GENETIC VARIABILITY AND CHARACTER ASSOCIATION OF ADVANCED LINES IN *Brassica rapa* L.

MD. ARIF HUSSAIN

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

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BY

MD. ARIF HUSSAIN

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Approved by:

(Prof. Dr. Md. Sarowar Hossain)
Supervisor

(Prof. Dr. Shahidur Rashid Bhuiyan)
Co-supervisor

(Prof. Dr. Md. Sarowar Hossain)
Chairman
Examination Committee

Prof. Dr. Md. Sarowar Hossain
Department of genetics and plant breeding
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Bangladesh
Mobile no. : 01552499169

CERTIFICATE

*This is to certify that thesis entitled, **"Genetic variability and character association of advanced lines 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 bonafide research work carried out by **Md. Arif Hussain**, **Reg. No. 08-03120** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2014 **(Prof. Dr. Md. Sarowar Hossain)**

Place: Dhaka, Bangladesh **Supervisor**

LIST OF ABBREVIATED TERMS

Abbreviation	Full word
%	Percent
ºC	Degree Celsius
@	At the rate
σ^2p	Phenotopic variance
σ^2g	Genotypic variance
σ^2e	Environmental variance
h^2b	Heritability in broad sense
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Anova	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
Cm	Centi-meter
CV%	Percentage of Coefficient of Variation
cv.	Cultivars
Df	Degrees of Freedom
et al.	And others
etc.	Etcetera
F_{12}	The twelve generation of a cross between two dissimilar homozygous parents
FAO	Food and Agricultural Organization
g	Gram
G	Genotype
GA	Genetic Advance
GCV	Genotypic coefficient of variation
HI	Harvest Index
IARI	Indian Agricultural Research Institute
J.	Journal
Kg	Kilogram
m	Meter

(Continued…)

Abbreviation	Full word
MS	Mean sum of square
MP	Murate Potash
m^2	Square meter
PCV	Phenotypic coefficient of variation
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate

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MD. ARIF HUSSAIN

ABSTRACT

An experiment was carried out with 24 genotypes including 4 check varieties of the species *Brassica rapa* L. in the experimental farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during November, 2013-March, 2014 for estimating the magnitude of variations in characters, heritability, genetic advance, character associations, direct and indirect effect of different characters on seed yield per plant. The phenotypic variances were higher than the genotypic variances. Significant variation was observed among all the genotypes for all the characters studied. Days to 50% flowering, days to 80% maturity showed moderate difference between the phenotypic and genotypic variance whereas minimum differences were found in number of primary branches per plant, number of secondary branches/plant, number of seeds per siliqua, siliqua length and thousand seed weight and yield per plant. Number of secondary branches per plant showed high heritability coupled with high genetic advance in percentage of mean. On the other hand days to 50% flowering, no. of siliqua per plant, yield per plant showed high heritability with moderate genetic advance in percentage of mean. Days to 80% maturity, no. of primary branches per plant, no. of seed per siliqua showed high heritability coupled with low genetic advance in percentage of mean. The significant positive correlation with seed yield per plant were found in thousand seed weight, no. of siliqua per plant, no. of primary branches per plant. Path co-efficient analysis revealed that plant height, no. of primary branches per plant, no. of siliqua per plant, siliqua length, thousand seed weight showed positive direct effect with yield per plant. Days to 50% flowering, days to 80% maturity, no. of secondary branches per plant, no of seed per siliqua showed negative direct effect on yield per plant. Beside these days to 50% flowering, days to 80% maturity, no. of secondary branches per plant, no of seed per siliqua showed negative direct effect on yield per plant. Considering all the characters related to yield and early maturity the two advanced lines G3 and G17 have the potentiality toward the development of improved variety that might be a trademark in *Brassica rapa* L. It may be concluded that a scope relies for further work with G1 (SAUSR-03) that was the earliest matured line with moderate yield.

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CHAPTER I

INTRODUCTION

Brassica rapa L. commonly known as field mustard or turnip mustard is a plant widely cultivated as an oil seed. Rapeseed is a major oilseed crop in Bangladesh. It contributes a lion share to the total edible oil production in the country. *Brassica rapa*, belonging to the family Brassicaceae and third most important oil crop in the world. 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. Among the oilseed crops, mustard and rape seed is in the second position after soybean (FAO, 2014). Total area of mustard and rapeseed in the world is 34.33 million hectares (FAO, 2013).

It occupies the 1st position in respect of area and production among the oil crops grown in Bangladesh. Though the local cultivars of *Brassica juncea* and *Brassica napus* are high yielding, they are not short durable. That's why *Brassica rapa* is grown widely in the country (Islam, 2013).

Rapeseed is a crop supplying both edible oil as well as for industrial uses. It is not only a high energy food but also a carrier for fat soluble vitamins (A, D, E and K) in the body. Poor intake of fat and oil reduce the availability of fat soluble vitamins and caused dietary imbalance and food wastage. In a balanced diet 20-25% of calories should come from fats and oils and the average need of fats and oil is about 37g per day (Rahman, 1981). The seeds of *Brassica rapa* contain 42% oil, 25% protein (Khaleque, 1985). It also serves as important source of raw material for industrial use such as in making soaps, paints, hair oils, lubricants, textile auxiliaries, pharmaceuticals etc. oil cakes and meals are used as animal feeds and manures.

About 0.832638 million tons of edible oil produced in Bangladesh which is very low against the requirement (BBS, 2011). To fulfil this lacking the country imports 0.89970 million tons of mustard oil that costs 371.8457000 million Tk. (BBS, 2011).

The targeted yield of oil seed in 2015-2020, 2020-2025 and 2025-2030 is 1730 kg ha^{-1}, 2141 kg ha^{-1} and 2572 kg ha^{-1} in Bangladesh that is now 1186 kg ha^{-1} only. In Bangladesh there is limited scope to increase acreage due to pressure of other crops. And there is limited scope to increase yield because farmers usually cultivate the existing low yielding varieties with low input and management and almost all cultivars are brown seeded and smaller in size (2-2.5 g/1000 seeds). Short duration variety like Tori-7 of *B. rapa* is still popular in Bangladesh because it can fit well into the T.Aman - Mustard – Boro cropping pattern. There is no improved short duration variety *B. rapa* is available to replace this short duration but low yielding variety.The above scenario indicates there should be an attempt to develop short duration and high yielding varieties of mustard with more oil percentage in seed, tolerant to biotic and abiotic stress to fulfill the requirement of edible oils of the country by increasing the production. The improved variety also should well fit into T. amon-Mustard-Boro cropping pattern.

One of the main objectives of any breeding program is to produce high-yielding and better-quality lines for release as cultivars to farmers. The prerequisite to achieve this goal is to find sufficient amount of variability, in which desired lines are to be selected for further manipulation to achieve the target. Analysis of variability among the traits and the association of a particular character in relation to other traits contributing to yield of a crop would be of great importance in planning a successful breeding program (Mary and Gopalan, 2006). Development of high-yielding cultivars requires a thorough knowledge of the existing genetic variation for yield and its components. The observed variability is a combined estimate of genetic and environmental causes, of which only the former one is heritable. However, estimates of heritability alone do not provide an idea about the expected gain in the next generation, but have to be considered in conjunction with estimates of genetic advance, the change in mean value among successive generations (Shukla *et al*., 2006). Seed yield is a complex character that can be determined by several components reflecting positive or negative effects upon this trait, whereas it is important to examine the contribution of each of the various components in order to give more attention to those having the greatest influence on seed yield (Marjanovic-Jeromela *et al.*, 2007). Determination of correlation coefficients is an important statistical procedure to evaluate breeding programs for high yield, as well as to examine direct and indirect contributions to yield variables (Ali *et al.*, 2003). Path coefficient technique splits the correlation coefficients into direct and indirect effects via alternative characters or pathways and thus permits a critical examination of components that influence a given correlation and can be helpful in formulating an efficient selection strategy (Sabaghnia *et al.*, 2010).

The present study was undertaken to find out the variability range, to select desired plant type of early maturity, to study the relation between different traits and the direct and indirect contribution of each trait towards yield in the advanced lines of *B. rapa* L.

Objectives

The present research work was undertaken with the following objectives:

- To evaluate the performances of individual genotypes
- To determine the nature of association, direct and indirect relationship between yield and yield contributing characters of the genotypes and
- To select promising genotypes considering early maturity and high yield

CHAPTER II

REVIEW OF LITERATURE

Brassica species has received much attention by a large number of researchers on various aspects of its production and utilization. *Brassica species* is the most important oil crop of Bangladesh and many countries of the world too. Many studies on the variability, interrelationship, path co-efficient analysis, heritability and genetic advance have been carried out in many countries of the world. The review of literature concerning the studies presented under the following heads:

2.1 Variability, heritability, genetic advance and selection in *Brassica species*

2.2 Correlation among different characters

2.3 Path co-efficient analysis

2.1. Variability, heritability, genetic advance and selection in different *Brassica species*:

Akbar *et al.* (2007) evaluated eight advanced lines of Zahid and two check variety of *Brassica junea* in Pakistan and studied variability, heritability and genetic advance of different yield components that were under experiment. The highest GCV was found in seed yield per plant followed by plant height, siliqua per plant and thousand grain weight while lowest GCV was in number of primary branches per plant. Highest heritability was found yield per plant followed by plant height, thousand grain weight, siliqua per plant and number of primary branches per plant. The maximum genetic advance was found in seed yield per plant followed by siliqua per plant, plant height, thousand grain weight and minimum in primary branches per plant.

Khan *et al.* (2013) evaluated thirty F7 segregating lines and two parents of *Brassica rapa* to study variability, heritability and genetic advance. The result revealed that except thousand seed weight, significant variation was presented among all the genotypes for all the characters. Highest genotypic, phenotypic and environmental variances were observed in plant height while lowest one was in length of siliquae followed by thousand grain weight. Thousand seed weight, number of secondary branches per plant, seeds per siliquae, and siliquae length showed high heritability along with low genetic advance in percent of mean. Considering important performances, the genotypes G-15, G-19, G-1, G-3, G-4, G-10, G-18, G21, and G-24 were found suitable for future breeding program.

Rashid (2007) studied variability of forty oleiferous *Brassica species*. High GCV (Genotypic Co-efficient of Variation) value was observed for days to 50% flowering, days to maturity, plant height and number of siliqua per plant.

A study was conducted by Hosen (2008) using five parental genotypes of *Brassica rapa* and their ten F_3 progenies including reciprocals. The result revealed that there were large variations present among all the genotypes used in the experiment. Number of primary branches per plant, number of secondary branches per plant, days to 50% flowering, length of siliqua, number of seeds per siliquae, thousand seed weight and yield per plant showed least difference between phenotypic and genotypic variances. The values of GCV and PCV indicated that there was considerable variation among the all characters except days to maturity. The plant height, days to 50% flowering and number of siliquae per plant showed high heritability with high genetic advance and genetic advance in percentage of mean.

A field experiment was conducted by Jahan (2008) to study on inter-genotypic variability and genetic diversity in 10 F_4 lines obtained through intervarietal crosses along with 8 released varieties of *Brassica rapa* during November 2007 to March 2008. Significant variation was observed among all genotypes for all the characters studied. Considering genetic parameters high genotypic co-efficient of variation (GCV) was observed for number of secondary branches/plant, siliquae/plant, yield/plant whereas days to maturity showed very low GCV. High heritability with low genetic advance in percent of mean was observed for days to maturity which indicated that non-additive gene effects were involved for the expression of this character and selection for suh trait might not be rewarding. High heritability with moderate genetic advance in percent of mean was observed for plant height and days to 50% flowering indicating that this trait was under additive gene control and selection for genetic improvement for this trait would be effective.

Alam (2010) conducted an experiment by using twenty six F4 populations of some inter-varietal crosses of *Brassica rapa* L. to study the variation among them. Higher phenotypic variation was present than the genotypic variation. High heritability with high genetic advance was found plant height, number of primary branches per plant, number of secondary branches per plant and number of siliquae per plant.

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

In an experiment Rashid (2007) studied variability of 40 oleiferous *Brassica species*. Result revealed that genotypes showed wider variation for morphological characteristics and thus were categorized under three cultivated species - *B. rapa*, *B. napus* and *B. juncea* considering genetic parameters. High GCV value was observed for days to 50% flowering, days to maturity, plant height and number of siliquae/plant.

Ali *et al.* (2013) conducted an experiment with thirty lines of *Brassica carinata* and reported that PCV and GCV ranged from 4.92-48.24% and 3.2-38.1%, respectively. The highest heritability values were recorded for pod length (0.83) followed by pods on main raceme and the genetic advance as percent of mean was the highest for seed yield per plant and pods on main raceme.

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

Parveen (2007) studied variability in F_2 progenies of the inter-varietal crosses of 17 *Brassica rapa* genotypes. The result revealed that there were significant variations among the different genotypes used in the experiment. Number of primary branches/plant and secondary branches/plant showed high heritability coupled with high genetic advance and very high genetic advance in percentage.

Afroz *et al.* (2004) studied genetic variability of 14 genotypes of mustard and rape. The highest genetic advance was observed in percent of pollen sterility.

Mahak *et al.* (2004) conducted an experiment on genetic variability, heritability, genetic advance and correlation for 8 quantitative characters. The phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all characters. High heritability coupled with high genetic advance in percentage of mean was observed for days to flowering, followed by thousand seed weight, days to maturity and plant height.

Niraj and Srivastava (2004) studied on variability and character association in Indian mustard of 21 genotypes of *Brassica juncea*. RH-9704 and IGM-21 recorded the highest seed yield. Phenotypic coefficient of variation was high for oil yield per plant, seed yield per plant and seed weight. Heritability was high for test weight, days to flowering, days to maturity and plant height.

Choudhary *et al.* (2003) studied variability in Indian mustard for 10 characters during rabi season in India. A wide range of variability was observed for all characters, except for primary branches per plant, siliqua length, number of seeds per siliqua and thousand seed weight. Genotypic and phenotypic coefficient of variability was recorded high for secondary branches per plant, seed yield per plant and number of siliqua per plant. High heritability coupled with high genetic advance as percentage of mean was observed for secondary branches per plant, seed yield per plant and number of siliquae per plant, indicating preponderance of additive gene action.

Genetic variability for 9 traits in 25 genotypes study by Pant and Singh (2001). Analysis of variance revealed highly significant genotypic differences for all traits studied, except for days to flowering, number of primary branches and oil content. Seed yield per plant had the highest coefficient of genotypic and phenotypic variability. All traits showed high heritability, with the highest value estimated for seed yield per plant. The estimates of genetic advance were comparatively low for oil content and days to flowering. The genotypic coefficient of variation and heritability estimates for oil content and days to flowering suggest that these traits cannot be improved effectively merely by selection.

Ghosh and Gulati (2001) studied genetic variability and association of yield components in Indian mustard among 12 yield components for 36 genotypes selected from different geographical regions. The genotypic and phenotypic coefficients of variability (GCV and PCV, respectively) were high in magnitude for all the characters except plant height. The differences between the PCV and GCV were narrow for all the characters studied, coupled with high heritability except plant height, indicating the usefulness of phenotypic selection in improving these traits. High heritability, coupled with high genetic advance was observed for oil content, harvest index, number of primary branches, number of siliquae on main shoot, main shoot length and number of seeds per siliqua. This result suggests the importance of additive gene action for their inheritance and improvement could be brought about by phenotypic selection.

Tyagi *et al*. (2001) evaluated forty-five hybrids of Indian mustard obtained from crossing 10 cultivars for seed yield and yield components. Variation was highest for plant height of parents and their hybrids. The seed yield per plant exhibited the highest coefficient of variation (41.1%).

An experiment was conducted by Khulbe *et al.* (2000) to estimates of variability, heritability and genetic advance for yield and its components in Indian mustard revealed maximum variability for seed yield. All the characters except oil content exhibited high heritability with high or moderate genetic advance, suggesting the role of additive gene action in conditioning the traits. Non-additive gene action appeared to influence the expression of days to maturity, while environment had a major influence on oil content. The use of pedigree selection or biparental mating in advanced generations was advocated to achieve substantial gains.

Afrin *et al.* (2011) conducted an experiment in *Brassica napus* and studied heritability. The plant height showed highest value of broad sense heritability while the number of primary branches per plant, number of secondary branches per plant, siliqua length, number of seed per siliquae, number of siliqua per plant, thousand seed weight and seed yield per plant showed moderate broad sense heritability. Days to 80% maturity showed lowest heritability.

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

Walle *et al.* (2014) carried out a study with thirty six genotypes of Ethiopian mustard (*Brassica carinata*) and result revealed that there were significant difference in days to 50% flowering, plant height and primary branches per plant. GCV was lower than the PCV for all yield related characters studied. High heritability with high genetic advance was observed in plant height, number of secondary branches per plant and days to 80% maturity.

Mekonnen (2014) evaluated thirty six genotypes of Ethiopian mustard, *Brassica carinata* to study variability. The GCV ranged from 4.3% to 44.14% and PCV from 8.3% to 91.7%. Comparatively high GCV estimates were observed for number of pods per plant, primary and secondary braches per plant, seed yield per plot, and seed yield per hectare. The highest PCV was in primary branches per plant. Higher GCV and PCV for seed yield, number of pods per plant, primary and secondary branches which indicated that, it might provide better scope for improvement through selection. Besides these, higher heritability along with higher genetic advance was observed in days to maturity, days to flowering, grain-filling period, number of pods per plant, secondary branches per plant, plant height, seed yield/plot and hectare and lowest one was in primary branches per plant.

2.2 Correlation among different characters

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

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

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

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

In an experiment Mahmud (2008) found highly significant positive association of seed yield per plant with number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant.

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.

Parveen (2007) conducted an experiment 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 siliquae and number of siliquae per plant, days to 50% flowering and length of siliqua.

Uddin *et al*. (2013) conducted an experiment with seven parental and twenty one F2 progenies of *Brassica rapa* to study correlation among different yield component and found that yield per plant had high significant positive correlation with number of primary branches per plant, number of secondary branches per plant and siliqua per plant at both phenotypically and genotypically and significant positive correlation at genotypically in days to flowering and days to maturity.

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

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. The number of siliqua per plant, 1000-seed weight, crop growth rate during 60-75 days after sowing and number of branches per plant were also positively associated with seed yield.

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

Akbar *et al.* (2007) evaluated eight advanced lines and two check variety of *Brassica junea* in Pakistan and reported that siliqua per plant had strong positive correlation with the seed yield followed by plant height while non-significantly negative correlation with thousand grain weight. But significantly negative correlation was present in siliqua per plant and primary branches per plant.

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

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

Mahak *et al.* (2004) conducted an experiment and studied correlation for 8 quantitative characters. Seed yield per plant showed positive correlation with number of primary branches, length of main raceme, 1000-seed weight and oil content. Selection should be applied on these traits to improve seed yield in Indian mustard.

An experiment conducted by Niraj and Srivastava (2004) on character association studies in Indian mustard of 21 genotypes of *Brassica juncea*. Seed and oil yields were positively and significantly correlated with plant height and primary branches but negatively correlated with test weight.

Pankaj *et al.* (2002) studied four parental cultivars and the 174 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 siliqua 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 siliquae and test weight at both levels. The number seeds per siliquae were positively associated with siliqua length and yield per plant at both levels.

Badsra and Chaudhary (2001) studied correlation on 14 traits of 16 Indian mustard genotypes. Seed yield was positively correlated with stem diameter, number of siliquae per plant and oil content, while oil content was positively correlated with harvest index only. Among the characters only 3 characters positively correlated with seed yield.

Association of yield components in Indian mustard among 12 yield components were studied in 36 genotypes selected from different geographical regions by Ghosh and Gulati (2001). Seed yield exhibited significant positive association with yield contributing traits like days to 50% flowering, days to maturity, plant height, number of secondary branches, number of siliquae on main shoot and oil content.

Days to maturity showed insignificant correlation with seed yield at both genotypic and phenotypic levels. The number of branches per plant and number of siliquae per plant showed significant negative correlation with number of seeds per siliqua and 1000 seed weight was reported by Malek *et al*. (2000), while studied correlation analysis.

Singh (2010) studied sixty two F1 and twenty four parental lines of Brassica juncea and observed that positive correlation was present in plant height, primary branches per plant, secondary branches per plant, seed per siliquae, thousand grain weight with seed yield.

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.

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

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

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

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 siliquae per plant and number of primary and secondary branches per plant.

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

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

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

Srivastava and Singh (2002) reported that number of primary branches per plant, number of secondary branches per plant and 1000 seed weight had strong direct effect on seed yield while working with Indian mustard (*B. juncea* L. Czern and

Coss). Results suggested that number of primary branches and 1000 seed weight were vital selection criteria for improvement-in productivity of Indian mustard.

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

Afroz *et al.* (2004) studied path analysis of fourteen genotypes of mustard and siliquae per plant, seed yield per plant, number of primary branches per plant and thousand seed weight.

Aytac *et al.* (2008) evaluated on six genotypes of spring rape seed and studied path coefficient and the result stated that plant height, number of siliqua per plant, seeds per siliquae had highest and positive direct effect on yield per plant for all cultivars except cv. Star.

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

Mekonnen *et al.* (2014) conducted an experiment to study path co-efficient in *Brassica carinata* and founded that days to maturity and secondary braches per plant had positive and direct genotypic correlation with seed yield.

The number of siliquae per plant had the highest positive direct effect on seed yield was observed by Yadava *et al.* (1996) when studied path co-efficient analysis of 6 yield components of 25 diverse varieties of Indian mustard.

Uddin *et al.* (2013) conducted an experiment with seven parental and twenty one F2 progenies of *Brassica rapa* to study path coefficient and reported that days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, siliquae length, seed per siliquae and thousand seed weight showed direct positive association with seed yield per plant while the plant height and days to maturity had direct negative association.

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental site

The present experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during November, 2013 to March, 2014. The location of the experimental site was situated at **23^0 74'** N latitude and **90^0 35'** E longitude with an elevation of 8.6 meter from the sea level.

3.2 Soil and Climate:

The experimental site was situated in the subtropical zone. The soil of the experimental site belongs to Agroecological region of “Madhupur Tract” (AEZ No. 28). The soil was clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH was 5.47 to 5.63 and organic carbon content is 0.82% (Appendix II). The records of air temperature, humidity and rainfall during the period of experiment were noted from the weather station, Sher-e-Bangla Agricultural University, Dhaka. (Appendix III).

3.3 Experimental materials:

A total number of 24 (twenty four) materials were used in this experiment where four were check varieties. All the Materials were collected from Department of Genetics and Pant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The materials used in that experiment is shown in Table -1.

Table 1: Materials used for the experiment

Sl. No.	Genotypes	Description of crosses
01	G1	SAUSR-03
02	G2	BARI-9×BARI-6(F_{12}) LINE-1
03	G3	BARI-6 ×TORI-7(F_{12}) LINE-1
04	G4	BARI-6×TORI-7 LINE-2
05	G5	BARI-9×BARRI-6 LINE-2
06	G6	SAU-1×SAU-2(F_4)
07	G7	SAU-1×BARI-15(F_4)
08	G8	SAUSR 17
09	G9	BARI-9×BARI-6(F_{12}) LINE-3
10	G10	F_6×BARI-9 LINE-1
11	G11	F_6× BARI-9 LINE-2
12	G12	BARI-6× TORI-7 (F_{12}) LINE-3
13	G13	BARI-6× TORI-7 LINE-4
14	G14	F_6× BARI-9 LINE-3
15	G15	F_6× BARI-9 LINE-4
16	G16	BARI-9× BARI-6 LINE-4
17	G17	(BARI-6×BARI-15) ×(F_1×BARI-15)
18	G18	P_5×P_{10} (F_7)
19	G19	P_7×P_{10} (F_7)
20	G20	(SAU-1×SAU-2) ×(F_1×SAU-2)
21	G21	BARI-15 (Check variety)
22	G22	BARI-6 (Check variety)
23	G23	SAU-2 (Check variety)
24	G24	TORI-7 (Check variety)

NB: SAU- Sher-e-Bangla Agricultural University, BARI- Bangladesh Agricultural Research Institute .All lines were advanced line

3.4 Methods

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

3.4.1 Land preparation

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

3.4.2 Fertilizer application

Fertilizers such as urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and boron were applied at the rate of 250, 170, 85, 150 and 1-1.5 kg per hectare respectively. Urea was applied by two installments. Total amount of TSP, MP, gypsum, borax and boron along with half of the urea were applied at the time of final land preparation as a basal dose. The second half of the urea was top-dressed at the time of flower initiation.

3.4.3 Application of manure and fertilizer

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

3.4.4 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each replication size was 20 m × 3.5 m, and the distance between replication to replication was 1 m. The spacing between lines to line was 30 cm. Seeds were sown in lines in the experimental plots on 30 November, 2013. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods were on the seeds.

3.4.5 Intercultural operations

Intercultural operations, such as weeding, thinning, irrigation, pest management, etc. were done uniformly in all the plots. One post sowing irrigation was given with cane after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. The first weeding was done after 15 days of sowing. At the same time, thinning was done for maintaining a distance of 10 cm from plant to plant in rows of 30 cm. apart. Second weeding was done after 35 days of sowing. Aphid infection was found in the crop during the siliqua development stage. To control aphids Malathion-57 EC @ 2ml/liter of water was applied. The insecticide was applied in the afternoon.

3.4.6 Crop harvesting

Harvesting was done from February- March, 2014 depending upon the maturity. When 80% of the plants showed symptoms of maturity i.e. straw color of siliqua, leaves, stems desirable seed color in the mature siliqua, the crop was assessed to attain maturity. At maturity, ten plants were selected at random from all lines in each plot. The sample plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants.

3.4.7 Data collection

For studying different genetic parameters and inter-relationships ten characters were taken into consideration.

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

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

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

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

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

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

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

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

ix. **1000 seed weight (g):** Weight in grams of randomly counted thousand seeds of each entry was recorded.

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

3.4.8 Statistical analysis

All the collected data of the study were used to statistical analysis for each character, analysis of variance (ANOVA), mean, range were calculated by using MSTATC software program and then phenotypic and genotypic variance was estimated by the formula used by Johnson *et al*. (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhary (1985) and Allard (1960). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952). Genotypic and phenotypic correlation coefficient was obtained using the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956); and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

Estimation of genotypic and phenotypic variances:

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

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

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

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

Estimation of genotypic and phenotypic co-efficient of variation:

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

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

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

Where, GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δ_g = Genotypic standard deviation

δ_p = Phenotypic standard deviation

$\bar{x}$ = Population mean

Estimation of heritability:

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

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

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

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

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

Estimation of genetic advance:

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

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

Where, GA = Genetic advance

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

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

δ_p = Phenotypic standard deviation

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

Estimation of genetic advance in percentage of mean:

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

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

Estimation of simple correlation co-efficient:

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

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

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

Path co-efficient analysis:

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) and Dabholkar (1992), using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable. In order to estimate direct & indirect effect of the correlated characters, say x1, x2 and x3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as shown below:

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

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

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

Where, r’s denotes simple correlation co-efficient and P’s denote path co-efficient (Unknown). P’s in the above equations may be conveniently solved by arranging them in matrix from.

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

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

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

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

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

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

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

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

R_{iy} = Correlation of the character with yield.

CHAPTER IV
RESULT AND DISCUSSION

The present study was conducted with a view to determine the variability among 24 materials of *Brassica rapa* L. genotypes and also to study the correlation and path co-efficient for seed yield and different yield contributing characters. The data were recorded on different characters such as days to 50% flowering, days to 50% maturity, plant height (cm), no. of primary branches per plant, no of secondary branches per plant, total no. of siliqua /plant, siliqua length (cm), number of seeds per siliqua, 1000 seed weight (g) and yield per plant (g). The data were statistically analyzed and thus obtained results are described below under the following heads:

- Variability study in *Brassica rapa* L.
- Correlation coefficient of characters
- Path coefficient analysis

4.1. Variability study in *Brassica rapa* L.

4.1.1. Variability among the genotypes of *Brassica rapa* L.

4.1.1.1 Days to 50% flowering

The analysis of variance (ANOVA) showed that significant difference was observed among all the genotypes (32.268**) studied for days to 50% flowering (Table 2). The days to 50% flowering was observed the highest in G21 (44.67 days) and lowest in G13 (34 days). Advanced line G13 showed early flowering than the popular check varieties G24 (40.33), G21 (44.67 days) respectably (Table 3). Phenotypic and genotypic variance for days to 50% flowering was observed as 13.96 and 9.15(Table 4), respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (9.90%) was higher than the genotypic coefficient of variation (8.02%), which suggested that environment has significant role on the expression of this trait. Field view at flowering stage is presented in plate 1. Sharma (1984) found low GCV and PCV values while, Tak and Patnaik (1977) found these values as 4.5% and 1.8% respectively but Biswas (1989) found high GCV and PCV for this trait.

4.1.1.2 Days to 80% maturity

From the ANOVA (Table 2), it was found that days to 80% maturity showed significant variations among the genotypes (66.094) at the level of 1% probability. The highest days to 80% maturity was observed in G19 and G24 (92.33 days) and the lowest days to maturity was observed in G1 (79.33 days). Here G1 showed better performance (early maturity) over the popular check varities (G21, G22, G23, G24). Phenotypic and genotypic variance for days to maturity was observed 27.01 and 19.54, respectively with high differences between them, suggested high influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation 5.97% was higher than the genotypic coefficient of variation (5.08%), which suggested that apparent variation not only due to genotypic effect but also due to environmental effect (Table 3). Mean performance of days to 80% maturity of 24 genotypes is presented in figure 1. Naznin (2013) also found low difference between PCV (22.15) and GCV (19.74) in *B. rapa* L.

4.1.1.3 Plant height (cm)

Highly significant variations were observed among the genotypes (111.380**) at 1% level of probability (Table 2) for this trait. In this study the highest plant height was observed in G22 (115.10cm) whereas the minimum plant height was observed in G2 and G10 (91.77cm). Phenotypic variance and genotypic variance were observed as 59.57 and 25.91, respectively (Table 3). The phenotypic variance appeared to be highly differ than the genotypic variance suggested that environmental effect was high on the expression of the genes controlling this trait. The higher PCV (7.76%) than the GCV (5.12%) from the Table 4 gave an information that there were much variation among the genotypes in case of plant height. Low phenotypic coefficient of variation and genotypic coefficient of variation was found by Ghosh and Gulati (2001).

4.1.1.4 Number of primary branches per plant

The highly significant differences were observed among the genotypes for number of primary branches per plant (111.380**). Among the 24 genotypes the highest number of primary branches per plant was observed in G3 (7.13) whereas the minimum number of primary branches/plant was observed in G22 (5.27). Advanced line G3 showed better performance than the check varieties. Phenotypic variance and genotypic variance were observed as 0.29 and 0.16 respectively (Table 3). The phenotypic variance (0.29) appeared to be higher than the genotypic variance (0.16) suggested environmental effect present on the expression of the genes controlling this trait. Relatively low difference between PCV (8.65%) and GCV (6.54%) value indicating the apparent variation not only due to genotypes but also due to the influence of environment. Comparison of primary branches per plant between G3 and checked variety G22 is presented in plate 2. Hosen (2008) showed least difference between phenotypic and genotypic variances.

4.1.1.5 Number of secondary branches per plant

Number of secondary branches per plant showed highly significant differences (Table 2) among the genotypes (5.852^{**}). Among the 24 genotypes the highest number of secondary branches per plant was observed in G17 (8.20) whereas the minimum number of secondary branches per plant was observed in G21 (1.40). Difference between phenotypic variance (2.08) and genotypic variance (1.88) were low that means less environmental effect involved in this character (Table 4). PCV (30.25%) higher than GCV (28.75%), higher values indicated presence of variability among the genotypes for this trait (Table 4). Comparison of secondery branches per plant between advanced line G17 and check variety G22 is presented in plate 3. Lekh *et al.* (1998) found highest genotypic coefficient of variation for number of secondary branches while working on 24 genotypes of *Brassica napus*.

4.1.1.6 Number of siliqua per plant

Highly significant variations was found for number of siliqua per plant (5.852) at 1% level of probability among the genotypes, (Table 2). The highest number of siliqua per plant was observed the highest in G17 (187.4) and the lowest in G22 (96.97). Advanced line G17 showed better performance than the check varieties (G21, G22, G23 and G24) for this trait. Number of siliqua per plant showed highly difference between phenotypic variance (454.38) and genotypic variance (180.84). The highest phenotypic variance and genotypic variance indicating large environmental influence, high genotypic variance indicating the better transmissibility of the character from parent to their offspring and the difference between the PCV (15.53%) and GCV (9.79%) was moderate, which indicating that existence of adequate variation among the genotypes. Mean performance of number of siliqua per plant of 24 genotypes is presented in figure 2. High genetic variation was also found by Kudla (1993). Low GCV (20.19) and high PCV (33.81) was found by Khan *et al*. (2013).

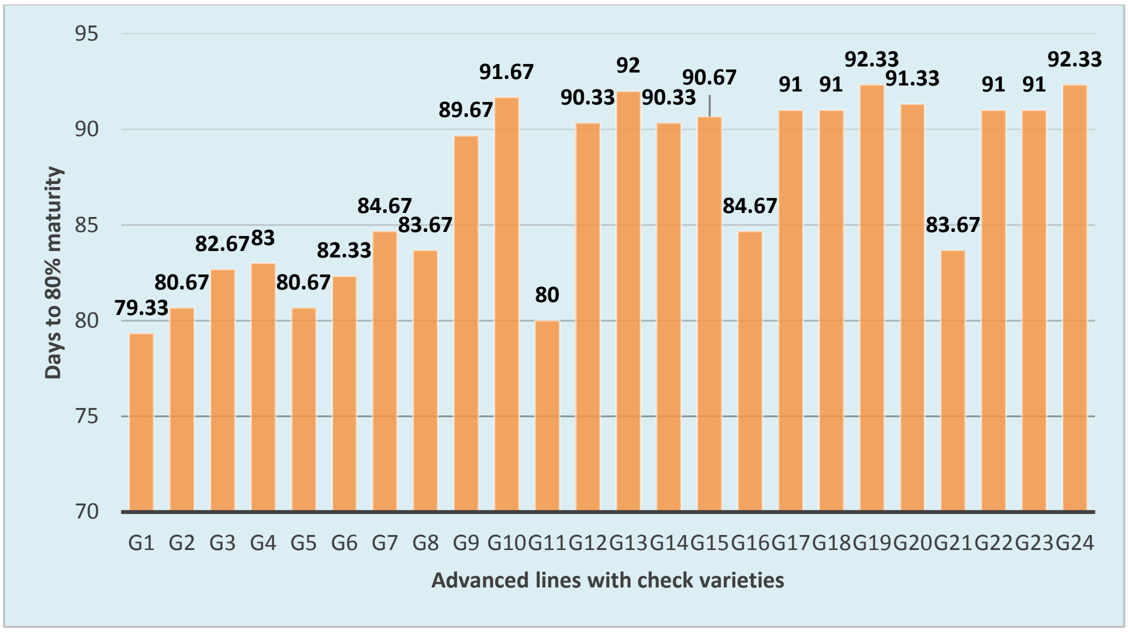

Figure 1. Mean performance of days to 80% maturity of the 24 genotypes

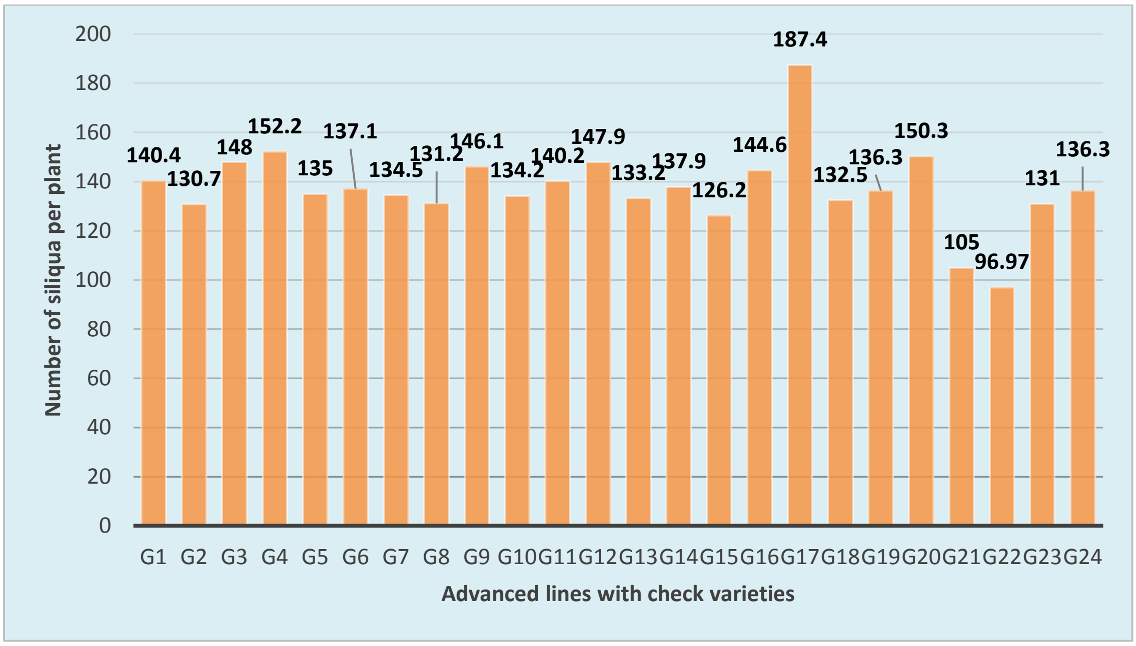

Figure 2. Mean performance of number of siliqua per plant of 24 genotypes

Plate 1. Photography showing field view at flowering stage

Table 2. Analysis of variance (ANOVA) for yield and its related characters of *Brassica rapa* L.

Sl No.	Characters	Mean sum of squares (MSS)		
		Replication	Genotypes	Error
	d.f	2	23	46
1	Days to 50% flowering	2.167	32.268**	4.804
2	Day to 80% maturity	12.875	66.094**	7.469
3	Plant height(cm)	691.300	111.380**	33.650
4	No.of primary branches/plant	0.049	0.616**	0.123
5	No. of secondary branches/plant	0.375	5.852**	0.201
6	No. of siliqua/plant	1798.143	816.063**	273.542
7	No. of seed/siliqua	2.035	5.363**	0.743
8	Siliqua length (cm)	0.258	0.411**	0.119
9	1000 seed weight(gm)	0.049	0.256*	0.090
10	Yield/plant (gm)	0.008	1.676**	0.222

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

Table 3. Mean performance of ten characters of 24 genotypes of *Brassica rapa* L.

Genotypes	Days to 50% flowering	Day to 80% maturity	Plant height (cm)	No. of primary branches	No. of secondary branches	No. of siliqua/plant	No. of seed/siliqua	Siliqua length (cm)	1000 seed weight(gm)	Yield/plant (gm)
G1	39.00	**79.33**	103.5	6.20	4.83	140.4	18.17	**5.12**	4.17	8.92
G2	37.00	80.67	**91.77**	6.00	3.93	130.7	19.90	6.15	4.14	7.87
G3	35.00	82.67	94.53	**7.13**	6.30	148.0	18.77	5.27	4.09	**9.44**
G4	35.67	83.00	93.17	6.10	4.13	152.2	18.77	6.27	3.69	8.74
G5	35.00	80.67	99.83	5.93	4.80	135.0	19.00	5.47	3.93	7.91
G6	39.33	82.33	106.8	6.00	4.77	137.1	20.03	5.95	**4.34**	8.95
G7	41.67	84.67	99.23	5.90	3.60	134.5	17.83	5.68	4.06	8.32
G8	37.67	83.67	92.07	5.97	4.87	131.2	18.50	5.36	4.15	8.09
G9	35.67	89.67	96.30	6.13	4.47	146.1	19.83	6.23	3.86	7.96
G10	34.67	91.67	**91.77**	5.97	5.87	134.2	19.98	**6.29**	3.72	8.47
G11	35.67	80.00	91.90	5.86	4.93	140.2	19.00	6.25	3.76	8.62
G12	35.33	90.33	99.77	6.60	5.17	147.9	20.07	6.04	4.15	9.26
G13	**34.00**	92.00	94.53	5.77	3.87	133.2	21.00	5.54	4.01	7.51
G14	36.00	90.33	101.1	5.63	4.90	137.9	21.53	5.90	3.87	8.02
G15	35.00	90.67	92.57	6.20	4.20	126.2	20.03	6.28	3.64	9.29
G16	37.67	84.67	99.07	6.30	3.53	144.6	17.60	5.54	3.83	8.22
G17	34.33	91.00	106.7	6.83	**8.20**	**187.4**	**16.83**	5.50	4.17	8.40
G18	34.33	91.00	101.7	6.57	6.40	132.5	19.50	6.01	3.60	7.12
G19	39.67	**92.33**	102.5	6.87	4.30	136.3	21.00	5.69	3.67	8.17
G20	43.33	91.33	108.0	7.07	7.50	150.3	18.20	5.49	3.55	7.24
G21	**44.67**	83.67	98.97	6.37	**1.40**	105.0	21.37	5.23	3.59	6.88
G22	43.33	91.00	**115.1**	**5.27**	4.60	**96.97**	20.87	5.97	**3.06**	**6.79**
G23	41.67	91.00	102.2	5.93	3.23	131.0	**22.00**	5.53	3.48	7.32
G24	40.33	**92.33**	103.0	6.20	4.77	136.3	19.53	5.69	3.82	8.17
Mean	37.75	87.08	99.42	6.20	4.77	137.30	19.55	5.77	3.85	8.15
CV (%)	5.81	3.14	5.84	5.66	9.39	12.05	4.41	5.98	7.80	5.78

Table 4. Estimation of genetic parameters for yield and yield contributing characters of 24 genotypes of *B. rapa* L.

SL. No.	Characters	Phenotypic variance (δ^2p)	Genotypic variance (δ^2g)	PCV (%)	GCV (%)
1	Days to 50% flowering	13.96	9.15	9.90	**8.02**
2	Day to 80% maturity	27.01	19.54	5.97	**5.08**
3	Plant height(cm)	59.57	25.91	7.76	**5.12**
4	No. of primary branches/plant	0.29	0.16	8.65	**6.54**
5	No. of secondary branches/plant	2.08	1.88	30.25	**28.75**
6	No. of siliqua/plant	454.38	180.84	15.53	**9.79**
7	No. of seed/siliqua	2.28	1.54	7.73	**6.35**
8	Siliqua length (cm)	0.22	0.10	8.06	**5.41**
9	1000 seed weight(g)	0.15	0.06	9.90	**6.11**
10	**Yield/plant (g)**	**0.71**	**0.48**	**10.31**	**8.54**

G3 **G22 (BARI sharisha-6)**

Plate 2. Comparison of Primary branches per plant between advanced line G3 and Check Variety G22 (BARI sharisha-6)

G17 **G22 (BARI sharisha-6)**

Plate 3. Comparison of Secondary branches per plant between advanced line G17 and Check Variety G22 (BARI sharisha-6)

4.1.1.7 Length of siliqua (cm)

The analysis of variance (ANOVA) showed that there was highly significant differences among the genotypes for days to maturity (0.411**) at 1%level of significance (Table 2). Length of siliqua was observed the highest in G10 (6.29 cm) and the minimum length of pod was observed in G1 (5.12 cm). In this study check varities showed smaller siliqua length than the advanced lines (Table 3). Length of siliqua showed phenotypic variance (0.22) and genotypic variance (0.10) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively medium PCV (8.06%) and GCV (5.41%) indicating that the genotype has moderate variation for this trait (Table 4) . Difference between PCV and GCV indicated high possibility of selecting this trait. High co-efficient of variation for this trait for both genotypic and phenotypic variability was recorded by Masood *et al.* (1999). Siliquae length of different advanced lines is presented in plate 4 and plate 5.

4.1.1.8 Number of seeds per siliquae

Significant differences among the genotypes were (5.363**) observed for number of seeds per siliquae (Table 2).The number of seeds per siliqua was observed highest in G 23 (22). The minimum number of seeds per siliqua was observed in G17 (16.83). The phenotypic and genotypic variances for this trait were 2.28 and 1.54 respectively (Table 3). The phenotypic variance appeared to be higher than the genotypic variance indicated influence of environment on the expression of the genes controlling this trait. The value of PCV and GCV were 7.73% and 6.35% respectively for number of seeds per siliqua which indicating less environmental effect exists among different genotypes. Due to less difference between GCV and PCV this trait can be improved through the selection. Similar variability was also recorded by Kumar and Singh (1994).

G3 **G24 (Tori-7)**

Plate 4. Comparison of Siliquae length between advanced line G3 and Check Variety G24 (Tori-7)

G10 **G24 (Tori-7)**

Plate 5. Comparison of Siliquae length between advanced line G10 and Check Variety G24 (Tori-7)

4.1.1.9 Thousand seed weight (g)

The significant differences were observed among the genotypes for number of primary branches per plant (0.256*) at 5% level of significance (Table 2). Thousand seed weight was found maximum in G6 (4.35 g) whereas the minimum thousand seed weight was found in G22 (3.06g). The important yield contributing character thousand seed weight of advanced line G6 was higher than the popular check varieties in this experiment (Table 3). Thousand seed weight showed very low phenotypic variance (0.15) and genotypic variance (.06) with little differences indicating that they were low responsive to environmental factors (Table 4). The phenotypic coefficient of variation (9.90%) and genotypic coefficient of variation (6.11%) were close to each other (Table 4). There was moderate difference between phenotypic and genotypic co-efficient of variation, indicating environmental influence on this character was moderate. Khan *et al*. (2013) found large difference between GCV (3.67) and PCV (18.09) while Naznin (2013) found very low difference (PCV=9.85 and GCV=8.13) in *B. rapa.* in this trait.

4.1.1.10 Yield per plant (g)

Seed yield per plant showed significant mean sum of squares (1.676**) due to different genotypes that suggested considerable range of variation for this trait (Table 2). Yield per plant was found maximum in G3 (9.44 g) when it was the minimum yield per plant was found in G22 (6.79g) advanced line (Table 3). Advanced line G3 showed better performance than the popular check varieties. The phenotypic variances and genotypic variances for this trait were 0.71 and 0.48 respectively (Table 4). The values are close to each other indicated less environmental influences on this trait. The values of PCV and GCV were 10.31% and 8.54% (Table 4) indicating that the genotype has minimum environmental variation for this trait. Mean performance of the 24 genotypes in yield per plant is presented in figure 3. Naznin (2013) and Akter (2010) found more PC value for the trait.

4.1.2 Heritability and genetic advance

4.1.2.1 Days to 50% flowering

Days to 50% flowering exhibited high heritability (65.58%), low genetic advance (5.05) with moderate genetic advance in percent of mean (13.37%) which revealed that the character was governed by additive gene action and high heritability indicates that this character is least influenced by the environmental effect. It showed moderate possibility for the selection of this trait (Table 5). Saifullah (2010) also found high heritability (88.86%) and low genetic advance (2.06%). Aktar (2010) and Khan *et al.*, (2012) supported the result.

4.1.2.2 Days to 80% maturity

Days to 80% maturity showed high heritability (72.35%) with low genetic advance (7.75) and genetic advance in percentage of mean (8.89%) indicated that this trait was controlled by non-additive gene action and selection for such trait might not be rewarding (Table 5). Naznin (2013) found high heritability (89.14%) with low genetic advance (8.69%) for the trait.

4.1.2.3 Plant height (cm)

The magnitude of heritability of this trait was moderate heritability (43.50%) with low genetic advance (6.92) and low genetic advance in percent of mean (6.96%). These findings were the indication of non-additive gene action and selection for such trait not be effective (Table 5). High heritability (92.48%) with moderate genetic advance (18.87) was found by Saifullah (2012) for the trait, where Naznin (2013) found high heritability (71.01%) with low genetic advance in percent of mean (9.49%) for this trait.

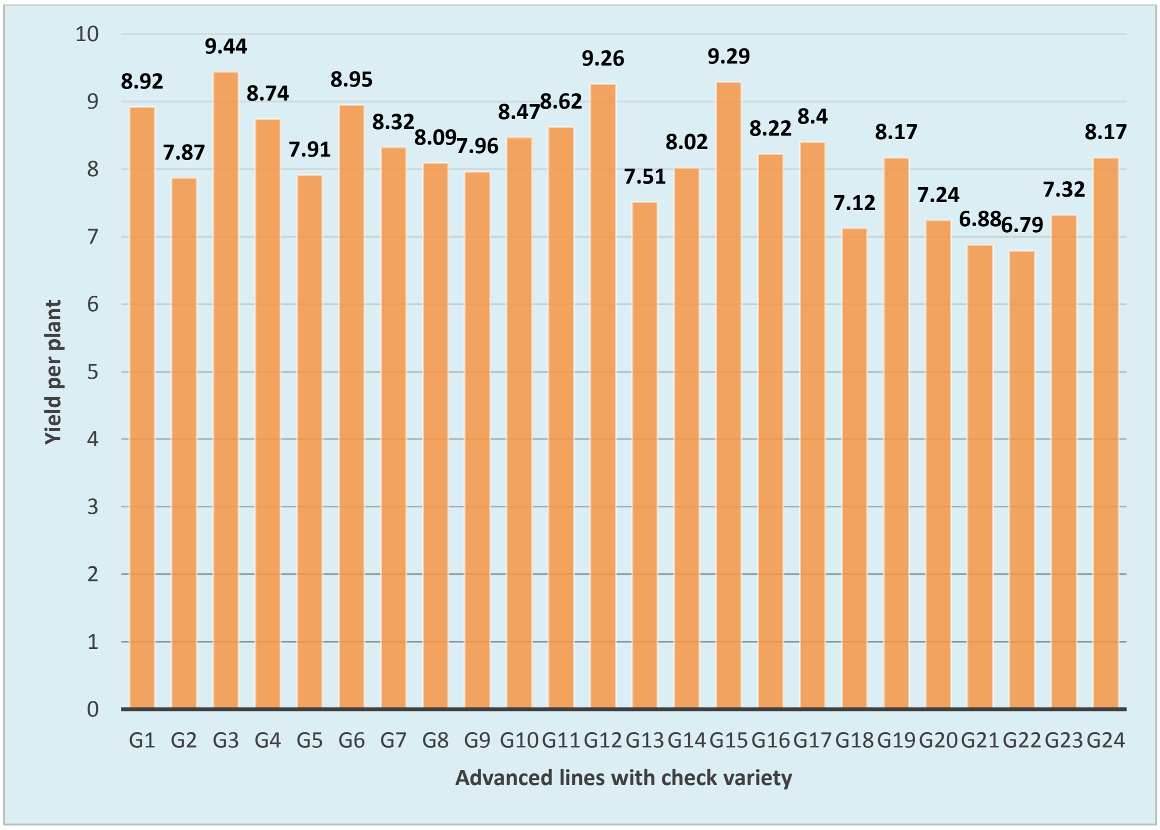

Figure 3. Mean performance of the 24 genotypes in yield per plant

Table 5. Heritability, genetic advance, genetic advance in percent of means for yield and yield contributing characters of 24 genotypes of *Brassica rapa* L.

SL. No.	Characters	Heritability (%)	GA	GA (%)
1	Days to 50% flowering	65.58	5.05	13.37
2	Day to 80% maturity	72.35	7.75	8.89
3	Plant height(cm)	43.50	6.92	6.96
4	No.of primary branches/plant	57.19	0.63	10.19
5	No. of secondary branches/plant	90.36	2.69	56.30
6	No. of siliqua/plant	39.80	17.48	12.73
7	No. of seed/siliqua	67.46	2.10	10.74
8	Siliqua length (cm)	44.99	0.43	7.47
9	1000 seed weight(g)	38.07	0.30	7.77
10	Yield/plant (g)	68.58	1.19	14.56

4.1.2.4 No .of primary branches per plant

Number of primary branches per plant exhibited high heritability (57.19%) and very low genetic advance (0.63) and genetic advance in percent of mean (10.19%) that determined the presence of non-additive gene effect on the character and for this reason, improvement through selection might not be so wise (Table 5). Khan *et al.* (2012) found high heritability (60.17%) and high genetic advance (17.89%) for the trait.

4.1.2.5 Number of secondary branches per plant

Number of secondary branches per plant exhibited high heritability (90.36%) with low genetic advance (2.69) and high genetic advance in percentage of mean (56.30%). These findings discovered that the action of additive gene involved on the expression of this character as well as a scope of improvement through selection must be rewarding (Table 5). Akter (2010) supported the result as he also found high heritability (89.65%) and low genetic advance (3.50%). Moderately high heritability coupled with low genetic advance was also found by Singh *et al*. (1987)

4.1.2.6 Number of siliqua per plant

Number of siliqua per plant exhibited moderate heritability (39.80%) with moderate genetic advance (17.48) and genetic advance in percentage of mean (12.73%). These results implied the possibility of predominance of additive gene action in the inheritance of this trait. There was both environmental and genotypic influence on the character (Table 5). This trait possessed moderate variation, it is moderate potential for effective selection for further genetic improvement of this character. Khan *et al.* (2013) also found moderate heritability (35.65%) with high genetic advance (48.78%) which supports the trait.

4.1.2.7 Number of seeds per siliquae

Number of seeds per siliquae showed high heritability (67.46%) with low genetic advance (2.10) and genetic advance in percent of mean (10.74%). The character was governed by non-additive genes and high heritability was being exhibited due to favorable environment rather than genotypes and selection for this trait may not be rewarding (Table 5). Saifullah (2010) also found high heritability (88.86%) and low genetic advance (2.06). Aktar (2010) and Khan *et al.*, (2012) supported the result.

4.1.2.8 Siliqua length (cm)

Siliqua length showed moderate heritability (44.99%) with very low genetic advance (0.43) and genetic advance in percent of mean (7.47%) that indicated that environmental effect was more than the genotypic effect and due to non-additive gene action selection for further improvement of the trait might not be effective (Table 5). Saifullah (2010) found the similar result for this trait.

4.1.2.9 Thousand seed weight (g)

The magnitude heritability of this trait was moderate heritability (38.07%) and low genetic advance (0.30) and low genetic advance in percent of mean (7.77%). These result indicated non-additive genes involvement in the expression of the trait and this with limited scope of improvement by direct selection (Table 5). Low heritability (16.09%) with low genetic advance (0.16) was found by Akter (2010) and high heritability (65.03%) with low genetic advance (0.31%) was stated by Saifullah (2010) for the trait.

4.1.2.10 Yield per plant (g)

High heritability (68.58%) coupled with low genetic advance (1.19) with moderate genetic advance in percent of mean (14.56%) indicated that low influence of genotypic materials and additive gene effect was present (Table 5).

Moderately possibility showed for the selection of this trait. Naznin (2013) found high heritability (57.05%) with low genetic advance (0.99%) for the trait.

4.2. Correlation co-efficient

Seed yield is a complex product being influenced by several quantitative traits. Some of these traits are highly associated with seed yield. The analysis of the relationship among those traits and their association with seed yield is very much essential to establish selection criteria. Breeders always look for genetic variation among traits to select desirable type. It is evident that in most of the cases, the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient. This indicated a strong inherent association between the characters studied and suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. In few cases, however, phenotypic correlation co-efficient were same or higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level.

4.2.1 Days to 50% flowering

Days to 50% flowering showed insignificant and positive correlation with days to 80% maturity (G = 0.015, P = 0.013), no. of seed per siliqua (G=0.190, P=0.194) at both genotypic and phenotypic level indicated that if days to 50% flowering increased then days to maturity also increased (Table 6). It also exhibited highly significant and positive interaction with plant height (G=0.550, P=0.544). However, it had highly significant and negative interaction with no. of secondary branches per plant (G=- 0.390, P=- 0.373), no. of siliqua per plant (G = - 0.580, P=- 0.492), siliqua length (G=- 0.421, P=- 0.369), thousands seed weight (G=- 0.413, P=- 0.409) (Table 6). It observed insignificant and negative interaction with no. of primary branches per plant (G=- 0.059, P=- 0.061). This trait had negative but highly significant interaction with yield per plant (G = - 0.533, P=- 0.491) (Table 5) both genotypic level and phenotypic level. This suggesting that if days to 50% flowering increased then yield/plant decreased and vice-versa. Parveen (2007) also revealed that days to 50% flowering had highly significant and negative interaction with yield per plant.

4.2.2 Days to 80%maturity

Days to 80% maturity showed significant and positive correlation with Plant height (G=0.308, P=0.311), number of secondary branches per plant at phenotypic level (P=0.254), no. of seed per siliqua at genotypic level (G=0.314) but high significant and positive correlation with no. of seed per siliqua at phenotypic level (P=0.359). It implied that yield could be improved by using above characters. Positive insignificant association of this trait was showed with number of primary branches per plant (G=0.050, P=0.120), number of siliqua per plant (G=0.008, P=0.029), siliqua length (G=0.218, P=0.196) and no. of secondary branches per plant (G=0.211) at genotypic level (Table 6). Insignificant association of these traits indicated that the association between these traits were largely influenced by environmental factors. There was negative but highly significant association of this trait with thousand seed weight (G=-0.480, P= - 0.434). Days to 80% maturity had negative significant interaction with yield/plant (P=- 0.299) at phenotypic level but highly significant with (G=-0.342) at genotypic level (Table 6). It indicates if days to 80% maturity increased then yield/plant decreased. Similar result was found by Zahan (2006) but Parveen (2007) reported insignificant and positive interaction with yield per plant for this trait.

Table 6. Genotypic and phenotypic correlation among different yield and yield contributing characters of 24 genotypes of *Brassica rapa* L.

Characters	Correlation	Day to 80% maturity	Plant height(cm)	No. of primary branches /plant	No. of secondary branches/ plant	No. of siliqua/ plant	No. of seed/ siliqua	Siliqua length (cm)	1000 seed weight (g)	Yield/ plant (g)
Days to 50% flowering	r_p	0.013	0.550**	-0.061	-0.373**	-0.492**	0.194	-0.369**	-0.409**	-0.491**
	r_g	0.015	0.544**	-0.059	-0.390**	-0.580**	0.190	-0.421**	-0.413**	-0.533**
Day to 80% maturity	r_p		0.311*	0.120	0.254*	0.029	0.359**	0.196	-0.434**	-0.299*
	r_g		0.308*	0.050	0.211	0.008	0.314*	0.218	-0.480**	-0.342**
Plant height(cm)	r_p			0.048	0.247*	-0.063	0.028	-0.280*	-0.292*	-0.379**
	r_g			0.046	0.259*	-0.119	0.021	-0.376**	-0.358**	-0.418**
No. of primary branches/plant	r_p				0.471**	0.537**	-0.366**	-0.313*	0.182	0.246*
	r_g				0.427**	0.529**	-0.476**	-0.328*	0.162	0.149
No. of secondary branches/plant	r_p					0.642**	-0.500**	0.030	0.164	0.203
	r_g					0.668**	-0.544**	0.029	0.170	0.170
No. of siliqua/plant	r_p						-0.623**	-0.042	0.522**	0.474**
	r_g						-0.719**	-0.154	0.470**	0.467**
No. of seed/siliqua	r_p							0.210	-0.408**	-0.358**
	r_g							0.231	-0.434**	-0.411**
Siliqua length (cm)	r_p								-0.208	0.173
	r_g								-0.291*	0.171
1000 seed weight(gm)	r_p									0.598**
	r_g									0.601**

*and** indicated significant at 5% and 1% level

4.2.3 Plant height (cm)

Plant height showed insignificant and positive interaction with number of primary branches per plant (G=0.046, P=0.048), number of seed per siliqua (G= 0.028, P=0.021). It implies that the variable had little role on yield per plant. It showed insignificant and negative correlation with number of siliqua per plant (G=-0.119, P=0.063). However, it had significant and positive interaction with no. of secondery branches/plant (G=0.259, P=0.247). Highly significant but negative interaction of this trait with siliqua length (G=- 0.376) and thousand seed weight (G=- 0.358) at genotypic level (Table 6). It also negatively significant with siliqua length (P=- 0.280) and thousand seed weight (P=- 0.292) at phenotypic level. Plant height showed highly significant but negative association with yield/plant (G=- 0.418, P=- 0.379) which indicated that if plant height decreased then yield/plant increased and vice versa (Table 6). Due to significant value the association between the traits is strong. Basalma (2008) reported negative correlation with seed yield for this trait.

4.2.4 Number of primary branches per plant

Number of primary branches per plant showed positive and highly significant interaction with number of secondary branches per plant (G = 0.427, P = 0.471), no. of siliqua per plant (G=0.529, P=0.537), whereas negative but highly significant association with no. of seed/siliqua (G=- 0.476, P=- 0.366). It had insignificant and positive correlation with thousand seed weight (G= 0.162, P= 0.182). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. It had significant but negative correlation with siliqua length (G=- 0.328, P=- 0.313). This trait showed positive and significant correlation with yield/plant (P=0.246) at phenotypic level but insignificant at genotypic level (G=0.149) that indicated if number of primary branches per plant increased then yield per plant also increased (Table 6). As the value of phenotypic correlation co-efficient was greater than genotypic correlation co-efficient, it showed that the apparent association of two characters was not only due to genes but also due to favorable influence of environment. Malik *et al.* (2000) reported similar result for number of primary branches and seed yield both at genotypic and phenotypic level.

4.2.5 Number of secondary branches per plant

Number of secondary branches per plant showed highly significant and positive interaction with number of siliqua per plant (G=0.668, P=0.642). It showed highly significant but negative correlation with number of seed per siliqua (G = - 0.544, P=- 0.500) followed by insignificant and positive correlation with thousand seed weight (G= 0.164, P= 0.170), siliqua length (G=0.029, P=0.030). The trait showed higher genotypic correlation to yield which indicated that their negative relationship was strong and due to genotypic effect and the lower phenotypic correlation was due to environment. This trait exhibited significant and positive correlation with yield per plant (G=0.170, P=0.203) which denoted if number of secondary branches per plant increased then yield/plant increased (Table 6). Naznin (2013) found positive significant relation with yield/plant.

4.2.6 Number of siliqua per plant

Number of siliqua per plant showed highly significant but negative correlation with number of seed per siliquae (G = -0.719, P=0.642). However, it had insignificant and negative correlation with siliqua length (G=-0.154, P=-0.042). It showed highly significant and positive correlation with thousand seed weight (G=0.470, P= 0.522). Highly significant positive correlation with yield per plant (G=0.470, P=0.522), it indicated that for the increased no. of siliqua/plant the yield/plant must be increased (Table 6). Uddin *et al*. (2013) conducted an experiment and found that yield had high significant positive correlation with number of siliqua per plant at both phenotypically and genotypically.

4.2.7 Number of seeds per siliqua

Number of seeds per siliqua showed highly significant and negative interaction with thousand seed weight (G=-0.434, P= -0.408), it had insignificant and positive correlation with siliqua length (G = 0.210, P = 0.231). Insignificant association of these traits indicated that the association between these traits largely influenced by environmental factors. Number of seeds per siliqua showed negative and highly significant association with yield per plant (G=- 0.411, P=-0.358) which indicated that if number of seeds per siliqua decreased then yield/plant increased (Table 6). Naznin (2013) found negative significant correlation of the trait with yield.

4.2.8 Siliqua length (cm)

Siliqua length showed significant and negative interaction with thousand seed weight (G=- 0.291) at genotypic level but insignificant association with phenotypic level (P=- 0.208). It showed insignificant positive association with yield per plant (G=0.171, P=0.173) that denoted, the larger the siliqua the more yield per plant (Table 6). Due to insignificant correlation this character play least role on yield/plant. As the value of phenotypic correlation co-efficient was greater than genotypic correlation co-efficient, it showed that the apparent association of two characters was not only due to genes but also due to favorable influence of environment. Saifullah (2010) reported positive significant correlation of the trait with yield.

4.2.9 Thousand seed weight (g)

Thousand seed weight showed positive highly significant correlation with seed yield per plant (G = 0.601, P = 0.598), that means if thousand seed weight increased then yield per plant also increased(Table 6). Due to significant value the association between the traits is strong It indicated that yield/plant could increase by improving this trait. Alam (2007) found no significant positive correlation of the trait with yield. Akter (2010) found positive significant correlation with yield per hectare at genotypic level but negative correlation at phenotypic level while Saifullah (2010) found positive significant correlation at both level.

4.3 Path Co-efficient analysis

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

4.3.1. Days to 50% flowering

Path co-efficient analysis revealed that, days to 50% flowering had negative direct effect (-0.166) on yield per plant (Table 7). This trait showed indirect positive effect on plant height (.0027), number of secondary branches per plant (.041). It had negative indirect effect on days to 80% maturity (-0.0019), number of primary branches per plant (-0.017), number of siliqua per plant (-0.022), number of seeds per siliquae (-0.0175), siliqua length (-0.127), thousand seed weight (-0.183). Finally days to 50% flowering made significant negative correlation with yield/plant (-0.491). Selection based on this character would not be effective. Due to insignificant value the association between the traits is weak.

Zahan (2006) reported that days to 50% flowering had negative direct effect on yield.

4.3.2. Days to 80% maturity

Path co-efficient analysis revealed that, days to 80% maturity had negative direct effect (-0.145) on yield per plant (Table 7). This trait had positive indirect effect through plant height (0.0015), number of primary branches per plant (0.033), number of siliqua per plant (0.0013), siliqua length (0.068). It had negative indirect effect on days to 50% flowering (-0.0022), number of secondary branches per plant (-0.028), number of seeds per siliqua (-0.0323), thousand seed weight (-0.195). Here, days to 80% maturity showed significant negative correlation with yield/plant (-0.299). Negative direct effects on plant yield were exhibited for days to maturity (- 0.015) observed by Ali *et al.* (2003).

4.3.3. Plant height (cm)

Plant height showed positive direct effect (0.0049) on yield/plant (Table 7) and positive indirect effects through number of primary branches/plant (0.0126). On the other hand, it had negative indirect effect on days to 50% flowering (-0.0022), days to 80% maturity (-0.045), number of secondary branches per plant (-0.027), number of siliqua per plant (-0.0028), number of seeds per siliqua (-0.0025), siliqua length (-0.097), thousand seed weight (-0.131). Plant height showed significantly negative correlation (-0.379) with yield/plant. So, yield per plant can be improved through direct selection of no. of primary branches per plant to reduce undesired indirect effect. Han (1990) working with *Brassica napus*, observed positive direct effect of plant height (0.321) on seed yield.

Table 7. Path co-efficient analysis showing direct and indirect effect of yield components on yield per plant in 24 genotypes of *Brassica rapa* L.

Characters	Days to 50% Flowering	Day to 80% maturity	Plant height (cm)	No. of primary branches/ plant	No. of secondary branches/ plant	No. of siliqua/ plant	No. of seed/ siliqua	Siliqua length (cm)	1000 seed weight (gm)	Yield/ plant (gm)
Days to 50% flowering	**-0.166**	-0.0019	0.0027	-0.017	0.041	-0.022	-0.0175	-0.127	-0.183	-0.491**
Day to 80% maturity	-0.0022	**-0.145**	0.0015	0.033	-0.028	0.0013	-0.0323	0.068	-0.195	-0.299*
Plant height(cm)	-0.091	-0.045	**0.0049**	0.0126	-0.027	-0.0028	-0.0025	-0.097	-0.131	-0.379**
No. of primary branches/plant	0.0101	-0.0174	0.00022	**0.274**	-0.052	0.0237	0.0330	-0.108	0.0816	0.246*
No. of secondary branches/plant	0.0620	-0.0369	0.0012	0.1292	**-0.110**	0.0284	0.0451	0.0103	0.0735	0.203
No. of siliqua/plant	0.0817	-0.0042	-0.0003	0.1473	-0.0705	**0.044**	0.0562	-0.0144	0.2340	0.474**
No. of seed/siliquae	-0.0322	-0.0521	0.00014	-0.1004	0.0549	-0.0275	**-0.090**	0.0724	-0.1828	-0.358**
Siliqua length (cm)	0.0613	-0.0285	-0.00136	-0.0858	-0.00329	-0.00185	-0.0189	**0.345**	-0.0932	0.173
1000 seed weight(gm)	0.0679	0.0631	-0.00142	0.0499	-0.0181	0.0231	0.0368	-0.0717	**0.448**	0.598**
										Residual effect =0.4506

Bold indicated the direct effect

4.3.4 Number of primary branches per plant

Path analysis showed that number of primary branches/plant had positive direct effect (0.274) on yield/plant (Table 7). It showed positive significant correlation (0.246) with yield/plant. This trait had positive indirect effect on days to 50% flowering (0.0101), plant height (0.00022), number of siliqua per plant (0.0237), number of seeds per siliqua (0.0330), thousand seed weight (0.0816). It had negative indirect effect on days to 80% maturity (-0.0174), number of secondary branches per plant (-0.052), siliqua length (-0.108). Number of primary branches/plant showed significant positive correlation (0.246) with yield/plant. Again value of the direct effect of it is very close to correlation coefficient. This result suggested that selection should be done based upon this trait for yield improvement per plant. Positive direct effect of plant height (0.32) on yield was observed by Han (1990) that supported the findings.

4.3.5. Number of secondary branches per plant

Path co-efficient analysis revealed that number of secondary branches per plant had negative direct effect (-0.110) on yield per plant (Table 7). This trait had positive indirect effect on yield via days to 50% flowering (0.0620), plant height (0.0012), number of primary branches/plant (0.1292), number of siliqua per plant (0.0284), number of seeds per siliqua (0.0451), siliqua length (0.0103), thousand seed weight (0.0735). Finally, number of secondary branches per plant showed positive correlation (0.203) with yield/plant. Therefore yield per plant can be improved through direct selection of no. of secondary branches per plant to reduce undesired indirect effect. 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/plant had positive direct effect (0.044) on yield per plant (Table 7). On the other hand, number of siliqua/plant had positive contribution via days to 50% flowering (0.0817), number of primary branches/plant (0.1473), number of seeds per siliqua (0.0562), thousand seed weight (0.2340). Number of siliquae/plant had negative indirect effect on days to 80% maturity (-0.0042), plant height (-0.0003), number of secondary branches per plant (-0.0705), siliqua length (-0.0144). Number of siliqua/plant had positive highly significant correlation (0.474) with yield per plant. It indicated that yield/plant can be improved through direct selection of no. of siliqua per plant and selection based on this trait would be rewarded. Marjanovic-Jeromela *et al.* (2008) worked on *Brassica napus* and found positive direct effect (0.26) for this trait on yield.

4.3.7 Number of seeds per siliquae

According to the path analysis co-efficient number of seeds per siliquae had direct negative effect (-0.090) on the yield per plant (Table 7). Positive indirect effect of the trait was found on plant height (0.00014), number of secondary branches per plant (0.0549), siliqua length (0.0724). This trait had negative indirect effect on days to 50% flowering (-0.0322), days to 80% maturity (-0.0521), number of primary branches/plant (-0.1004), number of siliqua/plant (-0.0275), thousand seed weight (-0.1828). Finally, number of seeds per siliquae had significant negative correlation with yield/plant . Selection based on this trait would not be wise. Tusar- Patra *et al*. (2006) concluded that the number of seeds per siliquae had negative direct effect on yield.

4.3.8. Siliqua length

Siliqua length had direct positive effect (0.345) on yield per plant (Table 7). On the other hand, length of siliqua had positive indirect effect on days to 50% flowering (0.0613). This trait had negative indirect effect on days to 80% maturity (-0.0285), plant height (-0.00136), number of primary branches/plant (-

0.0858), number of secondary branches per plant (-0.00329), number of siliquae/plant (-0.00185), number of seeds per siliqua (-0.0189), thousand seed weight (-0.1828). Siliqua length showed positive correlation with yield per plant. It denoted that yield/plant will be increased through direct selection of siliqua length. Ejaz-Ul-Hasan *et al.* (2014) observed that silique length had direct positive effect (0.241) on yield.

4.3.9 Thousand seed weight (g)

Thousand seed weight had positive direct effect on yield per plant (0.448), whereas positive indirect effect on days to 50% flowering (0.0679), days to 80% maturity (0.0631), number of primary branches/plant (0.0499), number of siliquae/plant (0.0231), number of seeds per siliqua (0.0368). This trait had negative indirect effect on plant height (-0.00142), number of secondary branches per plant (-0.0181), siliquae length (-0.0717). This trait showed positive highly significant correlation (0.598) with yield/plant (Table 7). Again value of the direct effect of it, is very close to correlation coefficient. This result suggested that selection should be done based upon this trait for yield improvement per plant. Kakroo and Kumar (1991) found that thousand seed weight had positive direct effect (0.784) on yield.

CHAPTER VI
SUMMARY AND CONCLUSION

This research work was carried out to study of some inter-varietal crosses of the species *Brassica rapa* L. for estimating the magnitude of variations in characters, variability and heritability, genetic advance, character associations, direct and indirect effect of different characters on yield. All the genotypes varied significantly with each other for all the characters indicated the presence of considerably variations among the genotypes studied.

In the study, variability analysis divulged that all lines varied significantly with each character which indicate the considerable variations among the genotypes studied. From the mean value among the genotypes was G13 early flowering, G1was early maturing. Whereas G21 was late flowering and G19 and G24 were late maturing. The plant height of G22 was highest and G2 and G10 were shortest. The genotype G3 produced highest number of primary branches/plant and G22 produced lowest number of primary branches/plant. The highest number of secondary branches/plant was observed in G17 whereas the lowest number of secondary branches/plant was observed in G21. The highest number of siliquae/plant was observed in G17 whereas the minimum number of siliquae/plant was observed in G22. The highest siliqua length was observed in G10 and G1 produced shortest siliqua. The highest number of seeds per siliqua was observed in G 23 whereas the minimum number of siliquae/plant was observed in G17. Thousand seed weight was found maximum in G6 whereas the minimum thousand seed weight was found in G22. The highest amount of yield per plant was observed in G3 whereas the minimum yield per plant was observed in G22.

However, the phenotypic variance and phenotypic coefficient of variation were higher than the corresponding genotypic variance and genotypic coefficient of variation for all the characters under study. High phenotypic and genotypic differences were found in plant height and number of siliquae per plant that stated the more environmental effect to control the characters. Days to 50% flowering, days to 80% maturity showed moderate difference between the phenotypic and genotypic variance indicating moderate influence of environment on them. Minimum differences between the genotypic and phenotypic variances were found in number of primary branches per plant, number of secondary branches/plant, number of seeds per siliqua, silique length and thousand seed weight, yield per plant indicating low environmental influence on them.

Plant height, number of primary branches/plant, number of siliqua/plant, length of siliqua, 1000 seed weight and yield per plant showed moderate genotypic and phenotypic coefficient of variation while the rest of the traits showed low co-efficient of variations.

No. of secondary branches per plant showed high heritability coupled with high genetic advance in percentage of mean. Whereas days to 50% flowering, no. of siliqua per plant, yield/plant showed high heritability with moderate genetic advance in percentage of mean that revealed the possibility of predominance of additive gene action in the inheritance of this character that means the characters could be improved through selection process. Days to 80% maturity, no. of primary branches per plant, no. of seed/siliquae showed high heritability coupled with low genetic advance in percentage of mean.

Correlation co-efficients among the characters were studied to determine the association between yield and yield components. The significant positive correlation with seed yield per plant were found in thousand seed weight (G=0.601, P=0.598), no. of siliqua per plant (G=0.467, P=0.474), no. of primary branches per plant (G=0.246). In addition, there were non-significant positive correlation with no. of secondary branches per plant (G=0.203, P=0.170) siliqua length (G=0.171, P=0.173).

Path co-efficient analysis revealed that plant height, no. of primary branches per plant, no. of siliqua per plant, siliqua length, thousand seed weight showed positive direct effect with yield per plant. Whereas days to 50% flowering, days to 80% maturity, no. of secondary branches per plant, no of seed per siliqua showed negative direct effect on yield per plant.

Among the twenty advanced lines and four check varieties, wide range of variations were observed in most of the characters. Important yield contributing character of the advanced lines of *Brassica rapa* such as no. of primary branches per plant, no. of secondary branches per plant, no. of siliqua per plant, siliqua length, thousand seed weight, yield/plant showed better performance than the check varieties . Advanced line G3 showed highest yield per plant as well as number of primary branches per plant with moderate early maturity. On the other hand G17 advanced line showed highest number of secondary branches per plant and number of siliqua per plant with nearly early matured plant. Considering all the characters related to yield and early maturity the two advanced lines G3 and G17 have the potentiality toward the development of improved variety that might be a trademark in *Brassica rapa* L. It may be concluded that a scope relies for further work with G1 (SAUSR-03) that was the earliest matured line with moderate yield.

CHAPTER V
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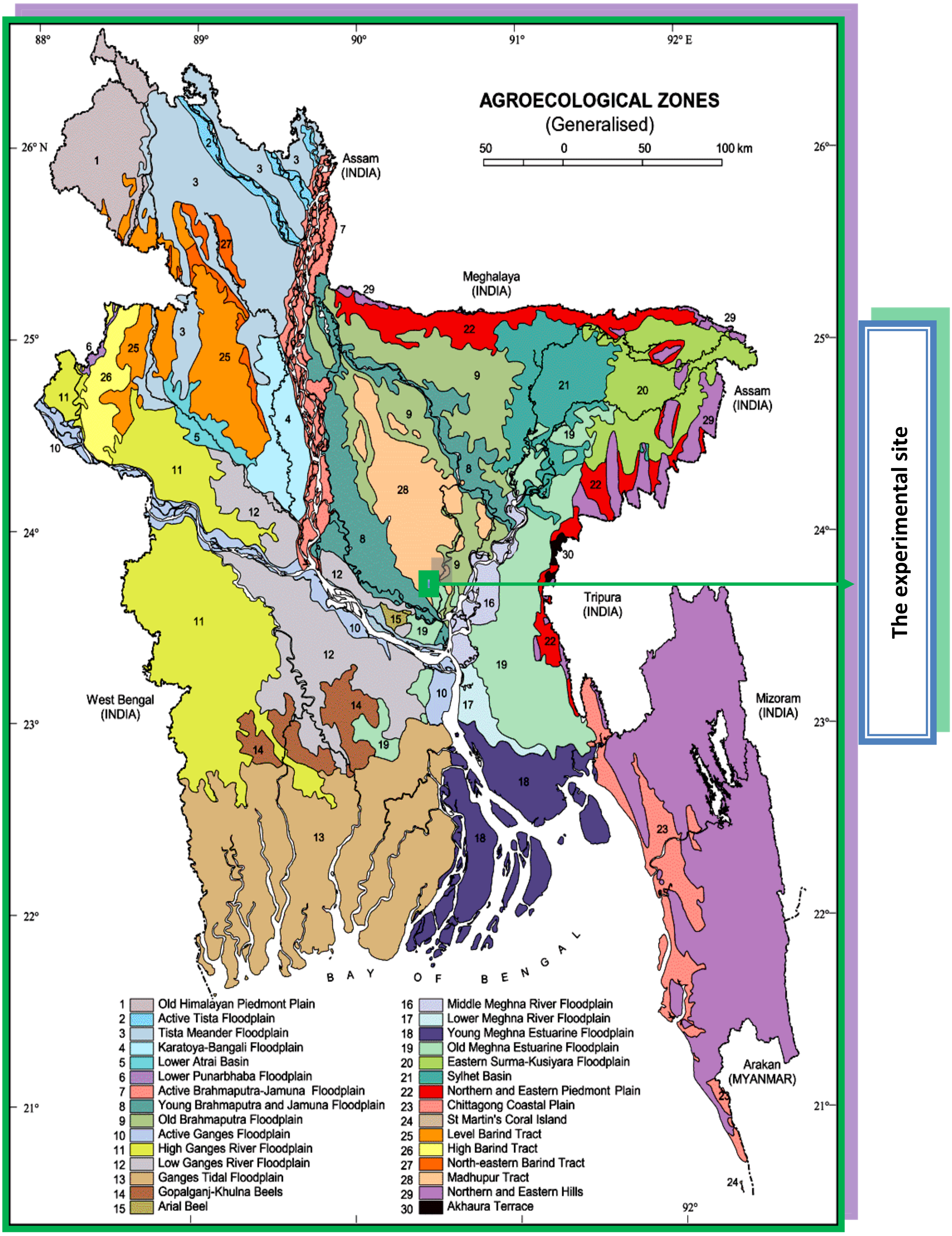
APPENDICES

Appendix I. Map showing the experimental site



Appendix II. Monthly average of Temperature, Relative humidity, Total rainfall of the experimental site during the period from November, 2013 to March, 2014

Month	*Air temperature (°c)			Relative humidity (%)	Total Rainfall (mm)
	Maximum	Minimum	Mean		
November, 2013	28.10	6.88	24.45	15.6	58.18
December, 2013	27.10	15.7	21.4	64	Trace
January, 2014	25.3	18.2	21.75	68	Trace
February, 2014	31.3	19.4	25.35	59	46
March, 2014	33.5	19.8	26.65	48	50

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

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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

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