SELECTION OF PROMISING LINES BASED ON CHARACTER ASSOCIATION IN *Brassica rapa* L.

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CERTIFICATE

This is to certify that the thesis, entitled ***"SELECTION OF PROMISING LINES BASED ON CHARACTER ASSOCIATION IN Brassica rapa L."****, submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in GENETICS AND PLANT BREEDING****, embodies the result of a piece of bona fide research work carried out by* ***Nargis Akter****, Registration No.* ***10-03821,*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2016
Place: Dhaka, Bangladesh

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ABSTRACT

A research was conducted by using six F_5 and three F_8 populations generated through inter-varietal crosses of *Brassica rapa* L. and grown in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2015 to February 2016 to study the variation in different characters, correlation between pairs of different characters and the direct and indirect effects of different traits on yield of the F_5 and F_8 materials to select high yielding and early mature plants. Considering genetic parameters, comparatively phenotypic variances were higher than genotypic variances for all characters studied. Number of primary branches per plant, number of secondary branches per plant, length of siliqua, number of seed per siliqua, thousand seed weight and yield per plant 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, thousand seed weight and yield per plant. The highest yield per plant (11.95 g) was found in BARI sarisha-6×BARI sarisha-15 S_1F_5. The advanced line BARI sarisha-6×BARI sarisha-15 S_2F_8 matured early (80.33 days) and produced moderate yield (4.35 g/ plant). The highest GCV (79.55 %) and PCV (79.62 %) were observed in number of secondary branch per plant. Number of siliqua per plant showed high heritability (96.69%) along with high genetic advance (88.55) and high genetic advance in percentage of mean (73.66%). The highest genetic advance (88.55%) was found for number of siliquae per plant. Moderate heritability (39.30%) with low genetic advance (3.06) was found for days to maturity. Yield per plant had non-significant and positive correlation with days to maturity, plant height, number of secondary branches per plant, number of siliqua per plant, siliqua length and thousand seed weight. The path co-efficient analysis revealed that number of siliqua per plant had the highest positive direct effect followed by number of seed per siliqua, number of secondary branches per plant and days to maturity. Populations of four most promising lines with higher yield were selected from different nine crosses of the F_5 and F_8 populations of *Brassica rapa* L.

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Dated: June, 2016 ***The Author***

Place: Dhaka, Bangladesh.

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(Nargis Akter)

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Abbreviations		Full word
°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
CEC	=	Cation Exchange Capacity
cm	=	Centimeter
CV%	=	Percentage of Coefficient of Variation
DAS	=	Days After Sowing
df	=	Degrees of Freedom
et al.	=	And Others
etc.	=	Etcetera
F_5	=	The 5th Generation of A Cross
F_8	=	The 8th Generation of a Cross
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
G	=	Genotype
hr.	=	Hour (s)
j.	=	Journal
kg	=	kilogram (s)
m	=	Metre
M.P.	=	Muriate of Potash
m^2	=	Meter Square
No.	=	Number
NS	=	Non Significant
R	=	Residual Effect
RCBD	=	Randomized Complete Block Design
SAU	=	Sher-e-Bangla Agricultural University
SE	=	Standard Error
T.S.P.	=	Triple Super Phosphate
t/ha	=	Tons per Hectare

CHAPTER I

INTRODUCTION

The species *Brassica rapa*, commonly known as field mustard or turnip mustard belonging to the family Brassicaceae (Naznin *et al*., 2015), is an important vegetable and oil seed crop growing in different parts of the world including Canada, China, Northern Europe and the Indian subcontinent (Islam *et al*., 2015). It has a great genetic diversity. Genetic diversity is the result of geographical separation or genetic barriers to cross ability and it plays a vital role in plant breeding (Jahan *et al*., 2013).

Brassica species can be grouped into cole, rapeseed and mustard. The rapeseed group includes *Brassica rapa* L. and *Brassica napus* L. The genetic constitution of *Brassica rapa* is AA and of *Brassica napus* is AACC (Islam *et al*., 2015). The mustard group includes *Brassica juncea* and *Brassica nigra*. The genetic constitutions of these two are AABB and BB respectively.

The species *Brassica* is popular for its multipurpose uses. Cole is consumed as vegetables and great source of edible oil and protein. Mustard oil is also used for hair dressing, body massing and preparing different types of pickles. It is also well known for several medicinal values (Islam *et al*., 2015).The seeds of *Brassica rapa* L. contain 42% oil and 25% protein (Khaleque, 1985). It is also a vital source of raw material for making soaps, paints, hair oils, lubricants, textile auxiliaries, pharmaceuticals and so on (Naznin *et al*., 2015). Moreover, the most important livestock feed is oil cake. Oil cake is also used as organic manure (Islam *et al*., 2015).

Rapeseed and mustard is in the second most important edible oil source in the world after soybean (FAO, 2014). Total area of mustard and rapeseed in the world is 34.33 million hectares (FAO, 2013). In 2012-2013, the edible oil production from major oilseed crops in the world is 497.9 million tons where rapeseed contributes 64.3 million tons (FAO, 2014).

In Bangladesh, *B. rapa* is the main oil yielding species of *Brassica* (FAO, 2013). Among the oil crops grown in Bangladesh *Brassica rapa* L. occupies the first position in respect of area and production (Naznin *et al*., 2015). During 2014-15, about 803 thousand acres of land was under rape and mustard cultivation where produced about 359 thousand tons of seed, and national average yield was 447 kg/acre in this country (BBS, 2015). Still the production is very low against the requirement of the country. In the year of 2013, the utilization of oil seed in Bangladesh was 1.8 million tons where 1.6 million tons was imported (FAO, 2013). So, it is very clear that the country is facing huge shortage in edible oils and a large portion of total edible oil consumed annually is imported (Islam *et al.*, 2015). The use of low yielding indigenous cultivars, improper management practices and reduction of cultivation area are the top causes behind these. But there is a limited scope for horizontal expansion of its cultivation due to the pressure of other crops. Therefore, production per unit area must be risen to rise the total production. Moreover the crop should fit in the cropping pattern (Naznin *et al*., 2015).

Brassica rapa is more popular than *Brassica napus* because of its earliness of flowering and maturity and lower fibre content in meal, low content of saturated fatty acid in oil and reduced silique shattering of yellow seed. On the other hand, though *Brassica napus* is more productive, late maturing and shattering habit are the main barriers to be an oil crop. A few varieties are available which produce reasonable amount of per hectare yield with maturity duration of 85-90 days. Still there is scope to lower maturity duration further without much lowering the yield. Separate crossing programmes were thus initiated six and nine years ago that ultimately led to the selection of six F_5 and three F_8 populations, the comparison of which will be carried out to select the higher yielding and short duration lines for future release.

Objectives

The study, therefore, was carried out with the following objectives:

(i) to compare yield and yield contributing traits among the different lines and to study the variability among F_5 and F_8 generation materials for selection of desired lines,

(ii) to study the inter-relationship and effect of characters on yield and

(iii) to select early maturing and high yielding lines for future release.

CHAPTER II

REVIEW OF LITERATURE

Brassica has drawn the attention of researchers of different countries of the world causing extensive researches on *Brassica* breeding for its improvement in respect of yield and yield contributing traits. A large number of literatures are available concerning this study. Some of them are discussed here.

2.1 Genetic variability, heritability and genetic advance in *Brassica spp.*

To develop high yielding varieties it is necessary to introduce successful breeding program with genetic variability. A lot of research works have been done regarding this variability. Some literatures concerning this are discussed here.

An experiment, conducted by Helal *et al*. (2014), showed that varieties produced the highest seed yields and 15% variation at genotypic and phenotypic level.

Mili (2014) conducted a field experiment using 66 F_5 genotypes of *Brassica napus* L. to study the genetic diversity, variability. She found the genotypes significantly variable for most of the characters and comparatively higher phenotypic variances than the genotypic variances for all the characters studied. Moreover, there were higher PCV 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) used thirty F_7 segregating lines and two parents of *Brassica rapa* for studying variability, heritability and genetic advance. The result revealed significant variation presented among all the genotypes for all the traits except thousand seed weight. Highest genotypic, phenotypic and environmental variances were observed in plant height. On the contrary, the lowest one was in length of siliquae followed by thousand grain weight. High heritability along with low genetic advance in percent of mean was found in thousand seed weight, number of secondary branches per plant, seeds per siliquae, and siliquae length but moderate heritability with high genetic advance was 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 fit for future breeding program.

An experiment was conducted by Abideen *et al.* (2013) to study the genetic variability and correlation among different traits in *Brassica napus*. Results showed highly significant differences among the genotypes for most of the characters. Non significant differences were noticed among the genotypes for primary branches and pods.

An evaluation made by Rameeh (2013) using twenty four rapeseed genotypes including two cultivars and 22 advanced lines based on randomized complete block design with three replications. Significant genotype effects were displayed for phenological traits, plant height, yield components and seed yield, indicating significant genetic differences among the genotypes. High broad sense heritability was estimated for phenological traits, pods on main axis and seed yield, signifying selection gain to improve these traits. Duration of flowering and pods on main axis

Belete *et al.* (2012) administered a research to estimate different genetic parameters for some agronomic traits of introduced Ethiopian mustard (*Brassica carinata* A. Brun) genotypes. The experiment was arranged in randomized complete block design having three replications at Holetta Research Center, Ethiopia. Except plant height and seed yield, analysis of variance showed significant difference among the genotypes for traits studied. The range of phenotypic coefficient of variation was between 1.2% to 10.2% and genotypic coefficient of variation ranged from 1.9% to 6.8%. The highest heritability value was observed by oil content (99.8%) succeeded 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 for oil content. For further variety development program, days to flowering, days to maturity and oil content are three important traits to be considered.

Zebarjadi *et al.* (2011) conducted an experiment to study using sixteen rapeseed genotypes in two conditions (irrigation and non-irrigation) to study some traits and to estimate genetic parameters. Statistical analysis revealed significant differences among the genotypes for 13 different traits, 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, while low genetic advance was observed for thousand kernel weight.

A research was conducted by Alam (2010) using 26 F_4 populations of some inter-varietal crosses of *Brassica rapa* to study the magnitude of variations in different traits, heritability and genetic advance. Significant variations were shown 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, thousand seed weight and yield per plant. Plant height, length of siliqua, number of siliquae per plant, days to 50% flowering displayed 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 using eight F_2 and eight F_4 populations of 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 significant variation present among all the genotypes employed 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 indicated least difference between phenotypic and genotypic variances. The value of GCV and PCV showed that there was least variation present among most of the traits. The days to maturity, length of siliqua, seeds per siliqua and thousand seed weight showed high heritability and 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).

Sheikh *et al.* (2009) studied the derivation of genetic variability in Ethiopian mustard (*Brassica carinata*) for quality traits through inter-specific hybridization. The result showed that inter-specific hybridization was used to improve the range of genetic variability in mustard for oil and meal quality traits from quality lines of *Brassica juncea*.

Saleh (2009) carried out a field experiment by exploiting twenty F_2 populations developed through inter-varietal crosses, along with three check variety of *Brassica rapa* L. to sought the variation in different traits, correlation between pairs of different traits and direct and indirect effects of different traits on seed yield per plant. From the values of mean, range and CV (%) of seed yield and yield contributing traits it was revealed that there were considerable variations present among all the genotypes exploited 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 exhibited least difference between phenotypic and genotypic variances. The value of GCV and PCV pointed out that there was least variation existing among most of the characters. The days to maturity, length of siliqua, seeds per siliqua and thousand seed weight showed high heritability along 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 unveiled 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.

Highest genotypic and phenotypic variances were reported by Aytac *et al.* (2008) 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 which revealed that additive gene effects are important in determining these traits and could be developed through mass selection.

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

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

An experiment was carried out by Jahan (2008) to study the inter-genotypic variability and genetic diversity in ten F_4 lines got through inter-varietal crosses along with eight released varieties of *Brassica rapa* L. High PCV was obtained 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 which depicted that non-additive gene effects were responsible for this character and selection of such trait might not be worthwhile. In case of plant height and days to 50% flowering high heritability with moderate genetic advance was perceived which pointed out that the trait was controlled by additive genes and selection for genetic improvement in the trait would be fruitful.

A research work was conducted by Parveen (2007) with F_2 population of some inter-varietal crosses of the species *Brassica rapa* L. for evaluating the magnitude of variations in characters, different heritability, genetic advance, character associations, direct and indirect effects of various characters on seed yield. There were significant variations among the various genotypes employed in the experiment. Contemplating genetic parameters, number of primary branches/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua, days to 50% flowering, thousand seed weight and yield/plant demonstrated least difference between genotypic and phenotypic variance. Plant height, length of siliqua, number of seeds per siliqua and days to 50% flowering depicted low genotypic and phenotypic coefficient of variation. Number of primary branches/ plant and secondary branches/ plant displayed high heritability combined with high genetic advance and very high genetic advance in percentage of mean. Nevertheless, yield/ plant, days to maturity and length of siliqua expressed low heritability. Correlation co-efficient analysis depicted that yield/ plant had non-significant positive relation 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 depicted that number of seeds/ siliqua showed highest direct effect on yield/ plant succeeded by plant height, number of secondary branches/ plant and number of siliquae/ plant. On the basis of the variability study, some F_2 plants exhibiting high heritability for yield contributing traits were selected from some of the cross combinations of the inter-varietal crosses of *Brassica rapa* L.

Ahlawat *et al.* (2006) studied genetic variability for 12 characters in 19 genotypes of Indian mustard *(Brassica juncea* L. Czern and Coss.). High phenotypic coefficient of variation was found than genotypic coefficient of variation for the characters of 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 thousand seed weight, number of siliquae per plant and plant height. Number of siliquae per plant and plant height having moderately high heritability along with high genetic advance implied that additive gene effects were significant for these characters and selection pressure could be applied on them for yield upgrade. Number of primary branches per plant and oil content had low heritability suggesting that these traits were under the impact of environmental factors.

Tyagi *et al.* (2001) reported highest variation in parents and their hybrids for plant height. Highest co-efficient of variation (41.1%) was found in seed yield per plant. Zhau *et al.* (1998) and Sengupta *et al.* (1998) found plant height to be responsive to gamma rays resulting substantially decreased plant height. Significant genetic variability was observed for this character by many workers like Kumar *et al.* (1996), Malik *et al.* (1995), Chauhan and Singh (1995), Kumar and Singh (1994), Yadava *et al.* (1993), Andarhennadi *et al.* (1991), Lebowitz (1989), Chaturvedi *et al.* (1988) and Gupta *et al.* (1987) among different genotypes of *B. napus*, *B. rapa* and *B. juncea*.

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

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

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

Katiyar *et al.* (1974) noticed high genetic co-efficient of variation for the traits of days to first flowering, plant height (cm) and seed yield per plant (g), on the contrary, low values were observed for other traits like days to maturity and number of primary branches per plant, at the time of observation 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. Lekh *et al.* (1998) recorded high genotypic and phenotypic co-efficient of variation for days to 50% flowering among 10 genotypes for each of *Brassica campestris*, *Brassica carinata* and *Brassica napus* and 24 genotypes of *Brassica juncea*.

Generally it is desirable that there is high number of seeds per siliqua. Plenty of literatures on the variability of number of seeds per siliqua are available. Kudla (1993) and later Kumar and Singh (1994) perceived significant variability in number of seeds per siliqua in oleiferous *Brassica* materials of diverse genetic base. Similar salient variability was studied by them in the genotypes of *Brassica napus*, *B. campestris* and *B. juncea*. In case of *Brassica campestris* genotypes Bhardwaj and Singh (1969) estimated GCV value of 35.85%.

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

Higher number of siliqua generally results higher seed yield. Great variation is monitored for this character. High genetic variation in number of siliqua was observed by Yin (1989) at the time of working with 8 cultivars of *Brassica napus.* Similar result of high variation for this character was also noticed by Kumar *et al.* (1996).

For the development of fruits in oil seed crops like mustard and rape seed, siliqua length is another important character. Peduncle, beak as well as siliqua length varies due to difference in genotypes. Olsson (1990) found high genetic variability for this character. Similar results were found by Lebowitz (1989) 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.

A very important character of rape seed and mustard is thousand seed weight, where the highest consideration is on the seed yield. It has been reported that this character varies widely from genotype to genotype 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.

Yield is the vital trait among various traits in every breeding program for oil crops. It is a complex trait which is influenced by various factors of production. Many 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 *Brassica juncea*.

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.

Malek *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_l< 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 and Kumar (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 *et al.* (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 Interrelationship among the traits

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, thousand 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 *et al* (2014) using ninety diverse genotypes of Indian mustard (*Brassica juncea* L. 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 the highest positive correlation with length of siliqua, number of siliqua per plant, seeds per siliqua and thousand 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 the 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, thousand 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, thousand 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, thousand 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 thousand 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 thousand 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 and Kumar (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 thousand 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 the 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 thousand 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 thousand 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 thousand 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 thousand seed weight had positive direct effect on seed yield.

Chaudhury and Kumar (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 and Chaudhary (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 METHOD

3.1 Experimental site

The experiment was conducted at the experimental field of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The duration was November, 2015 to February, 2016.

3.2 Soil and climate

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 land was medium high and the fertility level was medium. The site was in the subtropical climate zone. Climatic feature of this region was wet summer and dry winter. During the rabi season, generally the rainfall is very few, the temperature is moderate and the day length is short. 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 II).

3.3 Planting materials

Nine genotypes which were advanced lines obtained from various inter-varietal crosses of four genotypes (BARI sarisha-6, BARI sarisha-9, BARI sarisha-15 and SAU sarisha-1) were used as experimental materials. The list of the advanced lines is presented in Table1.

3.4 Methods

The following methods had been followed to carry out the experiment:

Plate 1. Photograph showing experimental field at early flowering stage

Table 1. List of materials used in the experiment

Designation	F_5 and F_8 populations	Sources
G1	SAU sarisha-1 × BARI sarisha-15 E_1F_5	SAU
G2	SAU sarisha-1 × BARI sarisha-15 E_2F_5	SAU
G3	SAU sarisha-1 × BARI sarisha-15 E_3F_5	SAU
G4	BARI sarisha-6 × BARI sarisha-15 S_1F_8	SAU
G5	BARI sarisha-6 × BARI sarisha-15 S_2F_8	SAU
G6	BARI sarisha-6 × BARI sarisha-15 S_3F_8	SAU
G7	BARI sarisha-6 × BARI sarisha-15 S_1F_5	SAU
G8	BARI sarisha-6 × BARI sarisha-15 S_2F_5	SAU
G9	BARI sarisha-9 × BARI sarisha-6 $S_{15}F_5$	SAU

3.4.1 Land preparation

The experimental field was prepared by several ploughing and cross ploughing followed by laddering and harrowing with the help of power tiller and country plough to bring about fine tilth. Weeds and other stubbles were removed carefully from the experimental field. Cowdung was applied during the final land preparation and leveled properly.

3.4.2 Manure and fertilizer application

Cowdung, urea, triple super phosphate (TSP), muriate of potash (MP), gypsum, zinc and boric acid were applied at the rate shown in table 1. Urea was applied by two installments. Total amount of TSP, MP, gypsum, zinc and boric acid along with half of the urea were applied at the time of final land preparation as a basal dose. The last half of the urea was applied as top-dressing at the time of flower initiation.

Table 2. List of fertilizers with doses and application procedures

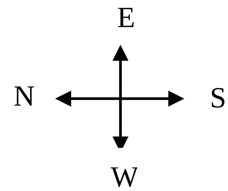
SL. No.	Fertilizer	Doses (kg/ha)	Application Procedure
1.	Urea	250	50% basal and 50% at the time of flower initiation
2.	TSP	170	as basal
3.	MP	85	as basal
4.	Gypsum	150	as basal
5.	Zinc oxide	5	as basal
6.	Boric acid	12	as basal
7.	Cowdung	10000	as basal

3.4.3 Experimental Design

After final land preparation field lay out was done. Seeds were laid out in a randomized complete block design (RCBD) with three replications. The size of the plot was 14m×22m. Each replication size was 4m×22m and distance between two replications was 75 cm. Distance between line to line was 30 cm and plant to plant was 10cm. 50cm×22m area of North was kept for path. Seeds were sown in lines in the experimental fields on 7 November, 2015. The seeds were placed at about 1.5 cm depth in the soil. All the clods were removed from the field. Seed germination started after 3 days of sowing. A pictorial view of experimental plot at flowering stage is shown 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 on time. First irrigation after sowing of seeds was given by cane to bring proper moisture condition of the soil ensuring uniform germination of seeds. For immediate release of rainwater from the experimental plot during the growing period, a good drainage system was maintained. The first weeding was done after 13 days of sowing. At the same time, thinning was done for maintaining a distance of 10 cm from plant to plant in rows



22 meter

4m		4m		4m	
R_1		**R_2**		**R_3**	
SAU-1 × BARI-15 E_1F_5 (7 lines)		SAU-1 × BARI-15 E_1F_5(7 lines)		BARI-9 × BARI-6 $S_{15}F_5$ (7 lines)	
SAU-1 × BARI 15 E_2F_5 (7 lines)		SAU 1 × BARI 15 E_2F_5(7 lines)		BARI 6 × BARI 15 S_2F_8 (8 lines)	
BARI 6 × BARI 15 S_2F_5 (6 lines)		SAU 1 × BARI 15 E_3F_5(6 lines)		BARI 6 × BARI 15 S_1F_8 (6 lines)	
BARI 6 × BARI 15 S_3F_8 (6 lines)	0.75 cm	BARI 6 × BARI 15 S_3F_8 (7 lines)	0.75 cm	BARI 6 × BARI 15 S_3F_8 (7 lines)	0.50 cm
BARI 6 × BARI 15 S_1F_5 (7 lines)		BARI 6 × BARI 15 S_2F_8 (7 lines)		SAU 1 × BARI 15 E_1F_5 (6 lines)	
SAU 1 × BARI 15 E_3F_5 (7 lines)		BARI 6 × BARI 15 S_1F_8 (6 lines)		SAU 1 × BARI 15 E_2F_5 (6 lines)	
BARI 6 × BARI 15 S_2F_8 (7 lines)		BARI 6 × BARI 15 S_2F_5 (7 lines)		BARI 6 × BARI 15 S_1F_5 (7 lines)	
BARI 9 × BARI 6 $S_{15}F_5$ (6 lines)		BARI 6 ×BARI 15 S_1F_5 (6 lines)		BARI 6 × BARI 15 S_2F_5 (6 lines)	
BARI 6 × BARI 15 S_1F_8 (7 lines)		BARI 9 × BARI 6 $S_{15}F_5$ (7 lines)		SAU 1 × BARI 15 E_3F_5 (7 lines)	

14 meter

Figure 1. Layout of the experimental design

of 30 cm apart. Second weeding was done after 21 days of sowing. Aphid infection was found in the crop during the siliqua development stage. Malathion-57 EC @ 2ml/liter of water was applied to control aphids. The insecticide was applied in the afternoon.

3.4.5 Harvesting

Harvesting was started from 12 February, 2016 and continued depending upon the maturity of the plants. The crop was evaluated to achieve maturity when 80% of the plants showed symptoms of maturity i.e., straw color of siliqua, leaves, stem and desirable seed color in the mature siliqua. Ten plants were selected at random from each progenies and a total of ninety plants from each replication were selected. The sample plants were harvested by uprooting and then tagged properly.

3.4.6 Collection of data

To study different genetic parameters and inter-relationships the following ten characters were taken into consideration:

1. Plant height
2. Number of primary branches/ plant
3. Number of secondary branches/ plant
4. Days to 50% flowering
5. Siliqua length
6. Number of siliqua/ plant
7. Number of seeds/ siliqua
8. 1000 seeds weight
9. Seed yield/ plant
10. Days to 80% maturity

3.4.7 Methods of collecting data

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

2. Number of branches/ plant: The total number of branches emerged from the main stem of a plant was enumerated as the number of primary branches per plant.

3. Number of secondary branches/ plant: The total number of branched emerged from the primary branch of a plant was enumerated as the number of secondary branches per plant.

4. Days to 50% flowering: Difference between the date of sowing to the date of 50% flowering of a line was counted as days to 50% flowering.

5. Siliqua length (cm): Measurement was taken in centimeter from the base to the tip of a siliqua without beak from five representative siliquae.

6. Number of siliquae/ plant: Total number of siliquae of each plant was counted and considered as the number of siliquae per plant.

7. Number of seeds/ siliqua: Well filled seeds were counted from five representative siliquae and considered as the number of seeds per siliqua.

8. Thousand seed weight (gm): Weight in grams of randomly counted thousand seeds was recorded.

9. Seed yield/ plant (gm): All the seeds by a representative plant were weighed in gram which was considered as the seed yield per plant.

10. Days of maturity: Number of days required from sowing to siliquae maturity of 80% plants of each entry.

3.4.8 Statistical analysis

All the collected data of the study were analyzed for different components. The data were used to statistical analysis for each character, analysis of variance (ANOVA), mean, range were calculated by MSTAT-C software program. The formula, used by Johnson *et al.* (1995), was applied to estimate phenotypic and genotypic variance. Heritability and genetic advance were measured using the formula used by Singh and Chaudhary (1985) and Allard (1960). Genotypic and phenotypic co-efficient of variation were estimated by the formula of Burton (1952). Simple correlation coefficient was calculated following the method outlined by Clarke (1973) and Singh and Chaudhary (1985). Lastly path co-efficient analysis was done using the formula suggested by Dewey and Lu (1959).

i. **Estimation of genotypic and phenotypic variances:** Genotypic and phenotypic variances were estimated using the formula given by Johnson *et al.* (1955).

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

Where,

MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

Where,

$\sigma^2 g$ = Genotypic variance,

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

ii. **Estimation of genotypic and phenotypic co-efficient of variation:** Genotypic and phenotypic co-efficient of variation were calculated by the following formula of Burton (1952).

$$GCV = \frac{\sigma_g \times 100}{\bar{X}}$$

$$PCV = \frac{\sigma_p \times 100}{\overline{X}}$$

Where,

GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

σ_g= Genotypic standard deviation

σ_p= Phenotypic standard deviation

$\overline{X}$= Population mean

iii. **Estimation of heritability:** Broad sense heritability was estimated by the formula given by Singh and Chaudhary (1985).

$$h_b^2(\%) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

h_b^2= Heritability in broad sense

σ_g^2= Genotypic variance

σ_p^2= Genotypic variance

iv. **Estimation of Genetic Advance in:** Genetic advance for different characters under selection was estimated by the following formula given by Allard (1960).

$$GA = \frac{\sigma_g^2}{\sigma_p^2}.K.\sigma_p$$

Where,

GA = Genetic advance

σ_g^2= Genotypic variance

σ_p^2= Genotypic variance

σ_p = Phenotypic standard deviation

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

v. **Estimation of Genetic Advance in percentage of mean:** The following formula, given by Comstock and Robinson (1952), was used to calculate genetic advance in percentage of mean.

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

vi. **Estimation of simple correlation co-efficient:** Simple correlation co-efficient (r) was estimated with the following formula (Clarke, 1973; Singh and Chaudhary, 1985).

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

Where,

$\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

vii. **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 denote 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):

$$P_{RY}^2 = 1 - \sum P_{iy} . r_{iy}$$

Where,

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

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

r_{iy} = Correlation of the character with yield

CHAPTER IV

RESULT AND DISCUSSION

The present experiment was conducted with a view to select short duration genotypes by comparing the performance of different F_5 and F_8genotypes 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_5 and F_8 populations

The analysis of variance of the data on different yield components and yield of nine genotypes of F_5 and F_8 populations was significant (Appendix III). The mean performance and range for all the characters were also significant (Appendix IV). Phenotypic variance, genotypic variance, phenotypic coefficient of variation and genotypic coefficient of variation for different yield related characters of six F_5 and three F_8 lines are presented in Table 3.

Table 3. Estimation of some genetic parameters in respect of nine lines of *Brassica rapa* L.

Sl. No.	Characters	Phenotypic variance (δ^2p)	Genotypic variance (δ^2g)	PCV (%)	GCV (%)	Heritability (%)	GA	GA (% of mean)
1	DF	28.12	23.22	14.17	12.88	82.58	9.02	24.11
2	DM	14.28	5.61	4.34	2.72	39.30	3.06	3.51
3	PH	104.96	71.01	9.50	7.81	67.66	14.28	13.23
4	NPB/P	1.35	1.14	18.61	17.13	84.79	2.03	32.50
5	NSB/P	6.90	6.89	79.62	79.55	99.81	5.40	163.72
6	NS/P	1976.51	1911.02	36.98	36.37	96.69	88.55	73.66
7	LS	0.16	0.12	7.00	6.19	78.39	0.64	11.30
8	NS/S	7.47	5.68	12.24	10.67	76.01	4.28	19.16
9	TSW	1.62	1.60	46.31	45.98	98.58	2.59	94.05
10	Y/P	7.32	7.18	41.11	40.71	98.06	5.46	83.04

DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, NPB/P = Number of primary branch per plant, NSB/P = Number of secondary branch 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.

4.1.1.1 Days to 50% flowering

Considerable variations were observed (74.56**) among nine F_5 and F_8 populations for days to 50% flowering (Appendix III). The days to 50% flowering was observed the lowest (33 days) in G6 (Appendix IV). The second lowest value was 33.67 which was found both in G5 and G7.

The F_5 and F_8 populations G5, G6 and G7 required lower flowering time than other genotypes. The genotypes G8 and G9 both showed 34 days to 50% flowering which was close to G5 and G7 (33.67 days). The days to 50% flowering of genotype G3 (41 days) was higher than that of genotype G4 (37.33 days).The highest days to 50% flowering (45 days) was observed in G1 and G2 (Appendix IV).

Phenotypic and genotypic variance for days to 50% flowering was observed 28.12 and 23.22 (Table 3) respectively. The less difference between phenotypic variance and genotypic variance indicates that the environment had less influence on expression of the genes controlling this trait. The phenotypic coefficient of variation was 14.17% and the genotypic coefficient of variation was 12.88% (Table 3) with least differences between them, suggested that the expression of the genes controlling this trait is least influenced by environment. 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 nine F_5 and F_8 populations for days to maturity (Appendix III). The lowest days to maturity was recorded in G5 (80.33 days). Among F_5 and F_8 population, second lowest days to maturity (85.67 days) was found in G6. The genotypes G4 and G7 showed similarity in days to maturity (86.67). The genotype G8 showed 88days to maturity which is very close to the genotype G3 (88.33 days). The genotype G2 and G9 showed 89.67 and 88.67 days to maturity respectively.

Plate 2. Photograph showing flowering of SAU sarisha-1×BARI sarisha-15 E_1F_5

Plate 3. Photograph showing flowering of BARI sarisha-6× BARI sarisha-15 S_3F_8

Plate 4. Photograph showing flowering of BARI sarisha-9 × BARI sarisha-6 $S_{15}F_5$

The highest days to maturity was found in G1 (90 days) among F_5 and F_8 populations (Figure 2).

The phenotypic variance for days to maturity was observed 14.28 and genotypic variance was 5.61 (Table 3). High differences between them indicated high influence of environment on the expression of the genes controlling the trait. The phenotypic coefficient of variation (4.34%) was higher than the genotypic coefficient of variation (2.72%) for days to maturity (Table 3) 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.

4.1.1.3 Plant height

From ANOVA (Appendix III), significant differences were observed among nine F_5 and F_8 genotypes (246.98**) for plant height. The highest plant height was recorded in G4 (123.15 cm). The genotypes G8 (114.6 cm) was taller than G3 (112.7 cm) but shorter thanG4 (123.15 cm). The plant height 98.26 cm, 108.7 cm, 107.2 cm, 110.9cm and 102.6cm were recorded for G1, G5, G6, G7 and G9 respectively. The lowest plant height was recorded in G2 (92.86) (Appendix IV).
Higher phenotypic variance (104.96) than the genotypic variance (71.01) was found for plant height that indicated high environmental influence on the expression of the concerned trait (Table 3). The higher PCV (9.50%) than the GCV (7.81%) from the Table 3 gave an information that there were much 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).

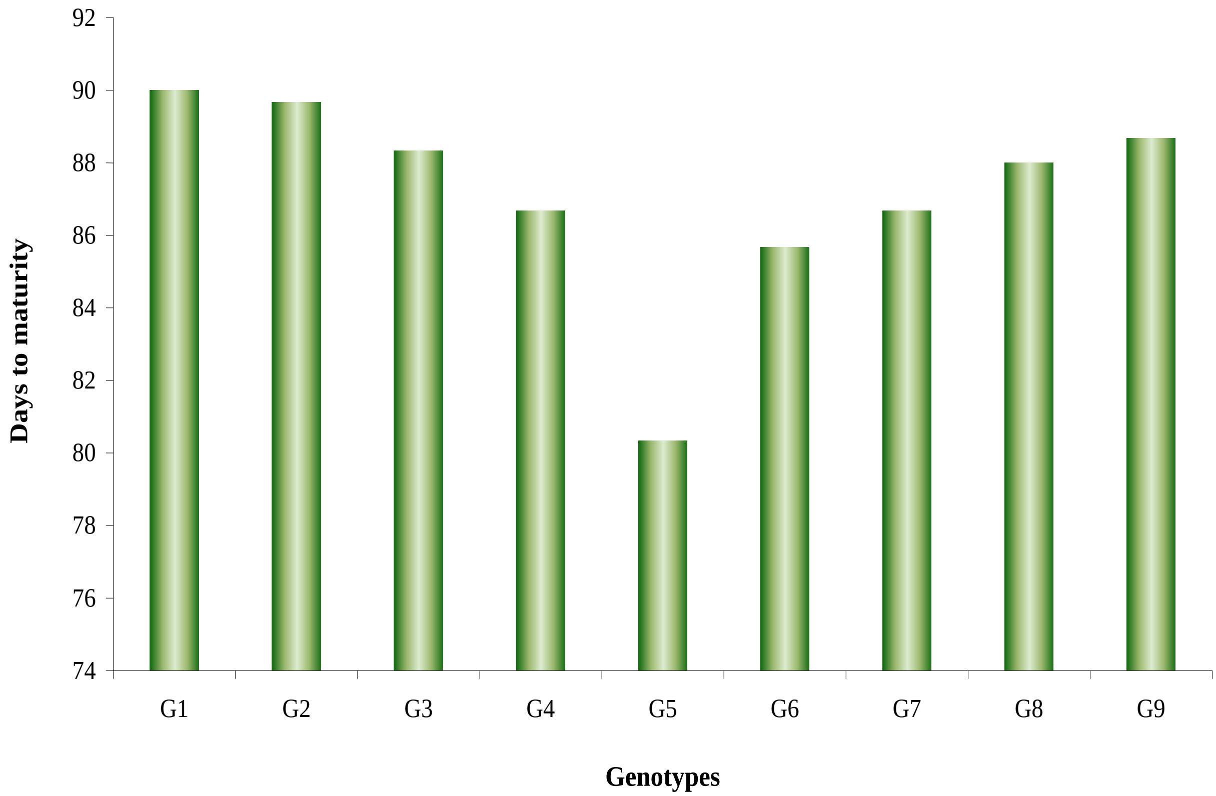


Figure 2. Mean performance of days to maturity of nine lines

Plate 5. Photograph showing differences in maturity of SAU sarisha-1 × BARI sarisha-15 E_1F_5 and BARI sarisha-6 × BARI sarisha-15 S_3F_8

4.1.1.4 Number of primary branches per plant

Significant variations were observed among nine F_5 and F_8genotypes (3.63**) at the level of 1% probability for primary branches per plant (Appendix III). Among the nine F_5 and F_8populations, G6 (8.07) showed the maximum number of primary branches per plant (Appendix III). The number of primary branches per plant of genotype G5 was 6.833 which was close to that of genotype G2 (6.733). Again the number of primary branches per plant of genotype G9 (6.667) was close to that of genotype G7 (6.533). The genotypes G4 presented higher number of primary branches per plant (6.433) than G1 (5.433) but close to genotype G7 (6.533). The genotype G8 exhibited 5.00 primary branches per plant which is higher than the genotype G3 (4.433). The lowest number of primary branches per plant was recorded in G3 (4.433) (Appendix IV).

Number of primary branches per plant showed that phenotypic variance (1.35) was moderately higher than genotypic variance (1.14) indicating moderate environmental influence on this character. Moderate difference between PCV (18.61%) and GCV (17.13%) value indicated that this trait is moderately influenced by the environment (Table 3). 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 nine F_5 and F_8 genotypes (20.68**) for number of secondary branches (Appendix III). Among the nine F_5 and F_8 populations the highest number of secondary branches per plant was observed in G9 (7.033) (Appendix IV). The genotypes G6 (5.067) and G7 (5.70) showed higher number of secondary branches per plant than the remaining genotypes. The genotype G4 (4.167) showed higher number of secondary branches per plant than both the genotypes G5 and G8 which presented similar

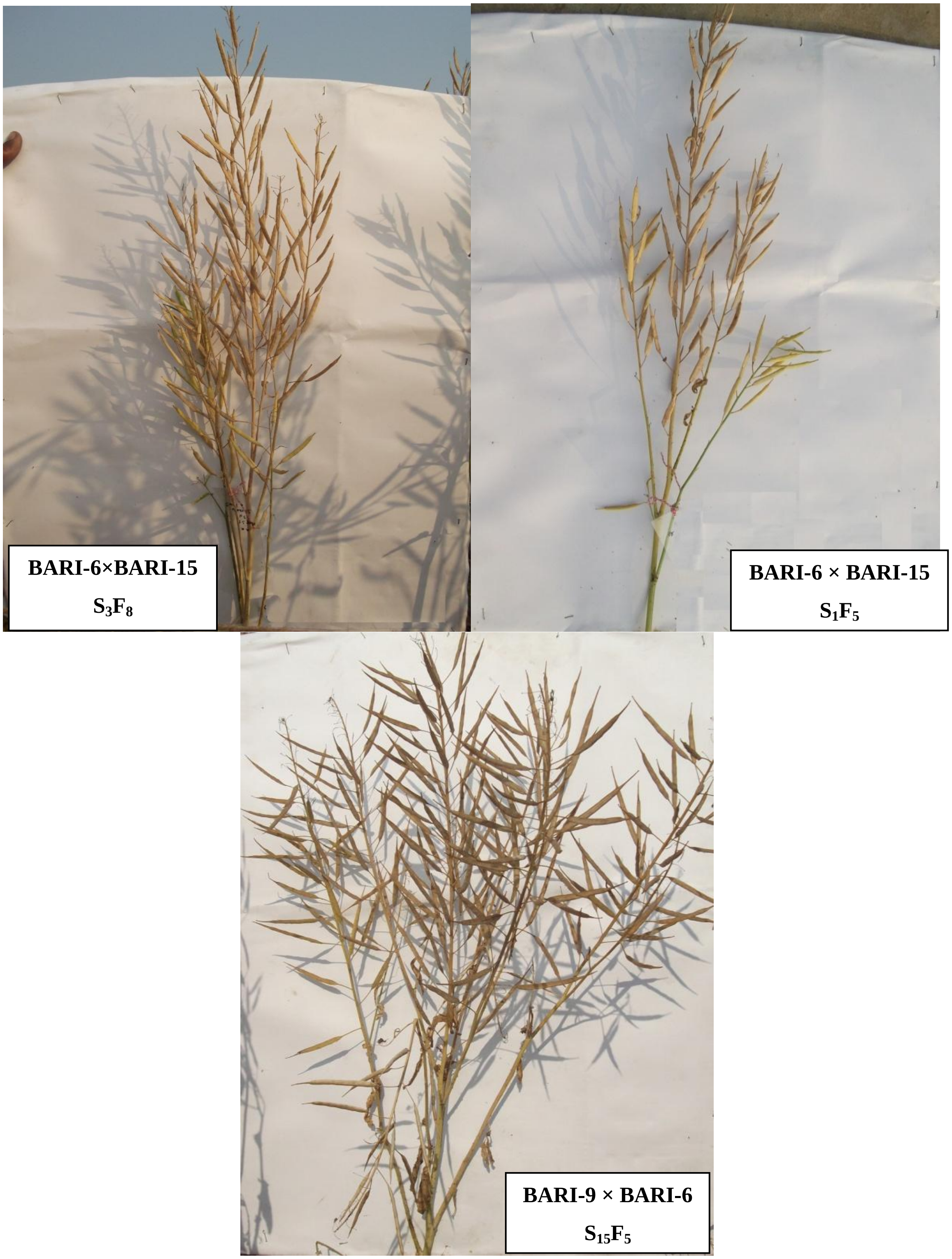


Plate 6. Photography showing difference in branching of F_5 and F_8 populations

number of secondary branches per plant (3.767). 0.1667 secondary branches per plant were recorded for the genotype G2. The lowest number of secondary branches per plant was recorded as 0.0333 for the genotypes G1and G3 (Appendix IV).

Number of secondary branches per plant showed phenotypic variance as 6.90and genotypic variance as 6.89 indicating ignorable environmental influence on this character and very lower difference between PCV (79.62%) and GCV (79.55%) value indicating less influence of environment (Table 3). 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 (Appendix III) there were highly significant variations among nine F_5 and F_8 genotypes (5798.54**) for number of siliqua per plant. 61.67, 72.07, 150.40, 125.80, 160.30,128.20 and 155.60 siliquae were recorded for the genotypes G1, G2, G5, G6, G7, G8 and G9 respectively. The G4 showed the highest number of siliqua (60.20) per plant in F_5 and F_8populations (Figure 2).

The value of phenotypic variance and genotypic variance were recorded as 1976.51 and 1911.02 respectively with moderate difference between them suggesting moderate environmental influence upon this trait (Table 3). PCV value was recorded as 36.98% and GCV value as 36.37%.This moderate difference between PCV and GCV also indicated moderate environmental influence upon this trait. Highest phenotypic variance, genotypic variance, phenotypic coefficient of variance and genotypic coefficient of variance for this trait were also observed by Jahan (2008).

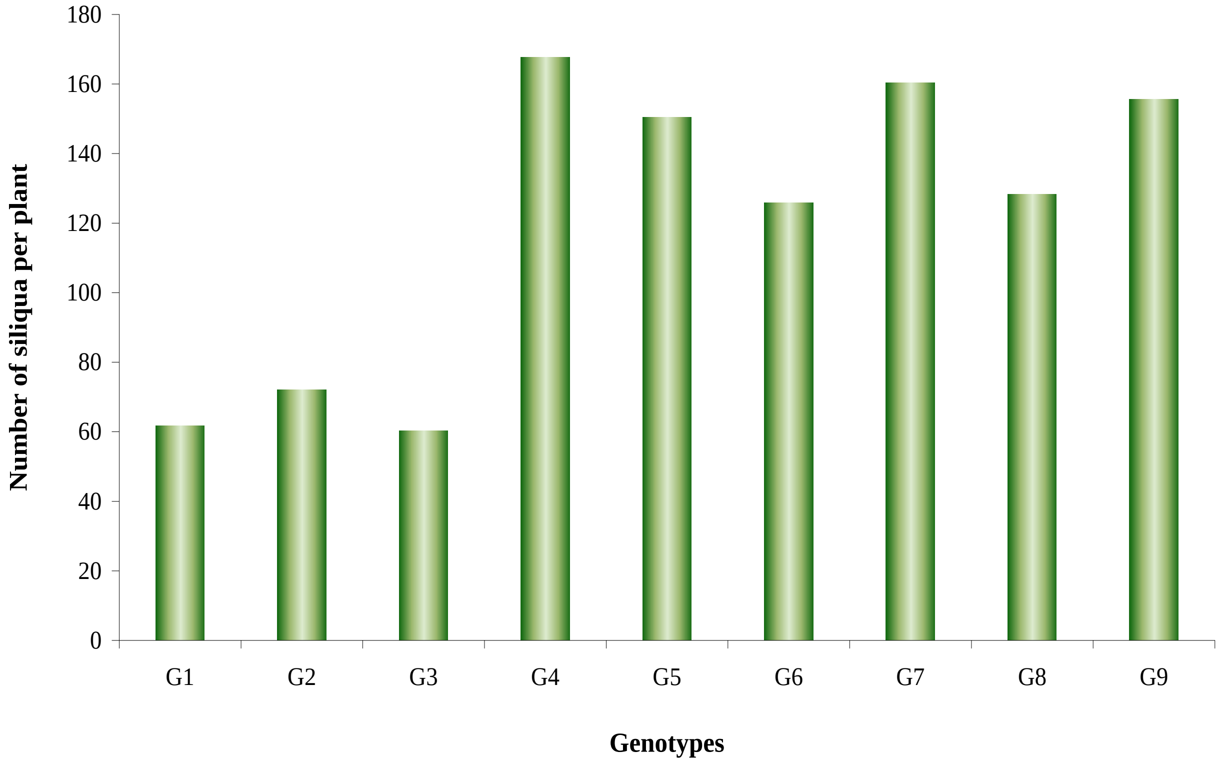


Figure 3. Mean performance of number of siliqua per plant of nine lines

4.1.1.7 Length of siliqua

There were highly significant variations among nine F_5 and F_8 genotypes (0.404**) for length of siliqua (Table 3). The length of siliqua of genotypes G1, G2, G3, G4, G7, G8, G9 were recorded 5.993 cm, 5.64 cm, 5.85 cm, 5.26 cm,5.94 cm, 5.73 cm and 5.64 cm respectively (Table 4). The highest length of siliqua was recorded in G6 (6.057 cm) which was close to G1 (5.993 cm), whereas the minimum length of siliqua was observed in G5 (4.93 cm). The genotypes G2 and G9 showed similar length of siliqua (5.64 cm).

The value of phenotypic and genotypic variance were 0.16 and 0.12 respectively for length of siliqua with little difference between them indicating that there were less effect of environment on this character (Table 3). According to Table 3, PCV and GCV were 7.00% and 6.19% respectively for length of siliqua which indicated that moderate variation existed among genotypes for this trait. Low co-efficient of variation and low genotypic and phenotypic variances for this trait were also 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 (18.81**) among nine F_5 and F_8 genotypes of *Brassica* used in the present experiment (Appendix III). The highest number of seed per siliqua was 25.42 for the genotype G2 which was very close for the genotype G3 (25.23) (Appendix IV). The genotype G1 showed lower number of seed (24.43) per siliqua than the genotype G3 (25.23) but higher than the other six genotypes. The remaining six genotypes, namely G4, G5, G6, G7, G8 and G9 presented 20.99, 21.62, 21.93, 22.18, 21.81 and 17.33 seeds per siliqua respectively among which the G9 genotype showed the lowest number of seeds per siliqua (Figure 3).

The magnitude of difference between phenotypic (7.47) and genotypic variance

Plate 7. Photograph showing difference in siliqua length of F_5 and F_8 populations

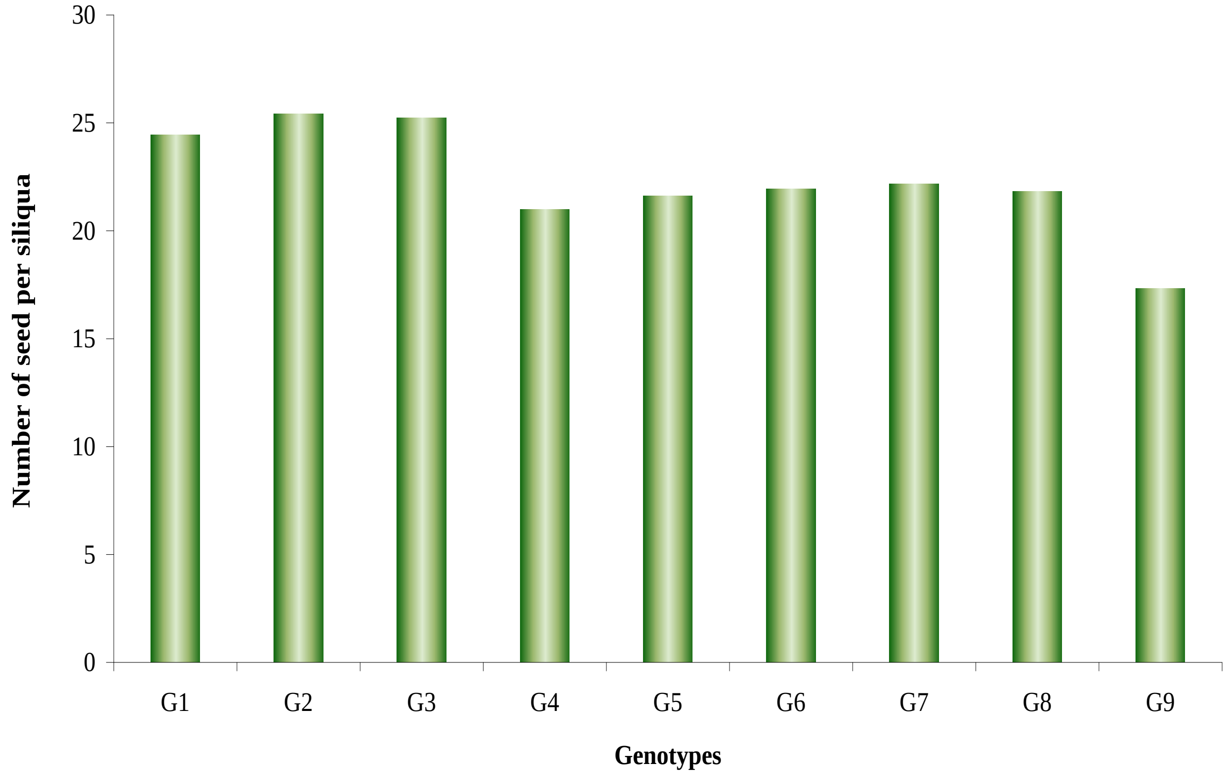


Figure 4. Mean performance of number of seed per siliqua of nine lines

(5.68) was moderate for number of seeds per siliqua which suggested that moderate environmental influence on this character (Table 3). The moderate value of phenotypic and genotypic coefficient of variance (12.24 and 10.67 respectively) for this character indicated the existence of adequate variation among the population with possibility of high potential for the selection (Table 3). Similar variability was also recorded by Kumar and Singh (1994).

4.1.1.9 Thousand seed weight

Among six F_5 and three F_8 populations, thousand seed weight was found maximum in G6 (4.807 g) while minimum thousand seed weight was found in G1 (Appendix III). The thousand seed weight was recorded 3.577 gm in G8 which was close to the genotype G4 (3.487 g). Thousand seed weight of genotype G9 was 3.130 g which was very close to that of genotype G5 (3.117 g). Similarly the genotypes G2 and G3 showed close value (1.230 g and 1.223 g respectively) for thousand seed weight. Thousand seed weight for the genotype G7 was recorded 2.957 g (Appendix IV).

Thousand seed weight showed very low difference between phenotypic variance(1.62) and genotypic variance (1.60) indicating that they were less responsive to environmental factors and the values of PCV and GCV were 46.31 % and 45.98% indicating that the genotype has considerable variations for this trait (Table 3). Parveen (2007) observed low phenotypic (0.08) and genotypic (0.16) variance; high phenotypic coefficient of variation (18.94%) and genotypic coefficient of variation (13.27%) for thousand seed weight.

4.1.1.10 Yield per plant

The mean square due to genotype from the analysis of variance was found statistically significant (21.67**) for yield per plant indicating the presence of genotypic differences present among the nine F_5 and F_8populations (Appendix III).

Yield per plant was recorded 5.367 g, 6.133 g, 4.353 g, 8.953g and 8.720g in G2, G4, G5, G8 and G9 respectively(Appendix IV). The genotype G6 showed 4.797 g yield per plant which was close to the genotype G3 (4.740 g). The highest yield (11.95 g) per plant was found in G7whereas the lowest yield (4.22 g) per plant was found in G1 (Figure 5).

The phenotypic and genotypic variance for yield per plant (7.32 and 7.18 respectively) suggested that less influence of environment on the expression of the genes controlling this trait. The values of PCV and GCV were 41.11% and 40.71 % indicating that the genotype has high variation for this trait (Table 3). Similar result was observed by Parveen (2007).

4.1.2 Heritability and 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

High heritability (82.58%) with high genetic advance in percentage of mean (24.11%) for days to 50% flowering was found in the six F_5 and three F_8 populations of *Brassica* (Table 3)**.** The result presented that most likely the heritability is due to presence of additive gene effects. Selection for this trait may be effective for this trait.

4.1.2.2 Days to maturity

Days to maturity showed moderate heritability (39.30 %) coupled with low genetic advance (3.06) and low genetic advance in percentage of mean (3.51%) (Table 3).The result presented the presence of non-additive gene effects and environment was mainly responsible for moderate heritability. Selection for this trait would not

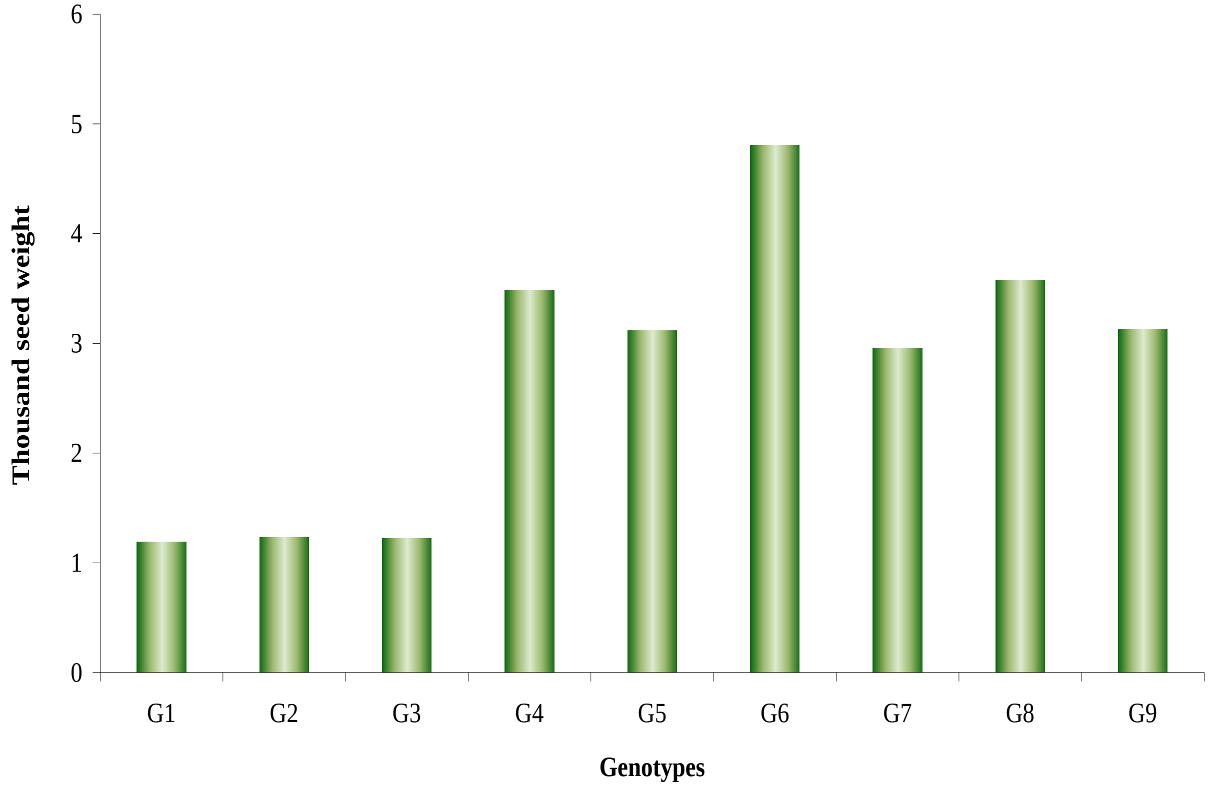


Figure 5. Mean performance of thousand seed weight of nine lines

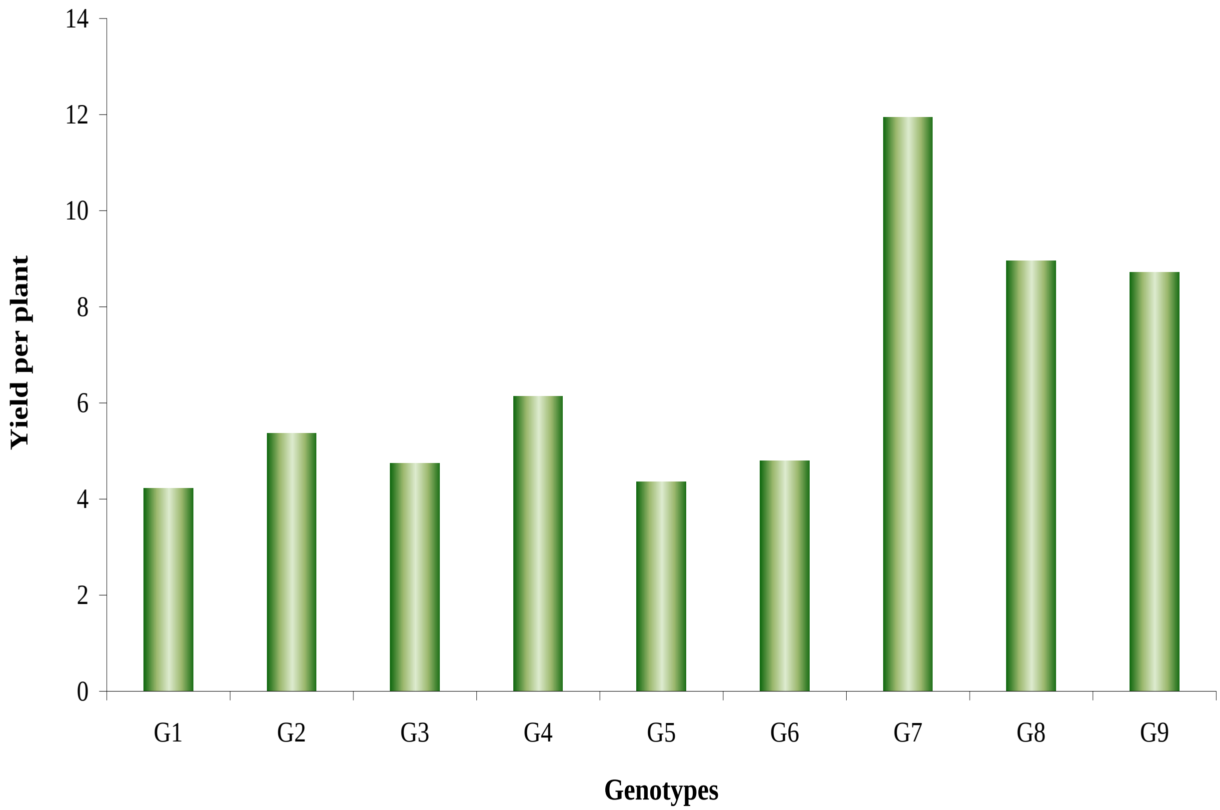


Figure 6. Mean performance of yield per plant of nine lines

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_5 and F_8 populations showed high heritability 67.66 % associated with moderate genetic advance in percentage of mean of 13.23 % (Table 3) and revealed that plant height is 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 *et al.* (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 high heritability 84.79% in conjunction with high genetic advance in percentage of mean (32.50%) (Table 3). These findings revealed that it was indicative of additive gene action. Selection for this trait may be effective. Low heritability coupled with low genetic advance was found by Singh *et al*. (1987).

4.1.2.5 Number of secondary branches per plant

High heritability (99.81%) accompanied with high genetic advance in percentage of mean (163.72 %) was calculated in respect of number of secondary branches per plant (Table 3). These findings discovered the action of additive gene effects on the expression of this trait. 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 tori.

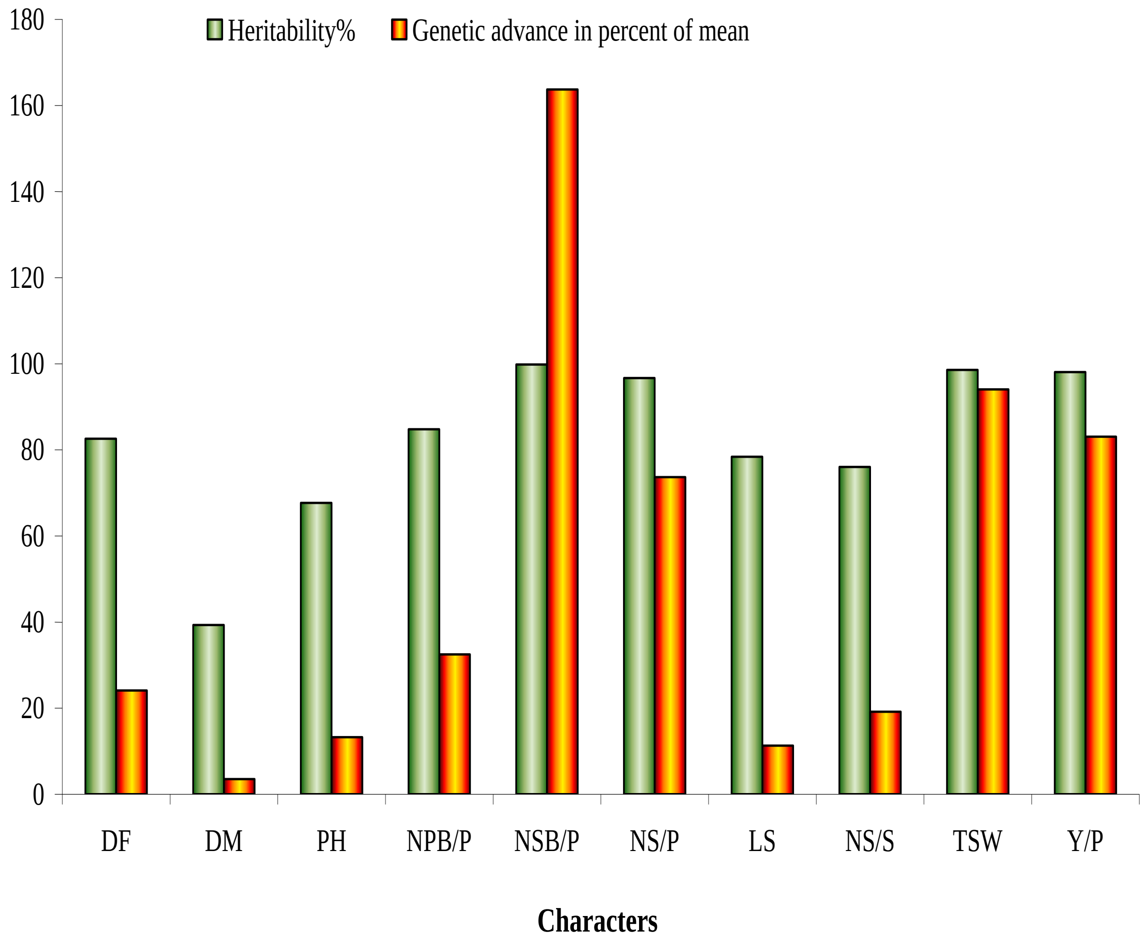


Figure 7. Heritability and genetic advance in percent of mean of different characters

4.1.2.6 Number of siliqua per plant

Number of siliqua per plant exhibited high heritability (96.69 %) along with high genetic advance (88.5) and high genetic advance in percentage of mean (73.66%) (Table 3). 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). Mahmood *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%).

4.1.2.4 Number of primary branches per plant

Number of primary branches per plant exhibited high heritability 84.79% in conjunction with high genetic advance in percentage of mean (32.50%) (Table 3). These findings revealed that it was indicative of additive gene action. Selection for this trait may be effective. Low heritability coupled with low genetic advance was found by Singh *et al*. (1987).

4.1.2.8 Number of seeds per siliqua

Number of seeds per siliqua showed high heritability (76.01%) coupled with low genetic advance (4.28) and moderate genetic advance in percentage of mean (19.16%) (Table 3). These finding exposed the non-additive gene effects on the expression of this character. Selection of this character is not effective. The high heritability is being exhibited due to high environmental effect. Low heritability coupled with low genetic advance for this trait was observed by Singh (1986).

4.1.2.9 Thousand seed weight

The magnitude of heritability in broad sense of this character was very high (98.58%) with high genetic advance in percentage of mean (94.05%) (Table 3).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 weight.

4.1.2.10 Yield per plant

Seed yield per plant showed high heritability (98.06%) accompanied with high genetic advance in percentage of mean (83.04%) (Table 3).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 (2013) 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 into 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 nine F_5 and F_8 lines of *Brassica rapa* L. are determined (Table 4 and 5). Many of the characters showed that 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 many 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 = 0.591, r_p= 0.609), length of siliqua (r_g = 0.205, r_p = 0.194). It exhibited significant and positive correlation with number of seed per siliqua (r_g = 0.780, r_p = 0.739), indicating a possible increase in seed per siliqua by increasing days to flowering. It also presented significant and negative correlation with number of secondary branches per plant (r_g = -0.899, r_p = -0.890), number of siliqua per plant (r_g= -0.849, r_p =-0.835) and thousand seed weight (r_g = -0.885, r_p = -0.875), indicating a possible increase in of secondary branches per plant, number of siliqua per plant and thousand seed weight by lowering days to flowering. However, the correlation of days to 50% flowering with plant height (r_g = -0.574, r_p = -0.517), number of primary branch per plant (r_g= -0.405, r_p = -0.398) and yield per plant (r_g = -0.503, r_p = -0.494) are insignificant and negative (Table 4 and 5). It indicated that if days to 50% flowering increases then plant height, number of primary branches and yield per plant decreases. Mili (2014) revealed that days to 50% flowering had significant and negative interaction with yield per plant.

4.2.2 Days to maturity

Significant and positive correlation between days to maturity and length of siliqua at genotypic and phenotypic level (r_g = 0.732, r_p = 0.653) indicated that if days to maturity increases then length of siliqua also increases. It had non-significant and positive correlation with number of seed per siliqua (r_g =0.302, r_p =0.263) and yield per plant (r_g =0.158, r_p =0.140), showing very little contribution of this trait toward the increase in seed per siliqua and yield per plant. It was found non-significant and negatively associated with plant height (r_g = -0.423, r_p = -0.357), number of primary branch (r_g= -0.412, r_p = -0.413), number of secondary branches (r_g = 0.387, r_p =0.365), number of siliqua per plant (r_g =-0.578, r_p = -0.541) and thousand seed weight (r_g= 0.540, r_p =0.501) (Table 4 and 5). 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 non-significant and positive correlation with number of secondary branches (r_g =0.54, r_p =0.34), number of siliqua per plant (r_g =0.57, r_p =0.38), thousand seed weight (r_g =0.05, r_p =0.17) and yield per plant (r_g= 0.58, r_p = 0.40). The results tend to emphasize very little contribution of number of plant height toward increase in secondary branches, number of siliqua per plant, thousand seed weight and yield per plant. It was insignificantly and negatively

Table 4. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different lines of *Brassica rapa* L.

Characters	DM	PH	NPB/P	NSB/P	NS/P	LS	NS/S	TSW	Y/P
DF	0.591	-0.574	-0.405	-0.899**	-0.849**	0.205	0.780*	-0.885**	-0.503
DM		-0.423	-0.412	-0.387	-0.578	0.732*	0.302	-0.540	0.158
PH			-0.171	0.355	0.567	-0.277	-0.256	0.495	0.241
NPB/P				0.539	0.487	-0.142	-0.388	0.591	-0.027
NSB/P					0.906**	-0.135	-0.922**	0.812**	0.619
NS/P						-0.449	-0.830**	0.769*	0.549
LS							0.270	-0.117	0.201
NS/S								-0.670*	-0.459
TSW									0.274

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

DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, NPB/P = Number of primary branch per plant, NSB/P = Number of secondary branch 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 5. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different lines of *Brassica rapa* L.

Characters	DM	PH	NPB/P	NSB/P	NS/P	LS	NS/S	TSW	Y/P
DF	0.609	-0.517	-0.398	-0.890**	-0.835**	0.194	0.739*	-0.875**	-0.494
DM		-0.357	-0.413	-0.365	-0.541	0.653	0.263	-0.501	0.140
PH			-0.199	0.345	0.542	-0.282	-0.280	0.487	0.233
NPB/P				0.535	0.481	-0.133	-0.380	0.590	-0.021
NSB/P					0.904**	-0.131	-0.903**	0.811**	0.619
NS/P						-0.447	-0.818**	0.767*	0.549
LS							0.287	-0.113	0.203
NS/S								-0.664	-0.444
TSW									0.272

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

DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, NPB/P = Number of primary branch per plant, NSB/P = Number of secondary branch 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.

associated with number of primary branches per plant (r_g= -0.171, r_p = -0.199), siliqua length (r_g = -0.40, r_p = -0.282), number of seed per siliqua (r_g=-0.256, r_p = -0.280) (Table 4 and 5). Shalini *et al*. (2000) also observed that plant height had low association 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 non-significantly correlated with number of secondary branches per plant (r_g =0.539, r_p =0.535), number of siliqua per plant (r_g =0.487, r_p =0.481) and thousand seed weight (r_g =0.591, r_p =0.590) and indicated that very little contribution of number of primary branches toward increase in secondary branches per plant, number of siliqua per plant and thousand seed weight. Malek *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 non-significant and negative interaction with length of siliqua (r_g =-0.142, r_p=-0.133), number of seed per siliqua (r_g=-0.388, r_p = -0.380) and yield per plant (r_g= -0.027, r_p= -0.021) (Table 4 and 5). 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.

4.2.5 Number of secondary branches per plant

The correlation of number of secondary branches per plant with number of siliqua per plant (r_g =0.906, r_p =0.904) and thousand seed weight (r_g=0.812, r_p =0.811) was significant and positive which indicated that the traits were less influenced by environment. It also had positive and non-significant correlation with yield per plant (r_g =0.619, r_p =0.619). Number of secondary branches had significant and negative interaction with number of seed per siliqua (r_g = -0.922, r_p = -0.903) indicating that a decrease 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 =-0.135, r_p = -0.131) (Table 4 and 5). 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 thousand seed weight (r_g = 0.769, r_p = 0.767) which indicated that improvement of thousand seed weight can be possible by improving number siliqua per plant. Dastidar *et al.* (2004) reported positive correlation between siliqua per plant and thousand seed weight. It presented insignificant and positive interaction with yield per plant (r_g = 0.549, r_p = 0.549). Whereas the significant and negative interaction was found in number of seed per siliqua (r_g =-0.830, r_p = -0.818) indicating that number of seed per siliqua will increase by decreasing the number of siliqua per plant. It has non-significant and negative correlation with siliqua length (r_g = -0.449, r_p = -0.447) (Table 4 and 5). 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 =0.270, r_p =0.287) and yield per plant (r_g =0.201, r_p =0.203) indicating very little contribution of this trait toward the increase in number of seed per siliqua and ultimately to yield per plant. It showed negatively insignificant interaction with thousand seed weight (r_g= -0.117, r_p = -0.113) (Table 4 and 5). 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 significant and negative interaction with thousand seed weight (r_g = -0.670, r_p = -0.664) indicating that thousand seed weight will increase by decreasing the number of seed per siliqua. It shows negatively insignificant association with yield per plant (r_g= -0.459, r_p = -0.444) (Table 4 and 5) which suggested that the association between these traits is 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 non-significant and positive interaction with yield per plant (r_g =0.274, r_p =0.272) (Table 4 and 5). Positive associations between thousand seed weight and yield per plant indicate that yield per plant will increase if thousand seed weight increases. 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 thousand seed weight which supports the present findings. Mili (2014) revealed that thousand seed weight had significant and positive interaction with yield per plant.

4.3 Path co-efficient analysis

The estimation of correlation coefficient, although, indicates 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 branches per plant, number of secondary branches 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 6.

4.3.1. Days to 50% flowering

Days to 50% flowering had negative direct effect (-0.779) on yield per plant. This trait showed indirect positive effect on yield per plant through days to maturity (0.456), plant height (0.268), number of primary branch per plant (0.215), number of seed per siliqua (0.872) and thousand seed weight (0.336). On the other hand, it showed indirect negative effect on yield per plant via number of secondary branch per plant (-0.709), number of siliqua per plant (-1.15) and siliqua length (-0.003). Finally it made significant negative correlation with yield per plant (-0.494) (Table 6). 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 (0.749) and had high positive direct effect (0.749) on yield per plant. This result suggested that yield per plant can be improved through direct selection of days to maturity. It was also found to influence the yield per plant in a positive direction through plant height (0.185), number of primary branches (0.223), number of seed per siliqua (0.390) and thousand seed weight (0.192).The indirect effect of this trait through days to 50% flowering (-0.475), number of secondary branches per plant (-0.291), number of siliqua per plant (-0.744) and siliqua length (-0.010) was negative (Table 6). 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 (-0.518) of plant height on yield per plant was found to be highly negative. The indirect effects through days to 50% flowering (0.403), number of primary branches per plant (0.108), number of secondary branches (0.275), number of siliqua per plant (0.746) and length of siliqua (0.004) were positive. However, this trait had negative and indirect effects on yield per plant via days to maturity (-0.268), number of seed per siliqua (-0.330) and thousand seed weight (-0.187) (Table 6). The correlation (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 negative direct effect on yield per plant (0.540). This trait had also positive indirect effect through days to 50% flowering (0.310),plant height(0.103), number of secondary branch (0.426), number of siliqua per plant (0.662) and siliqua length (0.002) on yield per plant. On the other hand, negative indirect effect was found through days to maturity (-0.309), number seed per siliqua (-0.448) on yield per plant and thousand seed weight (-0.226) (Table 6). Its correlation with yield per plant was negative and insignificant (-0.021).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 (0.797) on yield per plant. It had positive indirect effect via days to 50% flowering (0.38), number of siliqua per plant (0.48) and siliqua length (0.48) on seed yield per plant. Whereas, negative indirect effect of number of secondary branches per plant through days to maturity (-0.01), plant height (-0.04), number of primary branch per plant (-1.09), number of seed per siliqua (-2.36) and thousand seed weight (-0.01) on seed yield per plant. The genotypic correlation with yield per plant was highly significant and positive (0.42) (Table 6). 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 (1.38) on yield per plant followed by positive indirect effect via days to 50% flowering (0.651), number secondary branch per plant (0.720)and siliqua length (0.007).This trait had also negative indirect effect on yield through days to maturity (-0.406), plant height (-0.281), number of primary branch (-0.259), number of seed per siliqua (-0.965) and thousand seed weight (-0.294). Finally this trait had significant positive genotypic correlation (0.549) with yield per plant (Table 8). 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 (-0.016) of siliqua length on yield per plant was negative. The indirect effect of this trait on yield per plant through days to maturity (0.489), plant height (0.146), number of primary branch (0.072), number of seed per siliqua (0.338) and thousand seed weight (0.043) was positive, whereas, negative indirect effects of this trait were found on yield per plant via days to50% flowering (-0.151), number of secondary branch per plant (-0.104) and number of siliqua per plant (-0.615). The correlation with yield per plant was positive and non-significant (0.203) (Table 8). This finding suggested that this trait had influence on yield per plant through days to maturity, plant height, number of primary branch per plant, number of seed per siliqua and thousand seed weight. Han (1990) and Singh *et al.* (1987) reported that siliqua length had negative direct effect on yield per plant.

Table 6. Phenotypic path coefficient analysis showing direct and indirect effects of different characters on yield of *Brassica rapa L.* (bold number implies direct effect)

Characters	DF	DM	PH	NPB/P	NSB/P	NS/P	LS	NS/S	TSW	Y/P
DF	**-0.779**	0.456	0.268	0.215	-0.709	-1.15	-0.00301	0.872	0.336	-0.494
DM	-0.475	**0.749**	0.185	0.223	-0.291	-0.744	-0.0102	0.310	0.192	0.140
PH	0.403	-0.268	**-0.518**	0.108	0.275	0.746	0.0044	-0.330	-0.187	0.233
NPB/P	0.310	-0.309	0.103	**-0.540**	0.426	0.662	0.0021	-0.448	-0.226	-0.021
NSB/P	0.693	-0.274	-0.179	-0.289	**0.797**	1.24	0.0020	-1.06	-0.311	0.619
NS/P	0.651	-0.406	-0.281	-0.259	0.720	**1.38**	0.0069	-0.965	-0.294	0.549
LS	-0.151	0.489	0.146	0.072	-0.104	-0.615	**-0.0155**	0.338	0.0433	0.203
NS/S	-0.576	0.197	0.145	0.205	-0.720	-1.13	-0.0045	**1.18**	0.255	-0.444
TSW	0.682	-0.375	-0.252	-0.319	0.646	1.06	0.0018	-0.783	**-0.384**	0.272
Residual effects	0.00177									

DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, NPB/P = Number of primary branch per plant, NSB/P = Number of secondary branch 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

4.3.8. 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 8). 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 negative direct effect on yield per plant (-0.384) followed by positive indirect effect through days 50% flowering (0.01),number of secondary branch (0.07), number of siliqua per plant (-0.27) and siliqua length (0.01), whereas this trait showed negative indirect effect via days to maturity (0.34), plant height (0.04), number of primary branch (0.23) 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 8) 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. Kachroo 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 matures by 84 days with 8.45g 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_5 and F_8 populations of different cross combinations. Selection was carried out among the F_5 and F_8 populations as per objectives. The most promising plant populations with high yielding were selected from the F_5 and F_8 materials of the different cross combinations (Table 7).

4.4.1. SAU BARI sarisha-6 × BARI sarisha-15 S_1F_8 (G4)

Average number of siliqua of G1 was recorded 167.7 (Table 7) which was higher than BARI sarisha-15 (120.40) (Shakera, 2014). The average thousand seed weight was recorded as 3.49 g (Table 7) which was higher than Tori-7 (2.13 g) and BARI sarisha-15 (3.41 g) (Shakera, 2014) that meant seeds of population plants were larger than tori-7 and BARI sarisha-15 and had comparatively higher oil content. Yield per plant was recorded 6.13 g (Table 8) which was close to Tori-7 (6.82 g) (Shakera, 2014).

4.4.2. BARI sarisha-6 × BARI sarisha-15 S_1F_5 (G7)

Average number of siliqua per plant of G7 was recorded 160.30 (Table 7) which was higher than BARI Sarisha-15 (120.40) (Shakera, 2014). Average yield per plant was 11.95 (Table 7) which was higher than BARI Sarisha-15(8.45g) and Tori-7 (6.82g) (Shakera, 2014) indicating that this selected population was high yielding than BARI sarisha-15 and Tori-7.

4.4.3. BARI sarisha-6 × BARI sarisha-15 S_2F_5 (G8)

Average number of siliqua per plant of G8 was recorded 128.2 (Table 7) which was higher than BARI sarisha-15 (120.40) (Shakera, 2014). Average thousand seed weight was 3.58 (Table 9) which was higher than Tori-7 (2.13g) and BARI sarisha-15 (3.41 g) (Shakera, 2014) that meant seeds of G8 were larger than tori-7 and BARI sarisha-15 and had comparatively higher oil content. Average yield per plant was recorded 8.95g (Table 7) which was higher than BARI sarisha-15 (8.45g) and Tori-7 (6.82g) (Shakera, 2014) which indicated that this genotype was high yielding than Tori-7 and BARI sarisha-15.

4.4.4. BARI sarisha-9 × BARI sarisha-6 $S_{15}F_5$ (G9)

Average number of siliqua per plant of G9 was recorded 155.6 (Table 7) which was higher than BARI sarisha-15 (120.40) (Shakera, 2014). The genotype had average thousand seed weight 3.13g (Table 9) which was higher than Tori-7 (2.13g) (Shakera, 2014) that meant seeds of G9 was larger than tori-7 and had comparatively higher oil content. Average yield per plant was recorded 8.72g (Table 9) which was higher than BARI sarisha-15 (8.45g) and Tori-7 (6.82g) (Shakera, 2014) indicating that this was high yielding than BARI sarisha-15 and Tori-7.

Table 7. Selection of promising high yielding population from the F_5 and F_8 materials of different cross combinations

Genotypes	DM	NS/P	TSW (g)	Y/P (g)
BARI sarisha-6 × BARI sarisha-15 S_1F_8	86.67	167.7	3.49	6.13
BARI sarisha-6 × BARI sarisha-15 S_1F_5	86.67	160.3	2.96	11.95
BARI sarisha-6 × BARI sarisha-15 S_2F_5	88.00	128.2	3.58	8.95
BARI sarisha-9 × BARI sarisha-6 $S_{15}F_5$	88.67	155.6	3.13	8.72

Plate 8. Photography showing plants of BARI sarisha-6 × BARI sarisha-15 S_1F_8

Plate 9. Photography showing plants of BARI sarisha-6 × BARI sarisha-15 S_1F_5

Plate 10: Photography showing plants of BARI sarisha-6 × BARI sarisha-15 S_2F_5

Plate 11: Photography showing plants of BARI sarisha-9 × BARI sarisha-6 $S_{15}F_5$

SUMMARY AND CONCLUSION

This experiment was carried out during the period of November, 2015 to February, 2016 at the experimental farm of Sher-e-Bangla Agricultural University using six F_5 and three F_8 populations of *Brassica rapa* L. The research work was conducted to study variability, heritability, genetic advance and genetic advance in percentage of mean, character associations and direct and indirect effects of different traits on yield. The results of the present study are summarized as follows:

From variability analysis of F_5 and F_8 populations, it was observed that significant variation existed among all the genotypes used for all of the characters studied. The maximum days to 50% flowering (45 days) was found in G1 (SAU sarisha-1×BARI sarisha-15 E_1F_5) and G2 (SAU sarisha-1×BARI sarisha-15 E_2F_5) and the lowest (33 days) was in G6 (BARI sarisha-6×BARI sarisha-15 S_3F_8). The highest days to maturity (90days) was found in G1 (SAU sarisha-1×BARI sarisha-15 E_1F_5) and the lowest (80.33 days) were observed in G5 (BARI sarisha-6×BARI sarisha-15 S_2F_8). Plant height exhibited the highest (123.1 cm) in G4 (BARI sarisha-6×BARI sarisha-15 S_1F_8) and the lowest (92.86 cm) in G2 (SAU sarisha-1×BARI sarisha-15 E_2F_5). The highest number of primary branches per plant (8.07) was recorded in G6 (BARI sarisha-6×BARI sarisha-15 S_3F_8) and the lowest number (4.43) was recorded in G3 (SAU sarisha-1×BARI sarisha-15 E_3F_5). The highest number of secondary branches per plant (7.03) was observed in G9 (BARI sarisha-9×BARI sarisha-6 $S_{15}F_5$) and the lowest number (0.03) was observed in G1 (SAU sarisha-1×BARI sarisha-15 E_1F_5) and G3 (SAU sarisha-1×BARI sarisha-15 E_3F_5). The highest number of siliqua per plant (167.7) was in G4 (BARI sarisha-6×BARI sarisha-15 S_1F_8) and the lowest (60.20) in G3 (SAU sarisha-1×BARI sarisha-15 E_3F_5). The lowest length of siliqua (4.93 cm) was recorded in G5 (BARI sarisha-6×BARI sarisha-15 S_2F_8) and the highest length of siliqua (6.06 cm) was observed in G6 (BARI sarisha-6×BARI sarisha-15 S_3F_8). The number of seeds per siliqua (25.42) was found the highest in G2(SAU sarisha-1×BARI sarisha-15 E_2F_5) and the lowest (17.33) in G9 (BARI sarisha-9×BARI sarisha-6 $S_{15}F_8$). The thousand seed weight exhibited the highest (4.81 g) in G6 (BARI sarisha-6×BARI sarisha-15 S_3F_8) and the lowest (1.19 g) in G1 (SAU sarisha-1×BARI sarisha-15 E_1F_5). The yield per plant was maximum (11.95 g) in G7 (BARI sarisha-6×BARI sarisha-15 S_1F_5) and minimum (4.22 g) was observed in G1 (SAU sarisha-1×BARI sarisha-15 E_1F_5).

The phenotypic variance of F_5 and F_8 materials was considerably higher than the genotypic variance for all the characters studied. Number of primary branches per plant, number of secondary branches per plant, length of siliqua, number of seed per siliqua, thousand seed weight and yield per plant showed least difference between genotypic and phenotypic variance which indicated low environmental influence on these characters. Hence, selection will be beneficial for these traits. Plant height and number of siliqua per plant showed much difference between genotypic and phenotypic variance suggesting high environmental influence on the expression of these characters. Therefore, selection will not be beneficial for these traits.

In the six F_5 and three F_8 progenies for most of the characters wide range of variation was observed. In case of plant height and number of siliqua per plant showed higher influence of environment for the expression of these characters. The highest GCV (79.55 %) and PCV (79.62 %) were observed in number of secondary branch per plant. The lowest GCV (2.72%) and PCV (4.34%) were found in days to maturity.

High values for heritability and genetic advance for various traits indicated good genetic potential for selection and for use in future breeding programs. Number of siliqua per plant showed high heritability (96.69%) along with high genetic advance (88.55) and high genetic advance in percentage of mean (73.66%). High heritability (98.06%) along with high genetic advance in percentage of mean (83.04%) was observed for yield per plant. Moderate heritability (39.30%) with low genetic advance (3.06) was found for days to maturity.

Study on correlation revealed that yield per plant had positive association with days to maturity, plant height, number of secondary branches per plant, number of siliqua per plant, siliqua length and thousand seed weight (at both genotypic & phenotypic level).

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

Selection was carried out among the six F_5 and three F_8 materials of *Brassica rapa* for most promising lines with high yield. The performance of the nine lines was also compared with two check varieties. Based on the variability and as per our objectives four most promising populations (BARI sarisha-6×BARI sarisha-15 S_1F_8, BARI sarisha-6×BARI sarisha-15S_1F_5, BARI sarisha-6×BARI sarisha-15 S_2F_5 and BARI sarisha-9×BARI sarisha-6 $S_{15}F_5$) with higher yield were selected from the six F_5 and three F_8 populations. Among the lines the highest yield per plant (11.95 g) was found in BARI sarisha-6×BARI sarisha-15 S_1F_5. These lines possess excellent potential for use in future breeding programs.

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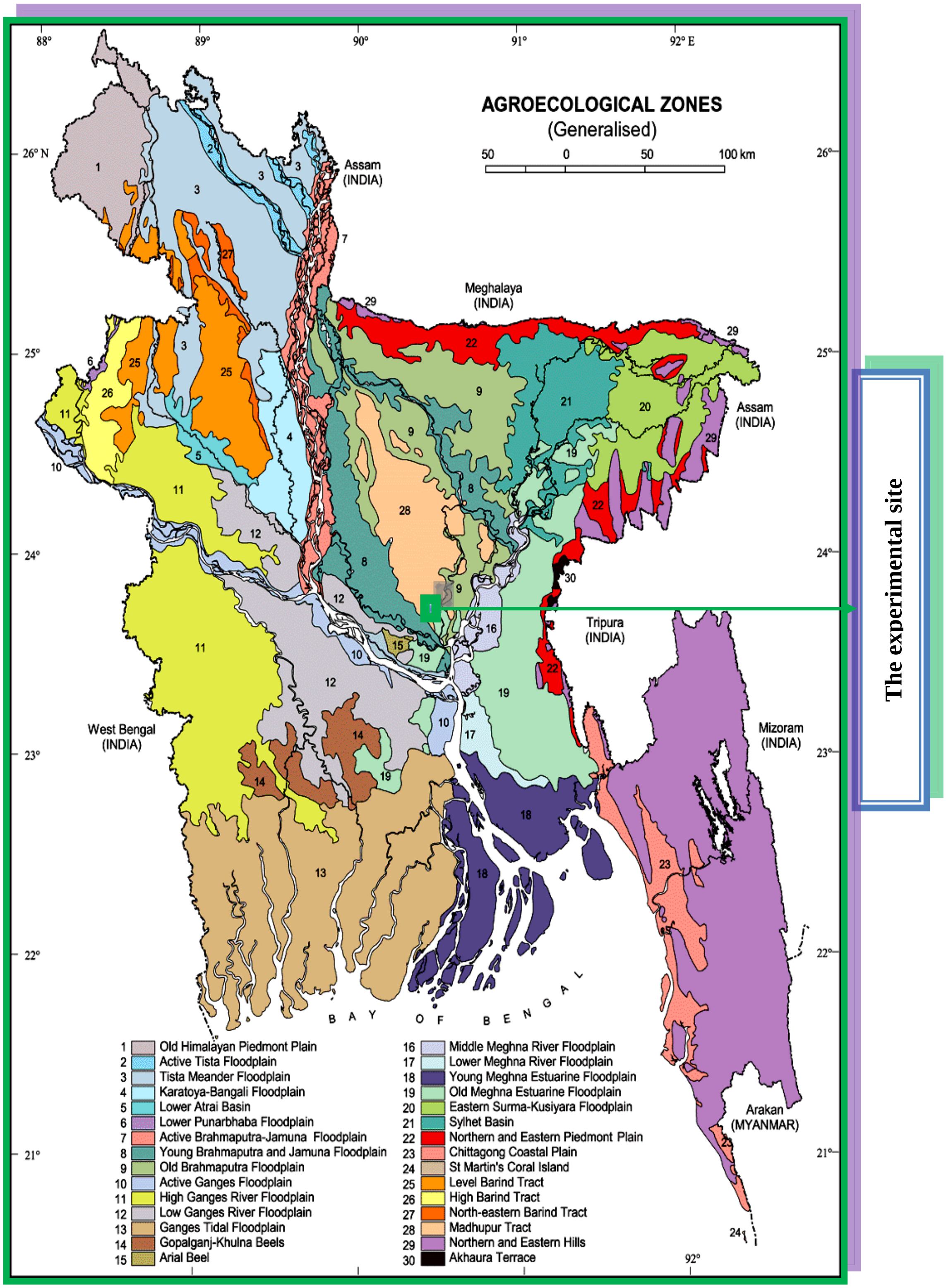
APPENDICES

Appendix I. Map showing the experimental site under the study



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

Month	Air temperature		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
November, 2015	28.10	06.88	58.18	1.56	5.8
December, 2015	25.36	05.21	54.30	0.63	7.9
January, 2016	21.17	15.46	64.02	0.00	3.9
February, 2016	24.30	19.12	53.07	2.34	5.7

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

Appendix III. Analysis of variance of ten important characters in respect of nine lines of *Brassica rapa* L.

Source of variation	df	DF	DM	PH	NPB/P	NSB/P	NS/P	LS	NS/S	TSW	Y/P
Replication	2	7.81	21.00	205.41	0.259	0.034	163.61	0.040	0.447	0.049	0.139
Genotypes	8	74.56**	25.50*	246.98**	3.63**	20.68**	5798.54**	0.404**	18.81**	4.82**	21.67**
Error	16	4.89	8.66	33.94	0.205	0.013	65.49	0.034	1.791	0.023	0.142

** Significant at 1% level of significance
* Significant at 5% level of significance
DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, NPB/P = Number of primary branch per plant, NSB/P = Number of secondary branch 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.

Appendix IV. Mean performance of nine lines of *Brassica rapa* L.

Genotypes	DF	DM	PH	NPB/P	NSB/P	NS/P	LS	NS/S	TSW	Y/P
G1	45.00 a	90.00a	98.26de	5.433c	0.0333f	61.67d	5.993ab	24.43ab	1.190d	4.220e
G2	45.00 a	89.67a	92.86e	6.733b	0.1667f	72.07d	5.64c	25.42a	1.230d	5.367d
G3	41.00ab	88.33a	112.7abc	4.433d	0.0333f	60.20d	5.85abc	25.23a	1.223d	4.740de
G4	37.33bc	86.67a	123.1a	6.433b	4.167d	167.7a	5.26d	20.99c	3.487b	6.133c
G5	33.67cd	80.33b	108.7bcd	6.833b	3.767e	150.4b	4.93e	21.62c	3.117c	4.353e
G6	33.00d	85.67a	107.2bcd	8.067a	5.067c	125.8c	6.057a	21.93c	4.807a	4.797de
G7	33.67cd	86.67a	110.9bc	6.533b	5.700b	160.3ab	5.94abc	22.18bc	2.957c	11.95a
G8	34.00cd	88.00a	114.6ab	5.00cd	3.767e	128.2c	5.73abc	21.81c	3.577b	8.953b
G9	34.00cd	88.67a	102.6cde	6.667b	7.033a	155.6ab	5.64bc	17.33d	3.130c	8.720b
$LSD_{(0.05)}$	3.83	5.10	10.08	0.783	0.197	14.01	0.319	2.32	0.262	0.652
SE (±)	1.66	0.97	3.02	0.37	0.88	14.65	0.12	0.83	0.42	0.90
Minimum	33.00	80.33	92.86	4.43	0.03	60.20	4.93	17.33	1.19	4.22
Maximum	45.00	90.00	123.15	8.07	7.03	167.67	6.06	25.42	4.81	11.95
Mean	37.41	87.11	107.89	6.24	3.30	120.21	5.67	22.33	2.75	6.58
Level of significance	**	*	**	**	**	**	**	**	**	**
CV (%)	5.92	3.38	5.40	7.25	3.48	6.73	3.24	5.99	5.49	5.72

** Significant at 1% level of significance

* Significant at 5% level of significance

DF = Days to 50% flowering, DM = Days to maturity, PH = Plant height, NPB/P = Number of primary branch per plant, NSB/P = Number of secondary branch 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.