VARIABILITY AND INTERRELATION OF TRAITS IN SEGREGATING GENERATIONS OF RAPESEED (*Brassica rapa* L.)

AMATULLAH SHAKERA

DEPARTMENT OF GENETICS AND PLANT BREEDING
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

DECEMBER, 2014

VARIABILITY AND INTERRELATION OF TRAITS IN SEGREGATING GENERATIONS OF RAPESEED (*Brassica rapa* L.)

BY
AMATULLAH SHAKERA

REGISTRATION NO. 08-03133

A Thesis
submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE

IN

GENETICS AND PLANT BREEDING

SEMESTER: JULY-DECEMBER, 2014

Approved by:

....	....
Prof. Dr. Md. Shahidur Rashid Bhuiyan	**Prof. Dr. Naheed Zeba**
Supervisor	Co-supervisor

....

Prof. Dr. Md. Sarowar Hossain

Chairman

Examination Committee

Dr. Md. Shahidur Rashid Bhuiyan
Professor
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh
Mobile: +8801552467945
e-mail: ipbscfc2009@gmail.com

CERTIFICATE

This is to certify that thesis entitled, "Variability and interrelation of traits in segregating generations of rapeseed (Brassica rapa L.)" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of ***MASTER OF SCIENCEin GENETICS AND PLANT BREEDING,*** *embodies the result of a piece of bona fide research work carried out by Amatullah Shakera, Registration No. 08-03133 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: December, 2014
Place: Dhaka, Bangladesh

....

Prof. Dr. Md. Shahidur Rashid Bhuiyan

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All the praises are due to the almighty Allah, who blessed the researcher to complete this work successfully. With sincere gratitude and appreciation to her reverend supervisor Professor Dr. Md. Shahidur Rashid Bhuiyan , Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research and preparation of this thesis.

The earnest indebtedness to her Co-supervisor Prof. Dr. Naheed Zeba, Department of Genetics and Plant Breeding, SAU for her continuous support, constructive criticism, and valuable suggestions.

The author expresses her sincere respect to the Chairman of the Department, Prof. Dr. Md. Sarowar Hossain, and also grateful to Prof. Dr. Firoz Mahmud and all other teachers of her department for their excellent guidance.

The author feels much pleasure to express special thanks to Dr. Akkas Ali , Senior Scientific officer, SAURES for his support throughout the research. The author also expresses thanks to Dr. Md. Motiar Rohman, Senior Scientific officer, BARI for his assistance for understanding the analysis using MSTAT-C software program and all the staffs of her Department, the staffs of the SAU library and the farm workers for their nice cooperation.

The author have received endless encouragement from her beloved friend Laila Jannatul Ferdous Bonna, Mahbuba Jamil, Md. Golam Robbani, Rozina Akter, Shakil Mahmud and junior Md. Abdur Rauf throughout her masters life. She also thankful to her younger sister Amatullah Sabera and brother Abdullah-as-sadique for their support.

The author, indeed, proud and delighted for her father and mother for their unparallel affections and for numerous sacrifices they have made for her research. This work is dedicated to her beloved parents.

December, 2014 *The Author*

SAU, Dhaka

SOME COMMONLY USED ABBREVIATIONS

Abbreviations	Full word
%	Percent
°C	Degree Celsius
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BSMRAU	Bangabundhu Sheikh Mujibur Rahaman Agricultural University
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of Coefficient of Variation
cv.	Cultivar (s)
DAS	Days After Sowing
df	Degrees of Freedom
DM	Dry Matter
EC	Emulsifiable Concentrate
et al.	And others
etc.	Etcetera
$F_{3:4}$	The third and fourth generation of a cross between two dissimilar homozygous parents
FAO	Food and Agricultural Organization
g	Gram (s)
G	Genotype
GN.	Genotype Number
HI	Harvest Index
hr.	Hour (s)
IARI	Indian Agricultural Research Institute
ICARDA	International Centre for Agricultural Research in Dry Areas
j.	Journal
kg	kilogram (s)
m	Metre
M.P.	Muriate of Potash
m^2	Meter Square
MOA	Ministry of Agriculture
NARS	National Agricultural Research System
No.	Number
NS	Non Significant
ppm	Parts Per Million
R	Residual Effect
RCBD	Randomized Complete Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SE	Standard Error
T.S.P.	Triple Super Phosphate
t/ha	Ton per hectare
Univ.	University
var.	Variety

LIST OF CONTENTS

LIST OF CONTENTS (CONTINUED)

LIST OF CONTENTS (CONTINUED)

LIST OF CONTENTS (CONTINUED)

LIST OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF PLATES (CONTINUED)

LIST OF APPENDICES

VARIABILITY AND INTERRELATION OF TRAITS IN SEGREGATING GENERATIONS OF RAPESEED (*Brassica rapa* L.)

ABSTRACT

BY

AMATULLAH SHAKERA

A research was conducted by using twenty F_3 and F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa* L and grown in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2013 to February 2014 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. 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. 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. Twenty one most promising plants with short duration and higher yield were selected from different five crosses of the F_3 and F_4 populations of *Brassica rapa* L.

CHAPTER I

INTRODUCTION

Rapeseed is a prime oilseed crop in Bangladesh. It contributes a lion share to the total edible oil production in the country. *Brassica rapa* L, commonly known as field mustard or turnip mustard belonging to the family Brassicaceae and third most important oil crop in the world.

Oleiferous *Brassica* species can be classified into three groups viz; the cole, the rapeseed and the mustard. The mustard groups include species like *Brassica juncea* Czern and Coss, *Brassica nigra* Koch and *Brassica carinata* Braun; while the rapeseed groups includes *Brassica rapa* L. and *Brassica napus* L. (Yarnell,1956). The genomic constitutions of the three diploid elemental species of *Brassica* are AA for *Brassica campestris*, BB for *Brassica nigra* and CC for *Brassica oleracea* having diploid chromosome number of 20, 16 and 18 respectively. On the other hand the species *Brassica juncea* (AABB), *Brassica carinata* (BBCC) and *Brassica napus* (AACC) are the amphidiploids. *Brassica*, accounting for over 16% of the world's edible oil supply (Anonymous, 2005). In 2012-2013, the edible oil production from major oilseed crops in the world was 497.9 million tons where rapeseed contributed 64.3 million tons. Among the oilseed crops, mustard and rapeseed is in the second position after soybean (FAO, 2014). Total area of mustard and rapeseed in the world is 34.33 million hectares (FAO, 2013).

The utilization of oil seed in Bangladesh is 1.8 million tons where 1.6 million tons is imported (FAO, 2013). In Bangladesh, *Brassica rapa* L is the main oil yielding species of *Brassica* (FAOSTAT, 2013). It is the top ranking oil seed crop in Bangladesh that covers about 60% of the total acreage land (BBS, 2010). Though the local cultivars of *Brassica juncea* and *Brassica napus* are high yielding, they are not short durable. That's why *Brassica rapa* L is grown widely in the country (Islam, 2013). It occupies the first position in oil crops with cultivated area 252238.13 ha which produced 0.246 million tons seed and average yield was 0.997 t/ha during 2010-2011 (BBS, 2011a).

Although a huge amount of oilseed is utilized in Bangladesh, the production is not sufficient to meet the requirement (Razzaque and Karim, 2007). As the population of Bangladesh is increasing and economic prosperity has been growing fast, it is now a challenge for accelerating the production of oils. It is essential to reduce the import dependence of it to insulate the domestic market from the volatility of the world market (Hossain, 2013). About 0.833 million tons of edible oil produced in Bangladesh which is very low against the requirement (BBS, 2011b). To fulfill this lacking, the country imports 0.899 million tons of mustard oil that costs 371.84 million Tk. (BBS, 2011c).

The total amount of land for mustard and rape was decreased due to increasing Boro rice cultivation (BBS, 2010). The area for rapeseed and mustard is reduced from 0.785 million acres to 0.578 million acres in 2001 to 2009. The area reduces to 26.32% for the crop (Bhuiyan, 2012). The area and production has been increased in 2013-2014 than 2012-2013. 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).

In spite of being a major oil producing crop, *Brassica sp*. has lower yield per hectare than the other developing countries. The yield potentialities of the commonly used varieties are in stagnant position. As *Brassica rapA* L is well suited in cropping pattern with rice variety i.e. Aman-Mustard-Boro, farmers rely mainly on short durable mustard varieties (Karim *et al*., 2014. The leading early variety of *Brassica rapa* in Bangladesh is Tori-7. However, it has lower yield of 1.1-1.3 t ha^{-1} (Karim *et al*., 2014). There is no improved early variety with higher yield to replace it.

For yield improvement, it is essential to have knowledge on genetic variability of different characters. A survey of genetic variability with the help of suitable parameters such as genotypic co-efficient of variation, heritability, and genetic advance are necessary to start an efficient breeding programme (Mishra *et al*., 1988). Moreover, knowledge of heritability is essential for selection based improvement, as it indicates the extent of transmissibility of a character into future generations (Sabesan*et al*., 2009).

The study of character is also essential for ascertaining their contribution towards yield. Measurement of correlation coefficient helps to identify the relative contribution of component characters toward yield (Panse, 1992). Direct and indirect effects of yield contributing characters on yield are also important during selection. Path co-efficient analysis is used to detect characters having direct and indirect effects on yield (Hasina and Alam, 1990).

Correlation in grouping with path analysis would give a better insight into cause and effect relationship between different pairs of characters. Knowledge of correlation between yield and its contributing characters are basic and foremost endeavor to find out guidelines for plant selection. Partitioning of total correlation into direct and indirect effect by path coefficient analysis helps in making selection more effective.

It is essential to develop short duration and high yielding varieties of mustard to meet the challenge of edible oils of the country by increasing the production. Segregating materials obtained through different intervarietal crosses of the species *B. rapa* will give an opportunity to select the desired plant types to meet the existing demand. Thus the present research work was undertaken to estimate the range of variability, to select early maturing desired plant types, to study the relations between the different traits and the contribution of each trait towards yield in the $F_{3:4}$ segregating population. Based on these findings, plants with desired characteristics will be selected from the segregating population to carry out further selection in the next generations. Therefore, this study will be carried out with objectives mentioned below.

1. To study the variability in F_3 and F_4 segregating population,
2. To study the interrelationships of yield contributing characters among themselves and with seed yield; and their direct and indirect effects and
3. To select early mature and high yielding plants.

CHAPTER II

REVIEW OF LITERATURE

Extensive researches on *Brassica* breeding have been performed in many countries for its improvement in respect of yield and yield contributing characters. A large number of literatures are available on variability, correlation and path analysis of yield and yield contributing characters of *Brassica* grown under a particular environment. An attempt has been made here to summarize the findings of this study relevant to the present investigation.

2.1. Genetic variability, heritability and genetic advance

Genetic variability is a prerequisite for initiating a successful breeding program aiming to develop high-yielding varieties. Large numbers of literatures concerning the variability in the *Brassica* spp. are available. These literatures are outlined here.

Helal *et al*. (2014) conducted an experiment 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.

A field experiment was conducted by Mili (2014) using 66 F_5 genotypes of *Brassica napus* L. to study the genetic diversity, variability. The genotypes were found significantly variable for most of the characters. Comparatively phenotypic variances were higher than the genotypic variances for all the characters studied. Also PCV were higher than the GCV for all the characters studied. Number of secondary branch, thousand seed weight, number of primary branch, number of siliqua per plant and seed yield per plant showed high broad base heritability.

Khan *et al.* (2013) evaluated thirty F_7 segregating lines and two parents of *Brassica rapa* to study variability, heritability and genetic advance. The result revealed that except thousand seed weight, significant variation was presented among all the genotypes for all the characters. Highest genotypic, phenotypic and environmental variances were observed in plant height while lowest one was in length of siliquae followed by thousand grain weight. Thousand seed weight, number of secondary branches per plant, seeds per siliquae, and siliquae length showed high heritability along with low genetic advance in percent of mean but moderate heritability with high genetic advance found in number of siliquae per plant. Considering important performances, the genotypes G-15, G-19, G-1, G-3, G-4, G-10, G-18, G21, and G-24 were found suitable for future breeding program.

Abideen *et al.* (2013) conducted an experiment to study the genetic variability and correlation among different traits in *Brassica napus*. Results revealed that highly significant differences among the genotypes for most of the traits. Non significant differences were observed among the genotypes for primary branches and pods.

Rameeh (2013) evaluated twenty four rapeseed genotypes including two cultivars and 22 advanced lines, were based on randomized complete block design with three replications. Significant genotypes effects were exhibited for phenological traits, plant height, yield components and seed yield, indicating significant genetic differences among the genotypes. High broad sense heritability were estimated for phenological traits, pods on main axis and seed yield, signifying selection gain for improving these traits. Duration of flowering and pods on main axis had high value of genetic coefficient of variation.

An experiment was conducted by Kumar *et al*. (2013) to study genetic diversity for agro-morphological and oil quality traits in indian mustard (*Brassica juncea* L). He reported that identification of diverse parents in any crop species like Indian mustard is the pre-requisite and in any crop improvement programme aimed to obtain the desirable recombinants in segregating generations. Greater contribution of additive genetic component was reflected by main shoot length, siliqua on main raceme, siliqua length, palmitic acid, oleic acid and linolenic acid with pronounced range of variation, high heritability coupled with high genetic advance under selection, which may be exploited in early segregating generations for yield and quality enhancement of Indian mustard. Amongst eight, five mono-genotype and clusters III, IV, I with 18, 12 and 11 genotypes, respectively, maximum divergence exhibiting mono-genotype clusters (VII and VIII) may be utilized through inter varietal hybridization to exploit high degree of genetic diversity between them. Noteworthy is that cluster VII exhibiting high genetic diversity for siliqua length, 1000 seed weight, harvest index and seed yield per plant; cluster II and VII for secondary branches per plant, siliqua on main raceme, 1000 seed weight and biological yield per plant heritability coupled with high heritability and genetic gain under selection, may prove their worth in genetic enhancement of mustard for yield and oil quality

Belete *et al.* (2012) undertaken an investigation to estimate various genetic parameters for some agronomic traits of introduced Ethiopian mustard (*Brassica carinata* A. Brun) genotypes. The experiment was laid out in randomized complete block design with three replications at Holetta Research Center, Ethiopia. Analysis of variance showed significance difference among the genotypes for traits studied except plant height and seed yield. Phenotypic coefficient of variation and genotypic coefficient of variation ranged from 1.2-10.2% and 1.9-6.8%, respectively. The highest heritability values was shown by oil content (99.8%) followed by days to flowering (96.5%) and days to maturity (89.1%). High heritability along with high genetic advance (as percent of mean) was recorded for days to flowering and oil content. Days to flowering, days to maturity and oil content are important traits to be considered for further variety development program.

Zebarjadi *et al.* (2011) conducted an experiment to study some traits and to estimate genetic parameters in sixteen rapeseed genotypes in two conditions (irrigation and non-irrigation). Statistical analysis showed significant differences among the genotypes based on the data for 13 different characters, including chlorophyll content (SPAD), sugar solution (SS), stem size (SS), plant height, oil percent, oil yield etc. In stress condition heritability was maximum for oil percentage, whereas low genetic advance was observed for thousand kernel weight.

Alam (2010) was conducted a research by using 26 F_4 populations of some inter-varietal crosses of *Brassica rapa*to study the magnitude of variations in different characters heritability, genetic advance. There were significant variations in number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, days to 50% flowering, length of siliqua, number of seeds per siliqua, 1000-seed weight and yield per plant. Plant height, length of siliqua, number of siliquae per plant, days to 50% flowering showed low difference between genotypic and phenotypic coefficient of variation. Plant height, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant showed high heritability coupled with high genetic advance and very high genetic advance in percentage of mean. However length of siliqua showed low heritability.

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. From the values of mean, range and CV (%) of seed yield and yield contributing characters, it was confirmed that there were considerable variation present among all the genotypes used in the experiment. 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 siliqua, seeds per siliqua, 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 siliqua, seeds per siliqua and 1000-seed weight showed high heritability with low genetic advance and high genetic advance in percentage of mean. Low to medium heritability of siliqua length was observed by Kachroo and Kumar (1991), Sharma (1984) and Yadava *et al*. (1996).

Aytac and Kinaci (2009) conducted an experiment with 10 winter rapeseed genotypes for variation, genetic and phenotypic correlations and broad sense heritability for seed yield, yield and quality characters for 2 years. They observed maximum broad sense heritability get genetic advance seed yield followed.

Sheikh *et al.* (2009) studied the induction of genetic variability in Ethiopian mustard (*Brassica carinata*) for quality traits through interspecific hybridization. The result revealed that interspecific hybridization was used to enhance the spectrum of genetic variability in mustard for oil and meal quality traits from quality lines of *Brassica juncea*.

Aytac *et al.* (2008) reported highest genotypic and phenotypic variances for seed yield per plant followed by seed yield and high heritability of seed yield per plant, seed yield, pods per main stem coupled with high genetic advance revealed that additive gene effects are important in determining these characters and could be improved through mass selection.

Saleh (2009) conducted a field experiment by using twenty F_2 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 direct and indirect effect of different characters on seed yield per plant. From the values of mean, range and CV (%) of seed yield and yield contributing characters it was confirmed that there were considerable variation present among all the genotypes used in the experiment. 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 siliqua, seeds per siliqua, thousand 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 siliqua, seeds per siliqua and thousand seed weight showed high heritability with low genetic advance and genetic advance in percentage of mean. Yield per plant had significant and highest positive correlation with length of siliqua, seeds per siliqua and thousand seed weight. The path co-efficient analysis revealed that siliqua per plant had highest positive direct effect followed by number of secondary branches per plant, days to 50% flowering, length of siliqua and plant height.

Hosen (2008) conducted a study by using 5 parental genotype of *Brassica rapa* L and their ten F_3 progenies including reciprocals. There are large numbers of variations present among all the genotypes used in the experiment. The plant height, days to 50% flowering, and number of siliquae per plant showed high heritability with high genetic advance and genetic advance in percentage of mean.

An experiment was carried out by Mahmud (2008) with 58 genotypes of *Brassica rapa* L to study inter genotypic variability. Significant variation 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, seed per siliqua and siliqua length.

An experiment was conducted by Jahan (2008) to study the inter-genotypic variability and genetic diversity in ten F_4 lines obtained through inter-varietal crosses along with eight released varieties of *Brassica rapa* L. High PCV was observed in plant height, number of secondary branches per plant, siliquae per plant, number of seed per siliqua, yield per plant than GCV. High heritability with low genetic advance in percent of mean was found in days to maturity that indicated non-additive gene effects were responsible of this character and selection of such trait might not be rewarding. In case of plant height and days to 50% flowering high heritability with moderate genetic advance was observed which indicated that the trait was controlled by additive genes and selection for genetic improvement in the trait would be effective.

Parveen (2007) carried out research work by using the F_2 population of some inter-varietal crosses of the species *Brassica rapa* L for estimating the magnitude of variations in characters, different heritability, genetic advance, character associations, direct and indirect effect of different characters on seed yield. There were significant variations among the different genotypes used in the experiment. Considering genetic parameters, number of primary branches/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua, days to 50% flowering, 1000 seed weight and yield/plant showed least difference between genotypic and phenotypic variance. Plant height, length of siliqua, number of seeds/siliqua and days to 50% flowering showed low genotypic and phenotypic coefficient of variation. Number of primary branches/plant and secondary branches/plant showed high heritability coupled with high genetic advance and very high genetic advance in percentage of mean. However, the yield/plant, days to maturity and length of siliqua showed low heritability. Correlation co-efficient analysis revealed that yield/plant had non significant positive association with plant height, number of secondary branches/plant, days to 50% flowering, length of siliqua, number of siliquae/plant and number of seeds/siliqua. Path coefficient analysis revealed that number of seeds/siliqua showed highest direct effect on yield/plant followed by plant height, number of secondary branches/plant and number of siliquae/plant. Based on the variability study, some F_2 plants showing high heritability for yield contributing characters were selected from some of the cross combinations of the intervarietal crosses of *Brassica rapa* L.

Genetic variability was studied by Ahlawat*et al.* (2006) for 12 characters in 19 genotypes of Indian mustard *(Brassica juncea* (L) czern & coss.). Estimate high phenotypic coefficient of variation than genotypic coefficient of variation were used for the characters numbers of primary and secondary branches, number of siliquae per plant and yield per plant, which indicated the presence of considerable amount of variation. Heritability and genetic advance were high for 1000-seed weight, number of siliquae per plant and plant height. Number of siliquae per plant and plant height had moderately high heritability with high genetic advance indicating that additive gene effects were important for these characters and selection pressure could be applied on them for yield improvement. Number of primary branches per plant and oil content had low heritability indicating that these traits were under the influence of environmental factors.

According to Tyagi *et al.* (2001) variation was the highest in parents and their hybrids for plant height. The seed yield per plant exhibited the highest co-efficient of variation (41.1%). Significant genetic variability was observed for this character by many workers like Andarhennadi *et al.* (1991), Malik *et al.* (1995), Kumar and Singh (1994), Yadava *et al.* (1993), Lebowitz (1989), Chaturvedi *et al.* (1988), Gupta *et al.* (1987) and Chauhan and Singh (1995) among different genotypes of *B.napus*, *B. rapa* and *B. juncea*.

Nanda *et al.* (1995) observed that days to first flowering varied both by genotypes and date of sowing, while working with 65 strains of *B. napus*, *B.juncea*, *B. carinata* and *B. rapa*. Many other researchers like Kumar and Singh (1994), Kumar *et al.* (1996), Kachroo and Kumar (1991), Andrahernnadi (1991), Lebowitz (1989), Biswas (1989), Singh *et al.* (1987), Chaudhury and Singh (1985), Yadava (1996) and Thakral (1982) found significant variations for this character while working with different genotypes of *Brassica napus*.

Dominance gene action was important in the expression of days to flowering was found by Jain *et al.* (1988). Significant genetic variability in days to 50% flowering in *B. napus* and *B. rapa* was observed by Singh *et al.* (1991).

Chandola *et al.* (1977) worked on 30 varieties of *B. campestris* and reported that the varietal differences were highly significant for plant height, due to varieties and growing conditions. They also found highly significant varietal differences for yield and six other yield components.

Katiyar *et al.* (1974) observed high genetic co-efficient of variation for days to first flowering, plant height (cm) and seed yield per plant (g), whereas low values were observed for other characters like days to maturity and number of primary branches per plant, while observing on genetic variability and genetic advance of seed yield and its components in Indian mustard.

The highest genotypic co-efficient of variation was calculated for secondary branches. High genotypic and phenotypic co-efficient of variation was recorded for days to 50% flowering among 10 genotypes for each of *Brassica campestris, Brassica carinata* and *Brassica napus* and 24 genotypes of *Brassica juncea* by Lekh *et al.* (1998).

Generally high number of seeds per siliqua is desirable. On the variability of this trait a good number of literatures are available. Significant variability in number of seeds/siliqua in oleiferous *Brassica* materials of diverse genetic base was observed by Kudla (1993) and Kumar and Singh (1994). Similar significant variability in the genotypes of *Brassica napus*, *B. campestris* and *B. juncea* were studied by them. Bhardwaj and Singh (1969) observed GCV value of 35.85% in case of *Brassica campestris* genotypes.

High co-efficient of variation for thousand seed weight, pod length and number of seeds per pod for both genotypic and phenotypic level was found by Masood *et al.* (1999) while working with seven genotypes of *Brassica campestris* and standard cultivar of *Brassica napus* to study genetic variability.

Higher seed yield is the result of higher number of siliqua. Large variation is involved for this trait. High genetic variation in number of siliqua was observed by Yin (1989) while working with 8 cultivars of *Brassica napus*. Kumar *et al.* (1996) also observed and reported similar results of high variation for this trait.

Singh *et al.* (1987) observed variable results of GCV (25.41%) and PCV (29.15%) in *Brassica campestr* is for siliquae number higher and the seed yield, GCV was reported to be also as 18.85% by Yadava (1996) and Bhardwaj and Singh (1969) reported 97.3% of GCV. Number of siliquae per plant is one of the most important traits of *Brassica spp*. This trait has high variation and a considerable part of which appeared to be influenced by environmental. High genetic variation was found by Kudla (1993). Similar results was also found by Andraherinadi *et al.* (1991), Biswas (1989), Jain *et al.* (1988), Chowdhury *et al.* (1987) and Alam *et al.* (1986).

Siliqua length is another important character for the development of fruits in oil seed crops like mustard and rape seed. Peduncle, beak as well as siliqua length varies due to difference in genotypes. High genetic variability was found by Olsson (1990) for this character. Lebowitz (1989) found similar results while working with *B. rapa* for siliqua length. Thurling (1983) reported that selection for increased siliqua length is an effective strategy for yield improvement through raising seed weight per siliqua.

Thousand seed weight is a very important character of rape seed and mustard, where highest consideration is on the seed yield. This character has been found to vary widely from genotypes to genotypes and from environment to environment. A good number of literatures are available on the variability of this trait.

According to Kumar and Singh (1994) in *B. juncea*, Kudla (1993) in rapeseed, Andarhennadi *et al.* (1991) in brown mustard, Biswas (1989) in *Brassica campestris*, Lebowitz (1989) in *B. rapa*, Yin (1989) in *B. rapa* and Chowdhury *et al.* (1987) in *B. rapa* found different degrees of significant variations among the genotypes for thousand seed weight.

In every breeding program, yield is the important character among various traits for oil crops. It is a complex trait which is influenced by various factors of production. A good number of literatures are available on the variability of this trait. High variability in different genotypes of *B. rapa* was reported by Sharma *et al.* (1994). Thakral (1982) also reported significant genetic variability in genotypes of *B. napus*. Similar high variability in different genotypes of *B. napus* was found by Khera and Singh (1988).

High degrees of variation for seed yield per plant in *B. rapa* was observed by Yin (1989) and Kudla (1993) in *B. napus* and Kumar *et al.* (1996) in *B. juncea*. Bhardwaj and Singh (1969) found GCV value of 96.99% among different strains of *B. rapa*.

Yadava (1973) found 48.76% GCV value among 29 strains of *B. juncea*. While Singh *et al.* (1987) found GCV and PCV values of 44.04% and 46.9% in *Brassicajuncea*.

Moderate heritability coupled with high genetic advance for seed yield per plant, number of secondary branches per plant, siliqua per plant, 1000 seed weight (g) and number of primary branches per plant was observed by Sheikh *et al.* (1999) while working with 24 genotypes of toria.

Lekh *et al.* (1998) carried out an experiment with 24 genotypes of *B. juncea* and 10 genotypes each of *B. campestris, B. carinata* and *B. napus* and observed highest genetic advance and high genotypic and phenotypic co-efficient of variation for days to 50% flowering and high heritability for other yield contributing characters.

Malik *et al.* (2000) observed very high broad sense heritability (h^2_b>90%) for number of primary branches per plant, days to 50% flowering and oil content while working with different strains of *B. napus*. They also observed low heritability (h^2_1, 50%) for plant height, number of siliqua/plant, number of seeds siliqua and seed yield. But high heritability for all these characters were found by Lodhi *et al.* (1979) while working with 55 genotypes of *B.napus*, *B. rapa* and *B. juncea*.

High heritability and genetic advance for number of siliqua per plant in *B. rapa* and *B. juncea* were observed by Varshney *et al.* (1986), but they found low heritability and genetic advance for plant height in all the three species. High narrow sense heritability and genetic advance for days to flowering and plant height were reported by Diwakar and Singh (1993) while working with segregating populations of yellow seeded Indian mustard (*B. juncea* L. Czern and Coss).

Low heritability and genetic advance for number of seeds per siliqua and seed yield per plant was reported by Singh (1986) while working with 22 genotypes of *B. napus*, *B. campestris* and *B. juncea*.

Low heritability for yield per plant was observed by Malik *et al.* (1995), Kumar *et al.* (1988) and Yadava *et al.* (1993). Chen *et al.* (1983) and Wan and Hu (1983) found high heritability and genetic advance for days to flowering, number of primary branches per plant and plant height.

Kwon *et al.* (1989) and Rao (1977) reported low heritability for siliqua length, but Kachroo and Kumar (1991), Yadava *et al.* (1978) reported low to medium for this trait.

Singh *et al.* (1987) studied 179 genotypes of Indian mustard and found high heritability for seed yield per plant and oil content and the lowest heritability for number of primary branches per plant. In a study of variability and correlations in some varieties of brown sarson, reported low heritability for siliqua length, number of seeds per siliqua and thousand seed weight was observed by Chaudhury *et al.* (1990).

Plant height and number of seeds per siliqua were highly heritable, whereas siliqua length, number of primary branches per plant were less heritable was observed by Labana *et al.* (1980) while working with 104 mutants of Indian mustard *B. juncea* L. Czern and Coss. Chandola (1977) observed low genetic advance for plant height while working with 30 varieties of *B. rapa*.

Paul *et al.* (1976) found in his study that a good genetic advance was expected from a selection index comprising seed yield, number of seeds per siliqua, number of primary branches per plant and number of siliquae per plant.

Katiyar *et al.* (1974) reported heritability in the broad sense was associated with high genetic advance for number of siliquae on the main shoot and seed yield per plant while working with *B. campestris L. var. sarson*. In a study of genetic variability, heritability and genetic advance of Indian mustard Katiyar *et al.* (1974) reported high heritability for days to flowering, plant height, number of primary branches and seed yield per plant, moderate for days to maturity and low for the number of secondary branches. He also reported low genetic advance for number of primary branches and high values for days to flowering, plant height and seed yield per plant.

According to Yadava (1973) high heritability in the broad sense and genetic advance for days in maturity, plant height and number of node on the main shoot among the nine traits studied in 29 varieties. The most important feature in winter rape plant selection for seed yield and number of branches was reported by Teresa (1987).

According to Knott (1972) and Seitzer and Evans (1978), selection for yield in early segregating generations was effective in developing high yielding cultivars of self pollinated crops. Selection for bold seed size from F_2 to F_5 generations was highly effective was observed by Gupta and Labana (1985) in Indian mustard.

2.2 Correlation among different characters

Analysis of correlation among different traits is important in breeding program. A good number of literatures are available on correlation among characters of *Brassica sp.* Some of these literatures are reviewed here:

Helal *et al.* (2014) conducted an experiment to study Genetic variability, correlation of yield and yield contributing characters and coefficient of variance in rapeseed or mustard. Correlation between seed yield and yield contributing characters showed significant and positively correlated with number of siliqua/plant, 1000 seed weight, straw yield, plant height, biological yield and harvest index. Correlation coefficient analysis of yield attributes had the highest and positive association with seed yield.

A research was conducted by Mili (2014) using 66 F_5 genotypes of *Brassica napus* L. to study correlation and path coefficient analysis. The significant positive correlation with seed yield per plant was found in number of siliqua per plant,siliqua length, number of seed per siliqua and thousand seed weight.

A research was conducted by Lodhi *e.t a.l* (2014) using ninety diverse genotypes of Indian mustard (*Brassica juncea* Czern & Coss) were evaluated for fifteen quantitative traits. Seed yield/ plant was found to be positively and significantly correlated with number of primary branches/plant, number of secondary branches/ plant, primary branch angle, main shoot length, siliqua length, and number of seeds/ siliqua and non-significant with days to maturity; seed yield/plant had negative association with oil content.

Rameeh (2012) aimed at finding out the planting date effect on yield associated traits and also determining the variations of correlations among the traits in different planting dates of rapeseed genotypes. Significant planting dates and genotypes effect for phonological traits, yield components, seed yield and oil percentage revealed significant differences of planting dates genotypes for these traits. The variation of correlation between duration of flowering and pods per plant was less than the correlation of duration of flowering to other traits in different planting dates.

Rameeh (2011) reported that thirty-six rapeseed genotypes including four cultivars and 32 advanced lines were evaluated in randomized complete block design with three replications. Siliquae per plant had significant positive correlation (0.80**) with seed yield. So any change for this trait will have considerable effect on seed yield.

A research was conducted by Alam (2010) using 26 F_4 populations of some inter-varietal crosses of *Brassica rapa*to study the correlation between pairs of different characters. Correlation study revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, number of siliquae per plant, number of seeds per siliqua and siliqua length.

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 correlation between pairs of different characters. Yield per plant had significant and highest positive correlation with length of siliqua, number of siliqua per plant, seeds per siliqua and 1000-seed weight.

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

An experiment was conducted by Basalma (2008) in Ankara conditions using 25 winter oil seed rape cultivars. Correlation analysis showed a high positive and statistically significant correlation between branches per plant, the number of pods on the main stem and plant height during two years. Plant height indicated negative correlation with seed yield, thousand seed weight and oil ratio.

Rashid (2007) carried out 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 was conducted 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 siliquae per plant, days to 50% flowering and length of siliqua.

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

Tusar *et al.* (2006) studied phenotypic correlation and observed that seed yield per plant was positively and significantly associated with plant height, total dry matter production and husk weight. The number of siliquae per plant, 1000-seed weight, crop growth rate during 60-75 days after sowing and number of branches per plant were also positively associated with seed yield.

Zahan (2006) studied correlation and reported that yield per plant had highly significant positive association with plant height, length of siliqua, siliquae per plant and seed per siliqua but insignificant negative association with days to 50% flowering and days to maturity.

Mahak *et al.* (2004) conducted an experiment and studied correlation for eight quantitative characters. Seed yield per plant showed positive correlation with number of primary branches, length of main raceme, 1000-seed weight and oil content. Selection should be applied on these traits to improve seed yield in Indian mustard. Afroz *et al.* (2004) also studied correlation and found seed yield per plant had significant and positive correlation with number of primary branches per plant and number of siliquae per plant.

A field experiment was conducted to determine the genetic potential of *Brassica* accessions. Result revealed that eight accessions were sown in randomized complete block design in four replications. Plant height, number of primary branches, number of secondary branches, number of pods per plant and seed index were found positively correlated with seed yield. So, the emphasis should be given during experimentation for improvement of plant height, number of primary branches, number of secondary branches, number of pods per plant and seed index for improvement in yield of seed in *Brassica* (Khan and Khan, 2003).

Pankaj *et al.* (2002) studied four parental cultivars and the F_4 progenies of resultant crosses for correlation between yield and yield component traits. The genetic correlation was higher than the phenotypic correlation for the majority of the characters. The number of siliquae per plant, which had the strongest positive and significant correlation with yield per plant at both levels, was positively associated with the number of seeds per siliqua and test weight at both levels. The number of seeds per siliqua was positively associated with siliqua length and yield per plant at both levels.

Srivastava and Singh (2002) studied correlation in Indian mustard [*Brassica juncea* L. Czern and Coss] for 10 characters was conducted with 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 siliquae and seeds per siliquae were highly associated with seed yield.

Malek *et al.* (2000) studied correlation analysis and reported that days to maturity showed insignificant correlation with seed yield at both genotypic and phenotypic levels. He also reported that number of branches per plant and number of siliqua per plant showed significant negative correlation with number of seeds per siliqua and 1000 seed weight.

Khulbe and Pant (1999) carried out a study of correlation in 8 Indian mustard (*Brassica juncea*) parents and their 28 F_1 hybrids and revealed 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 siliquae 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.

Thakral *et al.* (1999) studied correlation co-efficient on seed yield and yield contributing characters in eight Indian mustard (*Brassica juncea*) parents and their 28 F_1 hybrids grown at Hisar. The data indicated that higher seed yield could be obtained by selecting for increased plant height.

Zajac *et al.* (1998) studied phenotypic correlation between yield and its component and reported that strong positive correlation occurred between seeds per siliqua and actual yield. Positive but a weaker correlation was observed between seed yield and siliquae per plant. The number of seeds per siliqua had the greatest influence and siliquae number per plant had the smallest effect on yield.

Das *et al.* (1998) carried out an experiment with 8 genotypes of Indian mustard (*B. juncea*) and reported that the length of siliqua, seeds per siliqua had high positive genotypic correlation with seed yield per plant. The number of siliqua par plant, seed weight per plant and thousand seed weight were positively correlated with seed yield per plant were observed by Dileep *et al.* (1997).

Tyagi *et al.* (1996) carried out and experiment with six yield components in three cultivars of mustard and observed that plant height, siliqua per plant, siliqua length, seed weight, and seeds per siliqua had positive and significant effects on seed yield per plant.

Kumar *et al.* (1996) studied 12 genotypes of *B. juncea* for correlation analysis and found flowering time and plant height negatively correlated with number of primary branches per plant.

Uddin *et al.* (1995) while studied correlation analysis in 13 Indian mustard (*B. juncea*) and reported that seed yield per plant had high positive arid significant correlations with plant height and thousand seed weight, but high negative and significant correlations with seeds per siliqua at both genotypic and phenotypic levels.

Arthamwar *et al.* (1995) studied correlation and regression in *B. juncea*. Results revealed that weight of siliqua per plant showed the highest correlation with seed yield followed by number of siliqua per plant, number of seeds per siliqua and thousand seed weight.

Nanda *et al.* (1995) studied correlation analysis with 65 strains of *B. juncea*, *B. rapa* and *B.napus* and observed that positive association between yield and siliqua filling period. Similar results also found by Olsson (1990) in *B. napus*. He also observed positive correlation between siliqua density and yield.

Nasim *et al.* (1994) studied correlation analysis in *B. rapa* and found 1000 seed weight was significantly and positively correlated with seed yield per plant and number of siliqua per plant but significantly and negatively correlated with siliqua length and number of seeds per siliqua.

Ghosh and Mukhopadhyay (1994) studied Tori-7 (*B. campestris var. toria*) for evaluation of seed yield and 5 seed yield contributing characters and found that plant height, siliqua per plant, seeds per siliqua and thousand seed weight was significant and positively correlated with seed yield.

Ahmed (1993) worked with eight cv. of *B. campestris* and *B. juncea* for study of nature and degree of interrelationship among yield components and observed that siliqua length, number of siliqua per plant, number of seeds per siliqua and seed weight per siliqua was positively and linearly associated with seed yield per plant. He also observed that seed oil content was positively correlated with seed weight, but negatively correlated with number of seeds per siliqua.

Zaman *et al.* (1992) studied several yield contributing traits of Swedish advanced rape lines and reported that number of seeds per siliqua negatively correlated with siliqua per plant.

Reddy (1991) studied correlation analysis in Indian mustard (*B. juncea*) and reported that positive and significant correlation between seed yield and number of primary branches per plant, number of secondary branches per plant, siliqua per plant and seeds per siliqua.

Swain (1990) studied correlations of yield components in 15 genotypes of brown sarson (*B. campestris var. dichotoma*) and found that number of siliqua per plant was the most important characters to yield.

Chaudhury *et al.* (1990) observed seed yield was positively correlated with siliqua length when evaluated seven of *B. juncea*, two of *B. carinata* cultivars and one cultivar each of *B. campestris* and *B. tournefortii*.

Chay and Thurling (1989) studied the inheritance of siliqua length among several lines of *B. napus* and reported that the siliqua length when increased there was an increase in the number of seeds per siliqua and thousand seed weight. The siliqua length was positively correlated with both number of seeds per siliqua and thousand seed weight was observed by Singh *et al.* (1987) in *B. rapa*, Chowdhury *et al.* (1987), Lebowitz (1989) and Lodhi *et al.* (1979) in *B.juncea*.

Singh *et al.* (1987) observed number of primary branches per plant negatively correlated with siliqua length and 1000 seed weight, but positively correlated with number of siliqua per plant.

In *B. juncea* Chowdhury *et al.* (1987) and Yadava *et al.* (1978) observed thousand seed weight positively associated with days to 50% flowering and days to 80% maturity, but negative correlation was observed by Singh *et al.* (1987) and Shivahare *et al.* (1975).

Chowdhury *et al.* (1987) and Yadava *et al.* (1978) also reported that thousand seed weight negatively correlated with plant height, number of primary branches per plant and number of siliquae per plant.

Das *et al.* (1984) observed thousand seed weight had high significant genotypic and phenotypic correlation with seed yield.

Srivastava *et al.* (1983) observed that in *B. juncea*, 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.

Labana *et al.* (1980) observed plant height negatively correlated with siliqua length and seeds per siliqua. Chowdhury *et al.* (1987) studied 179 genotypes of Indian mustard and observed positive correlation of plant height with number of siliqua per plant, number of primary branches per plant and seeds per siliqua. Positive association of plant height with these three traits in eight strains of yellow sarson was also found by Banerzee *et al.* (1968).

Labana *et al.* (1980) also found that number of primary branches per plant was negatively correlated with plant height and siliqua length. Shivahare *et al.* (1975) observed days to flowering were positively correlated with primary branches per plant and plant height.

Increasing the number of branches is a means of increasing yield, since the number of primary and secondary branches have a significant positive correlation with seed yield (Katiyar and Singh, 1974).

Banerjee (1968) reported significant correlation between number of siliqua per plant and number of seeds per siliqua in yellow sarson. But negative genotypic correlation between number of siliqua per plant and number of seeds per siliqua in brown sarson and toria varieties was observed by Tak (1976) when studied with *B. rapa*.

Ramanujam and Rai (1963) observed significant positive correlations between yield and all the yield components in *B. rapa cv. yellow sarson*. Zuberi and Ahmed (1973) observed similar results in *B. rapa cv. toria*. Campbell and Kondra (1978) observed positive correlation between yield and the yield components in rape seed (*B. napus*). However, Campbell and Kondra (1978) observed negative correlation between yield and the yield components.

2.3 Path co-efficient analysis

When more characters are involved in correlation study, it becomes difficult to ascertain the traits which really contribute towards the yield. The path analysis under such situation helps to determine the direct and indirect contribution of these traits towards the yield.

Helal *et al.* (2014) conducted an experiment to study Genetic variability, correlation of yield and yield contributing characters and coefficient of variance in rapeseed or mustard. Path coefficient analysis of different yield contributing characters showed biological yield contributed maximum to seed yield with the highest correlation.

A research was conducted by Alam (2010) using 26 F_4 populations of some inter-varietal crosses of *Brassica rapa* to study the direct and indirect effect of different characters on seed yield. Path co-efficient analysis revealed that plant height, number of primary branches per plant, number of siliquae per plant, seeds per siliqua and siliqua length had the positive direct effect on yield per plant, days to 50% flowering, number of secondary branches per plant and 1000-seed weight had the negative effect on yield per plant.

Afrin (2009) conducted a field experiment with 22 *Brassica napus* L. advanced lines to study path coefficient. Path coefficient analysis showed that the plant height had maximum positive direct effect on seed yield followed by number of siliqua per plant and siliqua length and negative direct effect on number of secondary branches per plant and number of seeds per siliqua. Plant height, number of primary branches per plant and number of siliqua per plant were the most important contributors to seed yield per plant which could be taken in consideration for future hybridization program.

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.

An experiment was conducted by Parveen (2007) 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.

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.

Siddikee (2006) conducted and 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.

Srivastava and Singh (2002) 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 with Indian mustard (*B. juncea* L.). Results suggested that number of primary branches and 1000 seed weight were vital selection criteria for improvement in productivity of Indian mustard.

Shalini *et al.* (2000) studied path analysis of Indian mustard germplasm and observed that number of siliqua 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.

Khulbe and Pant (1999) studied path co-efficient analysis in eight Indian mustard (*B. juncea*) parents and their 28 F_1 hybrids. 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.

The number of seeds per siliqua exerted the highest effect on seed yield was observed by Masood *et al.* (1999) when they studied seven genotypes of *B. campestris* and standard cultivar of *B. napus*.

Sheikh *et al.* (1999) worked with 24 diverse genotypes of toria for assess the direct and indirect effect of seven quantitative and developmental traits on seed yield. Results revealed that thousand seed weight and siliqua per plant had highly positive direct effect on seed yield.

Yadava *et al.* (1996) when studied path co-efficient analysis of six yield components of 25 diverse varieties of Indian mustard and observed that number of siliqua per plant had the highest positive direct effect on seed yield.

Chauhan and Singh (1995) found high positive direct effect of days to 50% flowering, plant height, primary branches per plant, siliquae per plant and seeds per siliqua on seed yield while working with several strains of *B. juncea*.

Uddin *et al.* (1995) studied path analysis in 13 Indian mustard (*B. juncea*) and observed that seeds per siliqua and thousand seed weight had high positive direct effect on seed yield per plant. Chauhan and Singh (1995) observed that plant height, siliqua per plant and seeds per siliqua had high positive direct effect on seed yield.

Kachroo and Kumar (1991) studied several strains of *B. juncea* and found that thousand seed weight had positive direct effect, but days to 50% flowering and primary branches had negative indirect effect via seeds per siliqua on seed yield.

Kumar *et al.* (1988) found the indirect positive effect of days to 50% flowering on seed yield.

Han (1990) studied *B. napus* and observed negative direct effect of number of siliquae per plant, siliqua length and positive direct effect of seeds per siliqua and plant height on seed yield. Dhillor *et al.* (1990) observed the highest positive direct effect on seed yield per plant. Kudla (1993) reported that 1000 seed weight had positive direct effect on seed yield.

Chaudhary *et al.* (1990) observed that days to 50% flowering and plant height indirectly contributed to plant yield.

Dhillon *et al.* (1990) reported that the plant height had the highest positive direct effect on seed yield per plant in *B. juncea*, but Singh *et al.* (1978) also found negative direct effect of the trait on seed yield.

Chowdhury *et al.* (1987) worked with 42 strains of mustard and observed that siliqua length had highest positive direct effect and number of primary branches per plant had the highest negative direct effect on seed yield. On the other hand, Gupta *et al.* (1987) observed that primary branching and thousand seed weight had the direct effect on seed yield.

Varshney (1986) worked with several strains of *B. rapa* and observed that plant height, siliqua per plant and thousand seed weight had the negative direct effect on yield.

Kumar *et al.* (1984) worked with *B. juncea* and found negative indirect effect of days to flowering via plant height and siliqua length, but negative direct effect of these traits was observed by Singh *et al.* (1978). But many scientists like Singh *et al.* (1985) in *B. juncea*, Chen *et al.* (1983) in *B. napus* and Srivastava *et al.* (1983) in *B. juncea* observed that plant height, days to maturity, siliqua per plant, seeds per siliqua and thousand seed weight had positive direct and indirect effect on seed yield.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental site

The research work was conducted at the experimental farm of the Department of the Genetics and Plant Breeding, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. The time period of the experiment was November 2013 to February 2014. The soil of the experimental plot was clay loam with medium high with medium fertility level. The general climatic feature of the experimental site was subtropical climatic weather having wet summer and dry winter.

3.2 Soil and climate

The experimental site was situated in the subtropical zone. The soil of the experimental site belongs to Agroecological region of “Madhupur Tract” (AEZ No. 28). The soil was clay loam in texture 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 is 0.82% (Appendix II). The records of air temperature, humidity and rainfall during the period of experiment were noted from the weather station, Sher-e-Bangla Agricultural University, Dhaka 1207(Appendix III).

3.3 Plant materials

A total number of 23 (Twenty three) materials were used in this experiment where three were checks, twenty were $F_{3:4}$ segregating generations. All the Materials were collected from Department of Genetics and Pant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The materials used in that experiment is shown in Table -1.

3.4 Methods

The following precise methods have been followed to carry out the experiment:

3.4.1 Land preparation

The experimental plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good

Table 1. List of material used in experiment

Designation	F_3 and F_4 populations	Sources
G1	Tori-7 × BARI sarisha-6 F_3	SAU
G2	SAU sarisha-1 × BARI sarisha-15 s_1 F_3	SAU
G3	BARI sarisha-6 × SAU sarisha-1 s_1 F_4	SAU
G4	Tori-7 × SAU Sarisha-1 F_4	SAU
G5	Tori-7 × BARI sarisha-15 F_4	SAU
G6	SAU sarisha-2 × BARI sarisha-6 F_4	SAU
G7	SAU sarisha-1 × BARI sarisha-6 F_3	SAU
G8	SAU sarisha-2 × BARI sarisha-6 F_3	SAU
G9	BARI sarisha-6 × SAU sarisha-1 s_2 F_4	SAU
G10	SAU sarisha-3 × BARI sarisha-15 s_1 F_3	SAU
G11	SAU sarisha-2 × BARI sarisha-15 F_3	SAU
G12	BARI sarisha-15 × SAU sarisha-3 F_4	SAU
G13	BARI sarisha-15 × SAU sarisha-2 F_4	SAU
G14	BARI sarisha-15 × SAU sarisha-1 F_4	SAU
G15	BARI sarisha-6 × TORI-7 F_4	SAU
G16	BARI sarisha-6 × SAU sarisha-1 s_3 F_4	SAU
G17	BARI sarisha-6 × BARI sarisha-15 F_3	SAU
G18	TORI-7 × BARI sarisha-15 F_3	SAU
G19	SAU sarisha-1 × BARI sarisha-15 s_2 F_3	SAU
G20	SAU sarisha-3 × BARI sarisha-15 s_2 F_3	SAU
Checks		
Check 1	BARI sarisha-15	BARI
Check 2	Tori-7	BARI
Check 3	BARI sarisha-6	BARI

tilth. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

3.4.2 Application of manure and fertilizer

The crop was fertilized at the rate of 10 tons of Cow dung, 250 kg Urea, 175 kg Triple Super Phosphate (TSP), 85 kg Muriate of Potash (MP), 250 kg Gypsum, 3 kg Zinc Oxide and Boron 1 kg per hectare. The half amount of urea, total amount of Cow dung, TSP, MP, Gypsum, Zinc Oxide and Boron was applied during final land preparation. The rest amount of urea was applied as top dressing after 25 days of sowing.

3.4.3 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication size was 15m×3m, and the distance between replication to replication was 1m. The spacing between lines to line was 30cm. Seeds were sown in lines in the experimental plots on 05 November, 2013. 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. A pictorial view of experimental field at flowering stage is presented in Plate 1.

3.4.4 Intercultural operations

Intercultural operations, such as weeding, thinning, irrigation, pest management, etc. were done uniformly in all the plots. Irrigation was given with cane 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. At 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. Aphid infection was found in the crop during the siliqua development stage. To control aphids Malathion-57 EC @ 2ml/liter of water was applied. The insecticide was applied in the afternoon.

Plate 1: Photograph showing the experimental field at SAU during first flowering stage.

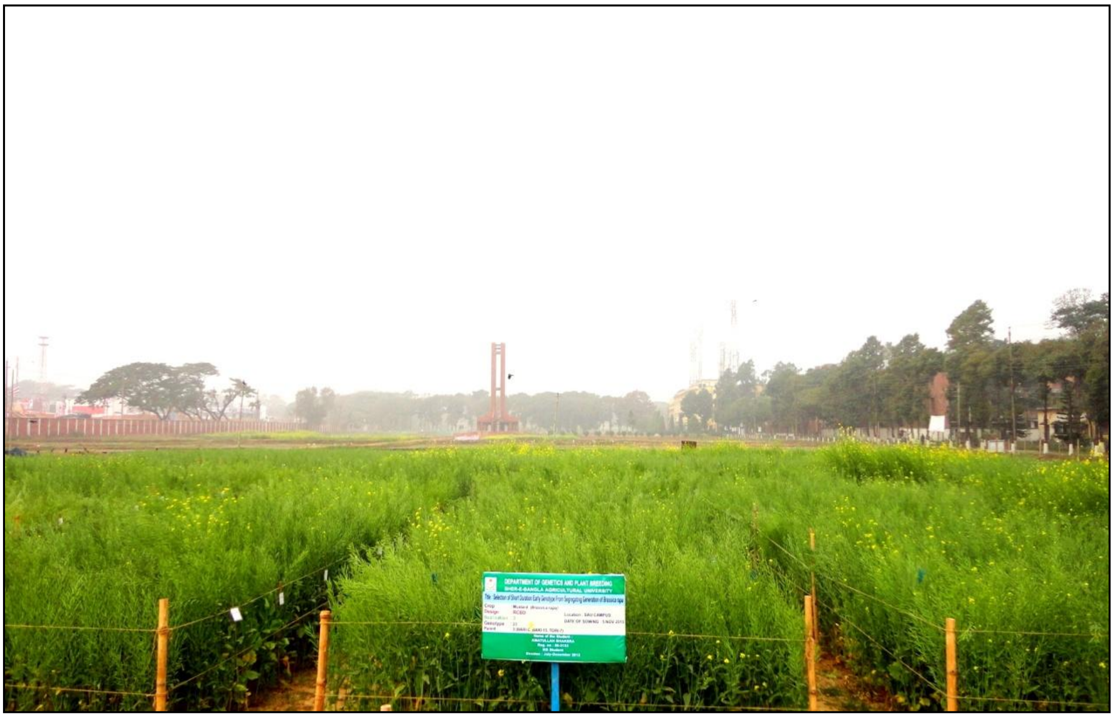


Plate 2. Photograph showing the experimental field at SAU during maturity stage.

3.4.5 Crop harvesting

Harvesting was done from 23th January to 14th February, 2014 depending upon the maturity. 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. Twenty one plants were selected at random F_3 and F_4 progenies in each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants. A pictorial view of experimental field at maturity stage is presented in Plate 2.

3.4.6 Data collection

For studying different genetic parameters and inter-relationships, ten characters were taken into consideration. The data were recorded on ten selected plants for each cross and ten selected plants for each parent on the following traits-

3.4.6.1 Days to 50% flowering

Days to 50% flowering were recorded from sowing date to the date of 50% flowering of every entry.

3.4.6.2 Days to maturity

The data were recorded from the date of sowing to siliquae maturity of 80% plants of each entry.

3.4.6.3 Plant height

It was measured in centimeter (cm) from the base of the plant to the tip of the longest inflorescence. Data were taken after harvesting.

3.4.6.4 Number of primary branches per plant

The total number of branches arisen from the main stem of a plant was counted as the number of primary branches per plant.

3.4.6.5 Number of secondary branches per plant

The total number of branches arisen from the primary branch of a plant was counted as the number of secondary branches per plant.

3.4.6.6 Number of siliquae per plant

Total number of siliquae of each plantwas counted and considered as the number of siliquae per plant.

3.4.6.7 Siliqua length

This measurement was taken in centimeter (cm) from the base to the tip of a siliqua without beak of the ten representative siliquae.

3.4.6.8 Number of seeds per siliqua

Well filled seeds were counted from ten representative siliquae, which was considered as the number of seeds per siliqua.

3.4.6.9 Thousand seed weight

Weight in grams of randomly counted thousand seeds of each entry was recorded.

3.4.6.10 Yield per plant

All the seeds produced by a representative plant was weighed in g and considered as the seed yield/plant.

3.4.7 Statistical analysis

All the collected data of the study were used to statistical analysis for each character, analysis of variance (ANOVA), mean, range were calculated by using MSTAT-C software program and then 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 Chaudhary (1985) and Allard (1960). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952). Genotypic and phenotypic correlation coefficient was obtained using the formula suggested by Clarke, 1973; Singh and Chaudhary, 1985. (1956); and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

3.4.7.1 Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula of Johnson *et al.* (1955).

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

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

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

3.4.7.2 Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the following formula (Burton, 1952).

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

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

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

3.4.7.3 Estimation of heritability

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

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

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

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

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

3.4.7.4 Estimation of genetic advance

The following formula was used to estimate the expected genetic advance for different characters under selection as suggested by Allard (1960).

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

Where, GA = Genetic advance

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

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

δ_p = Phenotypic standard deviation

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

3.4.7.5 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).

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

3.4.7.6 Estimation of simple correlation co-efficient

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

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

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

3.4.7.7 Path co-efficient 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 path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable.

In order to estimate direct & indirect effect of the correlated characters, say x1, x2 and x3 yield y, a set of simultaneous equations (three equations in this example) 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's denotes simple correlation co-efficient and P's denote path co-efficient (Unknown). P's in the above equations may be conveniently solved by arranging them in matrix from.

Total correlation, say between x1 and y is thus 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.

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985):

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

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 with a view to select short duration genotypes by comparing the performance of different F_3 and F_4 genotypes along with three check varieties of *Brassica rapa* L. The study was also 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. The data were recorded on different characters such as days to 50% flowering, days to maturity, plant height (cm), no. of primary branches per plant, no. of secondary branches per plant, no. of siliqua per plant, no. of seeds per siliqua, siliqua length (cm) thousand seed weight (g) and seed yield per plant (g). The data were statistically analyzed and thus obtained results are described below under the following heads:

- Variability
- Correlation coefficient of characters
- Path coefficient analysis
- Selection of early mature and high yielding plants

4.1 Variability

4.1.1 Variability in F_3 and F_4 populations

The analysis of variance (ANOVA) of the data on different yield components and yield of 20 genotypes of F_3 and F_4 populations are given in Table 2. The mean performance and range for all the characters are presented in Table 3. Phenotypic variance, genotypic variance, phenotypic coefficient of variation and genotypic coefficient of variation for different yield related characters 20 F_3 and F_4 genotypes are presented in Table 4.

4.1.1.1 Days to 50% flowering

Considerable variations were observed among 20 F_3 and F_4 populations for days to 50% flowering (Table 2). The days to 50% flowering were observed lowest (30.33 days) in G10 which is very close to G16 (30.67 days), G20 (30.67 days) (Table 3).

The F_3 and F_4 populations G10, G16, G20 require lower flowering times than the three checks varieties. The genotypes G7 and G8 showed days to 50% flowering (34.00 days), (34.00 days) respectively which is similar to BARI Sarisha-15 (34.00 days). The days to 50% flowering of genotypes G2 (32.67 days), G3 (32.33 days), G5(33 days), G6 (33.67 days), G9 (32.67 days), G12 (32 days), G14 (33.67 days), G15 (32.33 days), G17 (33.67 days), G18 (32.33 days), G19 (33 days) were lower the BARI Sarisha-15 (34.00 days) and BARI sarisha-6 (34.67days) but these genotypes showed higher days to 50% flowering than Tori-7 (31.67 days) (Table 3) . The highest day to 50% flowering (35 days) was observed in G4 (Table 3) which is higher than the three checks varieties (Table 3) (Figure 1). The variation of flowering between F_3 and F_4 populations and checks varieties has been shown (Plate 3)**.**

Phenotypic and genotypic variance for days to 50% flowering was observed 3.93 and 0.50 (table 4) respectively with high differences between them indicated high influence of environment on the expression of the genes controlling the trait. The phenotypic coefficient of variation (6.06%) was higher than the genotypic coefficient of variation (2.17%) (Table 4), which suggested that the apparent variation is not only due to genotypes but also environment has a significant role on the expression of this trait. High genotypic and phenotypic co-efficient of variation was recorded by Lekh *et al.* (1998).

4.1.1.2 Days to maturity

Significant difference was observed among 20 F_3 and F_4 populations (73.13**) for days to maturity (Table 2). The lowest days to maturity was recorded in Tori-7 (82 days). Among F_3 and F_4 population, the days to maturity were observed lowest (83 days) in G19 which is very near to G12 (83.33 days), G13 (83.33 days), and G14 (83.33 days) and G18 (83.33 days) (Table 3). These genotypes G12, G13, G14 and G19 showed lower days to maturity than the BARI Sarisha-15, BARI Sarisha-6 and higher than Tori-7. The days to maturity for genotypes G1, G2, G3, G4, G5, G6, G7, G8, G9, G10,G15, G16 and G17 were taken 86.00 days, 85.33 days, 88.67 days, 86 days, 85.67 days, 86.67 days, 88.00 days, 88.67 days, 89.33 days, 86.33 days, 87.67 days, 88.67 days and 85.67 days which is lower than BARI sarisha-6 but higher than BARI sarisha-15 (Table 3). The highest days to maturity was found in BARI Sarisha-6 (90 days). The genotypes G9 showed highest days to maturity

Table 2.Analysis of variance of ten important characters in respect of twenty F_3 and F_4 genotypes of *Brassica rapa* L.

Source of variation	df	Mean Sum of Squares of Characters									
		D50%F	DM	PH (cm)	NPB/P	NSB/P	NS/P	LS (cm)	NS/S	TSW(g)	Y/P (g)
Replication	2	4.62	0.32	98.63	6.45	10.51	2561.80	0.44	0.20	0.11	2.02
Genotype	19	4.93**	73.13**	73.62**	2.63**	12.30**	3405.05**	0.36	29.26**	0.85	15.05**
Error	38	3.42	1.95	46.95	1.61	4.34	1347.26	0.29	14.60	0.18	2.30

df= degree of freedom, D50%F= days to 50% flowering, DM= Days to maturity, PH= Plant height , NPB/P= Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P= Number of siliqua per plant, LS= Length of siliqua, NS/S= Number of seed per siliqua, TSW= Thousand seed weight, Y/P= yield per plant

Table 3.Mean performance of ten characters of three check varieties and twenty F_3 and F_4 genotypes of *Brassica rapa* L.

Genotype	D50%F	DM	PH (cm)	NPB/P	NSB/P	NS/P	LS (cm)	NS/S	TSW (g)	Y/P (g)
BARI Sarisha-15	34.00	84.00	108.70	6.83	3.77	120.40	4.94	21.62	3.41	8.45
Tori-7	31.67	82.00	102.50	6.37	7.93	184.40	5.16	18.59	2.13	6.82
BARI Sarisha-6	34.67	90.00	129.70	5.13	3.83	175.60	5.21	21.28	3.95	12.52
G1	31.67	86	118.3	8.90	10.23	242.00	5.47	16.29	2.83	12.12
G2	32.67	85.33	106	6.70	3.83	154.50	5.88	21.53	2.82	9.04
G3	32.33	88.67	104.2	5.33	1.53	156.00	5.30	18.67	3.05	7.61
G4	35	86	118.9	6.43	4.83	167.70	5.26	20.99	3.49	10.22
G5	33	85.67	107.2	8.06	5.07	125.80	6.06	21.93	4.81	12.52
G6	33.67	86.67	110.9	6.53	5.70	160.30	5.94	22.18	2.96	11.95
G7	34	88	114.6	5.00	3.77	128.20	5.73	21.81	3.38	8.95
G8	34	88.67	102.6	6.67	7.03	155.60	5.64	17.33	3.13	8.72
G9	32.67	89.33	112.2	7.00	7.80	147.10	5.43	19.61	3.73	10.22
G10	30.33	86.33	110.1	6.73	6.47	170.10	4.77	15.89	3.25	9.18
G11	31.67	84.33	109.9	6.33	3.40	131.30	5.92	22.34	3.25	10.22
G12	32	83.33	105.3	6.43	3.90	126.20	5.39	28.36	3.39	9.40
G13	34.33	83.33	113.1	7.13	4.77	161.90	5.71	20.75	3.41	9.12
G14	33.67	83.33	104	6.70	3.60	141.40	5.41	21.63	3.06	8.57
G15	32.33	87.67	112.6	7.10	5.83	195.20	4.81	16.83	3.24	9.57
G16	30.67	88.67	112.1	6.67	4.30	132.10	5.85	20.72	3.48	8.95
G17	33.67	85.67	117.4	6.03	6.43	122.60	5.58	15.66	3.29	11.60
G18	32.33	83.33	110.1	7.13	8.10	227.10	5.82	15.59	3.13	9.80
G19	33	83	107.5	6.37	3.53	111.50	5.57	21.16	3.47	9.39
G20	30.67	84.33	116.9	4.73	4.00	162.70	5.58	18.61	2.70	9.57
Mean	32.78	85.81	111.08	6.60	5.21	155.97	5.55	19.89	3.30	9.84
Max.	35	90	129.7	8.9	10.23	242	6.057	28.36	4.81	12.52
Min.	30.33	82	102.5	4.73	1.53	111.5	4.773	15.59	2.13	6.82

D50%F= days to 50% flowering, DM= Days to maturity, PH= Plant height , NPB/P= Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P= Number of siliqua per plant, LS= Length of siliqua, NS/S= Number of seed per siliqua, TSW= Thousand seed weight, Y/P= yield per plant. Max. = Maximum, Min= minimum.

Table 4. Estimation of some genetic parameters in respect of twenty F_3 and F_4 genotypes of *Brassica rapa* L.

Characters	o^2P	o^2g	PCV (%)	GCV (%)	h^2 (%)	GA	GA (% of mean)
D 50% F	3.93	0.50	6.06	2.17	12.78	0.52	1.60
DM	25.68	23.73	5.90	5.67	92.41	9.65	11.23
PH	55.84	8.89	6.75	2.69	15.92	2.45	2.21
NPB/P	1.95	0.34	21.14	8.83	17.43	0.50	7.59
NSB/P	6.99	2.65	50.78	31.28	37.95	2.07	39.70
NS/P	2033.19	685.93	28.91	16.79	33.74	31.34	20.09
LS	0.31	0.02	10.06	2.67	7.05	0.08	1.46
NS/S	19.49	4.89	22.19	11.11	25.09	2.28	11.47
TSW	0.40	0.22	19.16	14.28	55.54	0.72	21.92
Y/P	6.55	4.25	26.01	20.96	64.92	3.42	34.79

D50%F= days to 50% flowering, DM= Days to maturity, PH= Plant height , NPB/P= Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P= Number of siliqua per plant, LS= Length of siliqua, NS/S= Number of seed per siliqua, TSW= Thousand seed weight, Y/P= yield per plant, o^2P = phenotypic variance, o^2g = genotypic variance,PCV = phenotypic co-efficient of variation, GCV = phenotypic co-efficient of variation h^2 = heritability, GA = Genetic advance, GA (% of mean) = Genetic advance in percent mean.

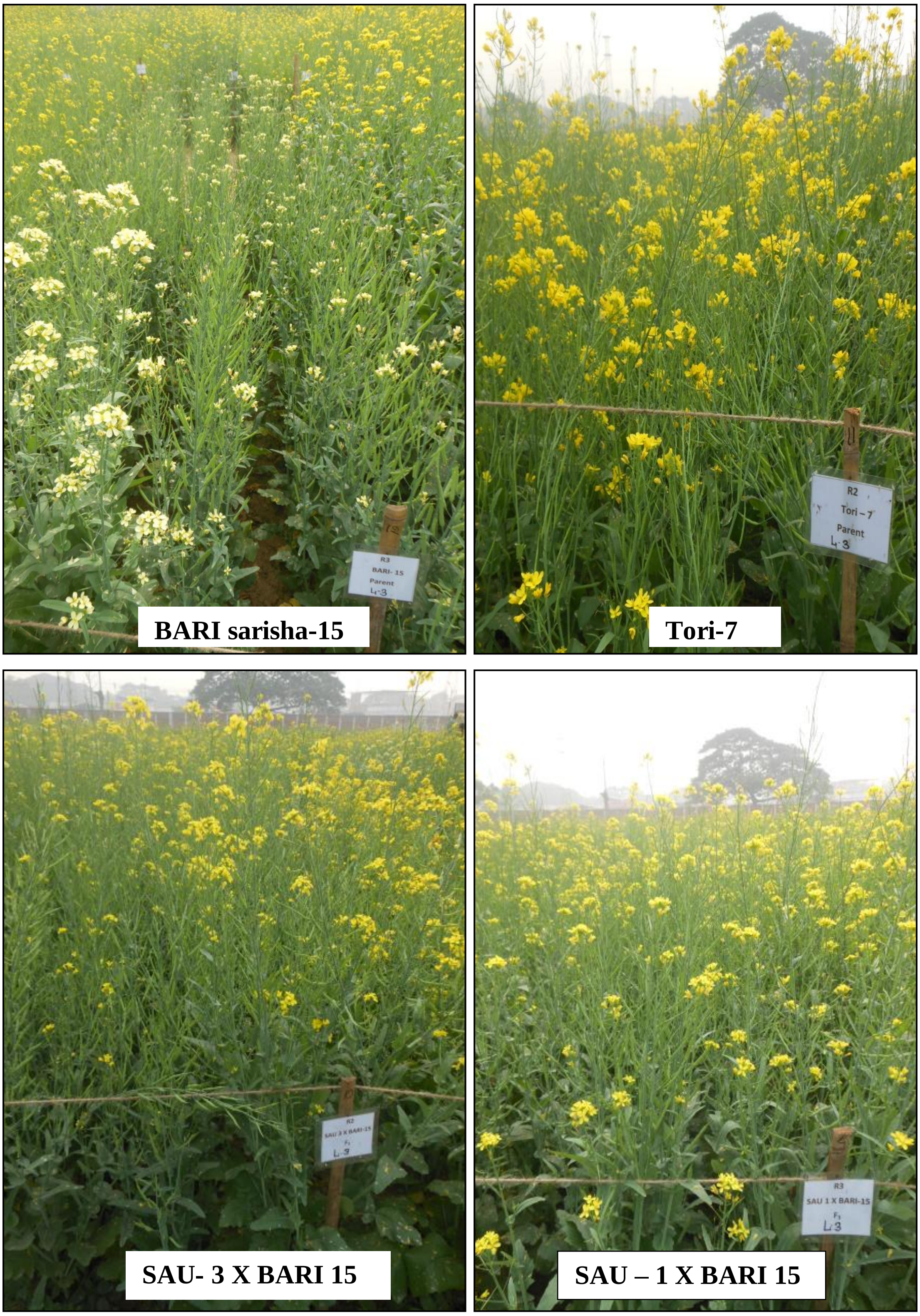


Plate 3.Photograph showing differences in flowering of check BARI sarisha-15, Tori-7 and (G19) SAU sarisha-1 × BARI sarisha-15, (G20) SAU sarisha-3 X BARI sarisha-15 .

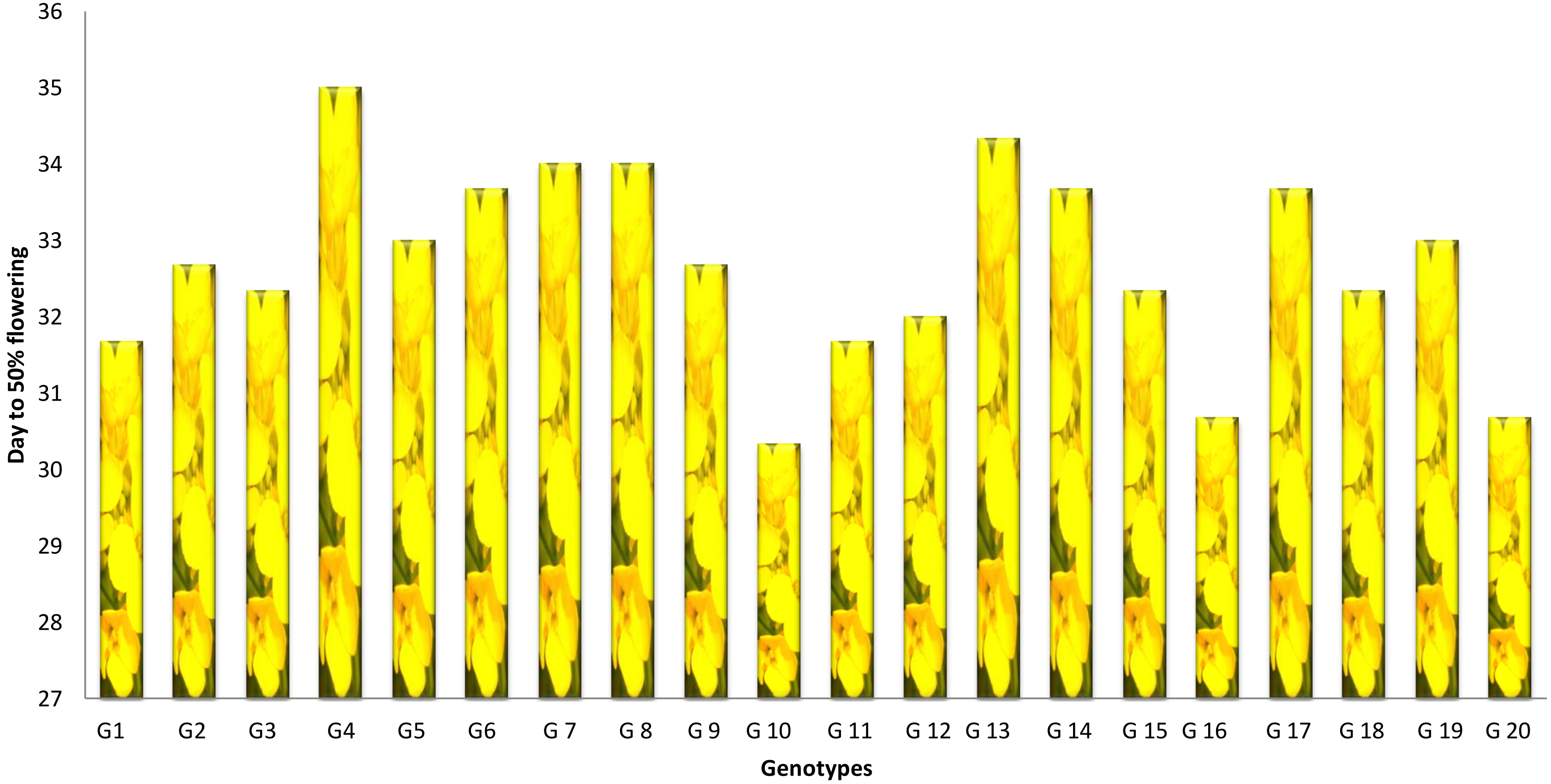


Figure 1. Mean performance of days to 50% flowering of twenty segregating genotypes

(89.33 days) among F_3 and F_4 populations (Table 3) (Figure2) which is close to BARI Sarisha-6. The variation between F_3 and F_4 populations and checks for days to maturity have been shown in Plate 4.

The phenotypic variance for days to maturity was observed 25.68 and genotypic variance was 23.73 (Table 4). The less differences between phenotypic variance and genotypic variance indicate that the environment has less influence on expression of the genes controlling this trait. The phenotypic coefficient and genotypic coefficient of variation for days to maturity were observed 5.90 and 5.67 (Table 4), respectively with least differences between them, suggested that the expression of the genes controlling this trait is least influenced by environment. Similar result for this trait was also observed by Kumar *et al*. (2013) and Katiyar*et al*. (1974).

4.1.1.3 Plant height

From ANOVA (Table 2), Significant differences were observed among 20 F_3 and F_4 genotypes (73.62**) for days to maturity. The highest plant height was recorded in BARI sarisha-6 (129.7 cm) In F_3 and F_4 genotypes, G4 was found with highest plant height (118.9 cm) which is very near to G1 (118.3 cm). The genotypes G4 and G1 were taller than BARI sarisha-15 (108.70) and Tori-7 (102.50) but shorter than BARI sarisha-6 (129.70). The plant height 106.00 cm, 104.20 cm, 107.20 cm, 105.30 cm, 104.00 cm 107.50 cm were recorded for G2, G3, G5, G12, G14, G19 respectively which is lower than BARI sarisha-15 and BARI sarisha-6 but higher than Tori-7 . The plant height for G6, G7, G9, G10, G11, G13, G15, G16, G17, G18, G20 were taken 110.90 cm , 114.60 cm, 112.20 cm, 110.10 cm, 109.90 cm, 113.10cm, 112.60 cm, 112.10 cm, 117.40 cm, 110.10 cm and 116.90 cm respectively which is higher than BARI sarisha-15 but lower than BARI sarisha-6 (Table 3). The lowest plant height was recorded in Tori-7 (102.50). Among F_3 and F_4 genotypes, G8 was found with lowest plant height (102.60 cm) which is lower than BARI sarisha-15 and BARI sarisha-6 but very close to Tori-7 (table 3).

Higher phenotypic variance (55.84) than the genotypic variance (8.89) was found for plant height that indicated high environmental influence on the expression of the concerned trait (Table 4). The higher PCV (6.75) than the GCV (2.69) from the Table 4 gave an information that there were much

Plate 4.Photograph showing differences in days to maturity of check BARI sarisha-15, BARI sarisha-6 and (G18) Tori-7 × BARI sarisha-15, (G19) SAU sarisha-1 × BARI sarisha-15 s_2

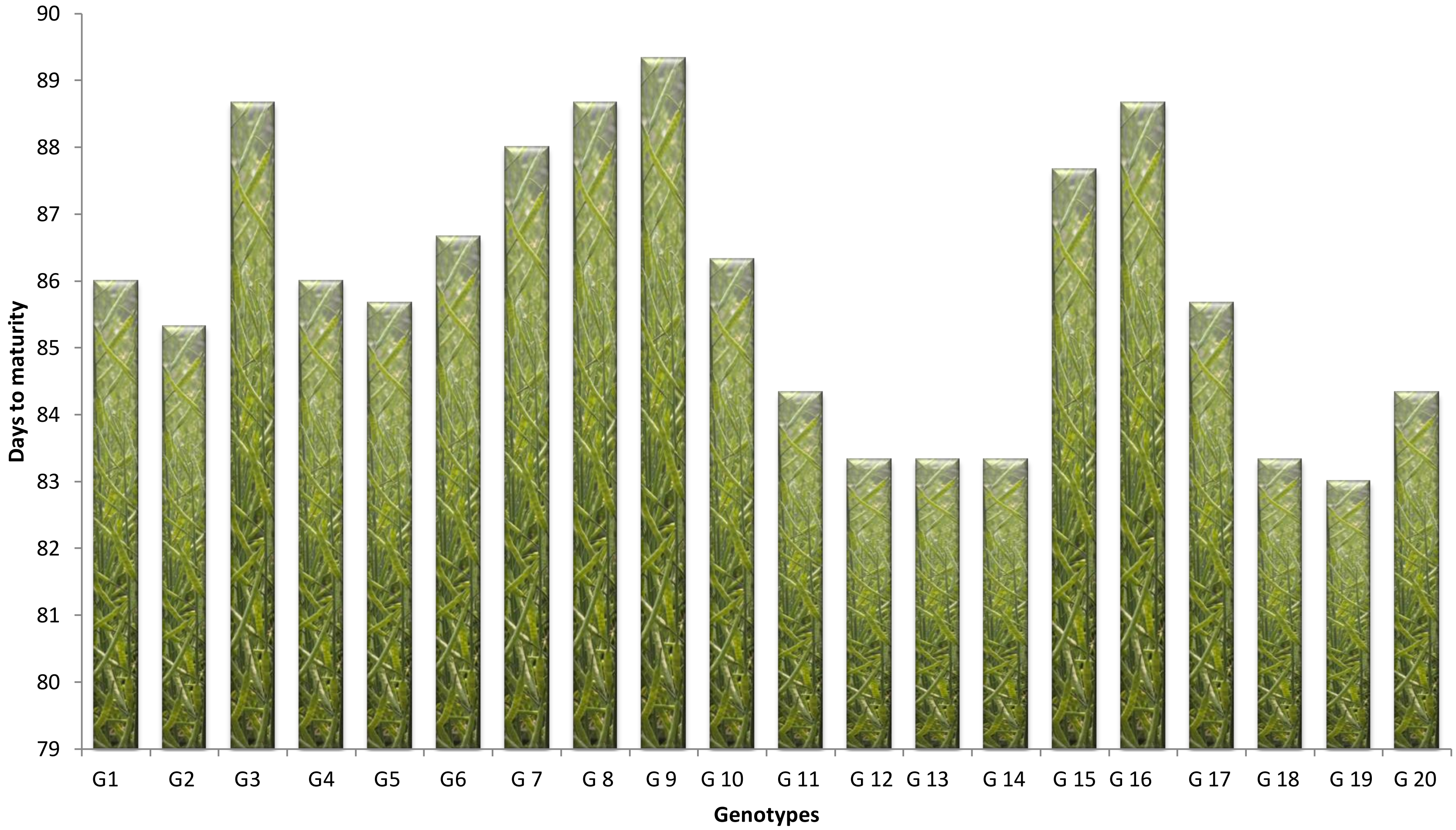


Figure 2. Mean performance of days to maturity of twenty segregating genotypes

variation among the genotypes in case of. plant height due to not only genotypes but also due to large influence of environment Jahan (2008) found low GCV (5.73) and high PCV (8.19). The highest variation in plant height among checks and their hybrid was observed by Tyagi *et al*. (2001).

4.1.1.4 Number of primary branches per plant

Significant variations were observed among 20 F_3 and F_4 genotypes (2.63**) at the level of 1% probability for primary branches per plant (Table 2). Among the 20 F_3 and F_4 populations, G1 (8.90) showed the maximum number of primary branches per plant which is higher than three checks varieties (Table 3). The number of primary branches per plant of genotypes G5 (8.06), G9 (7.00), G13 (7.13), G15 (7.10) and G18 (7.13) were higher than the three checks (Table 3). The genotypes G2, G4, G6, G8, G10, G12, G14 and G16 exhibited the number of primary branches per plant were 6.70, 6.43, 6.53, 6.67, 6.73, 6.43, 6.70 and 6.67 respectively (Table 3) which is higher than Tori-7 and BARI Sarisha-6 but lower than BARI Sarisha-15. The number of primary branches per plant of genotypes G3 (5.33), G11 (6.33) and G17 (6.03) were higher than BARI Sarisha-6 but lower than BARI Sarisha-15 and Tori-7. Among the 20 F_3 and F_4 populations, the minimum number of primary branches per plant was observed in G20 (4.73) which is very close to G7 (5.00), (Table 3). These genotypes G20 and G7 showed lower number of primary branches per plant than the three checks. Variations in number of primary branches per plant are shown in Plate 5.

Number of primary branches per plant showed phenotypic variance (1.95) is moderately higher than genotypic variance (0.34) indicating moderate environmental influence on these character and high difference between PCV (21.14%) and GCV (8.83%) value indicating that this trait is highly influenced by the environment (Table 4). Mili (2014) reported similar result for this trait.

4.1.1.5 Number of secondary branches per plant

From ANOVA significant difference were observed among 20 F_3 and F_4 genotypes (12.30**) for number of secondary branches (Table 2). Among the 20 F_3 and F_4 populations the highest number of secondary branches per plant was observed in G1 (10.23) (Table 3). The genotypes G1 (10.23) and G18 (8.10) showed higher number

Plate 5. Photograph showing differences in number of primary branches per plant in checks and F_3 and F_4 populations

of secondary branches per plant than three checks varieties (Table 3). The number of secondary branches per plant of genotypes G4 (4.83), G5 (5.07), G6 (5.70), G9 (7.80), G10 (6.47), G12 (3.90), G13(4.77), G15(5.83), G16(4.30), G17 (6.43) and G20(4.00) were higher than the BARI Sarisha-15 and BARI Sarisha-6 but lower than Tori-7 (Table 3). The genotypes G3, G11, G14, G19 showed number of secondary branches per plant were 1.53, 3.40, 3.60, and 3.53 respectively which is lower than all check varieties (Table 3). Among the 20 F_3 and F_4 populations the lowest number of secondary branches per plant was observed in G3 (1.53) (Table 3). The G2 (3.83) and G7 (3.77) exhibited equal number of secondary branches per plant to BARI Sarisha-6 and BARI Sarisha-15 respectively (Table 3). Variations in number of secondary branches per plant are shown in Plate 6.

Number of secondary branches per plant showed phenotypic variance (6.99) is higher than genotypic variance (2.65) indicating high environmental influence on these character and higher difference between PCV (50.78%) and GCV (31.28%) value indicating the apparent variation not only due to genotypes but also due to higher influence of environment (Table 4). Ahlawat *et al.* (2006) found higher phenotypic coefficient of variation than genotypic coefficient of variation for number of secondary branches while working on 19 genotypes of *Brassica juncea*.

4.1.1.6 Number of siliqua per plant

From the (Table 2) there were highly significant variations among 20 F_3 and F_4 genotypes (3405.05**) for number of siliqua per plant. The number of siliqua per plant was observed in G1 (242.00), G15 (195.20) and G18 (227.10) higher than three checks varieties (Table 3). The G1 showed the highest (242.00) number of siliqua per plant in F_3 and F_4 populations. The number of siliqua per plant of genotypes G2, G3, G4, G5, G6, G7, G8, G9, G10, G11, G12, G13, G14, G16, G17 and G20 were recorded154.50, 156.00, 167.70, 125.80, 160.30, 128.20, 155.60, 147.10, 170.10, 131.30, 126.20, 161.90, 141.40, 132.10, 122.60 and 162.70 respectively (Table 5) which are higher than Tori-7 and BARI Sarisha-6 but lower than BARI Sarisha-15 (Table 3). The G1 showed the lowest (111.50) number of siliqua per plant in F_3 and F_4 populations which is lower the three checks varieties (Table 3) (Figure 3).

The value of phenotypic variance and genotypic variance were recorded highest (2033.19), (685.93) respectively with high difference between them suggested there

Plate 6. Photograph showing differences in number of secondary branches per plant in checks and F_3 and F_4 populations

(16.79) respectively estimate high for number of siliqua per plant which indicate existence of adequate variation among the genotype (Table 4). The high GCV values of these characters suggest that the possibility of improving these trait through selection. Highest phenotypic variance, genotypic variance and phenotypic coefficient of variance, genotypic coefficient of variance for this trait were also observed by Jahan (2008).

4.1.1.7 Length of siliqua

The length of siliqua of genotypes G1, G2, G3, G4, G5, G6, G7, G8, G9, G11, G12, G13, G14, G16, G17, G18, G19, G20 were recorded 5.47 cm, 5.88 cm, 5.30 cm, 5.26cm, 6.06 cm, 5.94 cm, 5.73 cm, 5.64 cm, 5.43 cm, 5.92 cm, 5.39 cm, 5.71 cm, 5.41 cm, 5.85 cm, 5.58 cm, 5.82 cm, 5.57 cm and 5.58 cm respectively, which are higher than check varieties BARI Sharisa-6 (5.21 cm), BARI Sarisha-15 (4.94 cm) and Tori-7 (5.16 cm) (Table 3). The genotypes G10 and G15 showed length of siliqua were 4.77 cm and 4.81 cm which are lower than three check varieties (Table 3). In 20 F_3 and F_4 population, the highest length of siliqua was recorded in G5 (6.06 cm) which is very close to G2 (5.88 cm), G6 (5.94 cm), G11 (5.92 cm) whereas the minimum length of siliqua was observed in G10 (4.77 cm) (Table 3). Variation in length of siliqua are shown in Plate 7.

The value of phenotypic and genotypic variance (0.31) (0.02) respectively for length of siliqua with little difference between them indicating that there were less effect of environment on this character (Table 4). According to table 4, PCV and GCV (10.06%) (2.67%) respectively for length of siliqua which indicate that sufficient variation exist among genotypes for this trait. Low co-efficient of variation, genotypic and phenotypic variance for this trait was aslo recorded by Saleh (2009).

4.1.1.8 Number of seed per siliqua

The analysis of variance for number of seed per siliqua showed highly significant difference (29.26**) among 20 F_3 and F_4 genotypes of *Brassica* used in the present experiment (table 2). The length of siliqua of genotypes G5, G6, G7, G11, G12 and G14 were recorded 21.93 , 22.18, 21.81, 22.34, 28.36 and 21.63 respectively which are higher than three checks varieties BARI Sarisha-15 (21.62), Tori-7 (18.59) and BARI Sarisha-6 (21.28) (Table 3). The genotypes G1, G8, G10, G15, G17 and G18

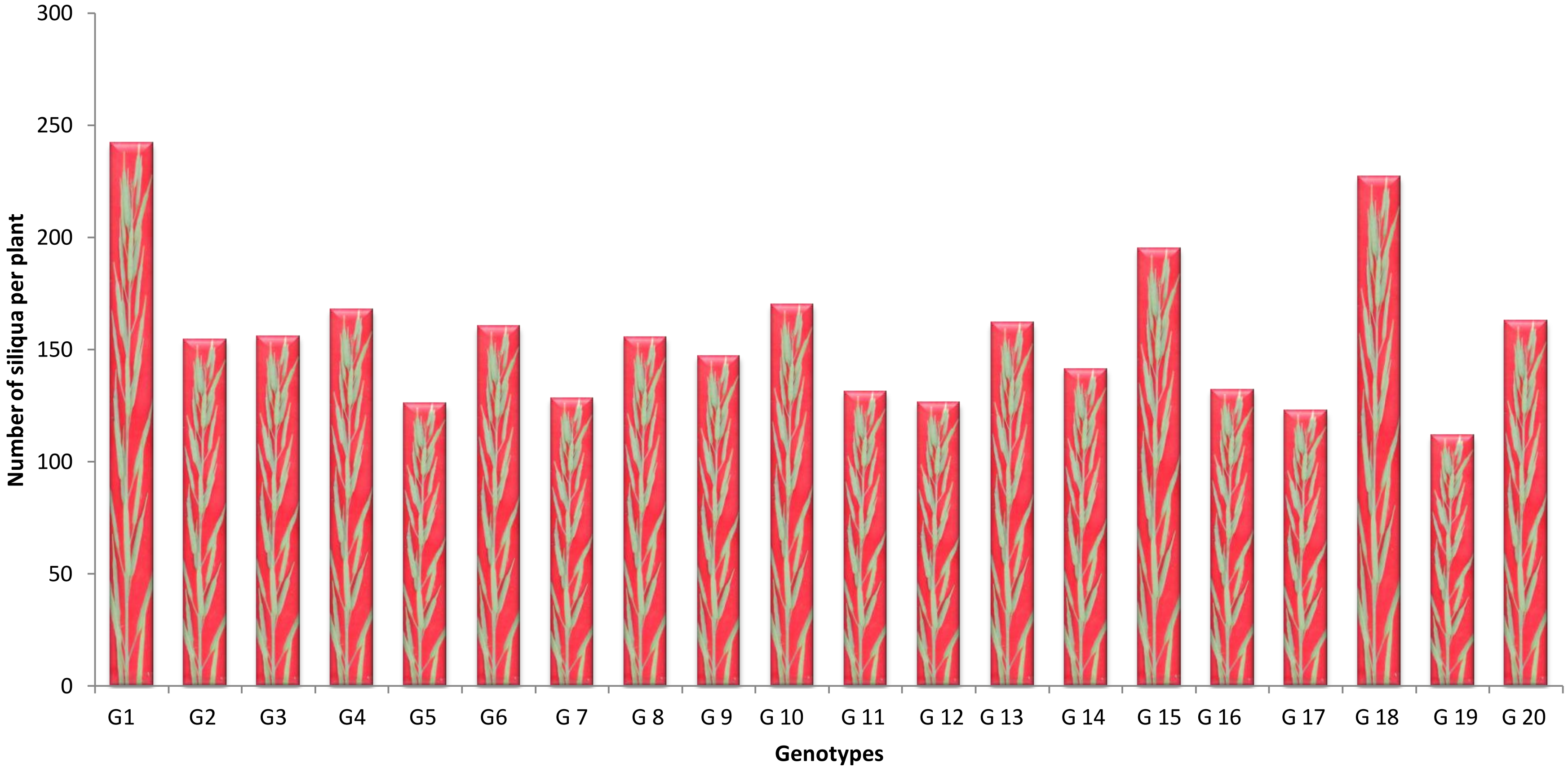


Figure 3. Mean performance of days to number of siliqua per of twenty segregating genotypes

Plate 7. Photographs showing differences in siliqua length in checks and F_3 and F_4 populations

showed length of siliqua were 16.29, 17.33, 15.89, 16.83, 15.66 and 15.59 respectively (Table 3). These genotypes G1, G8, G10, G15, G17 and G18 had lower number of seed per siliqua than three checks varieties. Number of seed per siliqua was observed in genotypes G3 (18.67), G4 (20.99), G9 (19.61), G13 (20.75), G16 (20.72), G19 (21.16) and G20 (18.61) which are higher than Tori-7 but lower than BARI Sarisha-15 and BARI Sarisha-6 (Table 3). In F_3 and F_4 populations, the number of seeds per siliqua was recorded highest in G12 (28.36) and minimum was recorded in G18 (15.59).

The magnitude of difference between phenotypic and genotypic variances (19.49), (4.89) respectively was higher for number of seeds per siliqua suggested that large environmental influence on this character (Table 4). The moderate value of phenotypic and genotypic coefficient of variance (22.19), (11.11) respectively for this character indicated that the existence of adequate variation among the population with possibility of high potential for the selection (Table 4). Similar variability was also recorded by Kumar and Singh (1994).

4.1.1.9 Thousand seed weight

Among 20 F_3 and F_4 populations, thousand seed weight was found maximum in G5 (4.81 gm) which is higher than three checks varieties BARI Sharisa-15 (3.41g), Tori-7 (2.13 g) and BARI Sharisa-6 (3.95 g) (Table 3). The thousand seed weight was recorded in G4 (3.49 g), G9 (3.73 g), G16 (3.48 g) and G19 (3.47 g) which are higher than BARI Sarisha-15 and Tori-7 (Table 3). Thousand seed weight of genotypes G1, G2, G3, G6, G7, G8, G10, G11, G12, G14, G15, G17, G18 and G20 were recorded 2.83g, 2.82 g, 3.05 g, 2.96 g, 3.58 g, 3.13 g, 3.25 g, 3.25 g, 3.39 g, 3.06 g, 3.24 g, 3.29 g, 3.13 g and 2.70 g respectively which are higher than Tori-7 but lower than BARI Sarisha-15 and BARI Sarisha-6 (Table 3). The minimum thousand seed weight was found in Tori-7 (2.13 g) (Table 3). The genotypes G13 (3.41 g) showed similar thousand seed weight to BARI sarisha-15 (Table 3).

Thousand seed weight showed very low phenotypic (0.40) and genotypic (0.22) variance with less differences indicating that they were less responsive to environmental factors and the values of PCV and GCV were 19.16 % and 14.28% indicating that the genotype has considerable variation for this trait (Table 4). Low phenotypic (0.08) and genotypic (0.16) variance and high phenotypic coefficient of variation (18.94%) and genotypic coefficient of variation (13.27%) for thousand seed weight was observed by Parveen (2007).

4.1.1.10 Yield per plant

The mean square due to genotype from the analysis of variance was found statistically significant (15.05**) for yield per plant indicating the presence of genotypic differences present among the 20 F_3 and F_4 populations (Table 2). Yield per plant was recorded in G1 (12.12g), G2 (9.04g), G4 (10.22 g), G6 (11.95 g), G7 (8.95g), G8 (8.72g), G9 (10.22g), G10 (9.18g), G11 (10.22g), G12 (9.40g), G13 (9.12g), G14 (8.57g), G15 (9.57g), G16 (8.95g), G17 (11.60g), G18 (9.80g), G19 (9.39g) and G20 (9.57g) which are higher than BARI Sharisa-15 (8.45g) and Tori-7 (6.82g) (Table 3). The highest (12.52 g) yield per plant among the 20 F_3 and F_4 populations were found in G5 which is equal to check variety BARI Sarisha-6 (12.52 g) (Table 3). The lowest yield per plant was recorded in Tori-7 (6.82g). Among F_3 and F_4 populations, the lowest (7.61 g) yield per plant in the 20 F_3 and F_4 populations was recorded in G3 which is higher than Tori-7 (6.82 g) but lower than BARI Sarisha-15(8.45g) and BARI Sarisha-6 (12.52g) (Table 3) (Figure 4).

The phenotypic and genotypic variance for yield per (6.55), (4.25) respectively suggested that considerable influence of environment on the expression of the genes controlling this trait. The values of PCV and GCV were 26.01% and 20.96 % indicating that the genotype has high variation for this trait (Table 4). Similar result observed by Parveen (2007).

4.1.2 Heritability, genetic advance

Heritability values are categorized by formula of Johnson *et al* (1955) as low (< 30%), medium (30 -60%) and high (> 60 %).

4.1.2.1 Days to 50% flowering

Low heritability (12.78%) with low genetic advance in percentage of mean (1.60%) for days to 50% flowering was found in the 20 F_3 and F_4 populations of *Brassica***.** It indicates that presence of non-additive gene effect and this character is highly influenced by environmental effects and selection would not be ineffective for this trait. (Table 4) (Ahlawat *et. al.* 2006.) Heritability and genetic advance in percentage of mean are shown in Figure 5.

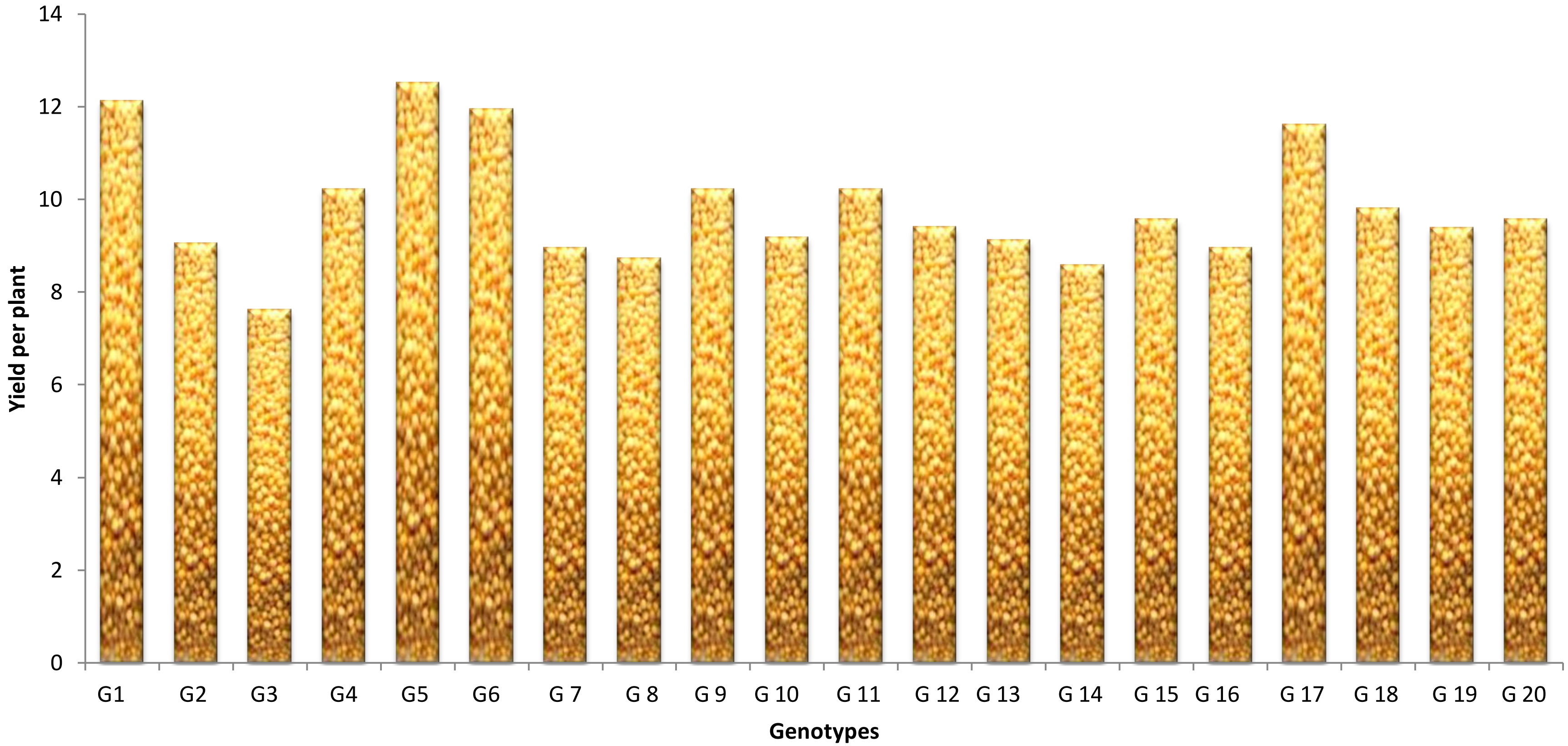


Figure 4. Mean performance of yield per plant of twenty segregating genotypes

4.1.2.2 Days to maturity

Days to maturity showed high heritability (92.41 %) coupled with moderate genetic advance in percentage of mean (11.23%) (Table 4).The result presented that due to presence of non-additive gene effect and environment was mainly responsible for high heritability. Selection for this trait would not be effective. Naznin (2013) found high heritability (89.14%) with moderate genetic advance (10.69%) . High heritability coupled with moderate genetic advance for this trait was also observed by Sharma (1984).

4.1.2.3 Plant height

Plant height of F_3 and F_4 populations showed low heritability 15.92 % associated with low genetic advance in percentage of mean of 2.21 % (Table 4), revealed that plant height is highly influenced by environmental effects and scope of improvement through selection may not be rewarding. High variability in plant height for *B. juncea*, *B. rapa* and *B. napus* was also observed by Varshney *et al*. (1986). Chandola (1977) observed low genetic advance for plant height while working with 30 varieties of *Brassica rapa* L.

4.1.2.4 Number of primary branches per plant

Number of primary branches per plant exhibited low heritability 17.43% conjunction with low genetic advance in percentage of mean (7.59%) (Table 4). These findings revealed that it was indicative of non-additive gene action. Selection for this trait may not be wise. Low heritability coupled with low genetic advance was also found by Singh *et al*. (1987).

4.1.2.5 Number of secondary branches per plant

Moderate heritability (37.95%) accompanied with high genetic advance in percentage of mean (39.70 %) was calculated in respect of number of secondary branches per plant (Table 4). These findings discovered the action of additive gene effects on the expression of this trait. The moderate heritability is being exhibited due to high environmental effects. Selection may be effective in such character. Sheikh *et al.* (1999) found moderate heritability coupled with high genetic advance in percentage of mean for number of secondary branches per plant while working with 24 genotypes of toria.

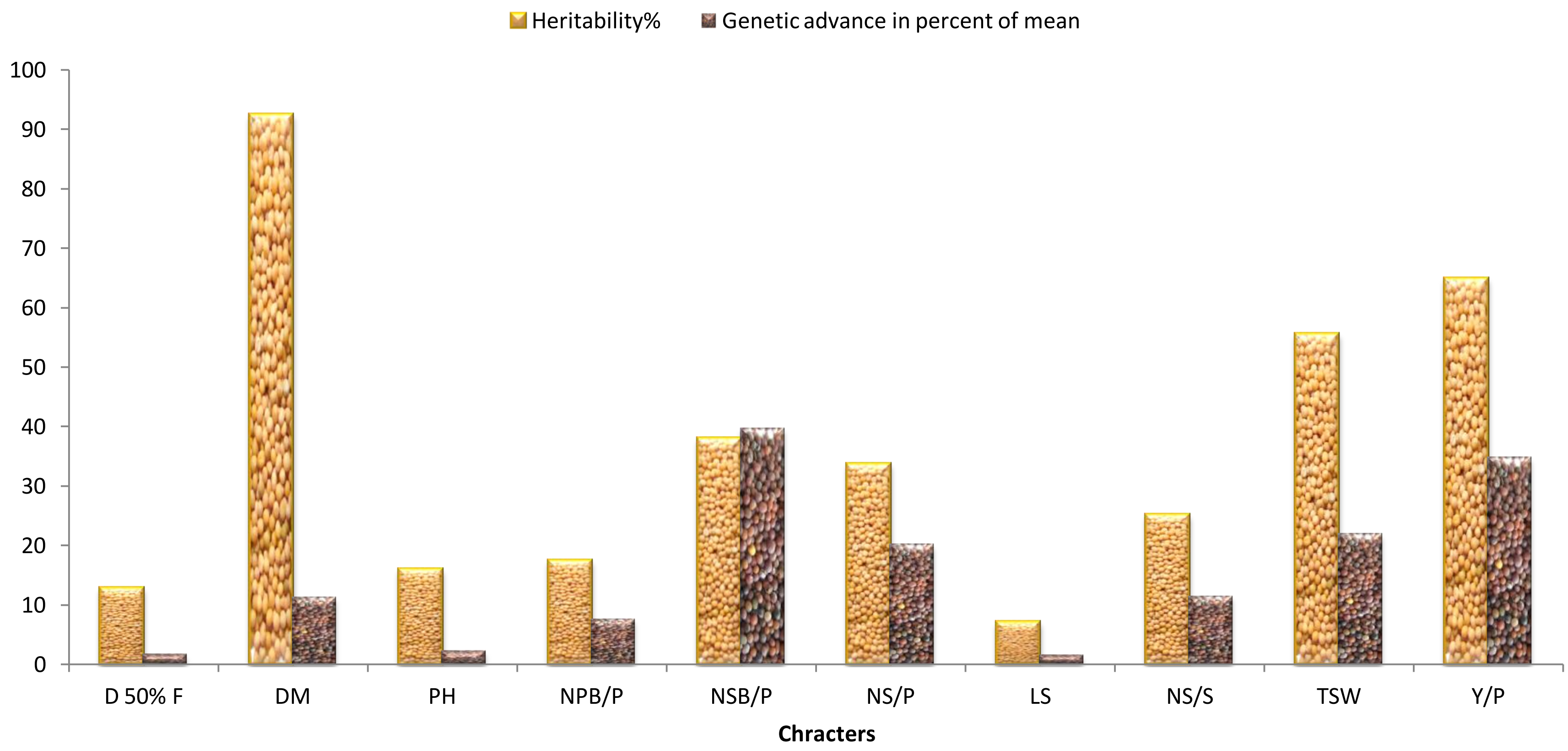


Figure 5. Heritability and genetic advance in percent mean of different characters

4.1.2.6 Number of siliqua per plant

Number of siliqua per plant exhibited moderate heritability (33.74 %) along with high genetic advance (31.34) (Table 4). These results revealed the possibility of predominance of additive gene action in the inheritance of this trait. This trait possessed high variation; it is high potential for effective selection for further genetic improvement of this character. High heritability coupled with high genetic advance for this trait was also observed by Sheikh *et al*. (1999). Mahmud *et al.* (2003) reported that the number of siliqua per plant were highly heritable coupled with high genetic advance. Khan *et al*. (2013) also found moderate heritability (35.65%) with high genetic advance (48.78%)

4.1.2.7 Siliqua length

Low heritability (7.05%) along with low genetic advance in percentage of mean (1.46%) was calculated in siliqua length (Table 4). It is indicated that 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 wise. High heritability for this trait was observed by Chaudhury *et al*. (1990). Similar results were also found by Kwon *et al*. (1989) and Rao (1977).

4.1.2.8 Number of seeds per siliqua

Number of seeds per siliqua showed low heritability (25.09%) coupled with low genetic advance (2.28) and medium genetic advance in percentage of mean (11.47%) (Table 4). These finding exposed the non-additive gene effect on the expression of this character. Selection of this character is not effective. The low heritability is being exhibited due to high environmental effect. Low heritability coupled with low genetic advance for this trait was also observed by Singh (1986).

4.1.2.9 Thousand seed weight

The magnitude of heritability in broad sense of this character was moderate (55.54%) with high genetic advance in percentage of mean (21.92%) (Table 4).These findings revealed that this trait was controlled by additive gene and selection for this character would be effective. Johnson *et al*. (1955) reported that heritability estimates along with genetic group were more useful in prediction selection of the best individual.

High heritability for this trait was also observed by Yadava *et al*. (1993). Ara (2010) reported the high heritability and genetic advance for thousand seed weigh.

4.1.2.10 Yield per plant

Seed yield per plant showed high heritability (64.92%) accompanied with low genetic advance (3.42) and high genetic advance in percentage of mean (34.79%) (Table 4).These finding revealed that the additive gene effect on the expression of this character and selection for this character would be effective. High heritability coupled with high genetic advance for this trait was also observed by Sheikh *et al*. (1999). High heritability and genetic advance for seed yield per plant was reported by Singh (1991) while working with 22 genotypes of *Brassica napus*. Rameeh (2014) found high heritability with high genetic advance for seed yield in *B. napus.*

4.2 Correlation coefficient

Correlation coefficient is a statistical measure which is used to find out the degree and direction of relationship between two or more variables. Yield is an important economic character which is influenced by several inter dependable quantitative characters. Thus selection for yield may not be effective unless the other yield components influence it directly or indirectly are taken in to consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated characters. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeder for making improvement through selection vis-à-vis provide a clear understanding about the contribution in respect of establishing the association by genetic and non-genetic factors (Dewey and Lu 1959). In this study, both genotypic and phenotypic correlation co-efficient of different characters of 20 F_3 and F_4 genotypes of *Brassica rapa* L are determined (Table 5 and 6). Most of the characters showed the genotypic correlation coefficients were higher than their respective phenotypic ones. These values indicated that these traits were strongly associated genetically and the phenotypic expression of these traits was less influenced by the environment. Similar result was found by Pankaj *et al.* (2002). In few cases, phenotypic correlation co-efficient were higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation acted in the same direction and finally maximized their expression at phenotypic level.

4.2.1 Days to 50% flowering

Days to 50% flowering showed insignificant and positive correlation with days to maturity (r_g = 0.27, r_p = 0.02), plant height (r_g = 0.2, r_p = 0.2), number of seed per siliqua (r_g =0.16, r_p = 0.12), thousand seed weight (r_g =0.26, r_p =0.06). It also exhibited significant and negative correlation number of primary branch (r_g = - 0.39, r_p = - 0.31) and yield per plant (r_g = - 0.35, r_p = - 0.31), indicating a possible increase in yield per plant by lowering to days to flowering and number of primary branch. However, the correlation of days to 50% flowering with number of secondary branch (r_g = -0.13, r_p = -0.07), number of siliqua per plant (r_g = -0.22, r_p =-0.12) and siliqua length (r_g = -0.05, r_p = -0.02) are insignificant and negative . (Table 5 and 6). It indicated that if days to 50% flowering increases then number of secondary branch, number of siliqua per plant, siliqua length decreases. Mili (2014) also revealed that days to 50% flowering had significant and negetive interaction with yield per plant.

4.2.2 Days to maturity

Significant and positive correlation between days to maturity and thousand seed weight at genotypic and phenotypic level (r_g = 0.34, r_p = 0.31) indicated that if days to maturity increased then thousand seed weight also increased. It had non-significant and positive correlation with plant height (r_g =0.03, r_p =0.08), number of secondary branches (r_g = 0.24, r_p =0.15), siliqua length (G=0.07, r_p =0.07) and yield per plant (r_g =0.05, r_p =0.02)showing very little contribution of this trait toward the increase in plant height, number of secondary branch , siliqua length and ultimately to yield per plant. Days to maturity showed significant and negative interaction with number of seed per siliqua (r_g = - 0.41, r_p = - 0.32) suggesting that number of seed per siliqua will increase if days to maturity will decrease. It was found non-significant and negatively associated with number of primary branch (r_g = - 0.13, r_p = - 0.06) and number of siliqua per plant (r_g =-0.01, r_p = -0.07) (Table 5 and 6). Insignificant association of these traits indicated that the association between these traits was largely influenced by environmental factors. Lodhi (2014) also revealed that days to maturity had non-significant and positive interaction with yield per plant.

4.2.3 Plant height

Plant height showed significant and positive correlation with number of primary branches (r_g =0.54, r_p =0.34), number of siliqua per plant (r_g =0.57, r_p =0.38) and yield per plant (r_g = 0.58, r_p = 0.40) whereas non-significant interaction with thousand seed weight (r_g =0.05, r_p =0.17) .The results tend to emphasize that improvement in yield per plant can be achieved by improving the characters primary number of siliqua per plant, plant height. It was significantly and negatively associated with number of secondary branches (r_g = -0.62, r_p = - 0.48), siliqua length (r_g = - 0.40) number of seed per siliqua (r_g =- 0.41, r_p =-0.38) (Table 5 and 6). Shalini *et al*. (2000) also observed that plant height was highly associated with seed yield. Similar result was reported by Srivastava *et al*. (1983). Significant positive correlation between plant height and seed yield was found by Khan and Khan (2003). Chaudhary *et al.* (1990) found positive correlation of plant height with number of seed per siliqua, number of siliqua per plant. Basalma (2008) reported opposite result for this trait.

4.2.4 Number of primary branches per plant

Number of primary branches per plant was found to be positively and significantly correlated with number of siliqua per plant (r_g =0.57, r_p =0.38) and yield per plant (r_g =0.43, r_p =0.32). This finding indicates that an increase in number of primary branches can result in increased number of siliqua per plant and ultimately increase yield per plant. It showed positive but non-significant correlation with number of secondary branches (r_g =0.08, r_p =0.07) and thousand seed weight (r_g =0.22, r_p =0.05) indicated that very little contribution of number of primary branches toward increase in of secondary branches and thousand seed weight. Malik *et al.* (2000) reported similar result for number of primary branches and seed yield both at genotypic and phenotypic level. Number of primary branches per plant had significant and negative interaction with number of seed per siliqua (r_g =-0.57, r_p = -0.32) whereas negative but non-significant interaction with length of siliqua (r_g =-0.01, r_p =-0.08) (Table 5 and 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Rashid (2007) found number of primary branches had positive and significant correlation with yield per plant.

Table 5. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different Genotype of *Brassica rapa* L.

	DM	PH (cm)	NPB/P	NSB/P	NS/P	LS (cm)	NS/S	TSW gm)	Y/P gm)
D50%F	0.27	0.2	-0.39*	-0.13	-0.22	-0.05	0.16	0.26	-0.35*
DM		0.03	-0.13	0.24	-0.01	0.07	-0.41**	0.34*	0.05
PH (cm)			0.54**	-0.62**	0.57**	-0.40**	-0.41**	0.05	0.58**
NPB/P				0.08	0.57**	-0.01	-0.57**	0.22	0.43**
NSB/P					0.05	-0.13	-0.92**	0.09	0.42**
NS/P						-0.35*	-0.61**	-0.37*	0.38*
LS (cm)							0.32	0.05	0.04
NS/S								0.01	0.04
TSW (gm)									0.49**

*= significant at 5% level of probability, **= significant at 1% level of probability
D50%F= days to 50% flowering, DM= Days to maturity, PH= Plant height , NPB/P= Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P= Number of siliqua per plant, LS= Length of siliqua, NS/S= Number of seed per siliqua, TSW= Thousand seed weight, Y/P= yield per plant

Table 6. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of *Brassica rapa* L.

	DM	PH (cm)	NPB/P	NSB/P	NS/P	LS (cm)	NS/S	TSW (gm)	Y/P (gm)
D50%F	0.02	0.2	-0.31*	-0.07	-0.12	-0.02	0.12	0.06	-0.31*
DM		0.08	-0.06	0.15	-0.07	0.07	-0.32*	0.31*	0.02
PH (cm)			0.34*	-0.48**	0.38*	-0.09	-0.38*	0.17	0.40**
NPB/P				0.07	0.38*	-0.08	-0.32*	0.05	0.32*
NSB/P					0.04	-0.04	-0.38*	0.14	0.35*
NS/P						-0.32*	-0.56**	-0.33*	0.32*
LS (cm)							0.22	0.05	0.01
NS/S								0.18	0.08
TSW (gm)									0.35*

*= significant at 5% level, **= significant at 1% level

D50%F= days to 50% flowering, DM= Days to maturity, PH= Plant height , NPB/P= Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P= Number of siliqua per plant, LS= Length of siliqua, NS/S= Number of seed per siliqua, TSW= Thousand seed weight, Y/P= yield per plant

4.2.5 Number of secondary branches per plant

The correlation between number of secondary branches and yield per plant was significant and positive at both genotypic (r_g =0.42) and phenotypic level (r_p =0.35) indicated that the traits were less influenced by environment. It also had positive and non-significant correlation with number of siliqua per plant (r_g =0.05, r_p =0.04) and thousand seed weight (r_g =0.09, r_p =0.14) . Number of secondary branches had significant and negative interaction with number of seed per siliqua (r_g = -0.92, r_p = -0.38) indicated that an decreases in number of secondary branches will increase the number of seed per siliqua. Negative and non-significant correlation was found between number of secondary branches and siliqua length (r_g =-0.13, r_p = -0.04) (Table 5 and 6). Non-significant association of these traits indicated that the association between these traits is largely influenced by environmental factors. These findings are showing similar to the reports of Verma *et al*. (2008).

4.2.6 Number of siliqua per plant

Siliqua per plant exhibited significant and positive correlation with yield per plant (r_g = 0.38, r_p = 0.32) indicated that improvement of yield per plant can be possible by improving number Siliqua per plant. Dastidar *et al.* (2004) reported positive correlation between siliqua per plant and seed yield. Whereas the significant and negative interaction was found in siliqua length (r_g =- 0.35, r_p = - 0.32), number of seed per siliqua (r_g =- 0.61, r_p = - 0.56) and thousand seed weight (r_g = - 0.37, r_p = -0.33) (Table 5 and 8) indicated that siliqua length, number of seed per siliqua and thousand seed weight will increase by decreasing the number of siliqua per plant. Ara (2010) reported that number of siliqua per plant had positive and significant effect on yield per plant.

4.2.7 Siliqua length

Siliqua length was found non-significant and positive association with number of seed per silique (r_g =0.32, r_p =0.22) , thousand seed weight(r_g =0.05, r_p =0.05) and yield per plant (r_g =0.04, r_p =0.01)indicated that very little contribution of this trait toward the increase in number of seed per silique, thousand seed weight and ultimately to yield per plant (Table 5 and 6) . Ali *et al*. (2013) reported that Positive and non-significant phenotypic correlation for pod length was found with main raceme length (0 .07), seeds per siliqua (0.17) and seed yield per plant (0.09).

4.2.8 Number of seeds per siliqua

Number of seeds per siliqua showed non-significant and positive interaction with thousand seed weight (r_g =0.01, r_p =0.18) and yield per plant (r_g =0.04, r_p =0.08) suggested that yield per plant can be increased by improving thousand seed and number of seeds per siliqua (Table 5 and 6). Insignificant association of these traits indicated that the association between these traits sis largely influenced by environmental factors. Lodhi (2014) also revealed that number of seeds per siliqua had non-significant and positive correlation with yield per plant.

4.2.9 Thousand seed weight

Thousand seed weight showed highly significant and positive interaction with yield per plant (r_g =0.49, r_p =0.35) (Table 5 and 6). Highly significant positive associations between thousand seed weight and yield per plant indicate that the traits were governed by same gene and simultaneous improvement would be effective. Saini and Kumar (1995), Kachroo and Kumar (1991) and Olsson (1990) found positive associations which support the results. Tuncturk and Ciftci (2007) reported positive correlation between seed yield with 1000-seed weight which supports the present findings. Mili (2014) also revealed that thousand seed weight had significant and positive interaction with yield per plant.

4.3 Path Co-efficient analysis

The estimates of correlation coefficient, although, indicate interrelationship of different traits, but it does not furnish information on cause and effect. Under such situation path analysis helps the breeder to identify the index of selection. Path coefficient analysis splits the correlation coefficient into direct and indirect effects. It reveals whether the association of the traits with yield is due to their direct effect or is a consequence of their indirect effect via other traits. Yield per plant was considered as a resultant (dependent) variable and days to 50% flowering, days to maturity, plant height, number of primary braches per plant, number of siliqua per plant, length of siliqua, number of seeds per siliqua and thousand seed weight were causal (independent) variables. Estimation of direct and indirect effect of path co-efficient analysis for *Brassica rapa* L is presented in Table 7.

4.3.1. Days to 50% flowering

Days to 50% flowering had positive direct effect (0.05) on yield per plant. This trait showed indirect positive effect on yield per plant through plant height (0.16), siliqua length (0.01), number of seed per siliqua (0.40). On the hand, it showed indirect negative effect on yield per plant via days to maturity (-0.27), number of primary branch (-0.39), number of secondary branch (-0.11), number of siliqua per plant (-0.17), thousand seed weight (-0.03) finally it made significant negative correlation with yield per plant (-0.35) (Table 7). Chauhan and Singh (1995) revealed that days to 50% flowering had positive direct effect on yield per plant. Mili (2014) also reported similar result.

4.3.2. Days to maturity

Path co-efficient analysis revealed that, days to maturity was positively correlated (0.05) and had high positive direct effect (0.50) on yield per plant. This result suggested that yield per plant can be improved through direction selection of days to maturity. It was also found to influence the yield per plant in a positive direction through plant height (0.52), number of secondary branches (0.2), thousand seed weight (0.04).The indirect effect of this trait through 50% flowering (-0.01), number of primary branches (-0.13), number of siliqua per plant (-0.01) and siliqua length (-0.02), number of seed per siliqua (-1.04) was negative (Table 7). Rashid (2007) revealed that days to maturity had positive direct effect on yield. Alam *et al.* (1986), Singh *et al.* (1985) and Srivastava *et al.* (1983) observed that days to maturity had positive direct and indirect effect on seed yield.

4.3.3. Plant height

The direct effect (0.77) of plant height on yield per plant was found to be highly positive. The indirect effects through days to 50% flowering (0.01), days to maturity (0.03), number of secondary branches (0.59), number of siliqua per plant (0.53), length of siliqua (0.19) and thousand seed weight (0.01) are positive. However, this trait had negative and indirect effects on yield per plant via number of primary branches (-0.54) and number of seed per siliqua (-1.01) (Table 7). The correlation

Table 7. Path coefficient analysis showing direct and indirect effects of different characters on yield of *Brassica rapa L* (boled number = direct effect)

	D50%F	DM	PH (cm)	NPB/P	NSB/P	NS/P	LS (cm)	NS/S	TSW (gm)	YP
D50%F	**0.05**	-0.27	0.16	-0.39	-0.11	-0.17	0.01	0.4	-0.03	-0.35*
DM	-0.01	**0.50**	0.52	-0.13	0.2	-0.01	-0.02	-1.04	0.04	0.05
PH (cm)	0.01	0.03	**0.77**	-0.54	0.59	0.53	0.19	-1.01	0.01	0.58**
NPB/P	-0.02	-0.11	-0.37	**0.01**	0.91	0.42	1.00	-1.46	0.05	0.43**
NSB/P	-0.01	0.38	0.48	1.09	**0.34**	-0.04	0.53	-2.36	0.01	0.42**
NS/P	-0.01	-0.01	0.44	0.68	-0.04	**0.74**	0.12	-1.5	-0.04	0.38*
LS (cm)	0.08	0.07	-0.31	-0.01	-0.11	-0.26	**-0.24**	0.83	-0.01	0.04
NS/S	2.01	-0.4	-0.31	-0.58	-0.78	-0.45	-0.08	**0.56**	0.07	0.04
TSW (gm)	-0.01	0.34	0.04	0.23	0.07	-0.27	0.01	-0.02	**0.1**	0.49**
R	0.24									

D50%F= days to 50% flowering, DM= Days to maturity, PH= Plant height , NPB/P= Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P= Number of siliqua per plant, LS= Length of siliqua, NS/S= Number of seed per siliqua, TSW= Thousand seed weight, Y/P= yield per plant

(0.58) between plant height and yield per was positive and significant indicated that direct selection for this trait will be rewarding for yield per plant improvement. Han (1990) and Singh (2004) also reported direct positive result for this character.

4.3.4. Number of primary branches per plant

Number of primary branches per plant exerted the positive direct effect on yield per plant (0.01). This trait had also positive indirect effect through number of secondary branch (0.91), number of siliqua per plant (0.42), siliqua length (1.00) and thousand seed weight (0.05) on yield per plant. On the other hand, negative indirect effect was found through days to 50% flowering (-0.02), days to maturity (-0.11), plant height (-0.37) and number seed per siliqua (-1.46) on yield per plant (Table 7). Its correlation with yield per plant was positive and highly significant (0.43) suggested that direct selection of this character may contribute in yield .Mahla *et al.* (2003). Gupta *et al.* (1987) observed that primary branching had the direct effect on seed yield.

4.3.5. Number of secondary branches per plant

Path co-efficient analysis revealed that number of secondary branches showed positive direct effect (0.34) on yield per plant. It had positive indirect effect via days to maturity (0.38), plant height (0.48), number of primary branch (1.09) ,siliqua length (0.53) and thousand seed weight (0.01) on seed yield per plant. Whereas, negative indirect effect of number of secondary branches per plant through days to 50% flowering (-0.01), number of siliqua per plant (-0.04) and number of seed per siliqua (-2.36) (Table 7). The genotypic correlation with yield per plant was highly significant and positive (0.42). This result exposed that yield per plant will be increased by direct selection of number of secondary branches per plant. Yadava*et al*. (1996) found the number of secondary branch had the highest positive direct effect on seed yield. Rashid (2007) observed that number of secondary branches per plant had the highest direct effect on seed yield per plant.

4.3.6. Number of siliqua per plant

Number of siliqua per plant had the positive direct effect (0.74) on yield per plant followed by positive indirect effect via plant height (0.44), number of primary branch (0.68) and siliqua length (0.12). This trait had also negative indirect effect on yield through days to 50% flowering (-0.01), days to maturity (-0.01), number secondary branch (-0.04), number of seed per siliqua (-1.5) and thousand seed weight (-0.04). Finally this trait had significant positive genotypic correlation (0.38) with yield per plant (Table 7). Hence, selection should be practiced for this trait which had more number of siliqua in order to improve seed yield. Shalini *et al*. (2000) found the number of siliqua per plant had the positive direct effect on seed yield. Sheikh *et al.* (1999) revealed that siliqua per plant had highly positive direct effect on seed yield.

4.3.7. Siliqua length

The direct effect (-0.24) of siliqua length on yield per plant was negative. The indirect effect of this trait on yield per plant through days to 50% flowering (0.08), days to maturity (0.07) and number of seed per siliqua (0.83) was positive .Whereas, negative indirect effect of this trait was found on yield per plant via plant height (-0.31), number of primary branch (-0.01), number of secondary branch (-0.11), number of siliqua per plant (-0.26) and thousand seed weight (-0.01).The correlation with yield per was positive and non-significant (0.04) (Table 7). This finding suggested that this trait has influence on yield per plant through 50% flowering, days to maturity, number of seed per siliqua . Han (1990) and Singh *et al.* (1987) reported that siliqua length had negative direct effect on yield per plant.

4.3.8. Number of seeds per siliqua

Number of seeds per siliqua had direct positive effect (2.56) on yield per plant. This trait had also indirect positive effect on yield per plant via days to 50% flowering (0.01) and thousand seed weight (0.07). On the other hand, indirect negative effect of this trait showed on yield per plant through days to maturity (-0.4), plant height (-0.31), number of primary branch (-0.58), number of secondary branch (-0.78), number of siliqua per plant (-0.45) and siliqua length (-0.08). Finally this trait had positive correlation (0.04) with yield per plant. (Table 7). Rashid (2007) reported that number of seeds per siliqua had direct positive effect on yield per plant. Parveen (2007) also found similar results for this trait.

4.3.9 Thousand seed weight

Path co-efficient analysis revealed that thousand seed weight exhibited positive direct effect on yield per plant (0.1) followed by positive indirect effect through days to maturity (0.34), plant height (0.04), number of primary branch (0.23), number of secondary branch (0.07) and siliqua length (0.01). Whereas this trait showed negative indirect effect via days 50% flowering (-0.01), number of siliqua per plant (-0.27) and number of seed per siliqua(-0.02) on yield per plant. Thousand seed weight had significant and positive correlation with yield per plant (0.49) (Table 9) indicated that direct selection of this trait will improve seed yield. Siddikee (2006) reported that thousand seed weight had the highest positive direct effect on seed yield per plant. Kachro and Kumar (1991) reported that thousand seed weight had positive direct effect on seed yield. Kudla (1993) reported that thousand seed weight had positive direct effect on seed yield.

4.4 Selection

At present, the cultivation of *Brassica* sp. are decreasing in Bangladesh due to pressure of Boro rice. The existing high yielding varieties such as BARI sarisha-6 is long durable which occupy land during Boro season as a result transplantation of Boro rice become delayed. Therefore, farmers prefer short durable and high yielding varieties which can fit with Aman- Mustard- Boro cropping system. The leading early variety of *Brassica rapa* L in Bangladesh is Tori-7. It has low seed yield per plant like 6.82 gm. Another variety of *Brassica rapa* L in Bangladesh is BARI sarisha-15 which become mature by 84 days with 8.45 seed yield per plant. Now a days, this variety is popular for its high yield and duration.

The objectives of our study are to select short duration and high yielding genotypes of *Brassica* which fit with Aman -Mustard-Boro cropping system. Variability was found for most of the characters in the F_3 and F_4 populations of different cross combinations. Selection was carried out among the F_3 and F_4 populations as per objectives. Twenty one most promising plants with high yielding and a short duration were selected from the F_3 and F_4 materials of the different cross combinations (Table 8).

4.4.1. BARI sarisha-15 × SAU sarisha-3 F_4

The five plants are selected from the genotype BARI sarisha-15 × SAU sarisha-3 F_4 which produced branches from second node of main stem. Branches made 60^0 angle with main stem that means the branches are spreading types which made the upper portion of plant U-shaped. The plant height of selected plant were recorded an

Table 8. Selection of promising high yielding short duration plants from the F_3 and F_4 materials of different cross combinations

Sl. no	$F_{3:4}$ populations	Plant No.	DM	PH (cm)	NPB/P	NSB/P	NS/P	TSW (g)	Y/P (g)
1	(G12) BARI sarisha-15 X SAU sarisha-3 F_4 , R1	8	80	105.3	7	5	149	3.23	9.12
2	R1	4	80	105.9	8	6	147	3.40	9.23
3	R2	12	80	107.31	10	7	145	3.36	9.32
4	R2	21	80	109.21	6	8	142	3.25	9.21
5	R3	23	80	106.56	7	4	139	3.21	9.18
6	R3	14	80	108.34	8	5	146	3.19	9.16
7	(G13) BARI sarisha-15 X SAU sarisha-2 F_4 R1	3	83	112.57	7	4	161	3.39	9.4
8	R1	15	83	114.3	8	4	160	3.30	9.23
9	R3	6	83	113.89	6	7	158	3.37	9.35
10	R3	8	83	115.87	7	5	165	3.37	9.38
11	(G14) BARI sarisha-15 X SAU sarisha-1 F_4 R1	8	83	103.64	10	4	158	3.49	9.39
12	R2	10	83	103.67	8	5	155	3.39	9.36
13	R2	5	83	102.53	8	7	157	3.46	9.38
14	R3	21	83	102.56	9	5	156	3.43	9.35
15	R3	18	83	104.21	7	6	154	3.43	9.33
16	R3	12	83	101.98	8	4	157	3.45	9.37
17	(G19) SAU sarisha-1 X BARI sarisha-15 s2 F_3 R1	3	78	108.70	6	5	141	3.06	8.57
18	R2	7	78	107.35	6	4	138	3.09	8.50
19	R2	9	78	109.43	7	5	144	3.10	8.58
20	(G18) Tori-7 × BARI sarisha-15 F_4R2	13	78	110.10	7	8.	137	3.04	8.45
21	R3	14	78	108.51	8	6	140	3.08	8.51

DM =Days to maturity,PH (cm) = Plant height, NPB/P = Number of primary branches per plant, NSB/P = Number of secondary branches per plant, NS/P = Number of siliqua per plant, TSW (g) = Thousand seed weight, Y/P (g) = Yield per plant.

Plate 8. Photographs showing early mature plant of BARI sharisa -15 × SAU sharisa -3 F_4

Plate 9. Photograph showing siliqua number of BARI sharisa -15 × SAU sharisa -3 F_4

Plate 10. Photographs showing siliqua orientation and siliqua length of BARI sharisa-15 × SAU sharisa-3 F_4

average 107.34 cm which is almost similar to the BARI sarisha-15 (108.70 cm) but higher than Tori-7 (102.50 cm) and lower than BARI sarisha-6 (129.70 cm) .The plant height of plant no.21 of R1 replication (109.21 cm) was higher average and BARI sarisha-15 (108.70 cm) and Tori-7 (102.50 cm). As branching was started from the lower node, the branches were tall and provided the chance of producing much number of siliqua per plant. The number of primary branches of plant no. 8 of R1 replication, plant no.12 of R2 replication and plant no. 23 and 14 of R3 replication were recorded 7, 10, 7 and 8 respectively (Table 8) which are higher than BARI Sarisha-15 (6.83), Tori-7 (6.37) and BARI Sarisha-6 (5.13). The number of secondary branches of plant no. 8 of R1 replication, plant no.12 of R2 replication and plant no. 23 and 14 of R3 replication were recorded 5, 7, 4 and 5 respectively (Table 8) which are higher than BARI Sarisha-15 (3.77) and BARI Sarisha-6 (3.83). The plant no. 21 of R2 replication was found highest (8) number of secondary branches than tree checks varieties. The number of siliqua of plant no. 8 of R1 replication, plant no.12, 21 of R2 replication and plant no. 23 and 14 of R3 replication were recorded 149,145,142,139 and 146 respectively (Table 8) which are higher than BARI Sarisha-15 (120.40). The plant no. 8 of R1 replication, plant no.12, 21 of R2 replication and plant no. 23 and 14 of R3 replication were observed with thousand seed weight 3.23g, 3.36g, 3.25, 3.21g and 3.19 g respectively (Table 8) which are higher than Tori-7 (2.13g) that means seeds of selected plant were larger than tori-7 and had comparatively higher oil content. The yield of plant no. 8 of R1 replication, plant no.12, 21 of R2 replication and plant no. 23 and 14 of R3 replication were recorded9.12g, 9.32g, 9.21g, 9.18g and 9.16g respectively by the duration 80 days (Table 8) which are higher than BARI Sarisha-15 (8.45g) and Tori-7 (6.82g) which indicated that these selected plants are high yielding and short durable than BARI sarisha-15 (84 days) and Tori-7 (82 days).

4.4.2. BARI sarisha-15 × SAU sarisha-2 F_4

The selected plants of this genotypes produced branches from second node of main stem and branches made 35^0 with main stem that indicated branches were compact to main stem and erect. So, the lodging was less and attack of *Alternaria* disease was less. As branching was started from lower node, so that the branches are tall. The plant height of selected plant no. 3, 15 of R1 replication and plant no. 6 and 8 of R3 replication were recorded 112.57 cm, 114.3 cm, 113.89 cm and 115.87 cm

Plate 11. Photographs showing early mature plant (blue tagged) of BARI sharisa -15 × SAU sharisa -2 F_4

Plate 12. Photograph showing branching plant of BARI sharisa-15 × SAU sharisa-2 F_4

Plate 13. Photograph showing siliqua orientation and siliqua length plant of BARI sharisa-15 × SAU sharisa-2 F_4

respectively (Table 8) which are higher than BARI Sarisha-15 (108.70 cm) and Tori-7 (102.50 cm) . The plant no. 3, 15 of R1 replication and plant no. 8 of R3 replication had the number of primary branches 7, 8 and 7 respectively (Table 8) which are higher than BARI Sarisha-15 (6.83), Tori-7 (6.37) and BARI Sarisha-6 (5.13). The number of secondary branches of plant no. 3, 15 of R1 replication and plant no.6 and 8 of R3 replication were recorded4, 4, 7 and 5 respectively (Table 8) which are higher than BARI Sarisha-15 (3.77) and BARI Sarisha-6 (3.83). The number of siliqua of plant no. 3, 15 of R1 replication and plant no.6 and 8 of R3 replication were recorded 161, 160, 158 and 165 respectively (Table 8) which are higher than BARI Sarisha-15 (120.40). The plant no. 3, 15 of R1 replication and plant no. 6 and 8 of R3 replication were recorded with thousand seed weight 3.39g, 3.30g, 3.37g and 3.37 respectively (Table 8) which are higher than Tori-7 (2.13g) that means seeds of selected plant were larger than tori-7 and had comparatively higher oil content. The yield of plant no. 3, 15 of R1 replication and plant no.6 and 8 of R3 replication were recorded 9.4g, 9.23g, 9.35g and 9.38g respectively by the duration 83 days (Table 8) which are higher than BARI Sarisha-15 (8.45g) and Tori-7 (6.82g) which indicated that these selected plants are high yielding and short durable than BARI sarisha-15 (84 days).

4.4.3 BARI sarisha-15 × SAU sarisha-1 F_4

The branching of selected plants of this genotype was started from second node of main stem and branches made 350 with main stem that indicated branches were compact to main stem and erect. The plant height of selected plant no. 8 of R1 replication, plant no.10, 5 of R2 replication and plant no. 21 and 18 of R3 replication were recorded103.64cm, 103.67cm, 102.53cm, 102.56 cm and 104.21cm respectively (Table 8) which are higher Tori-7 (102.50 cm) . The number of primary branches of plant no. 8 of R1 replication, plant no.10, 5 of R2 replication and plant no. 21, 18 and 12 of R3 replication were recorded 10, 8, 8, 9, 7 and 8 which are higher than BARI Sarisha-15 (6.83), Tori-7 (6.37) and BARI Sarisha-6 (5.13). The number of secondary branches of plant no. 8 of R1 replication, plant no.10, 5 of R2 replication and plant no. 21, 18 and 12 of R3 replication were recorded4, 5, 7, 5, 6 and 4 respectively (Table 8) which are higher than BARI Sarisha-15 (3.77) and BARI Sarisha-6 (3.83).

Plate 14. Photograph showing mature plant of BARI sharisa -15 X SAU sharisa -1 F_4 genotype

Plate15 .Photograph showing pod per plant of BARI sharisa -15 X SAU sharisa-1 F_4 genotype

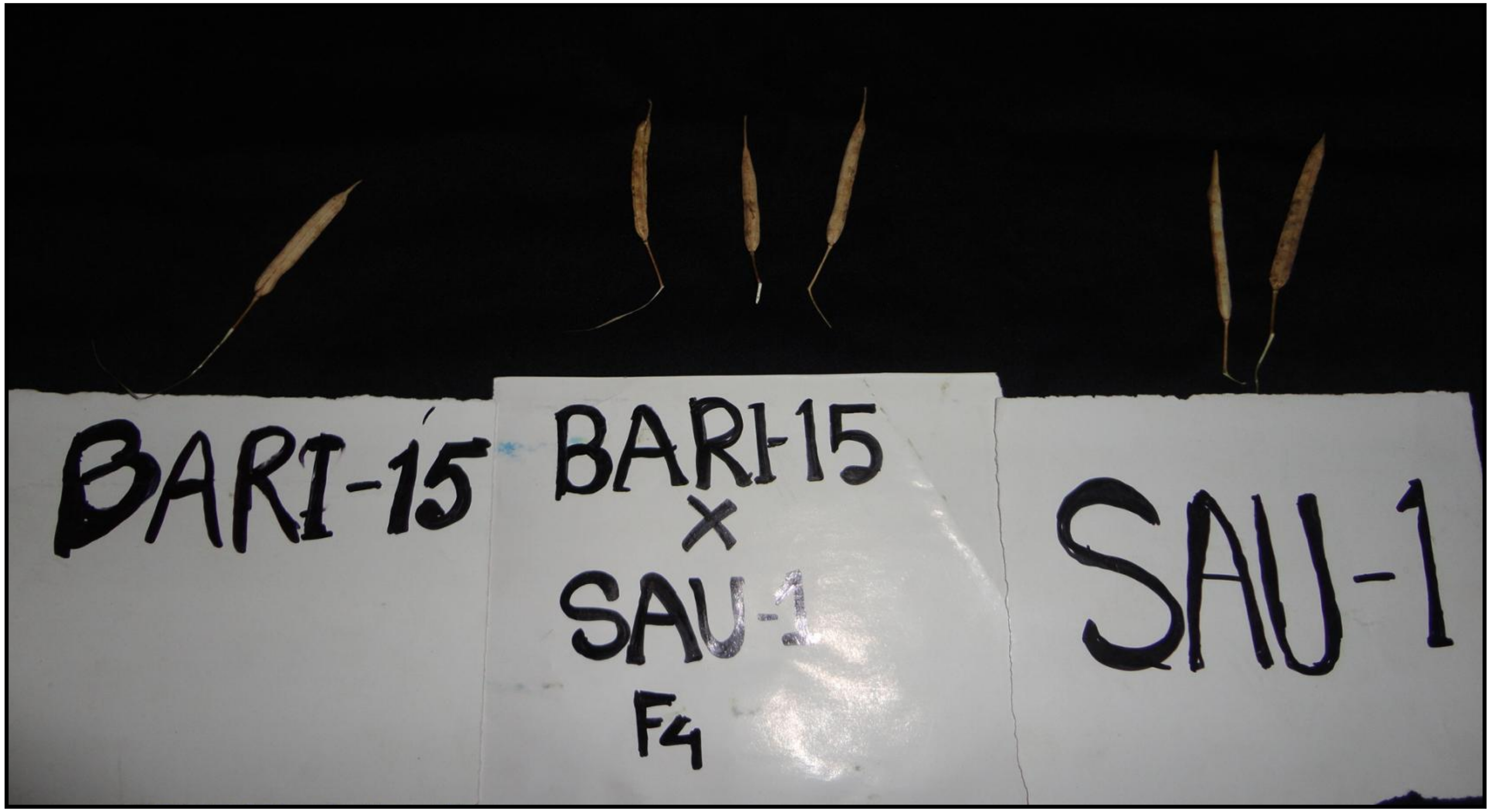


Plate 16. Photograph showing siliqua orientation and siliqua length plant of BARI sharisa -15 X SAU sharisa -1 F_4 genotype

The number of siliqua of plant no. 8 of R1 replication, plant no.10, 5 of R2 replication and plant no. 21, 18 and 12 of R3 replication were recorded 158, 155,157, 156, 154 and 157 respectively (Table 8) which are higher than BARI Sarisha-15 (120.40). The plant no. 8 of R1 replication, plant no. 5 of R2 replication and plant no. 21, 18 and 12 of R3 replication exhibited thousand seed weight 3.49g, 3.46g, 3.43g, 3.43g and 3.45g respectively (Table 8) which are higher than BARI sarisha-15 (3.41g) and Tori-7 (2.13g) that means seeds of selected plant were larger than BARI sarisha-15 and tori-7 and had comparatively higher oil content. The yield of plant no. 8 of R1 replication, plant no.10, 5 of R2 replication and plant no. 21, 18 and 12 of R3 replication were recorded 9.39g, 9.36g, 9.38g, 9.35g, 9.33g and 9.37grespectively by the duration 83 days (Table 8) which are higher than BARI Sarisha-15 (8.45g) and Tori-7 (6.82g) which indicated that these selected plants are high yielding and short durable than BARI sarisha-15 (84 days).

4.4.4. SAU sarisha-1 × BARI sarisha-15 s2 F_3

Branching was started from 1^{st} – 2^{nd} node of main stem and the branches were compact and erect. So that the infestation of *Alternaria* disease was low and the lodging was very low. As the branching is started from lower node, the branches are considerably tall. The plant height of selected plant no. 3 of R1 replication and plant no.7 and 9 of R2 replication were recorded 108.70 cm, 107.35 cm and 109.43 cm respectively (Table 8) which are higher Tori-7 (102.50 cm) and almost similar to BARI sarisha-15 (108.70). The plant no.9 had higher (7) number of primary branches than BARI Sarisha-15 (6.83), Tori-7 (6.37) and BARI Sarisha-6 (5.13). The number of secondary branches of selected plant no. 3 of R1 replication and plan no.7 and 9 of R2 replication were recorded 5, 4 and 5 respectively (Table 8) which are higher than BARI Sarisha-15 (3.77) and BARI Sarisha-6 (3.83). The number of siliqua of plant no. 3 of R1 replication and plant no.7 and 9 of R2 replication were recorded 141, 138 and 144 respectively (Table 4) which are higher than BARI Sarisha-15 (120.40). The thousand seed weight of plant no. 3 of R1 replication and plant no.7 and 9 of R2 replication were recorded 3.06g, 3.09g and 3.10g 45g respectively (Table 8) which are higher than Tori-7 (2.13g) that means seeds of selected plant were larger than tori-7 and had comparatively higher oil content. The plant no. 3 of R1 replication and plant no.7 and 9 of R2 replication had yield 8.57g, 8.50g and 8.58g respectively by the duration 78 days (Table 8) which are higher than BARI Sarisha-15

Plate 17. Photographs showing early mature plant (blue tagged) of SAU sharisa -1 × BARI sharisa -15 s2 F_3 genotype

Plate18 .Photograph showing pod per plant of SAU sharisa -1 × BARI sharisa -15 s2 F_3 genotype

Plate 19. Photograph showing branching of SAU sharisa -1 × BARI sharisa -15 s2 F_3

Plate 20. Photograph showing siliqua orientation and siliqua length of SAU sharisa -1 × BARI sharisa -15 s2 F_3

(8.45g) and Tori-7 (6.82g) which indicated that these selected plants are high yielding and short durable than BARI sarisha-15 (84 days) and Tori-7 (82 days).

4.4.5. Tori-7 × BARI sarisha-15 F_4

The selected plant produced branches from 2nd – 3rd node of main stem so that the branches were tall. Branches were made 450-600 angles with stem and made U shape appearance in upper part of plant like bushy structure not spreading type as tori-7 . The plant height of plant no. 13 of R2 replication was recorded 110.10 cm which is higher than BARI sarisha-15 (108.70 cm) and Tori-7 (102.50 cm) and the plant no.14 of R3 replication was found 108.51 cm which is similar to BARI sarisha-15 (108.70 cm) but higher than Tori-7 (102.50 cm). The number of primary branches of plant no. 13 of R2 replication and plant no. 14 of R3 replication were recorded 7 and 8 which are higher than BARI Sarisha-15 (6.83), Tori-7 (6.37) and BARI Sarisha-6 (5.13). The secondary branches of plant no. 13 of R2 replication was recorded 8 (Table 8) which is higher than Sarisha-15 (3.77), Tori-7 (7.93) and BARI Sarisha-6 (3.83) but the plant no.14 of R3 replication had secondary branches 6 (Table 8) which is higher than Sarisha-15 (3.77) and BARI Sarisha-6 (3.83). The number of siliqua of plant no. 13 of R2 replication and plant no. 14 of R3 replication were recorded 137 and 140 respectively (Table 8) which are higher than BARI Sarisha-15 (120.40).

The plant no. 13 of R2 replication and plant no. 14 of R3 replication had thousand seed weight 3.04g and 3.08g respectively (Table 8) which are higher than Tori-7 (2.13g) that means seeds of selected plant were larger than tori-7 and had comparatively higher oil content. The yield of plant no. 13 of R2 replication was recorded 8.45g by the duration 78 days (Table 8) which is similar to BARI Sarisha-15 (8.45g) and higher than Tori-7 (6.82g) which indicated that this selected plants are high yielding and short durable than Tori-7 (82 days) but short durable and similar yield of BARI Sarisha-15. The plant no. 14 of R3 replication had yield 8.51g respectively by the duration 78 days (Table 10) which is higher than BARI Sarisha-15 (8.45g) and Tori-7 (6.82g) which indicated that these selected plants are high yielding and short durable than BARI sarisha-15 (84 days) and Tori-7 (82 days).

Plate 21. Photographs showing early mature plant (blue tagged) of Tori-7 × BARI sarisha-15 F_4 genotype

Plate 22 . Photograpg showing pod per plant of Tori-7 × BARI sarisha-15 F_4 genotype

Plate 23. Photograph showing branching of Tori-7 × BARI sarisha-15 F_4 genotype

Plate 24. Photograph showing siliqua orientation and siliqua length of Tori-7 × BARI sarisha-15 F_4 genotype

SUMMARY AND CONCLUSION

An experiment was conducted during the period of November, 2013 to February, 2014, at the experimental farm of Sher-e-Bangla Agricultural University using twenty F_3 and F_4 populations of *Brassica rapa L* and three check varieties. The experiment was carried out to study variability, heritability, genetic advance and genetic advance in percentage of mean, character associations and direct and indirect effect of different traits on yield. The results of the present study are summarized as follows:

From variability analysis of F_3 and F_4 populations, it was observed that significant variation exist among all the genotypes used for all of the characters studied. The maximum days to 50% flowering was found in G4 (Tori-7 × SAU sarisha-1) and the lowest in G10 (SAU sarisha-3 × BARI sarisha-15 s_1). The highest days to maturity was found BARI sarisha-6 which is close G9 (BARI sarisha-6 × SAU sarisha-1 s_2) and lowest days were observed in Tori-7 (82 days). Plant height exhibited highest in BARI sarisha-6 and lowest in Tori-7. The genotypes G1 (Tori-7 × BARI sarisha-6), G4 (Tori7 × SAU sarisha-1) had higher plant height among F_3 and F_4 populations. The highest number of primary branches per plant was recorded in G1 (Tori-7 × BARI sarisha-6) and lowest number was recorded in G20 (SAU sarisha-3 × BARI sarisha-15 s2). The highest number of secondary branches per plant was observed in G1 (Tori-7 × BARI sarisha-6) and lowest number of secondary branch was observed in G3 (BARI sarisha-6 × SAU sarisha-1 s_1). The number of siliqua per plant showed highest in G1 (Tori-7 × BARI sarisha-6) and lowest in G19 (SAU sarisha-1 × BARI sarisha-15 s_2).The lowest length of siliqua was recorded in G10 (SAU sarisha-3 × BARI sarisha-15 s_1) and the highest length of siliqua was observed in G5 (Tori-7 × BARI sarisha-15).The number of seeds per pod was found highest in G12 and lowest in G18. The thousand seed weight exhibited highest in G5 (Tori-7 × BARI sarisha-15) and lowest in Tori-7. The yield per plant was highest in BARI sarisha -6 ,G5 and (Tori 7 × BARI sarisha-15) and lowest observed in Tori-7.

The phenotypic variance of F_3 and F_4 materials was considerably higher than the genotypic variance for all the characters studied. Days to maturity, number of primary branches per plant, length of siliqua, thousand seed weight showed minimum difference between genotypic and phenotypic variance which indicated low environmental influence on these characters. Plant height, number of siliqua per plant and number of seed per siliqua showed much difference between genotypic and phenotypic variance suggested that high environmental influence on expression of these characters.

In the twenty F_3 and F_4 progenies for most of the characters wide range of variation observed. In case of days to Plant height and number of siliqua per plant showed higher influence of environment for the expression of these characters. Number of secondary branches per plant, number of siliqua per plant, and yield per plant showed high genotypic and phenotypic coefficient of variation. Days to 50% flowering, days to maturity, plant height and siliqua length exhibited low genotypic and phenotypic coefficient of variation.

Thousand seed weight and yield per plant showed high heritability coupled with low genetic advance and very high genetic advance in percentage of mean, whereas days to maturity, showed high heritability with moderate genetic advance and genetic advance in percentage of mean that revealed the possibility of predominance of additive gene action in the inheritance of these character. Moderate heritability with high genetic advance in percentage of mean were found in number of secondary branches per plant and number of siliqua per plant that revealed the existence of additive gene action. Therefore, these characters could be improved through selection process. Days to 50% flowering, plant height, number of primary branches per plant, length of siliqua and number of seed per siliqua showed low heritability with low genetic advance and genetic advance in percentage of mean. As a whole, the low heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes for improvement of the crop.

Study on correlation revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, thousand seed weight (Both genotypic & phenotypic level).

Path co-efficient analysis revealed that days to 50% flowering , days to maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant , number of seeds per siliqua and thousand seed weight had the positive direct effect on yield per plant. Siliqua length had the negative direct effect on yield per plant.

Selection was carried out among the twenty F_3 and F_4 materials of *Brassica rapa*for most promising plants with high yield and a short duration. The performance of the segregating materials also compared with three check varieties. Based on the variability and as per our objectives twenty one most promising plants with short duration and higher yield were selected from the twenty F_3 and F_4 populations.

REFERENCES

Abideen, S.N.U., Nadeem, F. and Abideen, S.A. (2013). Genetic Variability and Correlation Studies in *Brassica napus*. Genotypes. *Int. J. Innov. Appl. Stud.*2(4): 574-581.

Afrin, K.S. (2009). Genetic variability, interrelationship, path coefficient and genetic diversity analysis in *Brassica napus*L. M.S. Thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

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

Ahmed, M.R. (1993). Study of agronomic value of resynthesized rapeseed lines and early generations of crosses "rsyn-lines x improved varieties. *Iranian J. Agril. Sci.***24**(3/4):1-13.

Alam, M.F. (2010). Variability studies in F_4 progenies of *Brassica rapa*obtained through intervarietal crosses. M.S. thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Alam, M.S., Rahman, A.R.M.S. and Khair. A.B.M.A. (1986). Genetic variability and character association in groundnut (*Arachishypogaea* L.). *Bangladesh J. Agron.***10**(4): 9-16.

Ali,Y., Farhatullah, Rahman, H., Nasim, A.,Azam, S.M. and Khan, A. (2013). Heritability and correlation analysis for morphological and biochemical traits in *Brassica carinata* . *Sarhad J. Agric.***29**(3): 359-369.

Allard, R.W. (1960). Principles of Plant Breeding. John Willey and Sons. Inc. New York.

Andrahennadi, C.P., Weerasena, L.A. and Aberyrantne, M.D.R.S. (1991). Evaluation of brown mustard germplasm in Srilanka. *CruciferaeNewsl*. **14**(15): 62-63.

Anonymous, (2005). FAO Production Year Book, Food and Agricultural Organization of United Nations, Rome 00108, Italy. **57.** pp. 115-133.

Ahlawat, A. K., Singh,S., and Singh, A.M., (2006). Genotypic and phenotypic variability in indian mustard.*New Botanist*. Vol. **33**: 99-105

Ara, S. (2010). Variability, Correlation and Path Coefficient in segregating population of *Brassica rapa*obtained through intervarietal crosses. M.S. thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Arthamwar, D.N., Shelke, V.B. and Ekshinge, B.S. (1995). Correlation and regression studies in mustard. Marathwada Agricultural University. *Indian J. Maharashtra. Agril. Univ*.**20**(2): 237-239.

Aytac, Z. and Kinaci, G. (2009). Genetic variability and association studies of some quantitative characters in winter rape seed (*Brassica napus* L.). *African J. Biotech.***8**(15): 3547-3554.

Aytac, Z., Kinaci, G. and Kinaci, E. (2008). Genetic variation, heritability and path analysis of summer rape seed cultivars. *J. Appl. Biol. Sci.***2**(3): 35-39.

Banerzee, H.T., Bhattacharjee, H. and Das, M. (1968). A note on there relationship between growth and yield of the yellow sarsonvar.prain. *Indian J. Agron*.**13**: 203-204.

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. (2010). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka. p. 194

BBS. (2011a). Statistical Yearbook of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka. p.477

BBS. (2011b). Yearbook of Agricultural Statistics of Bangladesh. Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka. p.101

BBS. (2011c). Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Ministry Planning, Govt. Peoples Rep. Bangladesh, Dhaka. p.322

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.

Bhardwaj, R.P. and Singh, R.R. (1969). Morphological and genetic variability in brown sarson (*Brassica campestris* var. brown sarson). *Madras Agric. J.***56**(1): 28-31.

Bhuiyan, M.S.R. (2012). Research and development of oilseeds: Past, present and future. Proc. nat. work. on research achievement of past ten years of pulses and oilseeds and future research strategies for sustainable crop production, Mar. 20-21, BARC, Dhaka, Bangladesh. pp. 23-41.

Biswas, K.P. (1989). Performance evaluation of 4th genotype of oleiferous*Brassica*. Proceeding of the 14th Annual Bangladesh Sci. Conf.

Burton, G.W. (1952). Quantitative inheritance in grass pea. Proc. 6thGrassl. Cong. **1**: 277-283.

Campbell, D.C. and Kondra. Z.P. (1978). Relationship among growth patterns, yield components and yield of rapessed. *Canadian. J. P1ant Sci.***58:** 87-93.

Chandola, R.F., Dixit, P.K., Sharina, K.N. and Saxena, D.K. (1977). Variability in *B.juncea* under three environments. *Indian J.Agric. Sci*.**47**(9): 680-683.

Chatterjee, S.D. and Bhattarcharya, B. (1986). Selection index in Indian mustard. *Indian J.Agric. Sci.***56**: 208-209.

Chaturvedi, G.S., Singh, B.B. and Chauhan. Y.S. (1988). Physiological analysis of yield in Indian mustard under irrigated condition. *Indian J. Plant Physiology*.**31**(1): 38-44.

Chaudhury, P.K. and Kumar, A. (1990). Association and Interdependence of morphophysiological characters under moisture stress in *Brassica. BeitrageZarTropichenLanduitshaft*.**18**(1): 43-47.

Chauhan, J. and Singh, P. (1995). Association of some morpho-physiol determinants with seed yield in toria (*Brassica campestris* L var. *toria*). Thesis Abst. **11**(1): 42-43.

Chay, P. and Thurling, N. (1989). Identification of Genus controlling siliqua length in spring rapeseed and their utilization for yield improvement. *Plant Breed*.**103**(1): 54-62.

Chen, C., Hwu, K.K., Liu, C.P. and Lin, M.S. (1983). Selection criteria for yield improvement in rape. *J. Agric. Asso. China*.**124**:63-73.

Chowdhury, B.D., Thakural. S.K., Singh, D.P. and Singh, P. (1987). Genetics of yield and its components in Indian mustard. *Narenda Deva J. Agril. Res.***3**(1): 37-43.

Clarke, G.M. (1973). Statistics and Experimental Design. Edward Arnold. London. pp. 230-240

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

Dastidar, K. K. G. and Patra, M. M. (2004), character association for seed yield components in Indian mustard (*Brassica juncea*L.Czem and Coss). *Ann.Agri.Bio.Res*. 9 : 155-160.

Das, K., Barua, P.K. and Hazarika, G.N. (1998). Genetic variability and correlation in Indian mustard. *J. Agril. Sci. Soc. North East India*.**11**(2): 262-264.

Das, M.L., and Rahman, A., Khan, M.H.R. and Miah, A.J. (1984). Correlation and path co-efficient studies in soybean. *Bangladesh. J. Bot*.**13**(1): 1-5.

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

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.

Dhillor, S.S., Labana, D.S. and Ahuja, K.L (1990). Association analysis in Indian mustard. *J.Agric. Res.***27**(3): 385-388.

Dileep, K., Arvind, S.V.K., Bali, D. and Kumar, K. (1997). Correlation and regression studies between different yields attribute and yield in mustard (*Brassica juncea* L.) *Part Univ.Agric. Tech*.**14**(2): 202-206.

Diwakar, M.C. and Singh, A.K. (1993). Correlation and path analysis of yield and yield attributes of toria (*Brassica rapa*var*napus*). *Indian J. Agril. Sci*. **63**(4):263-266.

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.

Ghosh, D.V. and Mukhopadhyay, D. (1994) Path analysis of yield and yield attributes of toria (*Brassica rapa* var. napus) as affected by date of sowing and plant density. *Indian J.Agril. Sci.***64**(1): 56-58.

Gupta, M.L. and Labana, K.S. (1985). Effect of selection for seed size and its correlated responses in Indian mustard. *Crop Improve.* **12**: 193-194.

Gupta, M.L., Lahana, K.S. and Badwal, S.S. (1987). Correlation and path co-efficient of metric traits contributing towards oil yield in Indian mustard. International rapeseed congress, Poznan. Poland.

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

Hasina, C. H. andAlam, H. F. (1990). Biometrics studies of yield in segregating population in Korean Iespedeza. *Agron. J.***48**: 261-264.

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.

Hossain, M.D. (2013). Food for the poor:achievement and challenges. The Daily Star.March 20.

Hosen, M. (2008). Variability, correlation and path analysis in F_3 materials of *Brassica rapa*. MS Thesis, Department of Genetic and Plant Breeding, SAU, Dhaka.

Islam, M.S. (2013). Variability among advanced lines in *Brassica rapa*. MS thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Jahan, N. (2008). Inter-genotypic variability and genetic diversity analysis in F_4 lines of *Brassica rapa*. MS thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Jain, A.K., Tiwaari. A.S. and Kushwah. V.S. (1988). Genetics of quantitative traits in Indian mustard. *Indian J. Genet. Plant Breed*.**48**(2): 117-119.

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

Kachroo, P. and Kumar, S. (1991). Genetic determination of seed yield through its components in mustard (*Brassica juncea* L.), *Indian J. Genet. Plant Breed.***17**(1): 82

Karim, M.M., Siddika, A., Tonu, N.N., Hossain, M. D., Meah, B. M.,Kawanabe. T., Fujimoto, and R. Okazaki, K.(2014). Production of high yield short Duration *Brassica napus* by interspecific hybridization between *B. oleracea* and *B. rapa*. *Breed Sci*. **63**(5): 495-502.

Katiyar, A.P. and Singh, B. (1974). Interrelationship among yield and its components in Indian mustard. *Indian J.Agric. Sci*.**44**: 287-290.

Katiyar, B.S., Lee. J. I. and Chae, Y.A. (1974). Genetic studies on some agronomic characters in rapeseed. *Korean J. Plant Breed*.**21**(1): 22-27.

Khan, R.S.A. and Khan, F.A. (2003). Evaluation of genetic potential of some *Brassica*germplasm collections. *Int. J. Agric. Biol*.**6**(4): 30-31.

Khan, F. U., Uddin, R., Khalil, I. A., Khalil, I. H. and Ullah, I. (2013). Heritability and genetic potential of *Brassica napus* genotypes for yield and yield components. *American-Eurasian J. Agric. Environ. Sci*. **13**(6):802-806.

Khan, M.H., Bhuiyan, S.R., Rashid, M.H., Ghosh, S. and Paul, S.K. (2013).Variability and heritability analysis in short duration and high yielding *Brassica rapa*L. *Bangladesh J. Agril. Res*.**38** (4): 647-657

Khera, M.K. and Singh, P. (1988). Sensitivity and performance of some *Brassica napus* genotypes in stress and non-stress environments. *Crop improvement*.**15**(2): 209-211.

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

Knott, D.R. (1972). Effects of selection for F_2 plant yield on subsequent generations in wheat. *Canadian. J. Plant Sci*.**52**: 721-726.

Kudla, M. (1993). Comparative analysis of winter swede rape genotypes. *BiuletyninstytutuHodowliRoslin*.**90**: 99-107.

Kumar, C.H.M.V., Arunachalam, V. and Rao, P.S.K. (1996). Ideotype and relationship between morpho-physiological characters and yield in Indian mustard (*B. juncea*). *Indian J. Agril. Sci*.**66**(1): 14-17.

Kumar, N., Bisht, J.K. and Joshi, M.C. (1988). Correlation and discriminant function of analysis in Indian mustard. *Indian J. Agric. Sci*. **58**(I): 51-52.

Kumar, P., Yadava, T.P. and Yadav, A.K. (1984). Association of seed yield and its component traits in the F_2 generation of Indian mustard. *Indian J. Agric. Sci*. **54**(7): 604-607.

Kumar, V. and Singh, D. (1994). Genetics of yield and its components in Indian mustard (*Brassica juncea* L. Czern and Coss). *Crop Res*. **7**(2): 243-246.

Kwon, B.S., Lee, J.I. and Chae, Y.A. (1989). Genetic studies on some agronomic characters in rapeseed, *Korean J. Plant Breed*.**21**(1): 22-27.

Kumar B., Pandey, A. and Singh S.,(2013). Genetic diversity for agro-morphological and oil quality traits in indian mustard (*Brassica juncea* L. Czern&Coss). *The Bioscan*. **8**(3): 771-775.

Labana, K.S., Chaurasia, B.D. and Singh. B. (1980). Genetic variability and inter-character associations in the mutants of Indian mustard. *Indian J. Agric. Sci*.**50**(1): 803-806.

Lebowitz, R.J. (1989). Image analysis measurements of repeatability estimates of siliqua morphological traits in *Brassica campestris* L. *Euphytica*.**43**(1-2): 13-116.

Lekh, R., Hari, S., Singh, V.P., Raj, L. and Singh, H. (1998). Variability studies in rapeseed and mustard. *Ann. Agril. Res*.**19**(1): 87-88.

Lodhi, B., Thakral, N.K., Avtar, R. and Sin, A. (2014). Genetic variability, association and path analysis in Indian mustard. *J. Oilseed Brassica*.**5**(1):26-31.

Lodhi, G.P., Singh. R.K. and Sharma, S.C. (1979). Correlated response in brown sarson. *Indian J. Genet*.**39**: 373-377.

Mahak, S., Singh, H.L., Satyendra and Dixit, R.K. (2004). Studies on genetic variability, heritability, genetic advance and correlation in Indian mustard [*Brassica juncea (L.)* Czern and Coss.]. *Plant Archives*.**4**(2): 291-294.

Mahla, H.R., Jambhulkar,S.J., Yadav, D.K. and Sharma, R. (2003). Genetic variability, correlation and path analysis in Indian mustard [*Brassica juncea*(L.) Czern and Coss.]. *Indian J. Genet. Plant Breed*.**63**(2): 171-172.

Mahmood, T., Ali, M., Iqbal, S. and Anwar, M. (2003). Genetic variability and heritability estimates in summer mustard (*Brassica juncea*). *Asian J. Plant Sci*.**2**(1): 77-79.

Mahmud, F., Rasul, M.G and Rahim, M.A. (2008). Genetic diversity analysis in some advanced lines of *Brasssicanapus*.*Sci. Asia*.**34**:432-434.

Mahmud, M.A.A. (2008). Intergenotypic variability study in advanced lines of *Brassica rapa*. MS Thesis, Department of Genetics and Plant Breedig, SAU, Dhaka.

Malek, M.A., Das, M.L. and Rahman, A. (2000). Genetic variability, character association and path analysis in rapeseed. *Bangladesh J. Agril. Sci*.**27**(1): 25-59.

Malik, M.A., Khan, A.S., Shafiullah, Khan, M.A., Khan, B.R. and Mohamand, A.S. (2000). Study of correlation among morphological parameters in different varieties/accessions of *Brassica* species. *Pakistan J. Biol. Sci.***3**(7): 1180-1182.

Malik. V., Singh, H. and Singh, D. (1995). Gene action of seed yield and other desirable characters in rapeseed. *Analysis Biol*.**11**(1/2): 94-97.

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.

Mili, S.M.S.K (2014). Genetic variability and character association in F_5 population of *Brassica* napus L.MS thesis, Dept. of Genetics and Plant Breeding, SAU, Dhaka.

Miller, P.A. Williams, J.G., Robinson, H.F. and Comstock, R.E. (1958). Estimates of genotypic and environmental variances and co-variances in upland cotton and their implication in selections. *Agron J.***501**: 126-131.

Mishra, L. K. and Verma, R. K. (1988). Correlation and Path Co-efficients analysis for morphological and quality traits in rice (*Oryza sativa* L.). *Plant Arc. **2***(2): 275-284.

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

Nanda, R., Bhargava, S.C. and Tomar, D.P.S. (1995). Rate and duration of siliqua and seed filling and their rotation to seed yield in *Brassica species. Indian J. Agric. Sci*.**64**(4): 227-232.

Nasim, M., Rahman, L., Quddus, M.A. and Shah-E-Alam, M. (1994). Correlation and path analysis in *Brassica campestris* L. *Bangladesh J. Agril. Sci*.**21**(10): 15-23.

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

Olsson, G. (1990). Rape yield-production components. *SverskFortidning*. **59**(9): 194-197.

Pankaj, S., gyanendra, T., Gontia, A.S., Patil, V.D. and Shah, P (2002) correlation studies in Indian mustard. *Agric. Sci. Digest*.**22**(2): 79-82.

Parveen, S. (2007). Variability study in F_2 progenies of the inter-varietal crosses of *Brassica rapa*. MS thesis, Department of Genetics and Plant Breeding, Shere-e-Bangla Agricultural University, Dhaka.

Pasne, C. N. and Maurya, D. M. (1992). Genetic Diversity in Breeding Lines of Two Crosses in Rainfed Lowland Rice. *Oryza*.**29**: 89-91.

Paul, N.K., Joarder, O.I. and Eunus, A.M. (1976). Genotypic and phenotypic variability and correlation studies in *B. juncea* L. *Zeitschrifl fur pflazenzuchtun*.**77**(2): 145-154.

Ramanujam, S. and Rai, B. (1963). Analysis of yield components in *Brassica campestris* var. yellow sarson. *Indian J.Genet*.**23**: 121-143.

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. (2012). Correlation analysis in different planting days of rapeseed varieties. Agricultual and Natural Resources Research Centre of Mazandran, Sari, Iran. *J. Agril. Sci.*.**7**(2): 123-126.

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

Rao, T.S. (1977). Genetics of yield components in brown sarson. *GeneticaIberica*. **29**(3/4): 219-227.

Rashid, M.H. (2007). Characterization and diversity analysis of the oleiferous*Brassica* species. MS thesis, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka.

Razzaque, M., Karim, M. A. (2007). Salinity problems and crop production in Bangladesh. *Bangladesh J. Agril. Sci*. **18**: 15-19.

Reddy, N.N. (1991). Correlation studies in Indian mustard (*Brassica juncea* L. Czern and Coss.). J. *Oilseeds Res*.**8**(2): 248-250.

Sabesan, T., Suresh, R. and Saravanan, K. (2009).Genetic Variability and Correlation for Yield and Grain Quality Characters of Rice Grown in Coastal Saline Low Land of Tamilnadu. *Electronic J. Plant Breed*.**1**: 56-59.

Saleh,M. A., (2009). Variability analysis and selection from F_2 materials generated through inter-varietal crosses of *Brassica juncea*. M.S. thesis, Department of Genetics and Plant Breeding, SAU, Dhaka.

Saini, H.C. and Kumar, R.P. (1995). Model plant architecturer through association and path co-efficient analysis in Indian Colza. *Indian J. Agril. Res.***29**(3): 109-115.

Seitzer, J.F. and Evans, L.E. (1978). Yield gains in wheat by pedigree method of selection and two early yield test. Z. *Pflanzenzuchtg.***80**: 1-10.

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

Sharma, S.K. (1984). Variation and correlation studies in Indian mustard (*B. juncea*). *Indian J. Agril. Sci*.**54**(2): 146-147.

Sharma, S.K., Rao, D., Singh, D.P., Harbir, S. and Singh, H. (1994). Correlation analysis of yield, biomass and its partitioning components in Indian mustard (*Brassica juncea* L. Czern. Coss.). *HarianaAgril. Univ. J. Res.***27**(2-4): 149-152.

Sheikh, F.A., Rathen, A.G. and Wani, S.A. (1999). Path analysis in toria (*Brassica campestris* L.) var. toria. *Adv. Plant Sci.***12**(2): 385-388.

Sheikh, F.A., Shashibanga, S.S., Najeeb, G.A. and Rather, A.G. (2009). Hybridization of Ethiopian mustard and *Brassica napus* assisted through cytogenetic studies. Department of Plant Breeding Genetics and Biotechnology, Punjab Agricultural University, Ludhiana, 141004, India.

Shivahare, M.D., Singh, A.B., Chauhan, Y.S. and Singh, P. (1975). Path co-efficient analysis of yield components in Indian mustard. *Indian J. Agric. Sci.***45**(9): 422-425.

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

Singh, A., Yadava, T.P., Asawa, B.M. and Gupta, V.P. (1978). Note on path coefficient analysis in Indian mustard. *Indian J. Agric. Sci.***48**(10): 622-623.

Singh, B. (2004). Character association and path analysis under dryland condition in Indian mustard (*Brassica juncea*L.). *CruciferaeNewsl.***25**: 99-100.

Singh, H. (1986). Genetic variability, heritability and drought indices analysis in *Brassica* species. *J. oilseeds Res.***3**(2): 170-177.

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

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

Singh, R.P., Malik, B.P.S. and Singh, D.P. (1987). Variation for morphological characters in genotypes of Indian mustard. *Indian J. Agric. Sci.***57**(4): 225-230.

Singh, R.S., Singh, P. and Dixit, R.K. (1987). Combining ability analysis of yield and developmental traits in Indian canola (*Brassica campestris* L. var. yellow sarsonprain). *Farm Sci.***12**(2): 170-174.

Srivastava P.P., Salara. B.S. and Gowda, M.V.C. (1983). Variability and correlation studies in groundnut (*Arachishypogaea*). *Crop improv.***25**(1): 122-123.

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

Swain, S.K. (1990). Correlation and path analysis in brown sarson (*Brassica campestris* var. dichotoma watt.). *Orissa J. Agril. Res.***3**(3-4): 197-200.

Tak, G.M. (1976). Correlation and path analysis of the yield components in the three forms of *Brassica campestris* L. *Crop Improvement.***3**(2): 43-52.

Teresa, W. (1987). Selection criteria of winter rape single plant and its seed yield. **In**: 7th International Rapeseed Congress, Poland.

Thakral, N.K. (1982). To study the association of some morphophysiological attributes with yield in toria (*B. campestris* Var. *Toria*). Thesis abstr.**8**(1): 66-67.

Thakral, N.K., Yadava, T.P., Kumar. P., Singh, A. and Chandra, N. (1999). Association analysis for some quantitative traits in Indian mustard. *CruciferaeNewsl*.**21**: 105-106.

Thurling, N. (1983). Variation in pod length in spring rape (*B. napus*) and its relationship to yield. **In**: Proceedings, Australian Plant Breeding conference. Adelaide, South Australia. pp. 14-18.

Tuncturk, M. and Ciftci, V. (2007). Relationships between yield and some yield components in rapeseed (*Brassica napus*ssp. *Oleifera*L.*)* cultivars by using correlation and path analysis. *Pakistan J. Bot*.**39**(1): 81-84.

Tusar, P., Maiti, S. and Mitra, B. (2006). Variability, correlation and path analysis of the yield attributing characters of mustard (*Brassica* spp.). *Res. Crops.***7**(1): 191-193.

Tyagi, M.K., Chauhan. J.S., Kumar, P.R. and Singh, K.H. (2001). Estimation of heterosis in Indian mustard [*Brassica juncea* (L.) Czern and Coss.]. *Annals Agric. Biol. Res*.**69**(2):193-200.

Tyagi, P.K., Singh, K., Rao, V. and Kumar, A. (1996). Correlation and path coefficient analysis in Indian mustard (*Brassica juncea* L.). *Crop Res. Hisar*.**11**(3): 319-322.

Uddin, M.J. (1994). Genetic divergence in mustard. *Bangladesh J. Plant. Breed.Genet.***7**(2): 23-27.

Uddin, M.J., Chowdhury, M.A.Z. and Miah, M.F.U. (1995). Genetic variability, character association and path analysis in Indian mustard *(Brassica juncea L.). Annals. Bangladesh Agril.***5**(1): 51-52.

Verma, R., Sharma,R. and Sharma, S. K.(2008) Association studies among yield and its component characters in Indian mustard (*Brassica juncea*L). *Indian J. Genet*. **68**(1): 87-89.

Varshney, S.K., Rai, B. and Singh, B. (1986). Component analysis of harvest index in *Brassica* oilseeds. *Indian J. Agric. Rev*.**20**(3): 129-134.

Walker, K.C. and Booth, E.J. (2001). Agricultural aspects of rape and other Brassica products. *Europian. J. Lipid. Sci. Technol*.**103**: 441-446

Wan, Y.L. and Hu, G.C. (1983). Studies on heritability, genetic correlations and genetic advances of the major characters in rape. *Chinese Oil Crops*.**1**: 1-7.

Yadava, O.P., Yadav, T.P. and Kumar, P. (1996). Combining ability studies for seed yield, its components characters and oil content in Indian mustard (*Brassica juncea*L. Czern and Coss.). *J. Oilseed Res*.**9**(1): 14-20.

Yadava, T.P. (1973). Variability and correlation studies in *Brassica juncea* L. Czern and *Coss. Madras. Agric. J*.**60**: 1508-1511.

Yadava, T.P., Yadav, A.K. and Singh, H. (1978). A concept of plant Ideotype in Indian mustard (*B. juncea* L. Czern and Coss). 5th International Rapeseed Conference.

Yadava, Y.P., Singh, H. and Singh, D. (1993). Gene action for seed yield and its attributes under research. *Indian J. Genet. Plant Breed*.**6**(1): 168-172.

Yarnell, S.H. (1956). Cytogenetics of vegetable crops 11. *Crucifers Bot. Rev.* **22**(2): 18-166.

Yin, J.C. (1989). Analysis on ecological, physiological and production characteristics of high quality rapeseed cultivars. *Acta Agric. Shanghae*.**5**(4): 25-32.

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

Zajac, T., Bieniek, J., Witkowiez, R. and Gierdziewicz, M. (1998). Individual share of field components in winter oilseed rape yield formation. *Academia RolniezawKraikowie,Poland*.**19**(2): 413-422.

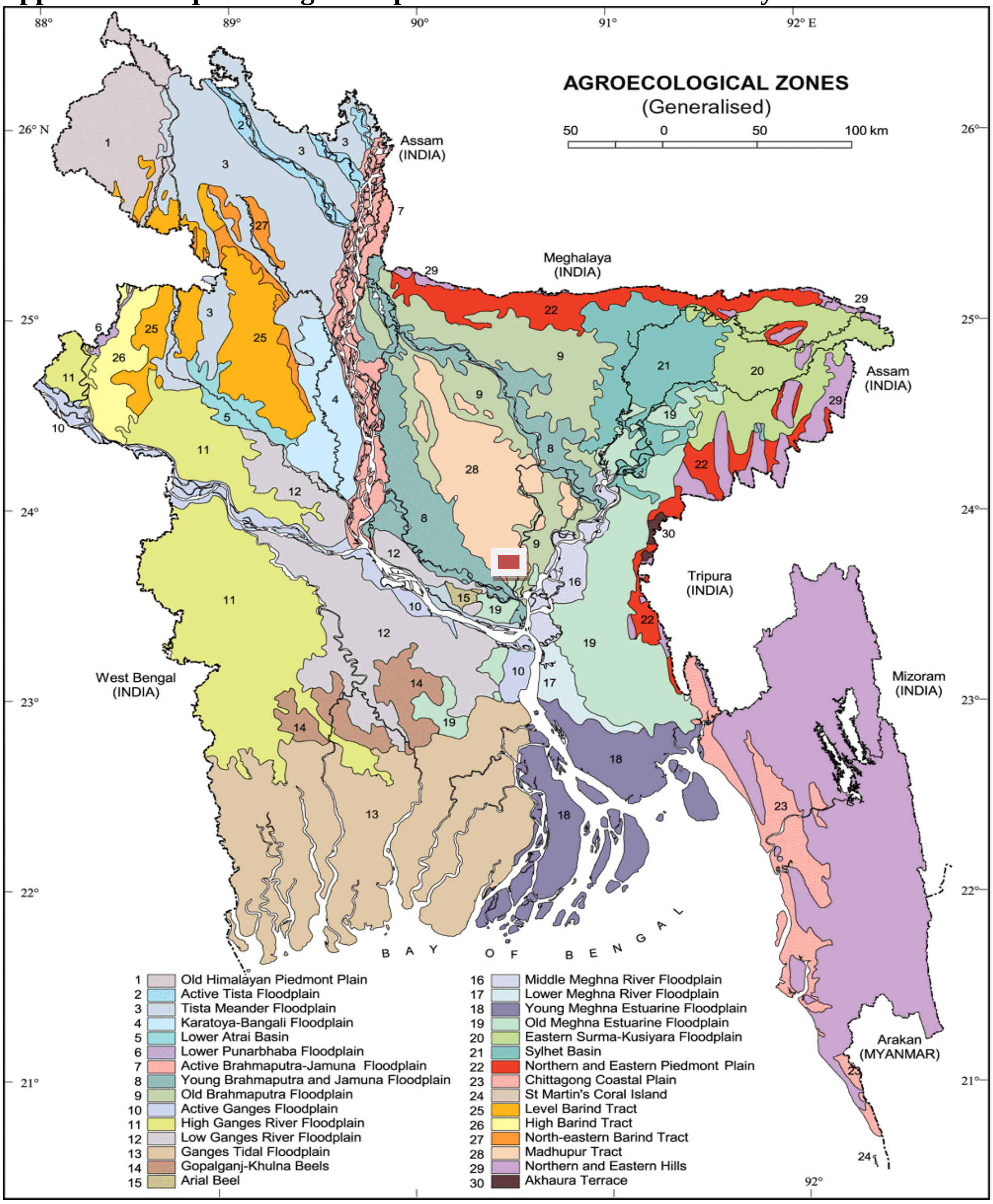
Zaman, M.W., Talukder, M.Z.I., Biswas, K.P. and Au, M.M. (1992). Development allometry and its implication to seed yield in *Brassica napus* L. *SverigesUtsades foreign Tidskrift*.**102**(2): 68-71.

Zebarjadi, A., Kakaei, M. and Mostafaie, A. (2011). Genetic variability of some traits in rapeseed (*Brassica napus* L.) under draught stress and non-stress condition. *Biharean Biologist*, *Oradea*.**5**(2):127-131.

Zuberi, M.I. and Ahmed, S.V. (1973). Genetic study on yield and some of its components in *Brassica campestris* var. *toria*. *Crop. Sci*.**13**: 13-15.

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

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

A. Physical composition of the soil

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 from November, 2013 to february, 2014

Month	Air temperature (ºc)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2013	28.10	6.88	58.18	1.56	**5.8**
December, 2013	25.36	5.21	54.30	0.63	**7.9**
January, 2014	21.17	15.46	64.02	0.00	**3.9**
February, 2014	24.30	19.12	53.07	2.34	**5.7**

Source: Weather station, Sher-e-Bangla Agricultural University, Dhaka-1207.