and genetic advance
- Correlation co-efficient
- Path co-efficient analysis

2.1. Variability, heritability and genetic advance

Bilal *et al*. (2015) studied 23 genotypes of *Brassica napus*. The study was undertaken to evaluate some indigenous rapeseed genotypes for adaptability and yield traits in the agro-climatic condition of Mansehra. These genotypes were evaluated in randomized complete block design with three replications. Heritabilities were moderate to high in magnitude for all traits. Thousand seed weight showed significant differences validating the presence of genetic variation among the tested accessions. Greater variability among the accessions for thousand seed weight was observed.

Rameeh (2015) evaluated 21 rapeseed genotypes which were selected based on diversity of agronomic characters. The genotypes were evaluated based on randomized complete block design with three replications. He reported that Broad sense heritability estimates varied from 0.18 to 0.98 for pods length and days to end of flowering after. High broad sense heritability was determined for phenological traits, plant height and seed yield demonstrating selection gain for improving these traits will be high. Pods on main axis and pods per plant had high value of genetic coefficient of variation.

Shaukat *et al*. (2015) evaluated eight *Brassica napus* genotypes to investigate genetic variability and heritability. They reported that analysis of variance showed highly significant differences ($P \leq 0.01$) among *Brassica napus* genotypes for primary branches per plant. The coefficient of variation for primary branches was 13.04 %. High broad sense heritability estimates were observed for primary branches per plant (0.83), plant height (0.78), pods per main raceme (0.65), seeds per pod (0.61), 1000-seed weight (0.61), while moderate heritability values were recorded for pod length (0.57), pods per plant (0.55), and seed yield per plant (0.50).

Begum (2015) conducted an experiment with 31 BC_1 F_5 genotypes of *Brassica napus* L. at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, to study the variability, correlation and path analysis during November 2014 to February 2015. The genotypes were found significantly variable for most of the characters. Comparatively phenotypic variances were higher than the genotypic variances for most of the character studied. Seed yield per plant (98.27) exhibited the highest value of heritability while days to 50% flowering (78.96) exhibited the lowest value of heritability. High heritability with high genetic advance in percent of mean was observed in number of primary branches per plant, number of secondary branches per plant which indicates additive gene action is controlling these traits. High heritability with moderate genetic advance was observed in number of siliqua per plant, number of seed per siliquae, thousand seed weight and seed yield per plant which indicated non additive gene is controlling these traits. The high GCV value was observed for number of secondary branches, number of primary branches, number of siliqua per plant, thousand seed weight and seed yield per plant with broad base heritability. It indicated that these traits were less affected by environment.

Sultana (2015) carried out an experiment by using sixty two F_4 genotypes of *Brassica napus* L. to study the variability, correlation, path analysis and genetic diversity. The genotypes were found significantly variable for most of the characters. The high GCV value was observed for number of secondary branches per plant (42.31). Number of secondary branches (98.70) exhibited the highest value of heritability followed by seed yield per plant (98.03) while days to maturity (88.02) exhibited the lowest value of heritability.

Parvin (2015) conducted an experiment with 30 BC_1 F_4 genotypes of *Brassica napus* L. to study the genetic variability, heritability, correlation and path coefficient analysis. The genotypes were found significantly variable for most of the characters. Phenotypic variances were comparatively higher than the genotypic variances for all the characters studied. PCV were higher than the

GCV for all the characters studied. Plant height (70.16%), number of primary branches per plant (71.79%), siliqua length (70.93%) and thousand seed weight (72.57%) showed high heritability with high genetic advance.

Siddika (2015) conducted an experiment to study the genetic variability, correlation and path analysis of *Brassica napus* L. with 30 F_2 genotypes. The genotypes were found significantly variable for all the characters. Phenotypic variances were higher comparatively than the genotypic variances for all the characters studied. All the characters studied, phenotypic co-efficient of variation (PCV) values were higher than the genotypic co-efficient of variation (GCV) values. Number of primary branches per plant(57.14%), number of secondary branches per plant(66.67%), no. siliqua per plant(56.84%), number of seeds per siliqua (64.89%) and showed high heritability and high genetic advance in percentage of mean.

Sharafi *et al*. (2015) conducted an experiment with twenty eight winter rapeseed cultivars to evaluate genetic variation. They reported that yield, number of branches per plant and plant height had the highest variation. Broad sense heritability estimates ranged from 6% to 87% for seed yield and pod length, respectively. These results showed that cultivars with higher number of pod per plant had higher seed production.

Iqbal *et al*. (2014) experimented with ten indigenous variety associated with eight important yield contributing characters of *Brassica rapa* in Pakistan to study variability. The traits showed highly significant differences in almost all traits. The highest heritability with higher genetic advance was reported in plant height while the seed per siliquae was found medium heritability along lower genetic advance. It was observed that indigenous accessions had great proportion of genetic variability.

An experiment was conducted by Muhammad *et al*. (2014) with four parental genotype along with twelve F_2 generation of *Brassica napus* and reported that days to 50% flowering were significantly different at 5% level of significance and plant height and pod length at 1% level of significance. Plant height and pod length high heritability and days to 50% flowering showed moderate heritability.

An experiment was conducted by Helal *et al*. (2014) to study genetic variability, correlation of yield and yield contributing characters and coefficient of variance in rapeseed or mustard. The results revealed that varieties produced the highest seed yields and 15% variation at genotypic and phenotypic level.

Rameeh (2014) carried out an experiment with 28 rapeseed genotypes which were selected based on different agronomic characters. Broad sense heritability estimates ranged from 0.12 to 0.98 for plant height and days to flowering, respectively. Genetic coefficient of variation, an indicator of the genetic diversity of the genotypes, varied from 18.7 to 26.8 for days to maturity and seed yield, respectively.

An experiment was conducted by Parvin (2014) with 40 genotypes of *Brassica napus* L. at the experimental field of Sher-e-Bangla Agricultural University, Dhaka to study the genetic diversity and characters association. Analysis of variance for each trait showed significance differences among the genotypes. The first two components with eigen value were greater than other components. The highest inter cluster distance was observed between cluster II and V and the maximum intra cluster distance was found in cluster I. Comparatively phenotypic variances were higher than the genotypic variances for all the characters studied. Number of siliqua per plant (99.986) exhibited the highest value of heritability and number of primary branches per plant (26.459) exhibited the lowest value of heritability. Correlation coefficients among the characters were studied to determine the association between yield and yield components.

Shakera (2014) conducted an experiment by using twenty F_3 and F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa* L. to study the variation in different characters, correlation between pairs of different characters and the direct and indirect effect of good yielding plants of the F_3 and F_4 material to select high yielding and early mature plants. Considering genetic parameters, comparatively phenotypic variances were higher than the genotypic variances for all the characters studied. Days to maturity, number of primary branches per plant, length of siliqua, thousand seed weight showed least difference between genotypic and phenotypic variance. High phenotypic and genotypic co-efficient of variation were found on number of secondary branches per plant, number of siliqua per plant and yield per plant. Thousand seed weight and yield per plant showed high heritability with low genetic advance and high genetic advance in percentage of mean.

An experiment was carried out by Hussain (2014) with 24 genotypes including 4 check varieties of the species *Brassica rapa* L. for estimating the magnitude of variations in characters, heritability, genetic advance, character associations, direct and indirect effect of different characters on seed yield per plant. Significant variation was observed among all the genotypes for all the characters studied. Days to 50% flowering, days to 80% maturity showed moderate difference between the phenotypic and genotypic variance. Number of secondary branches per plant showed high heritability coupled with high genetic advance in percentage of mean. On the other hand days to 50% flowering, no. of siliqua per plant, yield per plant showed high heritability with moderate genetic advance in percentage of mean. Days to 80% maturity, no. of primary branches per plant, no. of seed per siliqua showed high heritability coupled with low genetic advance in percentage of mean.

Abideen *et al*. (2013) studied with eight genotypes of *Brassica napus* and observed that there were highly significant variations among the genotypes for most of the traits studied. Non-significant differences were in primary branches per plant and pods per plant among the genotypes.

Ten *Brassica napus* L. cultivars was evaluated by Nasim *et al*. (2013) to study the genetic differences, inter relationships and the rate of heritability in these genotypes. For morphological parameters of thousand seed weight, days to half flowering, days to full flowering, siliqua width, siliqua length, seed per siliqua and plant height they found highly significant differences while for main raceme length, siliquae on main raceme and primary branches per plant, they found non-significant differences. Similarly for flower initiation, fifty percent flowering, complete flowering, plant height, seeds per siliqua and thousand seed weight they found high heritability and high heritable advances. High heritability (92.48%) with moderate genetic advance (18.87%) was also found by Saifullah (2010).

Two genotypes and twenty two advanced line of *Brassica napus* L. was characterized by Rameeh (2013) and he observed that the range of heritability in broad sense for the parameters of siliquae per plant and days to flowering were in the range of 21 percent to 94 percent, correspondingly.

Ahmad *et al*. (2013) conducted an experiment with thirty five advanced mutant lines along with a check variety of *Brassica napus* called Abasin-95 for variability analysis and reported that seed yield and days to flowering showed high genetic variability. High heritability and genetic advance was recorded for seed yield. The mutant lines OA5, G1 and 06 showed their superiority in high seed yield, thousand seed weight and earliness in flowering.

Belete *et al*. (2012) evaluated 5 *Brassica carinata* L. They found for all the parameters apart from two i.e., plant height and seed yield significant differences amongst these genotypes, for the traits of days to maturity and plant height they found the lowest phenotypic coefficient of variation and genotypic coefficient of variation which were 2.0 and 1.9 percent for days to maturity and 1.2 and 0.7 percent for plant height, respectively. The heritability values of 99.8 percent were recorded for oil content which was the top most of all and the second highest heritability value of 96.5 percent was found for days to flowering. While the lowest value found for plant height which was 36.0 percent due to greater ecological effect on this trait.

Zare and Sharafzadeh (2012) evaluated 8 *Brassica napus* L. genotypes through agro-morphological traits to investigate the differences, heritability and correlation among these genotypes for the traits of seed yield and related. Apart from siliqua length and seeds per siliqua, they found significant genetic differences for the traits of seed yield and related traits. Very high heritability in broad sense was found for days to flowering which was 93.3 percent and the lowest of 14.3 percent for siliqua length, while for the rest of parameters they found high heritability. Saifullah (2010) reported high heritability and moderate genetic advance for plant height.

An experiment was carried out by Roy *et al.* (2011) on rapeseed mustard and studied variability and heritability. The result revealed that significant varietal difference except the number of siliquae on main raceme. The PCV and the GCV was high in secondary branches per plant and number of siliqua per plant. High heritability along with high genetic advance as percent of mean was reported in plant height, seed yield, secondary branches per plant, siliqua per plant and seeds per siliquae.

An experiment was conducted by Rameeh (2011) with 36 *Brassica napus* L. cultivars to determine the associations for yield components in these genotypes. The broad sense heritability was in the range of 0.42 and 0.81 percent which were the heritability values respectively for 1000-seed weight and pods per plant. Similarly morphological parameters of pods main per raceme, seed per pod and pods per plant were highly heritable with heritability values of seventy percent, seventy seven percent and eighty one percent, correspondingly.

Patel (2011) experimented with three high yielding varieties and two very low quality varieties and their six generation cross product of *Brassica napus*. The result showed that the heritability in broad sense with high to moderate genetic advance was found in thousand seed weight, seed yield per plant. Moderate to high heritability associated with low genetic advance was recorded in days to maturity and days to flowering.

Tahira *et al.* (2011) conducted and experiment with ten wide genetic ranged variety of *Brassica juncea* to study heritability in broad sense and showed siliquae length, plant height and seed yield had high values.

Three rapeseed varieties (Foseto, Option 500 and Goliath) including the offspring of their F_2 and F_3 generations were planted for two years at complete randomized block design with three replications at experimental field of Rice and Citrus Research Institute, University of Agricultural Science and Natural Resources of Sari, Iran. The results indicated that all traits except date of maturity and number of seed per pod were significant at 1% probability. Also the estimation of coefficient of genotypic variation (GCV) showed less than the estimate of coefficient phenotypic variation (PCV). GCV values for number of pod per plant (16.93 and 23.57 in F_2 and F_3 generations, respectively) and seed yield (21.69 and 26.60 in F_2 and F_3 generations, respectively) was high, but for some traits were negligible. (Sadat *et al*., 2010).

Ara (2010) conducted a field experiment by using eight F_2 and eight F_4 populations generated through inter-varietal crosses along with three check variety of *Brassica rapa* to study the variation. The values of phenotypic variances were higher than corresponding genotypic variances. Days to 50% flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, length of siliquae, seeds per siliquae, 1000-seed weight and yield per plant showed least difference between phenotypic and genotypic variances. The value of GCV and PCV indicated that there was least variation present among most of the characters. The days to maturity, length of siliquae, seeds per siliquae and 1000-seed weight showed high heritability with low genetic advance and genetic advance in percentage of mean.

Xu and Yao (2009) studied the variation between yields per plant nine yield related characters in 24 rapeseed cultivars in China. Result showed that the positive effects of siliqua per raceme, filled seeds per siliqua and 1000 seed weight, yield per plant were significant.

Mahmud (2008) carried out an experiment with 58 genotypes of *Brassica rapa* to study inter genotypic variability. Signification was observed among all the genotypes for all the characters studied except thousand seed weight. High GCV value was observed for number of secondary branches per plant. High heritability values along with high genetic advance in percentage of mean were obtained for days to 50% flowering, number of secondary branches per plant, seeds per siliqua, and siliqua length.

Basalma (2008) evaluated 25 winter rapeseed genotypes for correlation and path analysis. Positively high correlation were found among the parameters of branches per plant, siliquae per main raceme and for plant height in both years. The correlation of plant height was negative with seed yield, thousand seed weight and for the trait of oil ratio in the first year of his study. He found from the judgment of seed and oil yield on other various yield constituent that oil contents are affected directly by seed yield.

A study was conducted by Uddin (2008) to study the variability among seven parental genotypes and their twenty one F_2 progenies of *Brassica rapa.* He found that the phenotypic variance were than more genotypic variance. High GCV was observed in secondary branches per plant. High heritability with high genetic advance was observed in the number of secondary branches per plant.

Baradan *et al.* (2007) reported results of the field studies in Iran to determine the variation in 15 rapeseed cultivars. Results of the analysis of variance showed significant differences between yield and number of siliqua, per plant, harvest index, oil percent. They noticed most important traits for high PCV and GCV for the number siliqua per plant and 1000 seed weight.

Kardam and Singh (2005) reported the nature and magnitude of associations for10 characters in progenies of Indian rapeseed obtained from six crosses during rabi 2002-03 in Rajasthan, India. PCV were higher in magnitude compared to GCV for most of the characters. Seed yield per plant was significantly and positively variable with plant height, number of seeds per siliqua and 1000-seed weight

An experiment was conducted by Katiyar *et al.* (2004) on variability for the seed yield in ninety inter-varietal crosses of *Brassica campestris*. Existence of significant variation among parents and crosses indicated the presence of adequate genetic variance between parents which reflected in differential performance of individual cross combinations.

Ali *et al.* (2003) conducted an experiment with 25 *Brassica napus* genotypes to study and find out the connection in yield components and how to increase yield in these genotypes. They found significant differences ($P<0.01$) for different parameters under study in these cultivars. The highest phenotypic and genotypic differences among the studied parameters were observed for siliquae per plant and on the second position was plant height. While seed yield per plant and siliquae per plant, correspondingly were the highest in phenotypic and genotypic coefficients of variability. They found highest (0.903) heritability value in broad sense for the parameter of days to maturity and 0.662 for flower duration, 0.548 for seed weight and 0.477 for seed yield.

Choudhary and Joshi (2001) evaluated genetic variation of some genotypes derivatives of *Brassica* inter-specific hybrids and found high genetic diversity for days to flowering, plant height, number of branch per plant, and 1000-seed weight. In a study, days to flowering and oil percent had the highest heritability while pods number per plant and defoliation had the least heritability.

An experiment was conducted by Shalini *et al*. (2000) to study variability in *Brassica juncea* L. Different genetic parameters was estimated to assess the magnitude of genetic variation in 81 diverse Indian mustard genotypes. The analysis of variance indicated the prevalence of sufficient genetic variation among the genotypes for all 10 characters studied. Genotypic coefficient of variation, estimates of variability, heritability values and genetic gain were moderate to high for 1000 seed weight, number of siliquae per plant and number of secondary branches per plant, indicating that the response to selection would be very high for these yield components. For the other characters, low coefficient of variation, medium to low heritability and low genetic gain were observed.

Masood *et al*. (1999) studied seven genotypes of *Brassica compestris* and standard cultivar of *Brassica napus* to calculate genetic variability. The co-efficient of variation was high for thousand seed weight, pod length and number of seeds number of seeds per pod for both genotypic and phenotypic variability. The genotypic and phenotypic correlation coefficients showed that seed yield per plant were significantly positively correlated with plant height, number of siliquae per plant and number of seeds per siliqua.

2.2. Correlation among different characters

An experiment was conducted by Bilal *et al*. (2015) with 23 genotypes of rapeseed to study the correlation between the yield and yield contributing characters. Positive significant correlation was observed between days to maturity and yield per plant (r = 0.279) as well as with 1000-seed weight (r = 0.057). Negative significant correlation was observed between plant height and pods per plant and 1000-seed weight. Number of pods per plant revealed positive significant correlation with 1000-seed weight and positive correlation with pod length, number of seeds per pod, yield per plant.

Begum (2015) conducted an experiment with 31 BC_1 F_5 genotypes of *Brassica napus* L. to study the variability, correlation and path analysis and found significant positive correlation between seed yield per plant with the number of primary branches, number of secondary branches, number of siliqua per plant and thousand seed weight.

Parvin (2015) conducted an experiment with 30 BC_1 F_4 genotypes of *Brassica napus* L. to study the genetic variability, heritability, correlation and path coefficient analysis. Correlation revealed that number of primary branches per plant(0.206), number of secondary branches per plant(0.231), number of siliqua per plant(0.592), siliqua length (0.426), number of seeds per siliqua(0.588), and thousand seed weight (0.651) had significant positive correlation with seed yield per plant.

An experiment was conducted by Siddika (2015) to study the genetic variability, correlation and path analysis of *Brassica napus* L. with 30 F_2 genotypes. Correlation analysis revealed that number of primary branches per plant (0.188), number of secondary per plant (0.216) number of siliquae per plant (0.688), siliqua length (0.415), number of seeds per siliqua (0.695), thousand seed weight (0.736).

Sultana (2015) carried out an experiment by using sixty two F_4 genotypes of *Brassica napus* L. to study the variability, correlation, path analysis and genetic diversity. The significant positive correlation with seed yield per plant were found with all most all the characters except days to 50% flowering (0.033) and days to maturity (-0.096).

Rameeh (2015) conducted an experiment with 36 rapeseed (*Brassica napus* L.) genotypes including four checks and 32 advanced lines and found that pods per plant, seeds per plant and 1000- seed weight traits were positively correlated with seed yield.

Parvin (2014) carried out an experiment with 40 genotypes of *Brassica napus* L. to study the genetic diversity and characters association. The significant positive correlation with seed yield per plant was found in days to 1^{st} flowering, days to 80% flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant and siliqua per plant.

Shakera (2014) conducted an experiment by using twenty F_3 and F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa* L. to study the variation in different characters, correlation between pairs of different characters and the direct and indirect effect of good yielding plants of the F_3 and F_4 material to select high yielding and early mature plants. Yield per plant had significant and the positive correlation with plant height, number of primary branches per plant number of secondary branches per plant, number of siliqua per plant and thousand seed weight.

Ejaz-Ul-Hasan *et al.* (2014) studied correlation between different traits of *Brassica napus* and reported high and positively significant phenotypic correlation between plant height and seeds per plant.

An experiment was carried out by Hussain (2014) with 24 genotypes including 4 check varieties of the species *Brassica rapa* L. for estimating the magnitude of variations in characters, heritability, genetic advance, character associations, direct and indirect effect of different characters on seed yield per plant. The significant positive correlation with seed yield per plant were found in thousand seed weight, no. of siliqua per plant, no. of primary branches per plant.

Halder *et al*. (2014) carried out an experiment with 14 genotypes including 11 advanced lines and 3 check varieties to study the correlation and observed that days to first flowering showed positive non-significant relationship with yield but high positive significant correlation with the days to 50% and 80% flowering. Highly significant negative correlation was found with number of secondary branches per plant and siliqua length.

Uddin *et al.* (2013) evaluated seven parental and twenty one F_2 progenies of *Brassica rapa* to study correlation among different yield component and found that yield per plant had high significant positive correlation with number of primary branches per plant, number of secondary branches per plant and siliqua per plant at both phenotypically and genotypically and significant positive correlation at genotypically in days to flowering and days to maturity.

Abideen *et al.* (2013) evaluated eight genotypes of *Brassica napus* and the resulted that positive phenotypic correlation was observed in plant height, pod length and seed yield. Significant positive correlation was also found in seed yield per plant and pods per plant.

Nasim *et al*. (2013) evaluated ten *Brassica napus* L. genotypes to determine correlation between various traits and observed that pod length was positive highly significantly ($p \leq 0.01$) and significantly ($p \leq 0.05$) correlated with thousand seed weight (0.59**) and pod width (0.37*) respectively. Pod width was revealed to have negative significant correlation with days to flowering initiation (-0.40*) whereas positive significant correlations with thousand seed weight (0.37*).

Ali *et al*. (2013) studied thirty lines of *Brassica carinata* and observed that highly positive phenotypic correlation for seed yield per plant with plant height and primary branches per plant which was the indication that the traits were the most important contributors to seed yield per plant.

Khayat *et al*. (2012) reported high positive correlation between plant height and yield per plant, siliqua per plant of *Brassica napus.*

An experiment was conducted by Maurya *et al*. (2012) with one hundred genotypes of *Brassica juncea* and observed that a high positive correlation was presented between length of siliquae, seed yield, thousand grain weight and days to 50% flowering.

Afrin *et al*. (2011) studied on *Brassica napus* and found positive correlation with seed yield per plant in plant height, number of primary branches per plant and number of siliquae per plant. Highest significant positive correlation was between days to 50% flowering and plant height.

Belet (2011) studied with different yield treating characters of *Brassica carinata* and found that genotypic correlation coefficient of seed yield per area had direct positive correlation with seed per pod and seed per plant.

An experiment was carried out by Tahira *et al*. (2011) with ten wide genetic ranged variety of *Brassica juncea* and the result revealed correlation among the different characters studied. The highest phenotypic correlation were found between plant height, branches per plant, siliqua length and seeds per siliquae. Seed yield was only significantly correlated with plant height and siliquae length. Plant height, branches per plant, siliqua length and thousand seed weight were genotypically correlated with yield per plant. A highly significant and strong positive genetic relation was observed between plant height and branches per plant, siliqua length and seed per siliquae.

Rameeh (2011) studied 36 *Brassica napus* L. cultivars to determine the associations for yield components in these genotypes in RCBD experimental design which consisted of three replications. Siliqua per plant was significantly and highly correlated with seed yield with correlation value of 0.80.

An experiment was conducted by Alam (2010) by using twenty six F_4 populations of some inter-varietal crosses of *Brassica rapa* to study correlation and it revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, number of siliqua per plant, seeds per plant, siliquae and siliquae at both genotypes and phenotypic level

Ara (2010) conducted a field experiment by using eight F_2 & eight F_4 populations generated through inter-varietal crosses along with three check variety of *Brassica rapa* to study correlation between pairs of different characters. Yield per plant had significant and highest positive correlation with length of siliquae, seeds per siliquae and 1000-seed weight.

Gangapur *et al*. (2009) experimented forty-six genotypes of Indian mustard (*Brassica junea*) under controlled and uncontrolled (disease and pest) condition and studied correlation and the result revealed that seed yield per meter was highly and significantly correlated with seed yield per plant, number of siliquae per plant number of primary and secondary branches per plant, yield per plant, thousand seed weight, number of seeds per siliquae at genotypic and phenotypic level under both protected and unprotected conditions.

Esmaeeli Azadgoleh *et al.* (2009) observed positively significant correlation of seed yield with number of pod per plant, number of pods in sub branches and number of seeds per pod.

A study was conducted by Hosen (2008) using five parental genotypes of *Brassica rapa* and their ten F_3 progenies including reciprocations. He found yield per plant showed highest significant and positive correlation with days to maturity followed by number of seeds per siliqua, number of secondary branches per plant, length of siliqua and number of siliqua per plant.

An experiment was conducted by Uddin (2008) to study the correlation among seven parental genotypes and their twenty one F_2 progenies of *Brassica rapa* and found positive significant association in seed yield per plant with number of primary branches per plant, number of secondary branches per plant and number of siliquae per plant.

An experiment was carried out by Parveen (2007) with F_2 population of *Brassica rapa* to study the correlation and observed that yield per plant had non-significant positive association with plant height, number of secondary branches per plant, number of seeds per siliqua and number of siliqua per plant, days to 50% flowering and length of siliqua

Jeromela *et al*. (2007) studied 30 rapeseed varieties and demonstrated that pods per plant have the highest correlation with seed yield.

Rashid (2007) conducted an experiment with 40 oleiferous *Brassica species* to estimate correlation and observed that, highly significant positive association of yield per plant with number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua and number of siliquae per plant.

An experiment on oleiferous *Brassica compestris* L. was conducted by Siddikee (2006) to study the correlation analysis. The results revealed that yield per plant highest significant positive correlation with number of siliqua per plant

Zahan (2006) studied correlation and observed highly positive association in yield per plant with plant height, length of siliquae per plant and per siliquae where insignificant negative association with days to 50% flowering and days to maturity.

Afroz *et al.* (2004) studied correlation and found seed yield per plant had significant and positive correlation with number of primary branches per plant and number of siliqua per plant. Path coefficient revealed maximum direct positive effects on plant height followed by number of siliqua per plant, seed yield per plant, number of primary branches per plant, 1000-seed weight and number of siliqua shattering per plant.

An experiment was conducted by Ali *et al.* (2003) with 25 winter rapeseed and observed that positive flowering duration was significantly correlated (0.238) with seed yield. Seed yield per plant was negatively and non-significantly correlated with days to maturity and branches per plant. The seed weight of these genotypes was positively and significantly correlated with harvest index, flower duration and seed yield.

Srivastava and Singh (2002) studied correlation in Indian mustard (*Brassica juncea* L. Czern and Coss) for 10 characters in 24 strains of Indian mustard along with 2 varieties. Results revealed that number of primary branches per plant, number of secondary branches per plant, 1000 seed weight (g) and oil percent were positively associated with seed yield.

Shalini *et al.* (2000) evaluated 81 genotypes of Indian mustard for the magnitude of association between their quantitative characters of secondary branches, plant height, number of siliqua and seeds per siliqua were highly associated with seed yield.

Khulbe and Pant (1999) evaluated eight Indian mustard (*Brassica juncea*) parents and their 28 F_1 hybrids and reported that the number of siliqua per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and harvest index were positively associated with seed yield.

The number of siliqua per plant, number of seeds per siliqua and plant height was significantly positively correlated with seed yield was observed by Masood *et al*. (1999) while studied seven genotypes of *B. campestris* and standard cultivar of *B. napus* to calculate correlation co-efficient.

In *B. juncea* Srivastava *et al*. (1983) observed that the number of primary branches per plant and secondary branches per plant, plant height and days to maturity showed significant positive association with the seed yield per plant. The number of primary branches showed positive and significant association with the number of secondary branches per plant, plant height and days to maturity. Plant height showed positive and significant correlation with the number of secondary branches and days to maturity.

2.3 Path co-efficient analysis

Sharafi *et al.* (2015) evaluated twenty eight winter rapeseed cultivars and results showed that number of pods per plant, number of seeds per pod, and 1000-seed weight had positive direct effect on seed yield.

Sultana (2015) carried out an experiment by using sixty two F_4 genotypes of *Brassica napus* L. to study the variability, correlation, path analysis and genetic diversity. Path co-efficient analysis revealed that days to 50% flowering, number of secondary branch, number of siliqua per plant, number of seed per siliqua, and thousand seed weight had the positive direct effect on yield per plant whereas days to 80% maturity, plant height, number of primary branch and siliqua length had the negative direct effect on yield per plant.

Begum (2015) conducted an experiment with 31 BC_1 F_5 genotypes of *Brassica napus* L. to study the variability, correlation and path analysis. Path analysis revealed that number of primary branches, number of secondary branches, number of siliqua per plant and thousand seed weight had the positive direct effect on yield per plant.

Parvin (2015) conducted an experiment with 30 BC_1 F_4 genotypes of *Brassica napus* L. to study the genetic variability, heritability, correlation and path coefficient analysis. Path co-efficient analysis revealed that plant height (0.464), number of primary branches per plant (0.436), number of secondary branches per plant(0.389), number of siliquae per plant (0.886), siliqua length(0.627), number of seeds per siliqua (0.584) and thousand seed weight

(0.608) had the positive direct effect on yield per plant and days to first flowering (-0.852) had the negative direct effect on yield per plant.

An experiment was conducted by Siddika (2015) to study the genetic variability, correlation and path analysis of *Brassica napus* L. with 30 F_2 genotypes. Path co-efficient analysis revealed that days to number of primary branches per plant (0.446), number of siliquae per plant (0.538), siliqua length (0.429), seeds per siliqua (0.112) and thousand seed weight (0.365) had the positive direct effect on yield per plant and days to first flowering, plant height, no. of secondary branches per plant had the negative direct effect on yield per plant.

An experiment was conducted by Ejaz-UI-Hasan *et al*. (2014) on *Brassica napus* and studied path coefficient. The result revealed that the highest direct positive effect of seeds per plant on yield and followed by days to maturity, days to flowering, seed per siliquae, siliqua length and thousand seed weight while height had direct negative effect on the yield per plant.

Parvin (2014) carried out an experiment with 40 genotypes of *Brassica napus* L. to study the genetic diversity and characters association. Path co-efficient analysis revealed that days to 1st flowering, days to 50% flowering, days to 80% flowering, days to maturity, number of secondary branches per plant, number of siliquae per plant, and thousand-seed weight (gm) had the positive direct effect on yield per plant.

Shakera (2014) conducted an experiment by using twenty F_3 and F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa* L. to study the variation in different characters, correlation between pairs of different characters and the direct and indirect effect of good yielding plants of the F_3 and F_4 material to select high yielding and early mature plants. The path co-efficient analysis revealed that plant height had the highest positive direct effect followed by siliquae per plant, number of seed per siliqua, number of secondary branches per plant.

An experiment was carried out by Hussain (2014) with 24 genotypes including 4 check varieties of the species *Brassica rapa* L. for estimating the magnitude of variations in characters, heritability, genetic advance, character associations, direct and indirect effect of different characters on seed yield per plant. Path co-efficient analysis revealed that plant height, no. of primary branches per plant, no. of siliqua per plant, siliqua length, thousand seed weight showed positive direct effect with yield per plant. Days to 50% flowering, days to 80% maturity, no. of secondary branches per plant, no of seed per siliqua showed negative direct effect on yield per plant. Beside these days to 50% flowering, days to 80% maturity, no. of secondary branches per plant, no of seed per siliqua showed negative direct effect on yield per plant.

Uddin *et al*. (2013) evaluated seven parental and twenty one F_2 progenies of *Brassica rapa* to study path coefficient and reported that days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, siliquae length, seed per siliquae and thousand seed weight showed direct positive association with seed yield per plant while the plant height and days to maturity has direct negative association

Emrani *et al*. (2012) evaluated two canola cultivars and found that negative indirect effect of plant height via number of seeds per fruits and thousand seed weight could mask the positive direct effect of plant height on seed yield per plant and positive correlation between number of fruits per plant and seed yield despite the indirect effects of number of fruits per plant via number of seeds per fruit and thousand seed weight.

Khayat *et al*. (2012) reported that the number of pods per plant had the highest direct effect on grain yield. In addition, total dry matter, 1000- grain weight, and flowering and days to maturity also had a high direct effect on grain yield.

An experiment was carried out by Afrin *et al.* (2011) with *Brassica napus* to identify the path co-efficient among the characters. The plant height was found the highest positive and direct effect on seed yield per plant followed by number of siliquae per plant and siliqua length.

An experiment was conducted by Tahira *et al*. (2011) with ten wide genetic ranged variety of *Brassica juncea* to study relationship among the characters. The result reported that plant height and siliquae length had positive direct on seed yield per plant while positive indirect effect of primary branches per plant via plant height and seed per siliquae provided significant effect on seed yield per plant. Siliqua length contributed negative indirect effect through plant height, seed per siliquae and thousand grain weight.

Alam (2010) studied path co-efficient analysis that revealed that plant height, number of primary branches per plant, number of siliqua per plant, seed per siliqua and siliqua length had the direct positive effect on yield per plant while days to 50% flowering, number of secondary branches per plant and thousand seed weight had the negative direct effect on yield per plant.

An experiment was conducted by Gangapur *et al*. (2009) with forty-six genotypes of Indian mustard (*Brassica juncea*) under controlled and uncontrolled (disease and pest) condition and studied path coefficient analysis. The number of siliquae per plant showed highest positive direct effect on seed yield in both protected and unprotected conditions. There were direct and indirect effect of number of primary branches per plant height in both phenotypically and genotypically under both controlled and uncontrolled condition.

An experiment was carried out by Mahmud (2008) with 58 genotypes of *Brassica rapa*. Path analysis showed that yield per plant had the highest direct effect on number of primary branches per plant, number of siliqua per plant, number of secondary branches per plant and number of seeds per siliqua.

Basalma (2008) reported that the direct effects of plant height, branches per plant, and number of seeds per pod and oil ratio were all negative and the effects of others characters were positive on seed yield.

The path co-efficient analysis by Hosen (2008) exhibited that thousand seed weight had the highest positive direct effect followed by days to 50% flowering length of siliqua, number of primary branches per plant, number of secondary branches per plant, days to maturity and number of seeds per siliqua while working with five parental genotypes of *Brassica rapa* and their ten F_3 progenies including reciprocals.

Rashid (2007) carried out an experiment with 40 oleiferous *Brassica species* to estimate path analysis and observed that yield per plant had the highest direct effect on days to maturity, number of seeds per siliqua, number of siliqua per plant and number of primary and secondary branches per plant.

Parveen (2007) conducted an experiment with F_2 population of *Brassica rapa* to study the path analysis and observed that number of seeds per siliqua showed highest direct effect on yield per plant.

By path analysis, Zahan (2006) reported that siliqua / plant had positive direct effect on yield/plant. And days to 50% flowering had negative direct effect on yield/plant.

Siddikee (2006) conducted an experiment on oleiferous *Brassica campestris L.* to study the path analysis and revealed that thousand seed weight had the highest positive direct effect on seed yield per plant.

Afroz *et al*. (2004) studied path analysis of 14 genotypes of mustard and observed that maximum direct positive effects on plant height followed by number of siliqua per plant, seed yield per-plant, number of primary branches per plant, 1000-seed weight and number of siliqua shattering per plant.

An experiment was carried out by Ali *et al*. (2003) with 25 winter rapeseed and observed that the direct effect of seeds per pod on plant yield was less but positive. Negative direct effects on plant yield were exhibited by days to maturity and branches per plant with values of -0.015 and -0.164, harvest index and seed weight were the only characteristics that exhibited the highest direct effect on yield per plant.

An experiment was carried out by Srivastava and Singh (2002) with Indian mustard (*B. juncea* L.) and reported that number of primary branches per plant, number of secondary branches per plant and 1000 seed weight had strong direct effect on seed yield while working. Results suggested that number of primary branches and 1000 seed weight were vital selection criteria for improvement in productivity of Indian mustard.

The number of siliquae per plant had the highest direct effect on seed yield followed by 1000 seed weight, number of primary branches per plant and plant height. Most of the characters had an indirect effect on seed yield was observed by Shalini *et al*. (2000) while studied path analysis of Indian mustard germplasm.

Khulbe and Pant (1999) evaluated Eight Indian mustard parents and their 28 F_1 hybrids to study path co-efficient analysis and the results revealed that harvest index, siliqua length, seeds per siliqua, siliqua per plant, thousand seed and days to initial flowering were the major traits influencing seed yield.

Masood *et al.* (1999) conducted an experiment with seven genotypes of *Brassica campestris* and standard cultivar of *Brassica napus* and observed that number of seeds per siliqua exerted the highest effect on seed yield.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site and duration

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 November 2015 to February 2016. The location of the experimental site was situated at 23^0 74' N latitude and 90^0 35' E longitudes with an elevation of 8.6 meter from the sea level. The research sites was shown in the photograph (Appendix I).

3.2 Soil and Climatic condition of the research site

The soil of the research site belongs to Agro ecological region of "Madhupur Tract" (AEZ No. 28). The soil was clay loam in texture with medium fertility level and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH was 5.47 to 5.63 and organic carbon content was 0.82% (Appendix II). The records of temperature, humidity and rainfall during the period of experiment were collected from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix III).

3.3 Materials used in the experiment

Seventeen (17) advanced populations of F_{14} segregating generation were used in this experiment. SAU sarisha1 (SAU 1) was used as check variety to compare the performances of the populations. Table 1 represented the materials used in the research work.

3.4 Methods

The following methods was followed to carry out the research work at the site with the materials:

3.4.1 Preparation of the experimental plot

By several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller the research plot was prepared to bring about good tilth. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

Table 1. Name of the advanced populations with their abbreviated forms

Sl. No.	Designation	F_{14} Populations
1	G1	BARI 9 X BARI 6 (A)
2	G2	BARI 9 X BARI 6 (B)
3	G3	BARI 9 X BARI 6 (C)
4	G4	BARI 9 X BARI 6 (D)
5	G5	BARI 9 X BARI 6 (E)
6	G6	BARI 9 X BARI 6 (F)
7	G7	BARI 9 X BARI 6 (G)
8	G8	BARI 9 X BARI 6 (H)
9	G9	BARI 9 X BARI 6 (I)
10	G10	BARI 9 X BARI 6 (J)
11	G11	BARI 6 X Tori 7, S_1
12	G12	BARI 6 X Tori 7, S_2
13	G13	BARI 6 X Tori 7, S_3
14	G14	BARI 6 X Tori 7, S_4
15	G15	BARI 9 x F_6 (A)
16	G16	BARI 9 x F_6 (B)
17	G17	BARI 9 x BARI6, S_2

Check variety , SAU sarisha1 (SAU 1)

3.4.2 Application of manure and fertilizer

The crop was fertilized at the rate of 10 tons of Cowdung, chemical fertilizers like Urea, Triple Super Phosphate (TSP) , Muriate of potash (MP) , Gypsum and Zinc sulphate and Boric Acid were applied in quantities of 250, 180, 85, 150, 3 and 13 kg/ha, respectively.

The half amount of urea, total amount of Cowdung, TSP, MP, Gypsum, Zinc Sulphate and Boric Acid were applied as basal dose during final land preparation. The rest amount of urea was applied as top dressing at flower initiation stage.

3.4.3 Experimental design and layout

After final land preparation field lay out was done. Randomized Complete Block Design (RCBD) with three replications was followed to carry out this research work. The total area of the experiment was $22m \times 14m = 308m^2$. Each replication size was $22m \times 3.5m$, and the distance between replication to replication was 1m. Line to line distance was 30 cm. Seeds were sown on 6 November, 2015. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods were on the seeds. Seeds germination were started three to four days after sowing.

3.4.4 Intercultural operations

Intercultural operations, such as weeding, thinning, irrigation, pest management, etc. were done uniformly in all the plots. One post sowing irrigation was given by sprinkler after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. The first weeding was done after 15 days of sowing. During the same time, thinning was done for maintaining a distance of 10 cm from plant to plant in rows of 30 cm apart. Second weeding was done after 35 days of sowing. The crop was protected from the attack of aphids by spraying Malathion-57 EC @ 2ml/liter of water. The genotypes differed widely for days to flowering. The insecticide was applied for the first time approximately before one week of flower initiation and it was applied for another two times at an interval of 15 days. To protect the crop from the Alternaria leaf spot, Rovral-50WP was sprayed at the rate of 2g/l at 50% flowering stage. Both the insecticide and fungicide were applied in the afternoon. A pictorial view of the experimental plot is presented in Plate 1.

3.4.5 Harvesting of the crop

When 80% of the plants showed symptoms of maturity i.e. straw color of siliqua, leaves, stems desirable seed color in the mature siliqua, the crop was assessed to attain maturity. At maturity, ten plants were selected at randomly from the rows of each replication. The sample plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from the sample plants.

3.4.6 Collection of data

Eleven parameters were taken into consideration for studying different genetic parameters and inter-relationships. A pictorial view of observation and data collection is presented in Plate 2. The data were recorded on ten selected plants for each cross on the following traits-

a. **Days to 50% flowering:** This data were recorded from sowing date to the date of 50% flowering of every entry.

b. **Days to 80% flowering:** Number of days to 80% flowering was counted when near about 80% flowering completed in each line.

Plate 1. The initial field view of the experimental plot

c. **Days to 80% maturity:** Days to 80% maturity data were recorded from the date of sowing to 80% siliquae maturity.

d. **Plant height (cm):** Plant height was taken after harvesting. Height was measured from the base of the plant to the tip of the longest inflorescence in centimeter .

e. **No. of primary branches / plant:** Branches arisen from the main stem of a plant was considered as the number of primary branches per plant.

f. **No. of secondary branches / plant:** Branches arisen from the primary branch of a plant was considered as the number of secondary branches per plant.

g. **No. of siliqua / plant:** Number of siliquae per plant was considered as the total number of siliquae of each plant.

h. **Siliquae length (cm):** Siliquae length was taken from the base to the tip of a siliqua in centimeter of the five representative siliquae

i. **No. of seeds / siliqua:** Well filled seeds were counted from five siliquae which was considered as the number of seeds per siliqua.

j. **Thousand-seed weight (g):** Randomly counted thousand seeds of each entry was recorded in grams.

k. **Seed yield per plant (g):** All the seeds produced by a representative plant was weighed in gram and considered as the seed yield per plant.

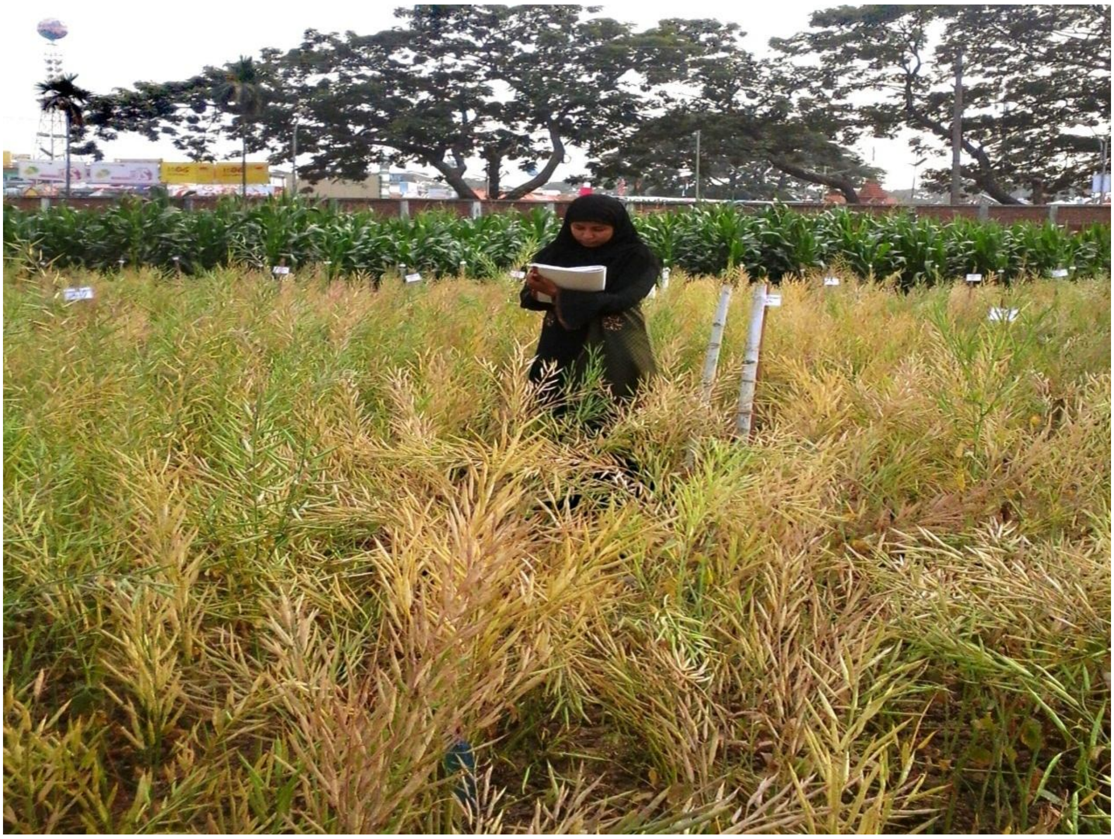


Plate 2. Photograph showing observation and data collection

3.5 Statistical analysis

The data were analyzed for different components. Phenotypic and genotypic variance was estimated by the formula used by Johnson *et al.* (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhury (1985) and Allard (1960). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952). Simple correlation coefficient was obtained using the formula suggested by Clarke (1973). Singh and Chaudhury (1985) and path coefficient analysis was done following the method outlined by Dewey and Lu (1995).

i) Estimation of Least Significant Differences (LSD):

Least Significant Differences were estimated according to the formula of Gomez and Gomez (1984).

$$\text{LSD}\alpha = t\alpha\sqrt{\frac{2s^2}{r}}$$

Here, α = Level of significance, t= tabulated t value with concerned df at same level of significance, s^2 = Error Mean Sum of Square and r = Number of replication.

ii) Estimation of genotypic and phenotypic variances:

By using the formula of Johnson *et al.* (1955) genotypic and phenotypic variances were estimated.

a. Genotypic variance, $\delta^2 g = \frac{\text{MSG} - \text{MSE}}{r}$

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

b. Phenotypic variance, Where, $\delta^2 p = \delta^2 g + \delta^2 e$

Where, $\delta^2 g$ = Genotypic variance,

$\delta^2 e$ = Environmental variance = Mean square of error

iii) Estimation of genotypic (GCV) and phenotypic (PCV) co-efficient of variation :

By using formula of (Burton, 1952) genotypic and phenotypic co-efficient of variation were calculated.

$$GCV = \frac{\delta_g \times 100}{\bar{x}}$$

$$PCV = \frac{\delta_p \times 100}{\bar{x}}$$

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

iv) Estimation of Broad sense heritability :

By using the formula suggested by Singh and Chaudhary (1985) Broad sense heritability was estimated.

$$h^2{}_b(\%) = \frac{\delta^2{}_g}{\delta^2{}_p} \times 100$$

Where, $h^2{}_b$ = Heritability in broad sense

$\delta^2{}_g$ = Genotypic variance

$\delta^2{}_p$ = Phenotypic variance

v) Estimation of genetic advance (GA):

Genetic advance was measured by using the formula as suggested by Allard (1960).

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

Where, GA = Genetic advance

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

δ_p = Phenotypic standard deviation

K = Selection differential which is equal to 2.06 at 5% selection intensity.

vi) Estimation of genetic advance in percentage of mean:

Genetic advance in percentage of mean was calculated by the following formula given by Comstock and Robinson (1952).

$$\text{Genetic Advance in percentage of mean} = \frac{\text{Genetic advance}}{\bar{x}} \times 100$$

Where, $\bar{x}$ =Mean value

vii) Estimation of simple correlation co-efficient:

By using the following formula (Clarke, 1973; Singh and Chaudhary, 1985) simple correlation co-efficient (r) was estimated.

$$r = \frac{\sum xy - \frac{\sum x \cdot \sum y}{N}}{\sqrt{[\{\sum x^2 - \frac{(\sum x)^2}{N}\}\{\sum y^2 - \frac{(\sum y)^2}{N}\}]}}$$

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

viii) Path analysis:

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) and Dabholkar (1992), using simple correlation values.

In order to estimate direct & indirect effect of the correlated characters, say x1, x2 and x3 yield y, a set of simultaneous equations is required to be formulated as shown below:

$$r_{yx1} = P_{yx1} + P_{yx2} r_{x1x2} + P_{yx3} r_{x1x3}$$

$$r_{yx2} = P_{yx1} r_{x1x2} + P_{yx2} + P_{yx3} r_{x2x3}$$

$$r_{yx3} = P_{yx1} r_{x1x3} + P_{yx2} r_{x2x3} + P_{yx3}$$

Where, r = simple correlation co-efficient

P = path co-efficient (Unknown)

Total correlation, say between x1 and y is partitioned as follows:

P_{yx1} = The direct effect of x1 on y.

$P_{yx2} r_{x1x2}$ = The indirect effect of x1 via x2 on y.

$P_{yx3} r_{x1x3}$ = The indirect effect of x1 via x3 on y.

By using the formula given below (Singh and Chaudhary, 1985) Residual effect (R) was calculated.

$$P^2_{RY} = 1 - \sum P_{iy} \, . \, riy$$

Where, P^2_{RY} = (R^2); and hence residual effect, $R = (P^2_{RY})^{1/2}$

P_{iy} = Direct effect of the character on yield

riy = Correlation of the character with yield

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to determine the breeding values in respect of genotypic effects and comparative performance of different advanced lines along with one check variety of *Brassica rapa.* The study was carried out to find out the phenotypic and genotypic variability, co-efficient of variation, heritability, genetic advance, correlation and path co-efficient to estimate direct and indirect effect of yield contributing traits on yield. All these accessions were grown in 2015-2016 in the field of Sher-e-Bangla Agricultural University. Data were recorded on different characters such as plant height, no. of primary branches per plant, no. of secondary branches per plant, days to 50% flowering, days to 80% flowering, days to 80% maturity, no. of siliqua per plant, no. of seeds per siliquae, siliqua length, thousand seed weight and seed yield per plant. The data were statistically analyzed and thus obtained results are described below under the following heads:

- ❖ Morphological characteristics of the genotypes
- ❖ Variability, heritability and genetic advance
- ❖ Correlation among different characters
- ❖ Path analysis

4.1 Morphological characteristics of the genotypes of *Brassica rapa* L.

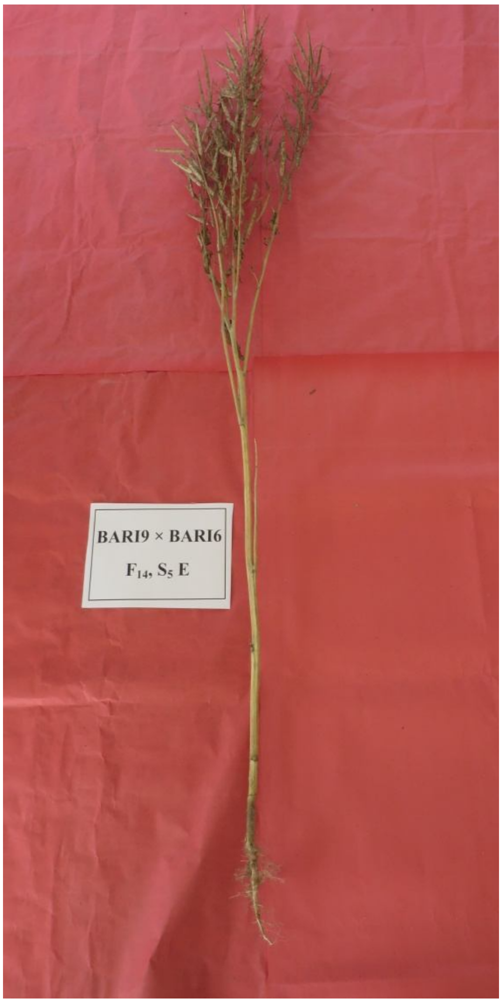
Brassica rapa, is an herbaceous annual or biennial species shows considerable variation in growth form and characteristics across the many cultivars. The leaves are large, soft, smooth, pinnatifid or lyrate . Medium tall, appressed type plant was found in G1, G3, G5, G6, G12 and G13. Tall, spreading type plant was found in G2. Medium tall, semi-spreading type plant was found in G4 and G9. Tall, spreading type was found in G7, Tall, semi-spreading was found in G8. Medium tall, spreading type plant was found in G10, G11 and G1. Dwarf, appressed type was found in G15 and G16. Dwarf, spreading type G17. In case of G1, G2, G8, G10, G15, G16 and G17 branching started from lower portion of the stem. In case of G3, G4, G6 and G11 branching started from middle of the stem and in case of G5, G9 and G13 branching started from upper portion of the stem. Long, roundish and both spreading and appressed type pod was found in G3. Long, flattened spreading type pod was found in G5, G9 and G11. Short, flattened and appressed type pod was found in G12, G14 and G17. Long and constricted type beak was found in G13, G14 and G15. Long, continuous and tapering type beak was found in G7. Short and constricted type beak was found in G17

Table 2. Morphological characteristics of the genotypes of *Brassica rapa* L.

Genotypes	Morphological characteristics			
	Plant type	**Branching point**	**Pod type**	**Beak type**
G1	Medium tall, appressed type	Branching started from lower portion of the stem	Medium in size, flattened, spreading type	Long, narrow and constricted
G2	Tall, spreading type	Branching started from lower portion of the stem	Long, flattened, more appressed type	Long and constricted
G3	Medium tall, appressed type	Branching started from middle of the stem	Long, roundish and both spreading and appressed type	Long and constricted
G4	Medium tall, semi-spreading	Branching started from middle of the stem	Long, flattened appressed type	Long and tapering
G5	Medium tall, appressed type	Branching started from upper portion of the stem	Long, flattened spreading type	Long, semi-tapering but slender
G6	Medium tall, appressed type	Branching started from middle of the stem	Medium in size, flattened, appressed type	Long and constricted
G7	Tall, spreading type	Branching started from middle of the stem	Long, flattened and appressed type	Long, continuous and tapering
G8	Tall, semi-spreading	Branching started from lower portion of the stem	Long, flattened and appressed type	Long and constricted
G9	Medium tall, semi-spreading	Branching started from upper portion of the stem	Long, flattened and spreading type	Long, narrow and constricted
G10	Medium tall, spreading type	Branching started from lower portion of the stem	Medium in size, flattened, spreading type	Long and constricted
G11	Medium tall, spreading type	Branching started from middle of the stem	Long, flattened and spreading type	Long and constricted

Table 2. (Cont'd)

Genotypes	Morphological characteristics			
	Plant type	**Branching point**	**Pod type**	**Beak type**
G12	Medium tall, appressed	Branching started from upper portion of the stem	Short, flattened and appressed type	Long, narrow and constricted
G13	Medium tall, appressed type	Branching started from upper portion of the stem	Long, flattened and appressed type	Long and constricted
G14	Medium tall, spreading type	Branching started from lower portion of the stem	Short, flattened and appressed type	Long and constricted
G15	Dwarf, appressed type	Branching started from lower portion of the stem	Long, flattened and appressed type	Long, narrow and constricted
G16	Dwarf, appressed type	Branching started from lower portion of the stem	Long, flattened and appressed type	Long and tapering
G17	Dwarf, spreading type	Branching started from lower portion of the stem	Short, flattened and appressed type	Short and constricted
SAU 1	Medium tall, spreading type	Branching started from middle of the stem	Short, flattened and spreading type	Short and constricted



G5 **G7**

Plate 3. Photograph showing appressed (G5) and spreading (G7) plant type

G5 **G1**

Plate 4. Comparison of branching point between G5 (Branching started from the upper portion of the stem) and G1 (Branching started from the lower portion of the stem) genotypes

G3 **G14**

Plate 5. Comparison of pod type between G3 (Long, roundish, spreading type) and G14 (Short, flattened, appressed type) genotypes

G7

SAU Sarisha 1

Plate 6. Comparison of beak type between G7 (Long, continuous) and SAU Sarisha 1 (Short, constricted)

4.2 Variability

The analysis of variance (ANOVA) of the data on different yield components and yield of *Brassica* are given in Table 3. The mean values over three replications for characters of all populations are presented in Table 4. Genotypic, phenotypic, environmental variance and genotypic, phenotypic and environmental co-efficient of variation are presented in Table 5. Among the genotypes almost all characters showed highly significant variation indicated wide scope for selection for these characters i.e. the data revealed substantial variability and thus high possibility of improvement in most of the traits. The variability in the present study indicated the potentiality of the materials and thus provided an opportunity for selecting desirable populations for releasing new varieties.

4.2.1 Plant height (cm)

Both genetic and environmental factors play a vital role in determining the plant height of a plant. Mean sum of square of plant height of the studied genotypes (93.158) showed highly significant variations at 1% level of probability (Table 3), which indicated that genotypic differences present among the genotypes under study. Range of plant height was 83.00 to 104.18 cm (Table 3) with the mean value of 94.86 cm (Table 5). Minimum plant height (83.00 cm) was recorded for genotype G16 and whereas, maximum plant height was recorded for genotype G7 (104.2) (Table 4) (Plate 7). G17 was found with moderate plant height (89.15 cm) with highest seed yield per plant (5.89 g) (Table 4).

Higher phenotypic variance (41.30) than the genotypic variance (25.93) was found in the study that indicated that the apparent variation was not only due to genotypes but also due to the influence of environment on the expression of the genes controlling this trait (Table 5).

The estimates of higher PCV (6.77%) than GCV (5.37%) also indicated presence of variability among the genotypes in respect of plant height (Table 5) (Figure 1). Ali *et al.* (2003) found low GCV and high PCV when studied inter-genotypic variability in *Brassica napus*.

Table 3. Analysis of variance of the data of eleven characters of 18 genotypes of *Brassica rapa* L.

Characters	Range		CV (%)	Mean sum of square		
	Min	Max		Replication (r-1) = 2	Genotype (g-1) = 17	Error (r-1)(g-1) = 34
Plant height (cm)	83.00	104.18	4.13	88.112	93.158**	15.373
Primary branches per plant	3.53	4.97	6.85	0.420	0.503**	0.077
Secondary branches per plant	0.07	2.30	53.45	0.869	0.692**	0.266
No. of siliqua per plant	58.05	93.07	8.02	106.289	268.183**	40.857
Siliqua length	5.73	6.97	4.11	0.160	0.253**	0.071
No. of seeds per siliqua	16.58	22.77	8.16	1.103	6.298**	2.108
Days to 50% flowering	29.67	36.67	1.93	0.074	5.966**	0.388
Days to 80% flowering	31.33	38.67	2.40	0.019	7.773**	0.685
Days to 80% maturity	79.33	86.33	1.16	1.500	7.882**	0.892
1000 seed weight (g)	2.89	3.72	6.60	0.122	0.136**	0.051
Seed yield per plant (g)	3.63	5.90	7.39	0.35	0.802**	0.135

** Denote significant at 1% level of probability

Table 4. Mean performance of eleven characters of 18 genotypes of *Brassica rapa* L.

Genotype	PH (cm)	PBP	SBP	SPP	SL (cm)	SPS	D50F	D80F	D80M	TSW (g)	SYP (g)
SAU 1	96.46	3.93	**0.07**	**58.05**	**5.73**	**22.77**	**36.67**	**38.67**	**86.33**	**2.89**	**3.62**
G1	91.66	3.96	0.57	75.62	6.31	17.14	31.33	33.33	80.00	3.55	4.53
G2	101.5	3.83	1.03	83.94	6.41	17.58	32.00	34.00	82.33	3.35	4.97
G3	98.29	3.86	0.97	81.85	6.76	17.85	32.67	35.00	80.00	**3.72**	5.31
G4	95.98	3.80	0.77	83.03	6.62	17.46	32.33	34.33	81.33	3.12	5.23
G5	96.33	3.56	0.70	64.23	6.96	18.49	31.33	33.67	80.67	3.68	4.59
G6	94.24	4.66	0.50	82.43	6.55	16.85	32.33	35.00	82.67	3.41	4.52
G7	**104.2**	3.63	1.17	71.49	6.47	16.99	33.00	36.67	82.67	3.72	5.27
G8	102.8	4.30	1.10	82.03	6.68	16.64	33.00	36.00	82.00	3.34	5.00
G9	95.57	4.43	1.07	86.11	6.30	17.08	31.67	34.67	81.33	3.34	5.13
G10	90.92	3.80	0.33	67.05	6.34	18.92	31.33	33.67	80.67	3.33	4.74
G11	90.96	**3.53**	1.27	74.88	6.57	**16.58**	32.33	34.33	**79.33**	3.37	4.62
G12	95.08	4.16	1.07	82.37	6.44	18.59	32.33	34.33	80.67	3.37	4.78
G13	98.08	3.76	**2.30**	82.72	6.51	17.29	31.67	33.33	81.33	3.46	5.63
G14	97.70	4.50	1.10	92.95	**6.97**	18.58	32.33	34.67	80.33	3.42	5.20
G15	85.71	3.70	1.43	85.69	6.42	16.71	30.67	32.67	79.67	3.54	4.73
G16	**83.00**	4.36	1.10	86.80	6.27	17.85	**29.67**	**31.33**	80.00	**3.72**	5.50
G17	89.15	**4.96**	0.83	**93.07**	6.14	16.76	33.00	35.67	80.67	3.34	**5.89**
LSD (5%)	6.50	0.46	0.85	10.61	0.44	2.40	1.03	1.37	1.56	0.374	0.60

PH = plant height (cm), PBP = primary branches per plant, SBP = secondary branches per plant, SPP = siliqua per plant, SL = siliqua length (cm), SPS = seeds per siliqua, D50F = Days to 50% flowering, D80F = Days to 80% flowering, D80M = days to 80% maturity, TSW = 1000 seed weight (g) and SYP = Seed yield per plant (g)

Table 5. Estimation of genetic parameters in eleven characters of 18 genotypes in *Brassica rapa* L.

Parameters	Mean	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	PCV (%)	GCV (%)	ECV (%)
Plant height (cm)	94.86	41.30	25.93	15.37	6.77	5.37	4.13
Primary branches per plant	4.04	0.22	0.14	0.08	11.56	9.32	6.85
Secondary branches per plant	0.96	0.41	0.14	0.27	66.20	39.06	53.45
No. of siliqua per plant	79.69	116.63	75.78	40.86	13.55	10.92	8.02
Siliqua length	6.47	0.13	0.06	0.07	5.61	3.82	4.11
No. of seeds per siliqua	17.78	3.50	1.40	2.11	10.53	6.65	8.16
Days to 50% flowering	32.20	2.25	1.86	0.39	4.66	4.23	1.93
Days to 80% flowering	34.52	3.05	2.36	0.69	5.06	4.45	2.40
Days to 80% maturity	81.22	3.22	2.33	0.89	2.21	1.88	1.16
1000 seed weight (g)	3.43	0.08	0.03	0.05	8.23	4.92	6.60
Seed yield per plant (g)	4.96	0.36	0.22	0.13	12.04	9.51	7.39

$\sigma^2 p$ = Phenotypic variance, $\sigma^2 g$ = Genotypic variance and $\sigma^2 e$ = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation.

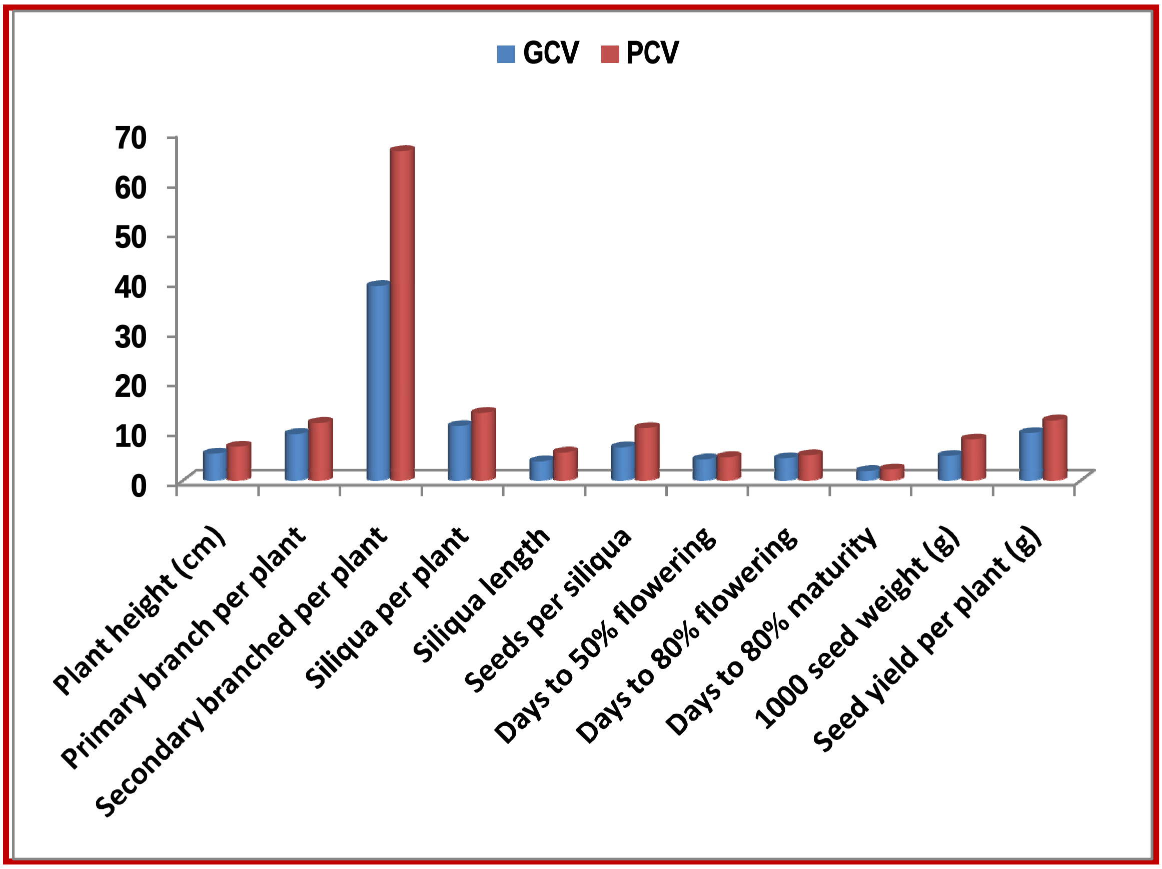


Figure 1. Genotypic and phenotypic co-efficient of variation in *Brassica rapa* L. genotypes

G7

G16

Plate 7. Photograph showing variation between highest (G7) and lowest plant height (G16)

4.2.2 Number of primary branches per plant

From the ANOVA Table (Table 3), it was found that primary branches per plant showed significant variations among the genotypes (0.503) at 1% level of probability. Minimum number of primary branches per plant was found in G11 (3.53), which gave lower seed yield per plant (4.62g). Whereas, the maximum number of primary branches per plant was found in G17 (4.96) (Plate 8), which showed the highest seed yield (5.89) (Table 4).

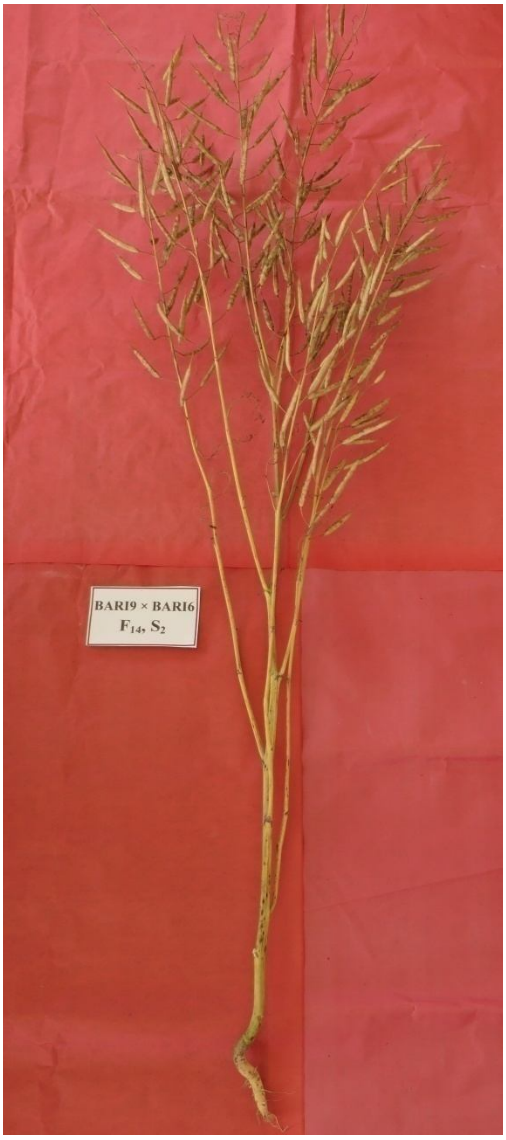
Phenotypic variance and genotypic variance were observed 0.22 and 0.14 respectively (Table 5), that indicated that there was little influence of the environment on the expression of the genes controlling this traits.

The PCV and GCV was 11.56 and 9.32 respectively which stated that the existence of inherent variability among the population with the possibility of high potential for selection. PCV and GCV value indicated the apparent variation mostly by genotypes but there was little influence of environment (Table 5) (Figure 1). High PCV and low GCV) was found by Shaukat *et al.* (2015) in *Brassica napus* for primary branches per plant.

4.2.3 Number of secondary branches per plant

From the Table 3, we found that the number of secondary branches per plant for the genotypes (0.692) showed statistically differences that indicated presence of variability among the genotypes. Highest CV% (53.45) indicated that the genotypes showed very much variability for the character (Table 3). SAU Sarisha1 (0.07) showed the lowest number of secondary branches with lowest number of siliqua per plant (58.05) and the lowest seed yield per plant (3.62 g). Whereas, the maximum number of secondary branches was found in G13 (2.30) with moderate number of siliqua per plant (82.72) which gave the second highest seed yield per plant (5.63 g) (Table 4).

Phenotypic variance and genotypic variance were observed as 0.41 and 0.14 respectively which indicated moderate environmental influence to the genotypes for the expression of this character (Table 5). ECV was much higher (53.45%) than GCV (39.06%) indicated that the environmental influence was much on the trait than the genotypes (Table 5). Roy *et al.* (2011) found significant differences for number of secondary branches per plant in *B. rapa.*



G17 **G11**

Plate 8. Photograph showing variation between highest (G17) and lowest (G11) number of primary branches of *Brassica rapa* L. genotypes

4.2.4 Days to 50% flowering

Days to 50% flowering (5.96) was statistically significant at 1% level of probability indicated that there were genotypic differences among the genotypes used under the study (Table 3). Data regarding days to 50% flowering ranged from 29.67 days to 36.67 days (Table 3). Minimum days to 50% flowering was found in G16 which showed the earliest 80% flowering (31.33 days), the highest thousand seed weight (3.72g) with higher seed yield per plant (5.50 g), on the other hand, SAU Sarisha1 required maximum days (36.67) to 50% flowering which required maximum days to 80% maturity (86.33) with the lowest thousand seed weight (2.89g) and seed yield (3.62 g) per plant (Table 4). Plate 9 showing the experimental field at 50% flowering stage.

Phenotypic variance (2.25) was higher than the genotypic variance (1.86) which indicated that variability for the character was influenced by genotypes and environment both. PCV and GCV was found 4.66% and 4.23% respectively, indicated low variability among the genotypes for the character (Table 5) (Figure 1). High PCV was recorded by Hussain (2014) in rapeseed.

4.2.5 Days to 80% flowering

High significant variations was found from the Table 3 for the days to 80% flowering at 1% level of probability among the genotypes. Minimum days to 80% flowering required in G16 (31.33) where maximum days to 80% flowering was required for the check SAU Sarisha1 (38.67) which required maximum days to 80% maturity (86.33) (Table 4). Plate 10 showing the experimental field at 80% flowering stage.

There was low difference between phenotypic (3.05) and genotypic (2.36) variance indicated less environmental influence on their phenotypic expression for the trait. PCV and GCV was 5.06% and 4.45% respectively that indicated low variations among all the genotypes and low environmental influence (Table 5). High phenotypic co-efficient of variation (PCV) and low Genotypic co-efficient of variation was four for the trait in *B. napus* by Kahrizi and Alaahvarand (2012). Plate 11 showing comparison between early flowering (G16) and late flowering (SAU Sarisha 1) line in the experimental field.

4.2.6 Days to 80% maturity

Data concerning days to 80% maturity showed significant difference (7.88) among the genotypes at 1% level of probability (Table 3). The data ranged from 79.33 to 86.33 days (Table 3). The highest days to 80% maturity was

Plate 9. Photograph showing the experimental field at 50% flowering stage

Plate 10. Photograph showing the experimental field at 80% flowering stage

G16 **SAU Sarisha 1**

Plate 11. Photograph showing comparison between early flowering (G16) and late flowering (SAU Sarisha 1) line in the experimental field

Plate 12. Photograph showing the experimental field at full pod development stage

Plate 13. Photograph showing the experimental field at harvesting stage

observed in SAU Sarisha 1 (86.33) which showed the lowest thousand seed weight (2.89g) and seed yield per plant (3.62g). Minimum days to maturity observed in G11 (79.33) which gave moderate seed yield (4.62g) per plant. The lowest CV% (1.16) indicated that the genotypes showed less variability for the character (Table 3). Plate 12 showing the experimental field at full pod development stage and Plate 13 showing the experimental field at harvesting stage.

Phenotypic variance (3.22) was higher than the genotypic variance (2.33) indicated the environmental influence on the phenotypic expression for the trait of the genotypes. Less difference between PCV (2.21%) and GCV (1.88%) indicated that there was low variation among the genotypes (Table 5). Naznin (2013) also found lower difference between PCV and GCV in *B. rapa.*

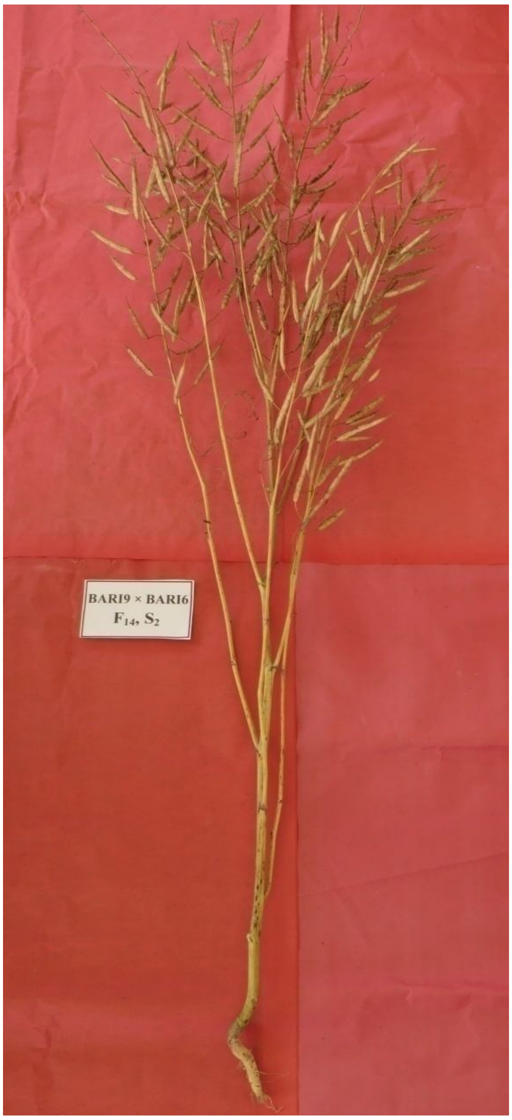
4.2.7 Number of siliqua per plant

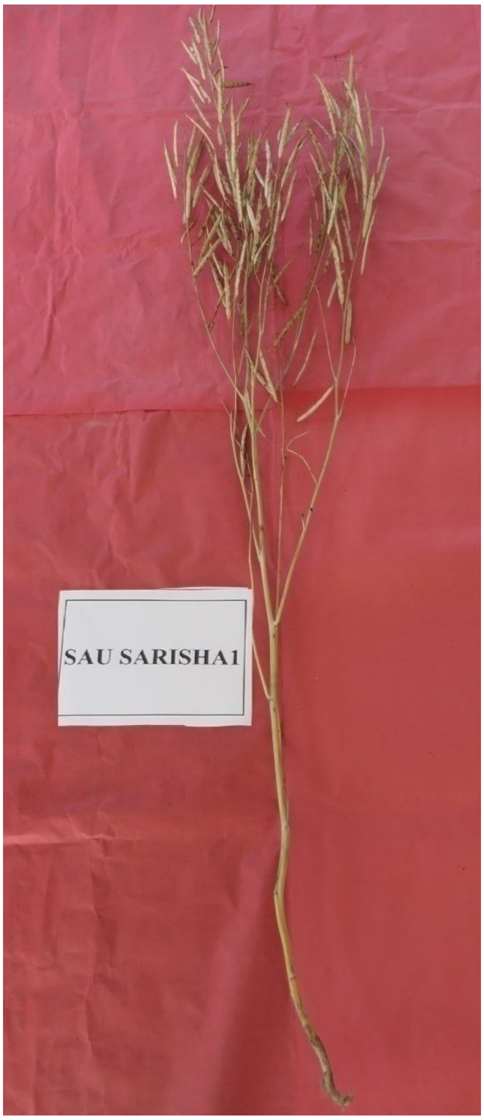
Data concerning number of siliqua per plant showed significant differences among the genotypes (268.18) at 1% level of probability (Table 3). Minimum no. of siliqua per plant was recorded for SAU Sarisha1 (58.05) which gave the lowest seed yield (3.62g) per plant. Whereas, maximum no. of siliqua per plant was recorded in G17 (93.07) which gave the highest seed yield (5.89g) per plant (Table 4) (Plate 14).

The phenotypic and genotypic variance was (116.63) and (75.78) respectively with high environmental variance (40.86), which indicated high environmental influence over the genotypes. High PCV (13.55) with low GCV (10.92) indicated that variation among the populations were not only due to the genotypes but also due to the environment (Table 5). Roy *et al.* (2011) found similar type of result i.e. high PCV (45.36) and low GCV (31.38) in *Brassica spp*.

4.2.8 Siliqua length (cm)

In the present experiment analysis of variance of the data for siliqua length showed highly significant differences among the genotypes. The mean square value (0.253) regarding the siliqua length indicated the presence of variability among the genotypes (Table 3). Maximum siliqua length (6.97 cm) was exhibited by G14 which gave higher no. of seeds per siliqua (18.58) and moderate seed yield (5.20g) per plant. The minimum siliqua length was observed in SAU Sarisha 1 (5.73 cm) but it showed the highest no. of seeds per siliqua (22.77) and the lowest seed yield (3.62g) per plant (Plate 15). G17





G17 **SAU Sarisha 1**

Plate 14. Photograph showing variation between highest (G17) and lowest (SAU Sarisha 1) siliqua per plant of *Brassica rapa* L. genotypes

G14

SAU Sarisha 1

Plate 15. Comparison of siliqua length between advanced population G14 (highest) and check variety SAU Sarisha 1 (lowest)

exhibited the second lowest siliqua length (6.14 cm) but gave the highest seed yield per plant (5.89g) (Table 4).

The phenotypic, genotypic and environmental variance was 0.13, 0.06 and 0.07 respectively. Higher environmental variance than the genotypic variance indicating very much environmental influence on phenotypic expression for this character. Phenotypic (PCV), genotypic (GCV) and environmental co-efficient of variation (ECV) values for siliqua length was 5.61% , 3.82% and 4.11% respectively which indicated that the genotypes were considerably variable for this character. The variation might be due to the environment as the ECV was moderate (4.11%) and higher than GCV (3.82%) (Table 5). Shakera (2014) found lower difference between the PCV and GCV in *B. rapa.*

4.2.9. Number of seeds per siliquae

Number of seeds per siliquae showed highly significant variations (6.29) among the genotypes from the Table 3 at 1% level of probability. The number of seeds per siliquae was observed highest in SAU Sarisha 1 (22.77) but it showed the lowest thousand seed weight (2.89g) and seed yield per plant (3.62g). The minimum no. of seeds per siliquae was observed in G11 (16.58) which gave moderate seed yield (4.62g) per plant. G17 gave lower no. of seeds per siliquae (16.76) but the highest seed yield (5.89g) per plant. It might be due to the highest no. of siliqua per plant (93.07).

Phenotypic variance (3.50) of the trait was moderately higher than the genotypic variance (1.40) that indicated moderate effect of the environment over the expression of the trait. Moderate genetic variance among the genotypes were found due to moderate differences between the PCV (10.53%) and GCV (6.65%). Which indicated moderate influence of the environment on the expression of the genes controlling this trait (Table 5). Nasim *et al.* (2013) found 21.36% PCV and 16.44% GCV in *B. napus*. Naznin (2013) also found same result in *B. rapa.*

4.2.10 Thousand seed weight (g)

Significant variations was found in case of thousand seed weight (0.14) among the studied genotypes at 1% level of probability (Table 3). Maximum thousand seed weight (3.72 g) was observed in G3 and G16 which gave higher seed yield per plant. Whereas, the minimum thousand seed weight was found in SAU Sarisha 1 (2.89 g) which gave the lowest seed yield (3.62g) per plant (Table 4).

Little difference between phenotypic (0.08) and genotypic (0.03) variance indicated very low environmental effect on the trait. Moderate difference between PCV (8.23%) and GCV (4.92%) showed moderate variation in genotypes (Table 5). Naznin (2013) found very low difference (PCV = 9.85 and GCV = 8.13) in *B. rapa*.

4.2.11 Seed yield per plant (g)

Yield is the most important trait for any crop. Seed yield per plant showed significant variations (0.802) among the genotypes at 1% level of probability (Table 3). The highest yield performance was found in G17 (5.89 g) with moderate plant height (89.15cm), maximum no. of primary branches per plant (4.96), highest no. of siliqua per plant (93.07) and moderate thousand seed weight (3.34g). The minimum seed yield per plant was found in the check variety SAU Sarisha 1 (3.62 g) which might be due to the lowest no. of siliqua per plant (58.05) and thousand seed weight (2.89g) (Table 4).

Phenotypic variance and genotypic variance for this trait was found 0.36 and 0.22 respectively that indicated environmental influences on this trait. PCV and GCV value was 12.04 and 9.51 respectively. PCV was slightly higher than GCV which indicated that the genotype had moderate variation for this trait (Table 5). Similar variability was also found by Ali *et al.* (2003) and Rameeh (2014) in rapeseed.

4.3 Heritability and genetic advance

Heritability and genetic advance are important selection parameters. Heritability estimates along with genetic advance are normally more helpful in predicting the gain under selection than heritability estimates alone. These are also indicative of the mode of gene action operated in trait expression.

4.3.1 Plant height (cm)

Plant height exhibited high heritability (62.78%) with low genetic advance (8.31) and genetic advance in percentage of mean (8.76) (Table 6) (Figure 2), indicated that the character was mostly governed by non-additive genes and more influence of the environment in the phenotypic expression of the character. Selection for such trait might not be rewarding. High heritability (92.48%) with moderate genetic advance (18.87) was found by Saifullah (2010) for the trait where Naznin (2013) found high heritability (71.01%) with low genetic advance (9.49) in *B. rapa*.

Table 6. Heritability, genetic advance and genetic advance in percent of mean for yield and yield contributing characters of 18 genotypes of *Brassica rapa* L.

Parameters	Heritability	Genetic advance (GA) (5%)	Genetic advance (% mean)
Plant height (cm)	62.78	8.31	8.76
Primary branches per plant	64.94	0.63	15.47
Secondary branches per plant	34.81	0.46	47.47
No. of siliqua per plant	64.97	14.45	18.14
Siliqua length	46.35	0.35	5.35
No. of seeds per siliqua	39.85	1.54	8.64
Days to 50% flowering	82.74	2.56	7.93
Days to 80% flowering	77.52	2.79	8.08
Days to 80% maturity	72.31	2.67	3.29
1000 seed weight (g)	35.72	0.21	6.05
Seed yield per plant (g)	62.30	0.77	15.46

4.3.2 Number of primary branches per plant

Number of primary branches per plant showed high heritability (64.94%) with low genetic advance (0.63) and moderate genetic advance in percentage of mean (15.47) indicated that this trait was controlled by non-additive genes and selection based on this character will not be rewarding for future breeding program. Sultana (2015) found high heritability (97.43) and low genetic advance (1.25) for this trait in *B. napus.*

4.3.3 Number of secondary branches per plant

Moderate heritability (34.81%) along with low genetic advance (0.46) and high genetic advance in percentage of mean (47.47) indicated moderate effect of the environment and presence of non-additive genes in the expression of the character. As a whole, the moderately high heritability coupled with low genetic advance indicated the lower possibility of selecting genotypes but high genetic advance in percentage of mean which indicated the possibility of predominance of additive gene, so much scope to improve. Sultana (2015) found high heritability (98.70%) and low genetic advance (1.78%) for this trait in *B. napus.*

4.3.4 Number of siliqua per plant

Number of siliqua per plant showed high heritability (64.97%) with moderately high genetic advance (14.45) and genetic advance in percentage of mean (18.14), revealed that the character was least influenced by the environmental effects and the possibility of predominance of additive gene action in the inheritance of this trait and indicated that this trait could be improved through selection process. Hussain (2014) found high heritability with moderate genetic advance in percentage of mean for this trait in *B. rapa*.

4.3.5 Siliqua length (cm)

Siliqua length exhibited moderate heritability (46.35%) with very low genetic advance (0.35) and genetic advance in percentage of mean (5.35) that indicated that the environmental effect was more than the genotypic effect and due to non-additive gene action, selection for further improvement of the trait might not be rewarding. Moderate heritability was due to high influence of the environment. Saifullah (2010) found the similar result in *B. rapa*.

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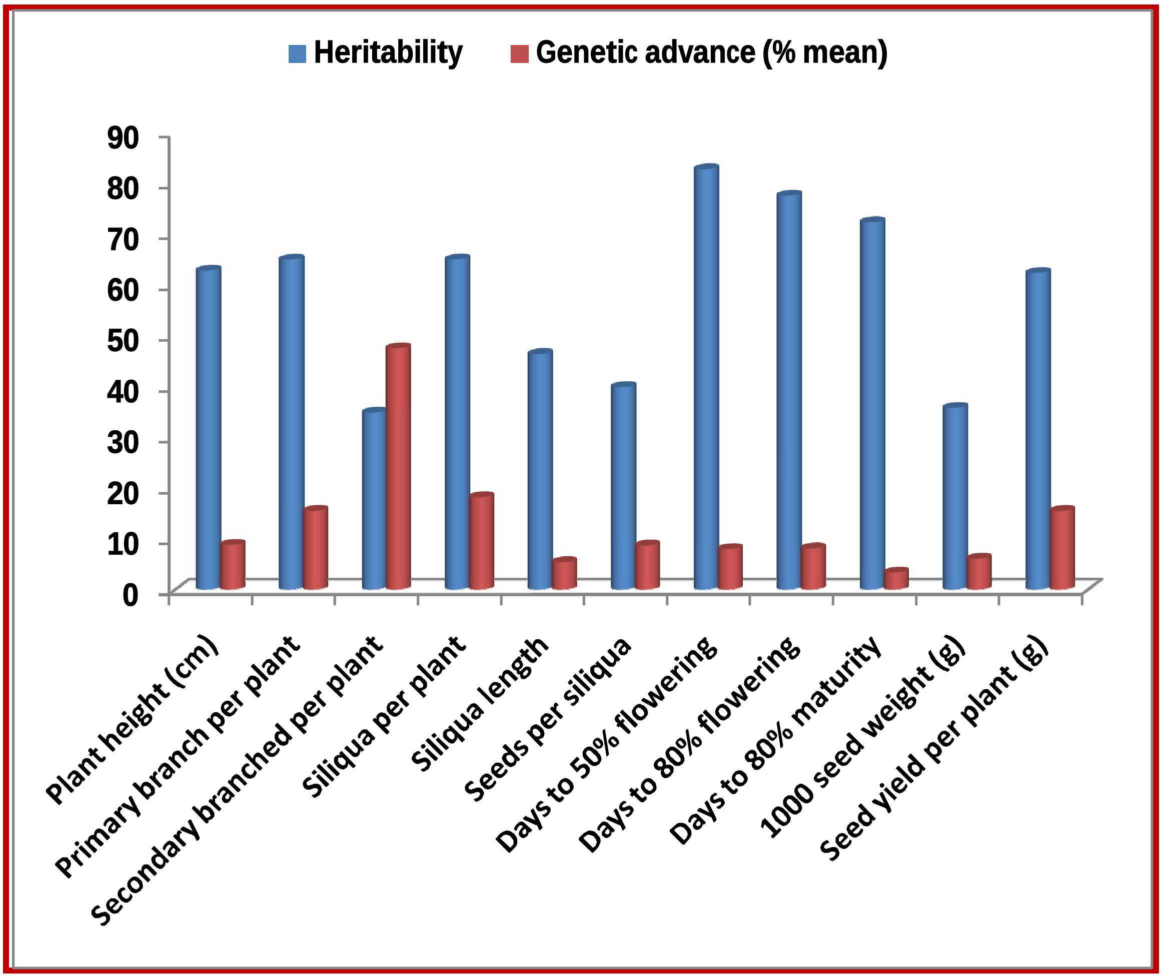


Figure 2. Heritability and genetic advance over mean in *Brassica rapa* L. genotypes

4.3.6 Number of seeds per siliquae

Number of seeds per siliquae showed moderate heritability (39.85%) with low genetic advance (1.54) and genetic advance in percentage of mean (8.64) revealed that there was an effect of non-additive genes and selection for the trait might not be wise. The environmental influence was high that might be the reason of the moderate heritability. High heritability (65.47%) with low genetic advance (4.53%) was found by Hussain (2014) for this trait in *B. rapa*.

4.3.7 Days to 50% flowering

Days to 50% flowering showed high heritability (42.74%) along with low genetic advance (2.56) and genetic advance in percentage of mean (7.93) (Table 6), which indicated that the character was governed by non-additive genes and high heritability was being exhibited due to favorable environment rather than genotypes and selection for this trait might not be rewarding. Saifullah (2010) found similar result for the trait that high heritability (88.86%) and low genetic advance (2.06) in *B. rapa*.

4.3.8 Days to 80% flowering

Days to 80% flowering showed high heritability (77.52%) with low genetic advance (2.79) and genetic advance in percentage of mean (8.08), that indicated that the character was mostly governed by non-additive genes and more influence of the environment in the phenotypic expression of the character, so improvement through selection might not be so wise. Environment was responsible for high heritability. Kahrizi and Alaahvarand (2012) found high heritability (93.18%) and low genetic advance (14.08) in rapeseed that was similar to the result.

4.3.9 Days to 80% maturity

This trait exhibited high heritability (72.31%) with low genetic advance (2.67) and genetic advance in percentage of mean (3.29), this result revealed the presence of non-additive genes and selection in that case might not be fruitful. Naznin (2013) found high heritability (89.14%) with low genetic advance (8.69%) in *B. rapa* for this trait which was similar to the result.

4.3.10Thousand seed weight (g)

Thousand seed weight showed moderate heritability (35.72%) with very low genetic advance (0.21) and low genetic advance in percentage of mean (6.05).

This result indicated non-additive genes involvement in the expression of the trait and there is limited scope of improvement by direct selection. High heritability (65.03%) with low genetic advance (0.31) was found by Saifullah (2010) in *B. rapa* for this trait.

4.3.11 Seed yield per plant

This trait showed high heritability (62.30%) with low genetic advance (0.77) and moderately high genetic advance in percentage of mean (15.46), which revealed that this character was governed by non-additive genes but moderately high genetic advance in percentage of mean indicated that possibility of predominance of additive gene, so much scope to improve, As a whole, the high heritability was being exhibited due to favorable influence of the environment rather than genotypes and the consequent low genetic advance indicated the lower possibility of selecting genotypes for this trait. Rameeh (2014) found high heritability with high genetic advance for seed yield in *B. napus*.

4.4 Correlation among different characters

Yield is controlled by polygene and highly influenced by the environment. For this reason, selection based on only yield itself is ineffective. Correlation co-efficient helps the plant breeders to select the yield contributing traits to be given importance by its nature and magnitude. Simultaneous improvement of various characters along with the yield is also possible through correlation co-efficient. Genotypic and phenotypic correlation co-efficient among 11 characters are presented in Table 7. It is evident that in some cases, the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient. This indicated a strong inherent association between the characters studied and suppressive effect of the environment modified the phenotypic expression of the characters by reducing phenotypic correlation relation values. On the other hand in some cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level.

Table 7. Phenotypic and Genotypic correlation coefficient among different pairs of yield and yield contributing characters for different genotype of *Brassica rapa* L.

		PBP	SBP	SPP	SL (cm)	SPS	D50F	D80F	D80M	TSW (g)	SYP (g)
PH (cm)	P	-0.086	0.200	-0.059	0.331*	0.109	0.390**	0.444**	0.326*	-0.038	0.080
	G	-0.272*	-0.036	-0.271*	0.307*	0.027	0.536**	0.668**	0.581**	-0.178	-0.094
PBP	P		0.031	0.620**	-0.038	0.054	0.054	0.111	0.048	-0.201	0.385**
	G		-0.370**	0.594**	-0.287*	-0.285*	0.046	0.121	0.045	-0.094	0.269*
SBP	P			0.505**	0.238	-0.193	-0.279*	-0.340*	-0.258	0.189	0.589**
	G			0.477**	0.422**	-0.974**	-0.527**	-0.457**	-0.546**	0.644**	0.606**
SPP	P				0.277*	-0.305*	-0.303*	-0.297*	-0.375**	-0.003	0.743**
	G				0.205	-0.886**	-0.481**	-0.413**	-0.538**	0.381**	0.700**
SL (cm)	P					-0.143	-0.299*	-0.187	-0.391**	0.397**	0.286*
	G					-0.730**	-0.454**	-0.387**	-0.606**	0.598**	0.261
SPS	P						0.468**	0.341*	0.452**	-0.416**	-0.280*
	G						0.739**	0.544**	0.785**	-0.618**	-0.910**
D50F	P							0.879**	0.684**	-0.523**	-0.315*
	G							0.994**	0.851**	-0.805**	-0.525**
D80F	P								0.613**	-0.361**	-0.281*
	G								0.858**	-0.703**	-0.378**
D80M	P									-0.390**	-0.380**
	G									-0.820**	-0.540**
TSW (g)	P										0.200**
	G										0.665**

** = Significant at 1%. * = Significant at 5%.

PH = plant height (cm), PBP = primary branch per plant, SBP = secondary branched per plant, SPP = siliqua per plant, SL = siliqua length (cm), SPS = seeds per siliqua, D50F = Days to 50% flowering, D80F = Days to 80% flowering, D80M = days to 80% maturity, TSW = 1000 seed weight (g , SYP = Seed yield per plant (g), P=Phenotypic correlation, G= Genotypic correlation

4.4.1 Plant height (cm)

Plant height showed significant and positive correlation with days to 50% flowering (P=0.390**, G=536**), days to 80% flowering (P=0.444**, G=0.668**), days to 80% maturity (P=0.326**, G=0.581**) and siliqua length (P=0.331*, G=0.307*). (Table 7). It indicated that if plant height increased then days to 50% flowering, days to 80% flowering , days to 80% maturity and siliqua length also increased. It also implied that highly significant positive associations between plant height and other characters indicated that the trait were governed by same gene and simultaneous improvement would be effective. The genotypic correlation co-efficient is higher than the phenotypic correlation co-efficient. This indicated that there was strong association between the characters genetically, but the phenotypic value was lessened by the significant interaction of the environment.

It had positive and insignificant interaction with secondary branches per plant (P=0.200), number of seeds per siliquae (P=0.109, G=0.027), seed yield per plant (P=0.080). (Table 7). Insignificant association of these traits indicated that the association between these traits is largely influenced by the environmental factors. Plant height had significant but negative correlation with number of primary branches per plant (G= -0.271*) and siliqua per plant (G= -0.271*) (Table 7) which indicated that if plant height increased then number of primary branches per plant and number of siliqua per plant will be decreased. However, it had negative and insignificant interaction with number of primary branches per plant (P= -0.086), number of siliqua per plant (P= -0.059), thousand seed weight (P= -0.038, G= -0.178) and seed yield per plant (G= -0.094) (Table 7). Insignificant association of these traits indicated that the association between these traits was largely influenced by the environmental factors and mostly independent in nature. Khayat *et al.* (2012) found significant positive correlation between seed yield and plant height in *B. napus*.

4.4.2 Number of primary branches per plant

Positive and significant correlation of number of primary branches per plant was observed with number of siliqua per plant (P=0.620**, G=0.594**) and seed yield per plant (P=0.385**, G=0.269*) (Table 7).This indicated that association between the characters is high and if number of primary branches increased then number of siliqua per plant and seed yield per plant also increased. It had significant but negative correlation with number of secondary branches per plant (G= -0.370**), siliquae length (G= -0.287*) and number of siliqua per plant (G= -0.285*) (Table 7), it indicated that if primary branches per plant increased then secondary branches per plant, siliquae length and number of siliqua per plant would be decreased. It also showed insignificant positive association with secondary branches per plant (P=0.031), number of seeds per siliquae (P=0.054), days to 50% flowering (P=0.054, G=0.046), days to 80% flowering (P=0.111, G=0.121), and days to 80% maturity (P=0.048, G=0.045). It also showed insignificant negative correlation with siliquae length (P= -0.038) and thousand seed weight (P= -0.201, G= -0.094). Insignificant association of this traits indicated that the association between these traits was largely influenced by the environmental factors and mostly independent in nature. Gangapur *et al.* (2009) found positive significant correlation between primary branches per plant and seed yield per plant in rapeseed.

4.4.3 Number of secondary branches per plant

Siliqua per plant (P=0.505**, G=0.477**), siliqua length (G=0.422**), thousand seed weight (G=0.644**) and seed yield per plant (P=0.589**, G=0.606**) showed highly significant positive association with number of secondary branches per plant (Table 7), that indicated that if number of secondary branches increased then siliqua per plant, siliqua length, thousand seed weight and seed yield per plant also increased and vice-versa. It showed significant negative correlation with seeds per siliquae (G= -0.974**), days to 50% flowering (P= -0.279*, G= -0.527**), days to 80% flowering (P= -0.340*, G= -0.457**) and days to 80% maturity (G= -0.546**). These indicated that if secondary branches per plant increased then seeds per siliqua, days to 50% flowering , days to 80% flowering , days to 80% maturity decreased and vice-versa. It showed positive but insignificant association with siliquae length (P=0.238) and thousand seed weight (P=0.189) and negative insignificant association with seeds per siliquae (P= -0.193) and days to 80% maturity (P= -0.258). Insignificant association of these traits indicated that the association between these traits was largely influenced by the environmental factors and mostly independent in nature. Naznin (2013) found positive significant relation with yield in rapeseed which is similar to the findings.

4.4.4 Number of siliqua per plant

Number of siliqua per plant showed significant positive correlation with siliquae length (P=0.277*) thousand seed weight (G=0.381**) and seed yield per plant (P=0.743**, G=700**) (Table 7) That indicated that association between the characters was high and if number of siliqua per plant increased then siliquae length, thousand seed weight and yield per plant also increased and vice-versa. This trait showed significant negative correlation with seeds per siliquae (P= -0.305*, G= -0.886**) days to 50% flowering (P= -0.303*, G= -0.481**) days to 80% flowering (P= -0.297*, G= -0.413**) and days to 80%

maturity (P= -0.375**, G= -0.538**), indicated that if number of siliqua per plant increased then seeds per siliquae, days to 50% flowering , days to 80% flowering and days to 80% maturity decreased and vice-versa. Siliqua per plant showed insignificant positive correlation with siliqua length (G=0.205) and insignificant negative correlation with thousand seed weight (P= -0.003). Insignificant association of these traits indicated that the association between there traits is largely influenced by the environmental factors. Bilal *et al.* (2015) and Rameeh (2011) also found positive significant correlation between siliqua per plant and seed yield in rapeseed.

4.4.5 Length of siliqua (cm)

Length of siliqua showed positive and significant correlation with thousand seed weight (P=0.397**, G=0.598**) and seed yield per plant (P=0.286*) (Table 7). This indicated that if siliqua length increased then thousand seed weight and seed yield per plant also increased and vice-versa. This trait showed significant but negative correlation with seeds per siliqua (G=-0.730**), days to 50% flowering (P= -0.299*, G= -0.454**), days to 80% flowering (G= -0.387**) and days to 80% maturity (P= -0.391**, G= -0.606**), this indicated that if siliqua length increased then seeds per siliqua, days to 50% flowering , days to 80% flowering and days to 80% maturity would be decreased and vice-versa. Siliqua length also showed insignificant positive association with seed yield per plant (G=0.261) and insignificant negative correlation with seeds per siliqua (P= -0.143) and days to 80% flowering (P= -0.187). Insignificant association of these traits indicated that the association between these traits was largely influenced by the environmental factors and mostly independent in nature. Saifullah (2010) found positive significant correlation of the trait with yield in *B. rapa*.

4.4.6 Number of seeds per siliquae

Number of seeds per siliquae showed highly significant and positive correlation with days to 50% flowering (P=0.468**, G=0.739**), days to 80% flowering (P=0.341**, G=0.544**) and days to 80% maturity (P=0.452**, G=0.785**). This indicated that association is high and if number of seed per siliquae increased then days to 50% flowering days to 80% flowering and days to 80% maturity increased and vice-versa. Higher value of genotypic correlation co-efficient than the phenotypic correlation co-efficient indicated that there is strong association between these characters genetically, but the phenotypic value is lessened by the significant interaction of the environment.

This trait showed negative significant correlation with thousand seed weight (P= -0.416**, G= -0.618**) and seed yield per plant (P= -0.280*, G= -0.910**), indicated that if seeds per siliquae increased then thousand seed weight and seed yield per plant decreased. Naznin (2013) found negative significant correlation with yield in rapeseed.

4.4.7 Days to 50% flowering

Days to 50% flowering showed highly significant positive correlation with days to 80% flowering (P=0.879**, G=0.994**) and days to 80% maturity (P=0.684**, G=0.851**), this indicated that if days to 50% flowering increased then days to 80% flowering and days to 80% maturity increased. It also showed negative but significant correlation with thousand seed weight (= -0.523**, G= -0.805**), and seed yield per plant (P= -0.315*, G= -0.525**), which indicated that if days to 50% flowering increased then thousand seed weight and seed yield per plant decreased. Nasim *et al.* (2013) found negative correlation with thousand seed weight in *B. napus*.

4.4.8 Days to 80% flowering

Days to 80% flowering showed positive and significant correlation with days to 80% maturity (P=0.613**, G=0.858**), this revealed that if days to 80% flowering increased then days to 80% maturity also increased. But this trait showed negative significant correlation with thousand seed weight (P= -0.361**, G= -0.703**) and seed yield per plant (P= -0.281* , G= -0.378**), which indicated that if days to 80% flowering increased then thousand seed weight and seed yield per plant decreased.

4.4.9 Days to 80% maturity

Negative but significant correlation was found in case of 80% maturity with thousand seed weight (P= -0.390**, G= -0.820**) and seed yield per plant (P= -0.380**, G= -0.540**), that indicated that if days to 80% maturity increased then thousand seed weight and seed yield per plant decreased. Parvin (2014) found significant positive correlation for this trait with yield per plant in *B. rapa*.

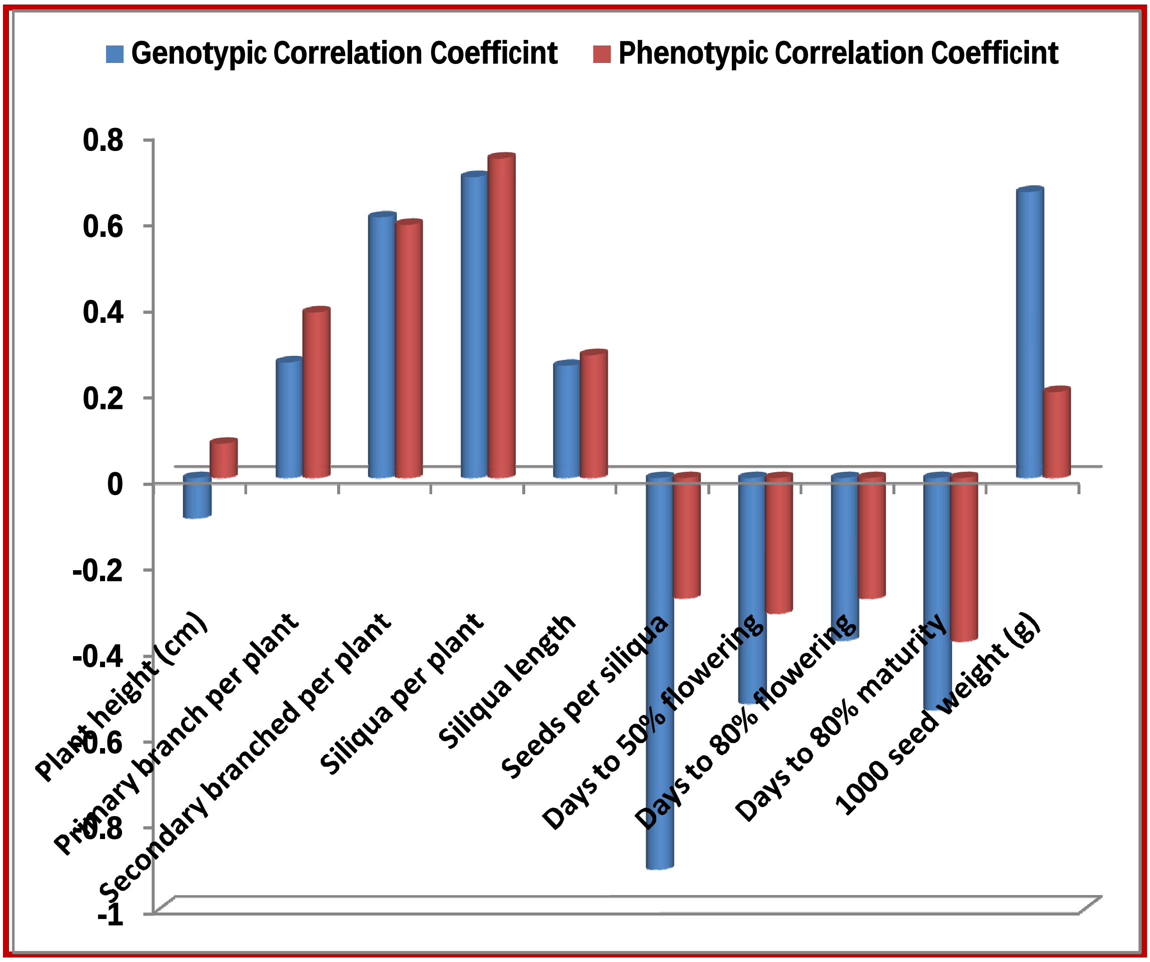


Figure 3. Genotypic and Phenotypic Correlation Co-efficient for eleven characters of *Brassica rapa* L. genotypes

4.4.10 Weight of 1000 seed (g)

Thousand seed weight showed significant positive correlation with seed yield per plant (P=0.200**, G=0.665**), that implied that if thousand seed weight increased then seed yield per plant also increased. Saifullah (2010) found positive significant correlation of the trait with seed yield in *B. rapa*.

4.5 Path co-efficient analysis

Correlation co-efficient determines association of characters that might not provide an exact picture of the relative importance of direct and indirect influence of each yield components on seed yield of the plant. A clear picture of the interrelationship between seed yield and others yield contributing characters, direct and indirect effects of them can be worked out by using path analysis at genotypic level which also measure the relative importance of each component on yield. Seed yield is considered as a dependent variable and days to 50% flowering, days to 80% flowering, days to 80% maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, siliqua length, number of seeds per siliqua and thousand seed weight were independent variable. Estimation of direct and indirect effect of path co-efficient analysis for *Brassica rapa* is presented in Table 8. Residual effects of their independent variables, which have influenced on yield to a medium extent, have been denoted as 'R'.

Table 8. Path co-efficient analysis showing direct and indirect effects of different characters on yield of *Brassica rapa* L.

Characters	Direct effect	Indirect effect via										Genotypic correlation with seed yield
		PH (cm)	PBP	SBP	SPP	SL (cm)	SPS	D50F	D80F	D80M	TSW (g)	
PH (cm)	-0.652	-	-0.211	-0.037	-0.060	0.267	0.009	0.629	-0.69	0.82	-0.17	-0.094
PBP	0.774	0.177	-	-0.378	0.132	-0.250	-0.090	0.054	-0.13	0.06	-0.09	0.269*
SBP	1.022	0.023	-0.286	-	0.106	0.367	-0.308	-0.618	0.48	-0.77	0.60	0.606**
SPP	0.222	0.177	0.460	0.487	-	0.178	-0.280	-0.564	0.43	-0.76	0.35	0.700**
SL (cm)	0.870	-0.200	-0.222	0.431	0.046	-	-0.231	-0.533	0.40	-0.86	0.56	0.261
SPS	0.316	-0.018	-0.221	-0.995	-0.197	-0.635	-	0.867	-0.57	1.11	-0.57	-0.910**
D50F	1.173	-0.349	0.036	-0.539	-0.107	-0.395	0.234	-	-1.03	1.21	-0.75	-0.525**
D80F	-1.04	-0.44	0.09	-0.47	-0.09	-0.34	0.17	1.17	-	1.21	-0.65	-0.378**
D80M	1.42	-0.38	0.03	-0.56	-0.12	-0.53	0.25	1.00	-0.89	-	-0.76	-0.540**
TSW (g)	0.93	0.12	-0.07	0.66	0.08	0.52	-0.20	-0.94	0.73	-1.16	-	0.665**

Residual effect: 0.323 ** = Significant at 1%. * = Significant at 5%.

PH = plant height (cm), PBP = primary branches per plant, SBP = secondary branches per plant, SPP = siliqua per plant, SL = siliqua length (cm), SPS = seeds per siliqua, D50F = Days to 50% flowering, D80F = Days to 80% flowering, D80M = days to 80% maturity, TSW = 1000 seed weight (g) and SYP = Seed yield per plant (g)

4.5.1 Plant height (cm)

The relationship between plant height and seed yield per plant was insignificant and negative as was pointed out by genotypic co-efficient of correlation (-0.094). However its direct effect was low and negative (-0.652). Plant height showed indirect negative effect on yield through number of primary branches per plant (-0.211), number of secondary branches per plant (-0.037), number of siliqua per plant (-0.060), days to 80% flowering (-0.69) and thousand seed weight (-017). On the other hand it should positive indirect effect via seeds per siliquae (0.009), siliquae length (0.267), days to 50% flowering (0.629) and days to 80% maturity (0.82) (Table 8), it indicated that correlation was mainly due to indirect effect of the character through another component trait, indirect selection through such trait the will be live in yield improvement. Basalma (2008) found direct negative effect of plant height (-0.28) on seed yield in rapeseed.

4.5.2 Number of primary branches per plant

Number of primary branches per plant had positive direct effect on yield per plant (0.774). This trait had positive indirect effect on yield via plant height (0.177), siliqua per plant (0.132), days to 50% flowering (0.054), and days to 80% maturity (0.06). On the other hand, this trait had indirect negative effect on yield via number of secondary branches per plant (-0.378), siliqua length (-0.250), seeds per siliquae (-0.090), days to 80% flowering (-0.13) and thousand seed weight (0.09), (Table 8).

Number of primary branches per plant finally made positive correlation with seed yield (0.269) which was highly significant. Its direct effect was higher and positive than the genetic correlation of co-efficient. In such situation direct selection for this trait should be practiced for yield improvement. Hussain (2014) reported that number of primary branches per plant had direct positive effect on seed yield in *Brassica rapa*.

4.5.3 Number of secondary branches per plant

Number of secondary branches per plant showed positive direct effect (1.022) on seed yield per plant. This trait showed positive indirect effect on seed yield via plant height (0.023), siliquae per plant (0.106), siliquae length (0.367), days to 80% flowering (0.48) and thousand seed weight (0.60). On the other hand it showed negative indirect effect on seed yield via primary branches per plant (-0.286), seeds per siliquae (-0.308), days to 50% flowering (-0.618) and days to 80% maturity (-0.77). Relationship between number of secondary branches per plant and seed yield per plant was highly significant as was pointed out by genotypic co-efficient of correlation (0.606), (Table 8). Direct effect is positive and higher than the genetic correlation of co-efficient it indicated true relationship between them and direct selection for this trait will be rewarding for yield improvement, path analysis done by Basalma (2008) indicated that number of secondary branches per plant had positive effect (0.077) on seed yield in rapeseed.

4.5.4 Number of siliqua per plant

Path co-efficient analysis revealed that number of siliqua per plant had positive direct effect (0.222) on seed yield followed by positive indirect effect via plant height (0.177), number of primary branches per plant (0.460), number of secondary branches per plant (0.487), siliquae length (0.178), days to 80% flowering (0.43) and thousand seed weight (0.35). This trait had negative indirect effect on yield via seeds per siliquae (-0.280), days to 50% flowering (-0.564) and days to 80% maturity (-0.76). Finally number of siliqua per plant had highly significant positive genotypic correlation (0.700) with yield per plant (Table 8). This result indicated that correlation between yield and this character was due to both direct and indirect effects via other component traits. Marjanovic–Jeromela *et al*. (2008) worked on *Brassica napus* and found positive direct effect (0.26) on yield.

4.5.5 Length of Siliqua (cm)

According to path co-efficient analysis siliqua length had direct positive effect (0.870) on seed yield per plant. It showed negative indirect effect via plant height (-0.200), number of primary branches per plant (-0.222), seeds per siliquae (-0.231), days to 50% flowering (-0.533), and days to 80% maturity (-0.86) on seed yield. Positive indirect effect of the trait was found on secondary branches per plant (0.431), siliqua per plant (0.046), days to 80% flowering (0.40) and thousand seed weight (0.56). Finally it made positive correlation with seed yield (0.261) (Table 8). Sultana (2015) observed that siliquae length had direct negative effect on yield in rapeseed.

4.5.6 Number of seeds per siliquae

Path co-efficient analysis showed that number of seeds per siliquae had direct positive effect (0.316) on yield per plant. This trait showed indirect negative effect via plant height (-0.018), number of primary branches per plant (-0.221), number of secondary branches per plant (-0.995), number of siliqua per plant (-0.197), siliquae length (-0.635), days to 80% flowering (-0.57) and thousand seed weight (-0.57) on yield per plant. On the other hand, this trait had positive indirect effect via days to 50% flowering (0.867) and days to 80% maturity

(1.11). Finally this trait showed significant negative genotypic correlation (-0.910) with yield per plant, (Table 8). As the direct effect was positive and high but the correlation was negative in such situation direct selection for such trait should be practiced to reduce the undesirable indirect effect. Sultana (2015) worked with *Brassica napus* and found that number of seeds per siliquae had positive direct effect on yield.

4.5.7 Days to 50% flowering

Days to 50% flowering had direct positive effect (1.173) on yield per plant. Negative indirect effect was found on seed yield via plant height (-0.349), number of secondary branches per plant (-0.539), number of siliqua per plant (-0.107), siliquae length (-0.395), days to 80% maturity (-1.03) and thousand seed weight (-0.75). While positive indirect effect was found via number of primary branches per plant (0.0236), number of seeds per siliquae (0.234) and days to 80% maturity (1.21). Days to 50% flowering showed significant negative genotypic correlation (-0.525) with seed yield per plant (Table 8), that indicated in such situation selection for such trait should be practiced to reduce the undesirable indirect effect. Parvin (2014) revealed that days to 50% flowering had positive direct effect on yield per plant in *B. napus.*

4.5.8 Days to 80% flowering

Path co-efficient analysis revealed that days to 80% flowering had direct negative effect on yield (-1.04). This trait showed negative indirect effect with plant height (-0.44), number of secondary branches per plant (-.47), number of siliqua per plant (-0.09), siliquae length (-0.34) and thousand seed weight (-0.56). On the other hand, it showed positive indirect effect with number of primary branches per plant (0.09), number of seeds per siliquae (0.17), days to 50% flowering (1.17) and days to 80% maturity (1.21) on yield per plant. This trait had significant negative genotypic correlation with yield per plant (-0.378) (Table 8), indicated that correlation was mainly due to indirect effect of the character through another component trait. Indirect selection through such trait will be live in yield improvement and it should be practiced to reduce the undesirable effect. The strongest positive direct effect of days to 80% flowering on yield in rapeseed was found by Ogrodowezyk and Wawrzyniak (2004) that was against the findings.

4.5.9 Days to 80% maturity

Days to 80% maturity showed highest positive direct effect on seed yield per plant (1.42). It showed negative indirect effect via plant height (-0.38), number of secondary branches per plant (-0.56), siliqua per plant (-0.12), siliquae length (-0.53), days to 80% flowering (-0.89) and thousand seed weight (-0,76) on yield per plant and it showed positive indirect effect via number of primary branches (0.03), number of seeds per siliquae (0.25) and days to 50% flowering (1.00) on yield per plant. This trait had significant negative correlation with seed yield (-0.540) (Table 8), indicated that direct selection for such trait should be practiced to reduce the undesirable indirect effect and direct selection for this trait will be rewarding for yield improvement. Parvin (2014) revealed that days to maturity had positive direct effect on yield when worked with *Brassica* species.

4.5.10 Thousand seed weight

Path analysis revealed that thousand seed weight had direct positive effect on seed yield per plant (0.93). It showed positive indirect effect via plant height (0.12), number of secondary branches per plant (0.66), siliquae per plant (0.08), siliquae length (0.52) and days to 80% flowering (0.73). This trait showed indirect negative effect via number of primary branches per plant (-0.07), number of seeds per siliquae (-0.20), days to 50% flowering (-0.94) and days to 80% maturity (-1.16). This trait had significant positive (0.665) correlation with seed yield per plant (Table 8). Its direct effect was higher and positive than the genetic correlation co-efficient, it revealed true relationship between them and direct selection for this trait will be rewarding for yield improvement. Sharafi *et al.* (2015) reported that thousand seed weight had highest positive direct effect on seed yield per plant in rapeseed.

The value of residual effect was 0.323. It indicated that beside the characters studied, there're some other attributes (approx. 32.3%) which contributed for yield.

CHAPTER V

SUMMARY AND CONCLUSION

This research work was carried out to compare the advanced populations of *Brassica rapa* obtained through advancing generations of different inter-varietal crosses and to estimate the variability among the characters, heritability, genetic advance, character association and direct and indirect effect of different considered traits on yield.

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University during November 2015 to February 2016 using 17 advanced populations of *Brassica rapa* and SAU sarisha1 as a check variety.

From variability analysis of F_{14} populations, it was observed that significant variation existed among all the genotypes used for most of the characters studied. The highest plant height found in G7 and the lowest in G16. The highest number of primary branches per plant was observed in G17 and the lowest number of primary branches per plant was found in G11. The highest number of secondary branches per plant was found in G13 and the check variety SAU Sarisha1 showed the lowest number of secondary branches per plant.

From this study, it could be said that all the advanced populations showed better performance than the check variety SAU Sarisha1 in respect of secondary branches per plant, no. of siliqua per plant, siliquae length, days to 50% flowering days to 80% flowering, days to 80% maturity, thousand seed and seed yield per plant except plant height, no. of primary branches per plant and no. of seeds per siliquae.

No. of siliqua per plant was found maximum in G17 followed by G14 and G16 and the lowest was found in SAU Sarisha1. The highest siliqua length was recorded in G14 followed by G5 and G3, and the lowest was found in SAU Sarisha1. The number of seeds per siliquae was found maximum in the check variety SAU Sarisha1 followed by G10, G14 and the lowest was found in G11.

Minimum days to 50% and 80% flowering was found in G16 followed by G15.The lowest days to maturity was observed in G11, G15 followed by G16, G1 and G3. SAU Sarisha1 took the longest time in case of 50% flowering, 80% flowering and 80% maturity. Thousand seed weight was found maximum in

G3, G7 and minimum in SAU Sarisha1. The seed yield per plant was found maximum in G17 and minimum in SAU Sarisha1.

However, the phenotypic variance and phenotypic co-efficient of variation was found higher than the corresponding genotypic variance and genotypic co-efficient of variation for all the characters under study. Higher phenotypic variance than the genotypic variance for all the characters indicated the greater influence of environment to express the characters. Higher phenotypic and genotypic differences were found in case of plant height and no. of siliqua per plant that stated the more environmental effect to control the characters.

On the other hand, days to 50% flowering, days to 80% flowering , days to 80% maturity, no. of primary branches per plant, no. secondary branches per plant, siliqua length, no. of seeds per siliquae, thousand seed weight and seed yield per plant showed least difference between phenotypic and genotypic variance indicated least environmental influence and additive gene action for the expression of the characters.

Moderate heritability with low genetic advance and high genetic advance in percentage of mean was found in case of number of secondary branches per plant indicated moderate effect of environment and presence of non-additive genes in the expression of the character, which resulted the lower possibility of the selection of genotypes but high genetic advance in percentage of mean which indicated the possibility of predominance of additive gene, so much scope to improve. High heritability with moderately high genetic advance in percentage of mean was observed in primary branches per plant, no. of siliqua per plant and seed yield per plant indicated medium possibility of selecting genotypes for further improvement.

High heritability with low genetic advance and genetic advance in percentage of mean was found in plant height, siliqua length, no. of seeds per siliquae, days to 50% flowering, days to 80% flowering and days to 80% maturity indicated that non-additive gene effects were involved for the expression of these characters and selection for genetic improvement for these traits would be ineffective.

Correlation co-efficient among the characters were studied to determine the association between yield and yield components. It is evident that in some of the cases genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient indicated a strong inherent association between the characters under study and suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. On the other hand, in some cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggested that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level. Significant phenotypic and genotypic positive association with seed yield per plant was found in case of number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and thousand seed weight. On the other hand, significant negative correlation in both phenotypic and genotypic level was found in no. of seeds per siliquae, days to 50% flowering, days to 80% flowering and days to 80% maturity.

Path co-efficient analysis revealed that number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, siliqua length, no. of seeds per siliquae, days to 50% flowering, days to 80% maturity and thousand seed weight had the positive direct effect on yield per plant whereas, plant height and days to 80% flowering had the negative direct effect on yield per plant.

The path co-efficient studies indicated that number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and thousand seed weight were the most important contributors to seed yield per plant.

Based on the results of the study, the following conclusion and recommendation may be drawn:

1. Moderate heritability with low genetic advance and high genetic advance in percentage of mean was found in case of number of secondary branches per plant. High genetic advance in percentage of mean indicated the possibility of predominance of additive genes and selection for genetic improvement for this trait would be effective.

2. High heritability with moderately high genetic advance in percentage of mean was observed in no. of primary branches per plant, no. of siliqua per plant and seed yield per plant indicated medium possibility of selecting genotypes for further improvement.

3. Significant positive correlation with seed yield per plant was found in case of number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and thousand seed weight. This result suggested that yield per plant can be increased by improving these characters.

4. Path co-efficient analysis revealed that number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, siliqua length, no. of seeds per siliquae, days to 50% flowering, days to 80% maturity and thousand seed weight had the positive direct effect on yield per plant. So yield improvement was associated with these characters.

Recommendation:

Based on the results of the study and above discussion it can be said that most of the advanced populations of *Brassica rapa* showed better performance than the check variety SAU Sarisha1 in case of important yield contributing characters. From this comparative study two advanced populations G16 and G17 were selected based on their better performances over the check variety and other advanced populations in respect of days to maturity, no. of primary branches per plant, no. of siliqua per plant, thousand seed weight and seed yield per plant for release as a new variety.

REFERENCES

Abideen, S.N.U., Nadeem, F. and Abideen, S.A. (2013). Genetic variability and correlation studies in *Brassica napus* L. genotypes. *Int. J. Innov. Appl. Stud*. **2**:574-581.

Afrin, K.S., Mahmud, F., Bhuiyan, M.S.R. and Rahim, M.A (2011). Assessment of genetic variation among advanced lines of *Brassica napus* L. *Agronomski Glasnik*. **73**(4-5): 201-226.

Afroz, R., Sharif, M.S.H. and Rahman, L. (2004). Genetic variability, correlation and path analysis in mustard and rapeseed (*Brassica spp*.). *Bangladesh J. Plant Breed. Genet*. **17**(1): 59-63.

Ahmad, B., Muhammad, S., Ali, J. and Ali, I. (2013). Genetic variability studies of some quantitative traits in advance mutant lines of winter rapeseed (*Brassica napus* L). *Life Sci. J*. **10**(12): 103-108.

Akter, M.M. (2010). Variability study in F_4 populations obtained through inter-varietal crosses of *Brassica rapa*. MS Thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Alam, M.F. (2010). Variability studies in F_4 progenies of *Brassica rapa*, obtained through inter-varietal crosses. M.S. Thesis. Dept. of Genetics and plant Breeding, SAU, Dhaka.

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.

Allard, R.W. (1960). Principles of plant breeding. Jhon Willey and Sons. Inc. New York. PP.36.

Ara, S. (2010). Variability, correlation and path coefficient in segregating population of *Brassica rapa* obtained through inter-varietal crosses. M.S. thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Baradaran, R., Majidi, E., Darvish, F., Azizi, M. (2007). Study of correlation relationships and path coefficient analysis between yield and yield components in rapeseed (*Brassica napus* L.). Birjand unit, I.A. University, Birjand, Iran. **12**(4): 811-819.

Basalma, D. (2008). The correlation and path analysis of yield and yield components of different winter rapeseed (*Brassica napus ssp. Oleifera* L.) cultivars. *Res. J. Agric. Biol. Sci*. **4**(2): 120-125.

BBS. (2015a). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning. Govt. People's Republic of Bangladesh, Dhaka. P.477.

BBS. (2015b). Statistical Year book of Bangladesh. Bangladesh Bureau of Statistics. Statistics Division, Ministry of Planning. Govt. People's Republic of Bangladesh, Dhaka. P.276.

BBS. (2015c). Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics. Ministry of Planning. Govt. People's Republic of Bangladesh. P.332.

Begum, M. (2015). Genetic variability, correlation and path analysis in BC_1 F_5 segregating generation of *Brassica napus*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Belet, Y.S. (2011). Genetic variability, correlation and path analysis studies in Ethiopian Mustard (*Brassica carinata* A. Brun). Genotypes. *Int. J. Plant Breed. Genet*. **5**(4): 328-338.

Belete, Y.S., Yohannes, M.T.W. and Wami, T.D. (2012). Analysis of genetic parameters for some agronomic traits of introduced Ethiopian Mustard (*Brassica carinata* A. Brun) Genotypes. *Int. J. Agric. Res.* **7**: 160-165.

Bilal, M., Khan, S.A., Raza, H., Ali, F., Masaud, S., Khan, N.A., Hussain, I. and Khan, J. (2015). Evaluation of some indigenous rapeseed genotypes for adaptability and yield traits in the agro-climatic conditions of Mansehra. *Int. J. Bio Sci.* **7**(5): 127-135.

Burton, G.W. (1952). Quantitative inheritance in grass pea. Proc. 6^{th} Grassl. Cong. **1**: 277-283.

Chauhan, J. and Singh, P. (1995). Association of some morpho-physiological determinates with seed yield in tori (*Brassica campestris* L. *var*.toria). Thesis Abst.

Chauhan, V.S. and Singh, P.K. (1985). Correlation and path analysis in lentil. *Lens*. **9**: 19-22.

Choudhary, B.R. and Joshi, P. (2001). Genetic diversity in advanced derivatives of *Brassica* interspecific hybrids. *Euphytica.* **121**(1): 1-7.

Clarke, G.M. (1973). Statistics and experimental design. Edward Arnold. London.

Comstock, K. and Robinson, P.R. (1952). Estimation of genetic advance. *Indian J. Hill*. **6**(2): 171-174.

Dabholkar, A.R. (1992). Elements of biometrical genetics. Concept Publishing, New Delhi, India.

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

Dhillon, S.S., Singh, K. and Brar, K.S. (1990). Diversity analysis of highly selected genotypes in Indian Mustard (*Brassica juncea* Czern and coss). *J. Oilseed Res.***13**(1):113-115.

Downey, R. K. and Robbelen, G.(1989). *Brassica species*: Oil crops of the world, their breeding and utilization. Mc Graw Hill Publishing Co., New York. pp. 339-374.

Ejaz-UI-Hasan, Mustafa, H.S.B., Bibi, T. and Mahmood, T. (2014). Genetic variability, correlation and path analysis in advanced lines of rapeseed (*Brassica napus*) for yield components. *Cercetari Agronomice in Moldova*. XLVII. 1(157).

Emrani, S.N., Arzani, A.H., Saeidi, G.O., Abtahi, M., Banifatemeh, M.O., Parsa, M.B. and Fotokian, M.H. (2012). Evaluation of induced genetic variability in agronomic traits by gamma irradiation in canola (*Brassica napus* L.). *Pakistan J. Bot*. **44**(4):1281-8.

Esmaeeli-Azadgoleh, M.A., Zamani, M. and Esmaeil, Y. (2009). Aagronomical important traits correlation in Rapeseed (*Brassica napus*L.) genotypes. *Res. J. Agric. Biol. Sci.* **5**(5): 798-802.

FAO. (2013). Food and Agriculture Organization of the United Nations, FAOSTAT. FAO Statistics Division.

FAO. (2014). Food and Agriculture Organization of the United Nations, Trade and Market Division. Food outlook. 33-102.

Gangapur, D.R., Prakash, B.G., Salimath, P.M., Ravikumar, R.L. and Rao, M. S. L. (2009). Correlation and path analysis in Indian mustard (*Brassica juncea* L. Czren and Coss). *Karmataka J. Agric. Sci*. **22**(5): 971-977.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedure for agricultural research (2nd ed.). Wiley, New York. pp.28-192.

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

Han, J. X. (1990). Genetic analysis of oil content in Rapeseed *Brassica napus*. Oil Crops china. **2**: 1-6.

Helal, M.M.U., Islam, M.N., Kadir, M. and Miah, M.N.H. (2014). Genetic Variability, Correlation and Path Analysis for Selection of Mustard (*Brassica* spp.). *Eco-friendly Agril. J.* **7**(12): 176-181.

Hosen, M. (2008). Variability, correlation and path analysis in F_3 materials of *Brassica rapa*. MS Thesis, Dept. Of Genetics and plant Breeding, SAU, Dhaka

Hussain, M.A. (2014). Genetic variability and character association of advanced lines in *Brassica rapa*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Iqbal, S., Farahtullah, Shah, S., Kanwal, M., Fayyaz, L. and Afzal, M. (2014). Genetic variability and heritability studies in indigenous *Brassica rapa* accession. *Pakistan J. Bot*. **46**(2): 609-612.

Jeromela, M. A., Marinkovic, R., Mijic, A., Jankulovska, Zdunic, M. (2007). Interrelation between oil yield and other quantitative traits in rapeseed (*Brassica napus* L.). *Sci. J. Agri.* **8**(2): 165-170.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimation of genetic and environmental variability in soybean. *Agron. J.* **47**: 314-318.

Kahrizi, D. and Alaahvarand, T. (2012). Estimation and interrelationship of genetic variability parameters of some morpho-phenological traits in spring rapeseed (*Brassica napus* L.). *Asian Biol. Sci*. **5**(7): 358-364.

Kardam, D.K. and Singh, V.V. (2005). Correlation and path analysis in Indian rapeseed *Brassica napus* L. grown under rainfed condition. Department of Plant Breeding and Genetics, SKN College of Agriculture, Jobner - 303329, Rajasthan, India. **14**(1): 56-60.

Katiyar, R.K., Chamola, R., Singh, H. B. and Tickoo, S. (2004). Heterosis and combining ability analysis for seed yield in Yellow Sarson. (*Brassica campestris)*. *Brassica*. **6** (1/2): 23-28.

Khaleque, M.A. (1985). A guide book on production of oil crops in Bangladesh. DAE and FAO/UNDP Project BGA/79/034, Strengthening the Agricultural Extension Service Khamarbari, Farmgate, Dhaka. P. 3.

Khayat, M., Lack, S. and Karami, H. (2012). Correlation and path analysis of traits affecting grain yield of Canola (*Brassica napus* L.) varieties. *J. Basic. Appl. Sci. Res*. **2**(6): 5555-5562.

Khulbe, R. K. and Pant, D. P. (1999). Correlation and path coefficient analysis of yield and its components in Indian mustard. *Crop Res. Hisar*. **17**(3): 371-375.

Mahmud, M.A.A. (2008). Inter Genotypic Variability study in advanced lines of *Brassica rapa*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Marjanovic-jeromela, A., Marinkovic, R., Mijic, A., Zdunic, Z., Ivanovska, S. and Jankulovska, M. (2008). Correlation and path analysis of quantitative traits in winter rapeseed (*Brassica napus* L.). *Agric. Conspec. Sci. Cus.* **73**(1): 13-18.

Masood, T., Gilani, M.M. and Khan, F.A. (1999). Path analysis of the major yield and quality characters in *Brassica campestris. J. Anim. Plant Sci*. **9**(4): 69-72.

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. Plant Sci*. **1**(23): 90-92.

MOA. (2014). Ministry of Agriculture. Government of People's Republic of Bangladesh. Crop Statistics Division.

Muhammad, A., Raziuddin, M. A., Raza, H., Rahman, A.U. and Imtiaz (2014). Combining ability and heritability studies for important traits in F_2 of *Brassica napus. J. Appl. Biol. Sci*. **14**(01): 14370-5858.

Nasim, A., Farhatullah, Iqbal, S., Shah, S. and Azam, S.M. (2013). Genetic variability and correlation studies for morpho-physiological traits in *Brassica napus* L. *Pakistan J. Bot*. **45**(4): 1229-1234.

Naznin, S. (2013). Variability, character association and divergence in rapeseed advanced line. MS Thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Ogrodowczyk, M. and Wawrzyniak, M. (2004). Adaption and path-coefficient analysis for assessment of relationship and interrelationship of yield and yield parameters of winter oilseed rapeseed. Rosliny Oleiste. **25**(2): 479-491.

Parveen, S. (2007). Variability study in F_2 progenies of Inter-varietal crosses of *Brassica rapa*. MS Thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Parvin, E. (2014). Genetic diversity and character association of *Brassica napus*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Parvin, F. (2015). Genetic variability and character association in BC_1 F_4 genetation of *Brassica napus*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Patel, P.J. and Vyas, S.R. (2011). Heritability and genetic advance for yield and quality traits in Indian mustard (*Brassica juncea* (L.) Czern and Coss. *Adv. Res. J. Crop Improv*. **2**(2): 212-214.

Rahman, L. (1981). Oil seed Resesrch & Development Activities at the BAU. Proc. Of the workshop on oil crop improvement, BARI., Oilseed Research Project. Ed. By Khuleque M.A., A.B.M. Abdul Khair, Md. Ali Akber & Md. Moszammal Haque, PP. 25.

Ram, H.H. and Hari, G.S. (1998). Crop Breeding and Genetics. Kalyani Publishers, New Delhi- 110002, pp: 381.

Rameeh, V. (2011). Correlation and path analysis in advanced lines of rapeseed (*Brassica napus*) for yield components. *J. Oilseed Brassica*. **2**(2): 56-60.

Rameeh,V. (2013). Multivariate analysis of some important quantitative traits in rapeseed (*Brassica napus* L.) advanced lines. *J. Oilseed Brassica*. **4**(2): 75-82.

Rameeh, V. (2014). Multivariate regression analysis of yield associated traits in rapeseed (*Brassica napus* L.) genotypes. *Adv. Agril*. 626434.

Rameeh, V. (2015). Heritability, genetic variability and correlation analysis of some important agronomic traits in rapeseed advanced lines. *Cercetari Agronomice in Moldova*. **48**(4): 71-80.

Rashid, M. H. (2007). Characterization and diversity analysis of the Oleiferous SAU, Dhaka.

Roy, S.K., Haque, S., Kale, V.A., Asabe, D.S. and Dash, S. (2011). Variability and character association studies in rapeseed-mustard (*Brassica sp*.) *J. Crop Weed*. **7**(2). 108-112.

Sadat, H. A., Nematzadeh, G. A., Jelodar, N. B. and Chapi, O. G. (2010). Genetic evaluation of yield and yield components at advanced generations in rapeseed (*Brassica napus* L.). *African J. Agric. Res*. ***5***(15): 1958-1964.

Saifullah, M. (2010). Variability study among the F_2 segregants of the inter-varietal crosses of *Brassica rapa*. MS Thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Shakera, A. (2014). Variability and inter relation of traits in segregating generations of rapeseed (*Brassica rapa* L.). MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Shalini, T.S., Sheriff, R.A., Kulkarni, R.S. and Venkataramana, P. (2000). Variability studies in Indian mustard [*Brassica juncea* (L.) Czern and Coss.]. *Res. Crops*. **1**(2): 230-234.

Sharafi, Y., Majidi, M. M., Jafarzadeh, M., and Mirlohi, A. (2015). Multivariate analysis of genetic variation in winter rapeseed (*Brassica napus* L.) cultivars. *J. Agric. Sci. Tech*. **17**(5): 1319-1331.

Shaukat, S., Khan, F. U. and Khalil, I. A. (2015). Genetic potential and heritability estimates of yield and yield associated traits in rapeseed *Brassica napus* L. *Int. J. Environ.* **4**(2): 330-340.

Siddika, K.S. (2015). Genetic variability, correlation and path analysis in F_2 segregating generation of in *Brassica napus*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Siddikee, M.A. (2006). Heterosis, intergenotypic variability, correlation and path analysis of quantitative characters of oleiferous *Brassica campestris* L. MS thesis. Dept. of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka.

Singh, P.K. and Chaudhary, B.D. (1985). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, India. pp.318.

Singh, R.P., Khera, M.K. and Gupta, V.P. (1991). Variability and correlation studies for oil and seed yield in gobhi sarson. *Crop Improvement*. **18**(2): 99-102.

Srivastava, M.K. and Singh, R.P (2002). Correlation and path analysis in Indian mustard. *Crop Res. Hisar*. **23**(3): 517-521.

Sultana, S. (2015). Genetic variability, correlation and path analysis in F_4 generation of *Brassica napus*. MS thesis, Dept. of Genetics and plant Breeding, SAU, Dhaka.

Tahira, Mahmood, T., Tahir, M.S., Saleem, U., Hussain, M. and Saqib, M. (2011). The estimation of heritability, associated and selection criteria for yield components in mustard (*Brassica juncea*). *Pakistan J. Agri. Sci*. **48**(4): 251-254.

Uddin, M.S. (2008). Variability study in F_2 progenies of *Brassica rapa*. MS Thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Uddin, M.S., Bhuiyan, M.S.R., Mahmud, F. and Kabir, K. (2013). Study on correlation and path coefficient in F_2 progenies of rapeseed. *Acad. J. Plant Sci*. **6**(1): 13-18.

Xu, S.Q. and Yao, X.T. (2009). Study on the correlation between yield characters and yield of superior rapeseed (*Brassica napus* L.) in north Zhejiang Province. *Adv. Res. J. Crop Improv*. **22**(2): 65-67.

Yarnell, S.H., Rai, B. and Singh, B. (1956). Component analysis of harvest index in *Brasica* oilseeds. *Indian. J. Agric. Res*. **20**(3): 129-134.

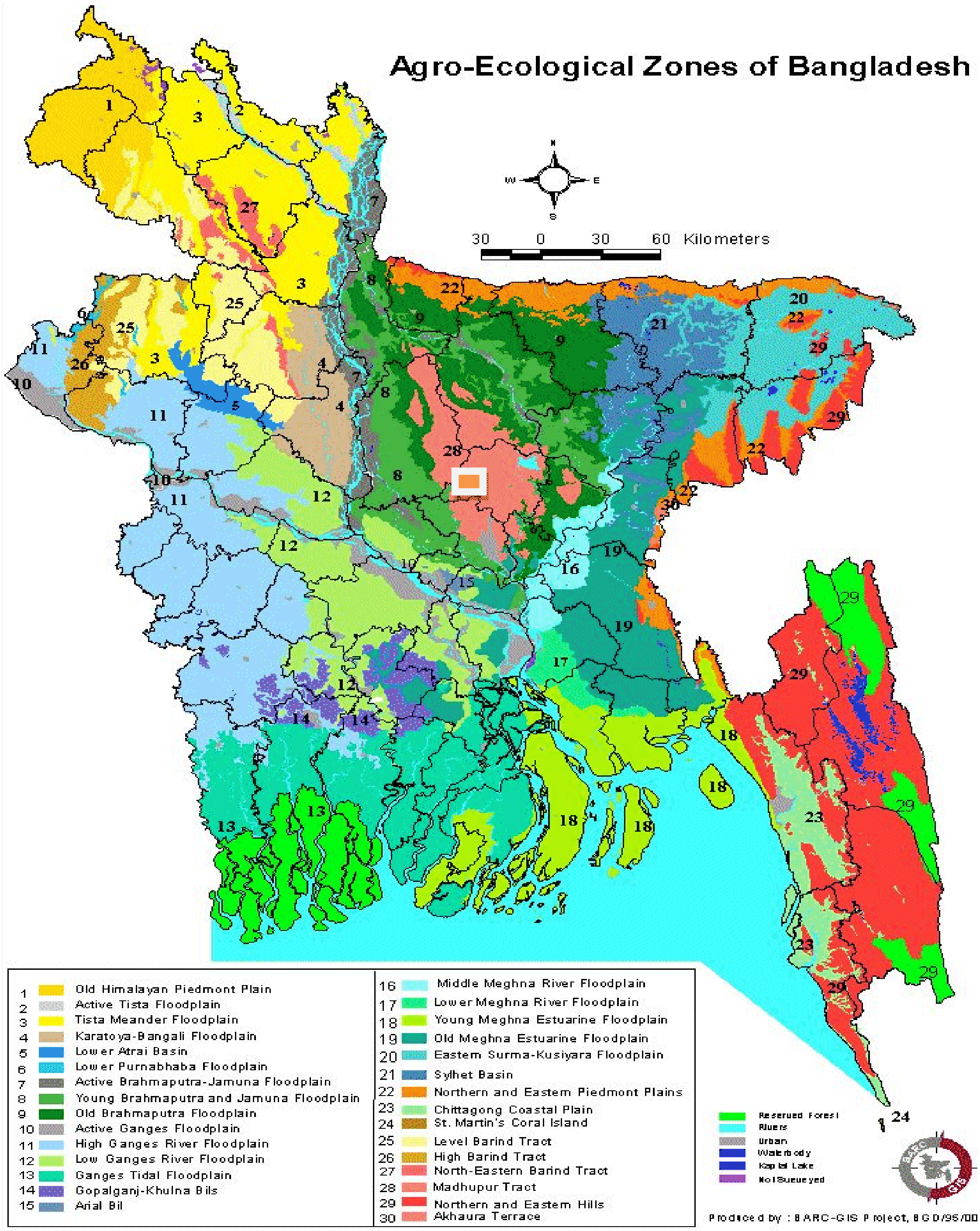
Zahan, M.I. (2006). Morphological characterization and genetic diversity in oleiferous *Brassica species*. MS Thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Zare, M. and Sharafzadeh, S. (2012). Genetic variability of some rapeseed (*Brassicanapus* L.) cultivars in Southern Iran. *African J. Agric. Res*. **7**(2): 224-229.

Zhou, Y.M.,Tan,Y.L., Liu, M.,Wei, Z.L., Yao, L. and Shi, S.W. (1998). Studies on irradiation induced mutation in rapeseed (*B. napus* L.). *Chinese J. Oil Crops Sci*. **20**(4): 1-5.

APPENDICES

Appendix I. Map showing the experimental site under the study



Legend showing the research site

Appendix II: Morphological, physical and chemical characteristics of initial soil (0-15 cm) depth of the experimental site

Soil separates	%	Methods employed
Sand	36.90	Hydrometer method (Day, 1915)
Silt	26.40	Do
Clay	36.66	Do
Texture class	Clay loam	Do

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Central library, Sher-e-Bangla Agricultural University, Dhaka.

Appendix III. Monthly average temperature, relative humidity and total rainfall and sunshine of the experimental site during the period the period from November, 2015 to February, 2016

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2015	34.7	18.0	77	227	5.8
December, 2015	32.4	16.3	69	0	7.9
January, 2016	29.1	13.0	79	0	3.9
February, 2016	28.1	11.1	72	1	5.7

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargaon, Dhaka–1212