SELECTION IN F_2 POPULATIONS BASED ON GENETIC VARIABILITY OF RAPESEED (*Brassica rapa L.*)

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SELECTION IN F_2 POPULATIONS BASED ON GENETIC VARIABILITY OF RAPESEED (*Brassica rapa L.*)

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CERTIFICATE

*This is to certify that thesis entitled, **"Selection in F_2 Populations Based on Genetic Variability of Rapeseed (Brassica rapa L.)."** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **MST: KEARA YEASMIN**, Registration No. **19-10080** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021

Place: Dhaka, Bangladesh

(Professor Dr. Md. Shahidur Rashid Bhuiyan)

Vice-Chancellor

Supervisor

DEDICATED
TO MY
BELOVED
FAMILY

ACRONYMS

Full word	Abbreviation
And others	et al.
Agro Ecological Zone	AEZ
Analysis of variance	ANOVA
At the rate	@
Bangladesh	BD
Bangladesh Institute of Nuclear Agriculture	BINA
Bangladesh Agricultural Research Institute	BARI
Bangladesh Agricultural University	BAU
Co-efficient of Variation	CV
Celsius	^{0}C
Centimeter	Cm
Degrees of Freedom	Df
Days after sowing	DAS
Et cetera	etc.
Food and Agricultural Organization	FAO
Genotypic Coefficient of Variation	GCV
Genetic Advance	GA
Genotypic correlation	r_g
Genotypic variance	σ_g^2
Gram	g
Heritability in broad sense	h^2b
Kilogram	Kg
Muriate of Potash	MOP
Metric ton	MT
Mean sum of square	MS
Milliliter	ml
Meter	m
Number	No.
Percentage of Coefficient of Variation	CV%
Percent	%
Phenotypic variance	σ_p^2
Phenotypic Coefficient of Variation	PCV
Phenotypic correlation	r_p
Randomized Complete Block Design	RCBD
Species	*sp.*
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
Standard error	SE
Triple Super Phosphate	TSP
Variety	Var.
United States Department of Agriculture	USDA

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SAU, Dhaka

LIST OF CONTENTS

LIST OF CONTENTS (CONTINUED)

LIST OF CONTENTS (CONTINUED)

LIST OF CONTENTS (CONTINUED)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

SELECTION IN F_2 POPULATIONS BASED ON GENETIC VARIABILITY OF RAPESEED (*Brassica rapa L.*)

ABSTRACT

An experiment was carried out with 39 F_2 populations of *Brassica rapa L*. at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during November 2019 to February 2020 considering thirteen yield contributing characters. To study 39 F_2 populations, the magnitude of variations in the characters, correlation, heritability, genetic advance, direct and indirect effect of different characters on seed yield per plant were taken under analysis. Significant variation was observed among all populations for all the characters. For all of the traits, the phenotypic variance was higher than the genotypic variation. Number of secondary branches per plant, total siliqua and yield per plant showed high genotypic and phenotypic coefficient of variance. Days to first flowering, days to 50% flowering and days to 80% flowering showed high heritability coupled with low genetic advance and low genetic advance in percentage of mean. Study on correlation revealed that yield/plant had significant and positive association with number of primary branches per plant; number of secondary branches/plant and total siliqua but non-significant and negative association with days to first flowering and yield per plant at both phenotypic and genotypic level. Path co-efficient analysis revealed that number of seeds per siliqua showed highest positive direct effect on yield/plant followed by days to maturity, days to 80% flowering, plant height, total siliqua and siliqua length. On the other hand, number of primary branches/plant, number of secondary branches/plant, days to 50% flowering, root length and thousand seed weight had negative direct effect on yield per plant. Selection was conducted among 39 F_2 populations of *Brassica rapa L*. to find out the early maturing and the highest yielding populations. 12 populations such as P5XP1, P5XP3, P1XP2, P1XP7, P6XP5, P7XP3, P3XP5, P3XP1, P3XP4, P4XP2, P5XP2, and P5XP7 were selected for high yielding and early maturing from the 39 populations for further trial.

CHAPTER I

INTRODUCTION

Brassica oilseed crop species like *Brassica napus, Brassica rapa* ,*Brassica juncea* are commonly called mustard. These oilseed crops collectively contribute about 15% of the world's total supply of vegetable oils (BBS, 2020). Oilseed *Brassica* species ranks the third most important sources of edible vegetable oil in the world after palm and soybean (Viraj Rathod and Solanki HV, 2019). Important oil crops like rapeseed and mustard belongs to the family Brassicaceae. It is originated from Asia , but now a days it is cultivating as a main commercial oil crop in Canada, China, Australia, and India and as well as Bangladesh. Rapeseed-mustatd is grown more or less all over Bangladesh, but mostly grown in the districts of Bogra, Sirajganj, Faridpur, Pabna, Rajshahi , Dinajpur, Kushtia Comilla, Jessore, , Kishhoregonj, Rangpur, Dhaka, Sylhet (BBS, 2019). These oilseed crops have a remarkable demand for edible oil in Bangladesh. Among the oilseed crops grown in our country it occupies first position of the list in respect of area and production (BBS, 2020). Oilseeds are relatively important oilseed crops in the economy of Bangladesh. Mustard-rapeseed- seeds, generally contain 40-44% oil, 17-25% proteins, 8-10% fibers, 6- 10% moisture and seed meal contains about 40% protein (Viraj Rathod and Solanki HV, 2019). Globally, this meal is the second most important economical protein source used in animal feed after soybean. These crops are primarily grown to produce edible oil and meal for animal feed; sometimes, small quantities are used directly for feed and planting seed. The oilcake contains high biological value of proteins and sufficient quantities of phosphorus and calcium and also is used as a very good animal feed as well as manure for various crops. *Brassica* oilseeds crops are used not only for edible purpose but also used in hair dressing, body massaging and in different types of pickles preparations. Substantial area mustard is grown with the aim of using its leaf as green vegetable. On the other hand use of mustard, although not frequent, is to use its flowers/inflorescence as a recipe for making a special fried diet diving it with thoroughly broken eggs indicating that there is an economic importance of its flowers using them as edible item. Rape oil is also used in food industry, as an illuminant and lubricant, and for soap manufacture. Rapeseed oil has potential market in emulsifying agents, polyamide fibers, and resins, detergent lubrication oils, and as a vegetable wax substitute. Due to the ability of the Brassica seeds to germinate and grow at low temperatures, these oilseed crops are among the few oil crops that can be grown in the temperate regions of the world. Among these Brassica oilseed crops, *B. napus* is predominantly grown in North American countries and *B. rapa* and *B. juncea* can also be found on limited areas (< 1%) *B. rapa* is more suited to short growing season areas and *B. juncea* is more suitable to the hotter and drier regions. Traditional rapeseed and mustard seeds contain a high level of erucic fatty acid in oil (> 40% of the total fatty acids) and a high level of glucosinolates in oil cake (> 100 µmol g− 1) (Rashid, 2013). The erucic acid is undesired in edible oil, while the oilcake containing a high level of glucosinolate is undesirable for use of this meal as protein source in animal feed. The oil and meal quality of Brassica oilseed crops has been dramatically improved (virtually eliminated erucic acid in oil and reduced glucosinolate content to <30 µmol g− 1 seed meal) in 1960s–1970s through many research, and the name 'canola' for this quality-improved-type Brassica oilseed crops has been adopted in most parts of the world.

Although a huge amount of oilseed is utilized in Bangladesh but the production is not sufficient to meet the requirement (Razzaque and Karim, 2007). As the population of Bangladesh is increasing and economic prosperity has been growing fast, it is now a challenge to us for accelerating the production of oils. About 0.25 million hectares area covered by rapeseed in Bangladesh and produce 0.92 metric tons (MT) per hectare yield in 2017-18 (USDA 2019). In 2018-2019, about 270138.5 hectares area covered by mustard oil in our country and produces 1154 kg per hectare yield (FAO, 2019). About 27 mustard and rapeseed varieties have been released in Bangladesh, among these 16 from Bangladesh Agricultural Research Institute (BARI), 5 from Bangladesh Institute of Nuclear Agriculture (BINA), 2 from Bangladesh Agricultural University (BAU), three from Sher-e-Bangla Agricultural University (SAU) and 2 from Bangladesh Agricultural Development Corporation (BADC) but most of them are not popular to the farmers due to their long duration and also low to moderate yield. Therefore, there is a scope to increase the yield level of rapeseed- mustard by using HYV seed and by adopting proper management practices. There are major activities of plant breeding are building up a gene pool of variable germplasm, selection of individual from the gene pool and utilization of selected individual to evolution a superior variety (Zayaet et al., 2008). And farmers feel the necessity of short durational variety of mustard that can grow successfully in between the two rice crops like T. Aman-Mustard-Boro cropping pattern. In these circumstances, separate crossing programs have been thus inaugurated in 2018 which ultimately led to the selection of 39 promising populations of *Brassica rapa*. The present experiment was aimed to identify the short duration and high yielding population to solve the current problems of the crop through comparing these 39 F_2 populations of *Brassica rapa L.*

Objectives

The present research work was undertaken with the following objectives:

1. To compare F2 populations of *Brassica rapa L*. based on short duration, yield and yield contributing traits
2. To study the genetic variability among 39 populations
3. To select early maturing and high yielding populations for further trial

CHAPTER II
REVIEW OF LITERATURE

Brassica rapa L. commonly called turnip, turnip rape, field. Mustard and it is self-incompatible species *Brassica rapa L.* is a economically importance crops of Bangladesh and many countries of the world too. These crops have received much attention by a large number of researchers on various aspects of its production and utilization. A review of the previous research and findings of researchers having relevance to this study which were gathered from different sources like thesis, journals, reports, literature etc. will be represented in this chapter. Some of the literature related to this investigation is reviewed in this chapter are given below under the following heads:

2.1 Genotypic and phenotypic variability

Jarman Gadi *et al*. (2019) studied with thirty six genotypes of *Brassica sp.* Analysis of variance was highly significant among all the genotypes for all ten characters evaluated which obtained the presence of considerable genetic variability among the genotypes for days to 50% flowering, plant height, days to maturity, siliqua on main shoot, total no of siliqua per plant, no of seed per siliqua, seed yield.

According to Sikarwar *et al*. (2017) analysis of variance pointed out highly significant differences for all the characters in 21 diverse genotypes of yellow sarson (*Brassica rapa Var.* yellow sarson) for ten yield contributing characters. He observed high genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) and for number of primary branches per plant, number of secondary branches per plant followed by seed yield per plant. And he found low PCV and GCV for days to first flowering, plant height and length of silliqua.

An experiment was conducted by Sohail *et al.* (2017) on intra-specific quantitative characters among 253 *Brassica rapa* genotypes. Among the genotypes significant variations were recorded for leaf length and width, plant height, primary branches per plant, days to first flowering, days to 50% flowering, days to 80% flowering, days to maturity, main raceme length, pod length, pod width, stem thickness, thousand seed weight and seed yield per plant.

Siddika (2015) was performed an experiment to study the genetic variability of *Brassica rapa L*. with 30 F2 genotypes and the genotypes were significantly variable for all the characters. Genotypic variances were than the phenotypic variances for all the characters. The value of Genotypic co-efficient of variation (GCV) is lower than the Phenotypic co-efficient of variation (PCV) values.

An experiment was conducted by Iqbal *et al.* (2014) using 10 indigenous variety with 8 important yield contributing characters of *Brassica rapa.* The result revealed highly significant differences in almost all traits except siliqua width which observed significant variation.

An experiment was undertaken by Jahan *et al.* (2014) using 10 lines of *Brassica rapa L.* Among all the genotypes for all the studied characters he found significant variation. High genotypic coefficient of variations (GCV) and low phenotypic coefficient of variations (PCV) were found for number of secondary branches per plant, siliqua per plant, yield per plant, whereas days to maturity showed very low GCV.

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

Halder (2013) conducted an experiment with 11 advanced lines of *Brassica rapa* and found significant variations among the genotypes for all the characters. Genotypic variance was lower than the phenotypic variances for all character. Difference between genotypic and phenotypic variances was minimum in number for primary branches per plant, days to 50% flowering and days to 80% flowering, length of silliqua, seeds per siliqua and thousand seed weight.

Roy *et al.* (2011) executed an experiment on rapeseed mustard for studying variability. Significant varietal difference on main raceme except the number of Siliqua was observed. High PCV and low GCV were observed in secondary branches per plant and number of siliqua per plant.

An experiment was carried out by Alam *et al.* (2010) with twenty six populations of some inter-varietal crosses of *Brassiec rapa* to study the variation among them. Higher phenotypie variation was observed than the genotypic variation. High heritability with high genetic advance was observed for, number of secondary branches per plant and number of siliqua per plant plant height, number of primary branches per plant.

Aytac and Kinaci (2009) performed an experiment with 10 winter rapeseed genotypes for variation, genetypic and phenotypic correlations and broad sense heritability for seed yield and quality characters for 2 years. And finding significant differences for all yield and quality character indicated the presence of sufficient genetic variability for effective selection. Genetic advance, variability, broad sense heritability, was maximum for seed yield.

Saleh (2009) conducted a field experiment utilizing 20 F_2 populations developed through inter-varietal crosses along with 3 check variety of *Brassica rapa L.* to find out the variation in different traits. Therefore considerable variations present among all the genotypes used in the experiment. Resulting showed the values of phenotypic variances were higher than corresponding genotypic variances. Least difference between phenotypic and genotypic variances was exhibited in days to 50% flowering, days to maturity, number of primary and secondary branches per plant, 1000 seed weight, length of siliqua, seeds per siliqua and yield per plant.

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

Parveen (2007) study on the variability in F_2 progenies of the inter-varietal crosses of 17 genotypes of *Brassica rapa*. Resulting significant variations among different genotypes were observed. High heritability coupled with high genetic advance in percent of mean was found in number of primary branches per plant.

Mahak *et al.* (2004) was carried out an experiment on genetic variability, heritability, genetic advance and correlation for 8 quantitative characters. The phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV) for all characters that was studied. Therefore, high heritability coupled with high genetic advance in percentage of mean was found for days to 50% flowering, followed by days to maturity and plant height, thousand seed weight.

Ali *et al.* (2003) performed an experiment with 25 winter type rapeseed varieties introduced from diverse sources of the world and observed phenotypic and genotypic variances were highest for siliqua per plant and plant height, whereas the maximum genotypic and phenotypic coefficients of variability were observed in siliqua per plant and seed yield per plant.

Mahmood *et al*. (2003) carried out a field experiment with mustard and computed broad sense heritability, coefficient of variability and genetic advance value for plant height, siliqua per plant, primary branches and seed yield per plant in four single crosses. Therefore number of siliqua per plant was highly heritable coupled with high genetic advance and coefficient of variability.

An experiment was carried out by Khulbe *et al.* (2000) to estimate the variability, heritability and genetic advance for yield and its components in Indian mustard and thus resulting maximum variability for seed yield. All the characters exhibited high heritability with high or moderate genetic advance except oil content, as a result the role of additive gene action in conditioning the traits. And finding non-additive gene action appeared to influence the expression of days to maturity, while environment had a major influence on oil content.

Masood *et al.* (1999) conducted an experiment on seven genotypes of *Brassica campestries* and standard cultivar of *Brassica napus* to calculate genetic variability. And found the co-efficient of variation was high for siliqua length, number of seeds per siliqua thousand and seed weight for both genotypic and phenotypic variability. Seed yield per plant were significantly positively correlated with plant height, number of siliqua per plant and number of seeds per siliqua.

2.2 Heritability and genetic advance in *Brassica sp.*

Sikarwar *et al.* (2017) carried out an experiment for the assessment heritability and genetic advance in twenty one diverse genotypes of yellow sarson *(Brassica rapa Var.* yellow sarson) for 10 yield and yield contributing characters. Higher estimates of broad sense heritability were found for all studied characters. Therefore high genetic advance along with high heritability was observed for number of secondary branches per plant, number of primary branches per plant, seed yield per plant, length of main raceme, number of siliqua on main raceme and number of seeds per siliqua.

Afrin *et al.* (2016) conducted an experiment on the 15 F_4 population considering different morphological attributes of *Brassica rapa*. Highest value for heritability was observed in the number of secondary branches per plant while the primary branches per plant found lowest value. Moderate heritability was observed in days to 50% flowering, days to 50% maturity, plant height yield per plant, thousand seed weight and siliqua length.

Nazneen *et al.* (2015) performed an experiment to evaluate thirty three genotypes of *Brassica rapa L.* and observed that number of siliqua per plant, number of secondary branches per plant and number of primary branches per plant showed high heritability coupled with high genetic advance in percent of mean.

Sultana (2015) carried out an experiment utilizing sixty two F4 genotypes of *Brassica napus L.* and observed that the highest value of heritability for number of secondary branches followed by seed yield per plant whereas days to maturity showed the lowest value of heritability.

Ejaz-Ul-Hasan *et al.* (2014) conducted an experiment on heritability of *Brassica napus* thus exhibited plant height, yield per plant and days to 50% flowering showed high heritability.

Walle *et al.* (2014) performed an experiment on 36 genotypes of Ethiopian mustard (*Brassica carinata)* and found that there were significant difference in days to, plant height and primary branches per plant and 50% flowering. Therefore PCV was higher than the GCV for all yield related studied characters. High heritability with high genetic advance was exhibited in plant height, days to 80% maturity and number of secondary branches per plant.

Fayyaz and Afzal (2014) conducted a field experiment on indigenous lines to check locally collected *Brassica rapa* accessions for heritability and genetic advance. Therefore the highest heritability with higher genetic advance was showed in plant height which provided the evidence that this trait was under the control of additive genetic effects while rest of the traits observed variable trends.

An experiment was carried out by Iqbal *et al.* (2014) using 10 indigenous variety with 8 important yield contributing characters of *Brassica rapa.* Therefore they revealed highest heritability in association with higher genetic advance in plant height while the seed per siliqua showed medium heritability along lower genetic advance.

An experiment was carried out by Rameeh (2013) to evaluated twenty four rapeseed genotypes including 2 cultivars and 22 advanced lines, were based on randomized complete block design with three replications. Significant genotypes effects were exhibited for seed yield, plant height, indicating significant genetic difference among the genotypes. Therefore high broad sense heritability was exhibited for pods on main axis and seed yield. And duration of flowering and pods on main axis had exhibited high value of genetic coefficient of variation.

Rameeh (2013) conducted an experiment with 24 rapeseed genotypes including 2 cultivars and 22 advanced lines, were based on randomized complete block design with 3 replications. The results of factor analysis showed 4 factors including sink factor (pods length, pod per plant and seed yield), fixed capital factor (phenological traits), and metric factor (plant height) and observed genetic diversity.

Rameeh (2012) performed an experiment on twenty rapeseed genotypes including four cultivar and 16 advanced lines based on randomized complete block design with three replications. Significant genotypic effect was found for plant height, seed yield except seeds per siliqua. High broad sense heritability observed for plant height, siliqua per plant, 1000-seed weight. Therefore days to maturity had low value of genetic coefficient of variation.

Afrin *et al.* (2011) carried out an experiment in *Brassica napus* and studied heritability whereas the plant height exhibited highest value of broad sense heritability. Lowest heritability was found for number of secondary branches per plant, siliqua length, number of seed per sihqua, number of siliqua per plant, thousand seed weight and seed yield per plant.

Mahmud *et al.* (2011) executed an experiment with five advanced line of *Brassica rapa* along with 3 commercially cultivated varieties as cheek were evaluated to study the genetic divergence in respect of 10 different morphological characters. Relationship was not found between genetic divergence and geographic distribution of the genotypes. Number of secondary branches per plant, plant height and seeds per siliqua contributed maximum towards the total divergence. Therefore considering diversity pattern, genetic stanis, line 39 and line 44 from cluster I; line 50, line 52; line 42 from cluster 11: line 2, line 43 and line 45 from cluster V; line 54 and line 58 from cluster VI- might be selected as suitable parents in future hybridization program.

Alam (2010) performed an experiment to study the twenty six populations of some inter-varietal crosses of *Brassica rapa* and found the variation among them. Higher phenotypic variation was observed than the genotypic variation. Therefore high heritability with high genetic advance was exhibited for plant height, number of primary branches per plant, number of secondary branches per plant and number of siliqua per plant.

Ara (2010) studied on eight F_2 and eight F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa* and found the variation. Therefore the values of phenotypic variances were higher than genotypic variances. Days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, length of siliqua, seeds per siliqua, days to maturity, 1000-seed weight and yield per plant exhibited least difference between genotypic and phenotypic variances.

Aytac and Kinaci (2009) carried out an experiment with ten winter rapeseed genotypes for variation, genetypic and phenotypic correlations and broad sense heritability for seed yield, yield and quality characters for two years. The results exhibited significant differences for all yield and quality characters under studied and indicated the presence of sufficient genetic variability for effective selection. Therefore broad sense heritability, variability, genetic advance were maximum for seed yield.

Saleh (2009) conducted an experiment using 20 F_2 populations developed through inter-varietal crosses, along with three check variety of *Brassica rapa L.* The result revealed high heritability along with low genetic advance and genetic advance in percentage of mean were observed in days to maturity, seeds per siliqua, length of siliqua, and thousand seed weight.

A study was performed by Hosen (2008) using 5 parental genotypes of *Brassica rapa* and their ten F_3 progenies. The result exhibited that there were large variations present among all the genotypes. Number of primary branches per plant, days to 50 % flowering, number of secondary branches per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and yield per plant exhibited least difference between genotypic and phenotypic variances. Therefore the values of PCV and GCV indicated that there was considerable variation among the all characters except days to maturity. The plant height, number of siliqua per plant and days to 50 % flowering exhibited high heritability with high genetic advance and genetic advance in percentage of mean.

A research work was carried out by Rashid (2007) on 40 *Brassica species*. The result revealed high heritability values along with high genetic advance in percentage of mean was showed for number of seeds per siliqua, siliqua length, number of primary and secondary branches per plant.

Parveen (2007) carried out an experiment to study the variability in F_2 progenies of the inter-varietal crosses of seventeen genotypes of *Brassica rapa*. Thus resulting exhibited significant variations among different genotypes. High heritability coupled with high genetic advance in percent of mean was exhibited in number of primary branches per plant.

Afroz *et al*. (2004) conducted an experiment to study on genetic variability of 14 genotypes of mustard and rape. Therefore the highest genetic advance was found in percent of pollen sterility.

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

2.3 Analysis of correlation

A research work was undertaken by Kumari *et al.* (2017) to study the correlation among thirteen quantitative and qualitative characters of forty four genotypes of yellow sarson (*Brassica rapa var.* yellow sarson). Therefore seed yield per plant showed significant and positive correlation with biological yield while positive but non-significant correlation with, seeds per siliqua, and days to maturity, 1000-seed weight, siliqua length while non-significant negative correlation with plant height and primary branches per plant, significant and negative correlation coefficient of oil content were observed. The result of correlation analysis also found that the oil content exhibited negative and non-significant association with plant height length, length of main raceme and primary branches per plant while seeds per siliqua and days to 50% flowering showed significant and positive correlation with oil content. Then 1000 seed weight showed significant positive correlation with siliqua length and seeds per siliqua.

An experiment was carried out by Halder *et al.* (2016) to study the interrelationship among the characters of 11 advanced lines and three popular check varieties of *Brassica rapa L.* Through genotypic correlation coefficient, it was revealed that yield per hectare had positive and highly significant correlation with days to number of primary branches per plant, first flowering, and days to 80% flowering and while days to 50% flowering and length of siliqua were negatively correlated with yield.

Naznin *et al.* (2015) studied on 33 genotypes of *Brassica rapa L.* to study their character association. The result of correlation analysis revealed that the seed yield per plant showed significant positive correlation with number of siliqua per plant, number of primary and secondary branches per plant.

An experiment was executed by Bilal *et al.* (2015) with twenty three genotypes of rapeseed to study the correlation between the yield and yield contributing characters. The result raveled positive significant correlation between days to maturity and yield per plant. Then negative significant correlation was exhibited among plant height, pods per plant and 1000-seed weight. Number of pods per plant obtained positive significant correlation with 1000-seed weight.

Mokonnen *et al.* (2014) conducted an experiment on *Brassica carinata* and found that seed yield per plant were positively correlated with plant height, secondary branches per plant, days to maturity and thousand seed weight at both phenotypic and genotypic level. There were also found that plant height was strongly and positively correlated with number of pods per plant.

Hussain (2014) carried out an experiment with twenty four genotypes including four check varieties of the species *Brassica rapa L.* for estimating the character associations. The significant positive correlation was found in thousand seed weight, number of primary branches per plant, number of siliqua per plant, with seed yield per plant.

Shakera (2014) executed an experiment with 20 F_3 and F_4 populations generated through inter-varietal crosses along with three check variety of *Brassica rapa L.* to study correlation between pairs of different characters to early mature plants select and high yielding. The result reveled yield per plant exhibited significant and the positive correlation with plant height, number of secondary branches per plant, number of primary branches per plant, number of siliqua per plant and thousand seed weight.

Uddin *et al.* (2013) performed an experiment with 7 parental and 21 F_2 progenies of *Brassica rapa* to study correlation among different yield component and observed that yield per plant had high significant positive correlation with number of primary and secondary branches per plant and siliqua per plant at both phenotypic and genotypic level and significant positive correlation at in days to flowering and days to maturity.

Maurya *et al.* (2012) executed an experiment with one hundred genotypes of *Brassica spp*. and the result of correlation analysis revealed high positive correlation between length of siliqua and seed yield.

Rameeh (2011) conducted an experiment with 36 rapeseed genotypes and four cultivars and 32 advanced lines were evaluated in randomized complete block design with three replications. Siliqua per plant had significant positive correlation (0.80**) with seed yield was observed through correlation analysis. So any change for this trait will have considerable effect on seed yield.

Alam (2010) carried out an experiment by using 26 F_4 populations of some inter-varietal crosses of *Brassica rapa* to study correlation and observed the significant positive association with plant height, number of primary and secondary branches per plant, number of siliqua per plant.

A field experiment was undertaken by Khan (2010) with 32 genotypes of *Brassica rapa* including two commercially cultivated varieties as cheeks to study correlation. The result of correlation was revealed highly significant positive association of seed yield per plant with number of primary and secondary branches per plant, and number of pods per plant.

Afrin (2009) performed a field experiment with 22 *Brassica napus L*. advanced lines to study the genetic variability. Therefore the significant positive correlation with seed yield per plant was observed in plant height, number of primary branches per plant and number of siliqua per plant. The highest significant positive correlation was observed between plant height and days to 50% flowering.

A study was performed by Hosen (2008) using 5 parental genotypes of *Brassica rapa* and the 10 F_3 progenies. He observed yield per plant showed highest significant and positive correlation with days to maturity followed by number of seeds per siliqua, length of siliqua and number of siliqua per plant and number of secondary branches per plant.

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

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

Mahak *et al.* (2004) carried out an experiment to studied correlation for eight quantitative characters. Seed yield per plant observed positive correlation with length of main raceme, number of primary branches, 1000-seed weight and oil content.

Afroz *et al.* (2004) conducted an experiment to study the correlation and found seed yield per plant had significant and positive correlation with number of siliqua per plant and number of primary branches per plant.

Srivastava and Singh (2002) carried out an experiment to study the correlation in Indian mustard *(Brassica juncia L.)* for 10 characters in 24 strains of Indian mustard along with 2 varieties. Therefore found that the number of primary branches per plant, number of secondary branches per plant, 1000 seed weight (g) and oil percent were positively associated with seed yield.

2.4 Path co-efficient analysis

Path coefficient analysis calculates the correlations between yield and its contributing components, taking account of the cross correlation, either positive or negative (Tollenaar *et al*., 2004). When many characters are involved in correlation study it becomes difficult to ascertain the traits which really contribute towards the yield and path analysis under such situation helps to determine the direct and indirect effect of these traits towards the yield.

Kumari *et al.* (2017) conducted an experiment on different character pairs of yellow sarson (*Brassica rapa Var*. Yellow Sarson) and it was observed that the path coefficient analysis of biological yield exerted maximum direct effect whereas siliqua length and oil content exhibited negative direct effect and days to 50% flowering exerted negative indirect effect on seed yield.

Islam *et al.* (2016) was studied on twenty one F9 populations from inter- varietal crosses of *Brassica rapa L.* and result of path co-efficient analysis concluded that plant height, number of primary branches per plant, seeds per siliqua, siliqua length and number of siliqua per plant, exhibited the positive direct effect and days to 50% flowering, number of secondary branches per plant and thousand seed weight exhibited the negative direct effect on yield per plant.

A research work was conducted by Naznin *et al.* (2015) to study on 33 genotypes of *Brassica rapa L.* in order to find out their path coefficient of seed yield/plant. Therefore the Path analysis found that the number of siliqua/plant, number of primary and secondary branches/plant were the most important contributors to seed yield/plant.

Sharafi *et al.* (2015) performed an experiment on 28 winter rapeseed cultivars and revealed that the number of pods per plant, number of seeds per pod and 1000 seed weight had positive direct effect on seed yield.

An experiment was undertaken by Mekonnen *et al.* (2014) to study path co-efficient in *Brassica carinata* and revealed that secondary branches per plant and days to maturity had positive and direct genotypic correlation with seed yield.

Shakera (2014) carried out an experiment using 20 F_3 and F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa L.* to study the direct and indirect effect of good yielding plants of the F_3 and F_4 material to select high yielding and short duration plants. The path co-efficient analysis exhibited plant height had the highest positive direct effect followed by number of seeds per siliqua, siliqua per plant, number of secondary branches per plant.

Uddin *et al.* (2013) carried out an experiment with 7 parental and 21 F_2 progenies of *Brassica rapa* to study the path coefficient and revealed that number of primary branches per plant, days to 50 % flowering, number of secondary branches per plant, number of siliqua per plant, siliqua length, seed per siliqua and thousand seed weight exhibited direct positive association with seed yield per plant while days to maturity and the plant height had direct negative association.

Tahira *et al.* (2011) performed an experiment with 10 wide genetic ranged variety of *Brassica junce* to study relationship among the characters. Therefore the result revealed that plant height and siliqua length had positive direct effect on seed yield per plant and positive indirect effect on seed yields per plant. And also found that the siliqua length contributed negative indirect effect through plant height, seed per siliqua and thousand grain weights.

A field experiment was undertaken by Ara (2010) with eight F_2 and eight F_4 populations generated through inter-varietal crosses, along with three check variety of *Brassica rapa* to study the direct and indirect effect of different characters on seed yield per plant of the F_2 and F_4 materials to select the plants with higher potential. The result of Path co-efficient analysis found that siliqua per plant had the highest positive direct effect followed by plant height number of secondary branches per plant, days to 50% flowering and length of siliqua.

Khan (2010) performed a field experiment with 32 genotypes of *Brassica rapa* and two commercially cultivated varieties as checks to study path coefficient. Path analysis revealed that, yield per plant had the highest direct effect on number of primary and secondary branches per plant, number of pods per plant, number of branches per plant and number of seeds per pod.

An experiment was undertaken by Mahmud (2008) with 58 genotypes of *Brassica rapa*. The result of path analysis revealed that yield per plant had the highest direct effect on number of 2 primary and secondary branches per plant, number of siliqua per plant, and number of seeds per siliqua.

Parveen (2007) carried out an experiment with F_2 population of *Brassica rapa* to study the path analysis and the result was found that the number of seeds per siliqua exhibited highest direct effect on yield per plant.

Zahan (2006) conducted an experiment on *Brassica spp*. and reported that siliqua per plant had positive direct effect on yield per plant while (lays to 50% flowering had negative direct effect on yield per plant.

An experiment was conducted by Parveen (2007) to study the variability in F_7 progenies of the inter-varietal crosses of 17 *Brassica rapa* genotypes. The result found that there were significant variations among the different genotypes used in the experiment. Therefore number of primary and secondary branches per plant exhibited high heritability coupled with high genetic advance and very high genetic advance in percentage of mean.

Afroz *et al.* (2004) conducted an experiment to 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, 1000-seed weight, seed yield per plant, number of primary branches per plant and number of siliqua and shattering per plant.

CHAPTER III

MATERIALS AND METHODS

In this chapter briefly describes the materials and methods that are used in performing the research work. The present study was administered at Sher-e-Bangla Agricultural University, Dhaka– 1207, Department of Genetics and Plant Breeding during November 2019 to February 2020. Thirty – nine F_2 populations of rapeseed (*Brassica rapa L.*) were planted in randomized block design with three replications in plot size of 19× 13 m. The information regarding the materials and methods of this experiment is discussed below:

3.1 Experimental site

The location of the experimental site was situated at 230 77' N latitude and 900 37' E longitudes with an elevation of 13.03 meters from the sea level (www.distancesfrom.com). The experimental field was situated to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (www.banglapedia.com).The experimental field was presented in the map of AEZ of Bangladesh in Appendix I.

3.2 Soil and climate

The land was medium to medium high with medium fertility level. The soil texture was clay loam and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH of the soil was 5.50 to 5.55 and organic carbon content is 0.82% (Appendix II). The experimental site was situated in the subtropical climatic zone with dry winter and wet summer. Generally moderate temperature, very few rainfall and short day length are observed during the Rabi season. The records of humidity, rainfall and air temperature during the period of experiment were shown in (Appendix III)

3.3 Experimental materials

The seeds of 39 F_2 populations of *Brassica rapa L.* used as experimental materials were given from the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University. The materials used in the experiment are given in Table 2 and the parents of the experimental materials are given in Table 1.

Table 1. List the parents of F_2 populations

SL.No	Parents	Designation
1	BARI Sarisha-14	P1
2	SAU Proposed -4	P2
3	Yellow Special	P3
4	Local Tori-7	P4
5	BARI Sarisha-17	P5
6	BARI Sarisha-15	P6
7	BARI Sarisha-6	P7

Table 2. List the F_2 populations used in the study

SL.No.	Designation	F_2 Populations
1	P1× P2	BARI Sarisha-14 × SAU Proposed -4
2	P1× P3	BARI Sarisha-14 × Yellow Special
3	P1× P4	BARI Sarisha-14 × Local Tori-7
4	P1× P6	BARI Sarisha-14 × BARI Sarisha-15
5	P1× P7	BARI Sarisha-14 × BARI Sarisha-6
6	P2× P1	SAU Proposed -4 × BARI Sarisha-14
7	P2× P3	SAU Proposed -4 × Yellow Special
8	P2× P4	SAU Proposed -4 × Local Tori-7
9	P2× P7	SAU Proposed -4 × BARI Sarisha-6
10	P3× P1	Yellow Special × BARI Sarisha-14
11	P3× P2	Yellow Special × SAU Proposed -4
12	P3× P4	Yellow Special × Local Tori-7
13	P3× P5	Yellow Special × BARI Sarisha-17
14	P3× P6	Yellow Special × BARI Sarisha-15
15	P3× P7	Yellow Special × BARI Sarisha-6
16	P4× P1	Local Tori-7 × BARI Sarisha-14
17	P4× P2	Local Tori-7 × SAU Proposed-4
18	P4× P3	Local Tori-7 × Yellow Special
19	P4× P5	Local Tori-7 × BARI Sarisha-17
20	P4× P6	Local Tori-7 × BARI Sarisha-15
21	P4× P7	Local Tori-7 × BARI Sarisha-6
22	P5× P1	BARI Sarisha-17 × BARI Sarisha-14
23	P5× P2	BARI Sarisha-17 × SAU Proposed-4
24	P5× P4	BARI Sarisha-17 × Local Tori-7
25	P5× P6	BARI Sarisha-17 × BARI Sarisha-15
26	P5 × P7	BARI Sarisha-17 × BARI Sarisha-6
27	P5× P3	BARI Sarisha-17 × Yellow Special
28	P6× P1	BARI Sarisha-15 × BARI Sarisha-14
29	P6× P2	BARI Sarisha-15 × SAU Proposed-4
30	P6× P4	BARI Sarisha-15 × Local Tori-7
31	P6× P5	BARI Sarisha-15 × BARI Sarisha-17
32	P6× P7	BARI Sarisha-15 × BARI Sarisha-6
33	P6× P3	BARI Sarisha-15 × Yellow Special
34	P7× P1	BARI Sarisha-6 × BARI Sarisha-14
35	P7× P2	BARI Sarisha-6 × SAU Proposed-4
36	P7× P4	BARI Sarisha-6 × Local Tori-7
37	P7× P5	BARI Sarisha-6 × BARI Sarisha-17
38	P7× P6	BARI Sarisha-6 × BARI Sarisha-15
39	P7× P3	BARI Sarisha-6 × Yellow Special

3.4 Methods

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

3.4.1 Land preparation

The experimental plot was prepared by ploughing and cross ploughing followed by laddering and also power tiller as well as harrowing with a tractor due to excellent tilth. Weeds and stubbles were eliminated thoroughly from the experimental field and leveled effectively.

3.4.2 Application of manures and fertilizers

Urea, Triple Super Phosphate (TSP), Gypsum, Zinc oxide Muriate of potash (MOP) and Boric acid were applied to the experimental plot at the proper time. Total amount of cowdung, the first half amount of urea, Gypsum, Zinc Oxide TSP, MOP and Boric acid were applied during final land preparation as basal dose. After that the rest amount of urea was applied as top dressing after 25 days of sowing in the experimental plot. List of manures and fertilizers with doses and procedures of application is shown in table 3.

Table 3. List of fertilizers and manures with doses and procedures of application are:

Serial No	**Fertilizers/ manures**	**Dose**		**Procedures of application**
		Applied in the plot	**Quantity/ha**	
1	Cowdung	125 kg	5 ton	As basal
2	Urea	7 kg	250 kg	50% basal and 50% at the time of flower initiation
3	MOP	2 kg	75 kg	As basal
4	TSP	4.5kg	170 kg	As basal
5	ZnO	80g	3kg	As basal
6	Gypsum	4 kg	150 kg	As basal
7	Boric acid	300 kg	10 kg	As basal

3.4.3 Experimental design and layout

After final land preparation field layout was done. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and the total area of the experiment was 19m × 13m = 247m2. Each replication size was 19m×3m. Distance between replication to replication was 1m. Spacing between line to line was 30cm and plant to plant was 10 cm. Layout of the experimental design is presented in figure 1.

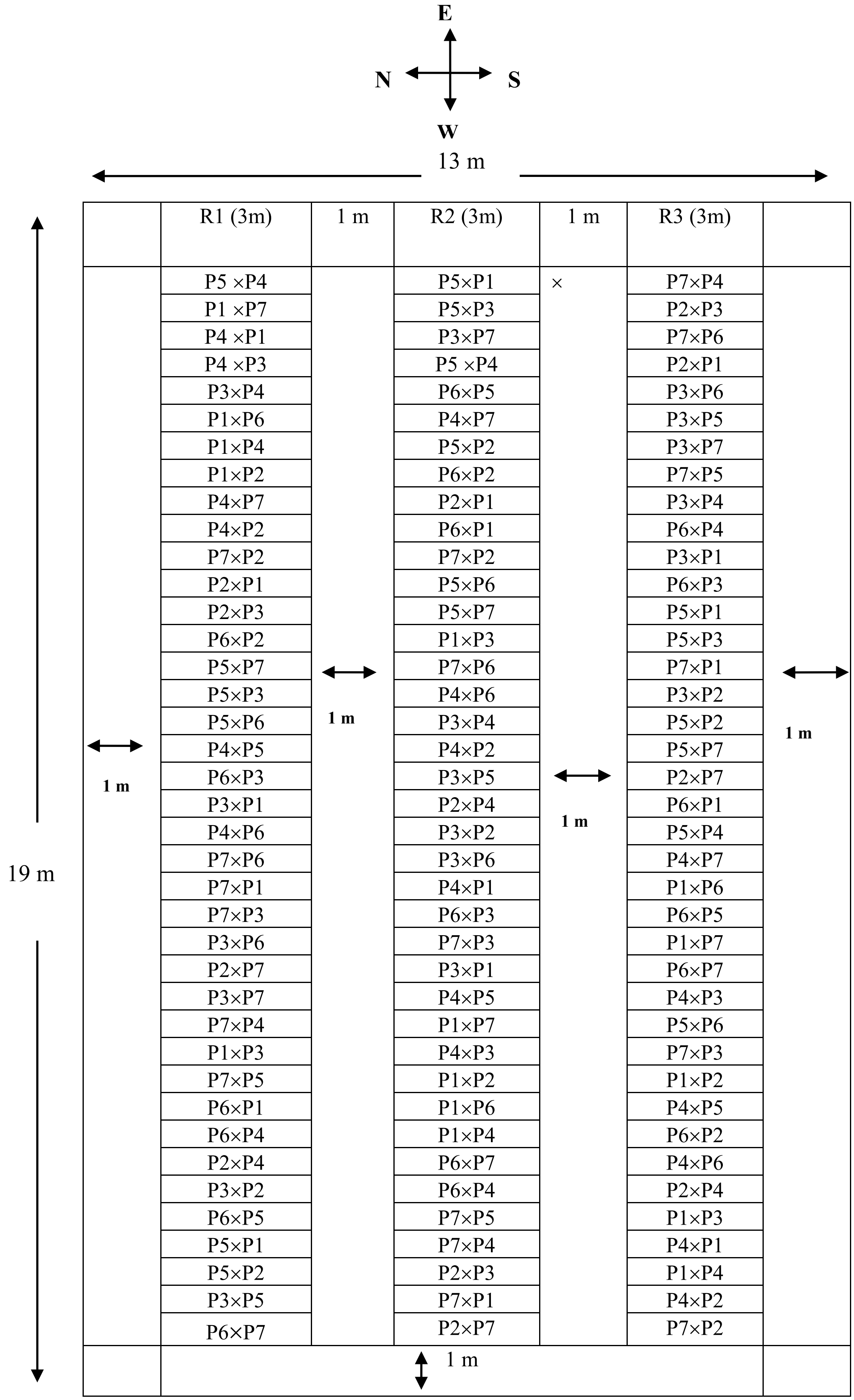

Figure 1. Layout of the experimental design

3.4.4 Seed selection and sowing

Healthy and pure seeds were selected and avoiding the unfilled seeds. In the experimental field, seeds were sown in lines in the experimental field on 8 November, 2019 maintaining a soil depth at about 1.5cm. The seeds were covered with soil carefully after sowing so that no clods were found to suppress the seeds. Germination of seeds was started three to four days after sowing.

3.4.5 Irrigation and drainage

Sprinkler irrigation was given after sowing of seeds to maintain moisture condition of the soil and to ensure uniform seed germination. Second irrigation was given before the flower initiation (23 DAS). Forty days after sowing third irrigation were given when the pod appeared. Sixty days after sowing fourth irrigation was given when seeds appeared in the pod. Good drainage system was maintained in the field to drain out the excess water. Special care was taken during irrigation to avoid the water pressure.

3.4.6 Intercultural operations, insect and disease control

There are various intercultural operations like weeding, thinning were done to ensure normal growth and development of the plants. First weeding was done after 15 days of sowing in the field. At the similar time, thinning was also done for maintaining 30 cm distance from line to line and 10 cm distance from plant to plant. Then after 25 days of sowing, second weeding was done. No remarkable disease and pest attack was observed in the field.

3.4.7 Crop harvesting

Harvesting was done from 11th to 22th February, 2020 on the basis of the maturity. When plants exhibited 80% maturity like straw color of siliqua, leaves. For morphological analysis ten plants were selected at random from the advanced populations in each replication. The plants were harvested by uprooting after that they were tagged properly. On the basis of different parameters data were recorded from these plants.

A pictorial view of experimental plot at growth stage, flowering and harvesting stage is presented in plate 1, 2 and 3.

Plate 1: The pictorial view of experimental plot during growth stage.

Plate 2: The pictorial view of experimental plot during flowering stage.

Plate 3: The pictorial view of experimental plot during harvesting stage.

3.4.8 Data collection

For studying various genetic parameters and inter-relationships, 13 characters of ten plants were taken such as days to first flowering, days to 50% flowering, days to 80% maturity, plant height, root length, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, number of seeds per siliqua, length of siliqua, thousand seed weight, seed yield per plant.

3.4.9 Data collection methods

The data were taken on ten selected plants for each cross on the following traits:

3.4.9.1 Days to 1st flowering

Days to 1st flowering was counted when the treatments of each row in the field showed the 1st flower bloom. Counting should be started from sowing date to the date of appearance of first flower bloom.

3.4.9.2 Days to 50% flowering

Days to 50% flowering was counted when near about fifty percent plants had at least one open flower of each line. Counting should be started from sowing date to the date of 50% flowering.

3.4.9.3 Days to 80% flowering

Days to 80% flowering was counted when near about fifty percent plants had at least one open flower of each line. Counting should be started from sowing date to the date of 80% flowering.

3.4.9.4 Days to 80% maturity

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

3.4.9.5 Plant height (cm)

Data of plant height were recorded after harvesting. Plant height was measured in centimeter (cm) which was starting from the base of the plant to the tip of the longest inflorescence.

3.4.9.6 Root length (cm)

Measurement of root length was started from the portion situated just below the starting point of the shoot to the end portion of the plant. It was measured in centimeter (cm) and data were recorded after harvesting the plants.

3.4.9.7 Number of primary branches per plant

The total number of branches that were derived from the main stem of a plant was considered as primary branches and record was taken after counting.

3.4.9.8 Number of secondary branches per plant

The total number of branches derived from the primary branches of a plant was counted and deliberated as number of secondary branches per plant.

3.4.9.9 Number of siliqua per plant

Total number of siliqua of each plant were estimated and considered as the number of siliqua per plant.

3.4.9.10 Length of Siliqua (cm)

Five representative siliqua were taken randomly from each selected plant and measured in centimeter from the base to the tip of a siliqua without beak.

3.4.9.11 Number of seeds per siliqua

Five siliqua were selected randomly from the sample plants and record was kept after counting the seeds from the siliqua.

3.4.9.12 Thousand seed weight (g)

Ten plants of each cross were selected and thousand seeds from each entry were taken and weighted in grams.

3.4.9.13 Seed yield per plant (g)

Seeds obtained from a representative plant were weighted in gram and considered as the seed yield per plant.

3.4.10 Statistical analysis

The data obtained for different characters were analyzed statistically by using Statistix 10 software to find out the significance of the difference among the 39 F_2 populations of *Brassica rapa L*. After that the significance of the differences among the treatments was calculated by least significant difference (LSD) test at 5% level of probability .Therefore phenotypic and genotypic variance was estimated by the formula used by Johnson *et al.* (1955). Then phenotypic and genotypic coefficient of variation was estimated by the help of the formula of Burton (1952). Then genetic advance was computed by using the formula of Allard (1960) while genetic advance in percentage of mean was measured by using the formula given by Comstock and Robinson (1952). Analysis of path coefficient was done by the outlined method suggested by Dewey and Lu (1959). Phenotypic and genotypic correlation obtained by using the formula of Al-Jibouri *et al.* (1958). After that heritability in broad sense was calculated by using the formula given by Singh and Chaudhary (1985).

3.4.10.1 Analysis of variance

According to Cochran and Cox (1957), the analysis of variance for different characters was carried out utilizing mean data in order to assess the genetic variability among populations. The level of significance was tested at 1% and 5% using F test. The model of ANOVA was used given below:

Sources of variation	Degrees of freedom (D.F.)	Mean sum of squares (MS)	Expected MS
Replication	(r-1)	Mr	p$\sigma_r^2 + \sigma_e^2$
Population	(p-1)	Mp	$r\sigma_p^2 + \sigma_e^2$
Error	(p-1) (r-1)	Me	σ_e^2
Total	(rp-1)		

Here, p = number of treatments (population) in the experiment

r = number of replications in the experiment

σ_r^2= variance due to replications in the field

σ_p^2= variance due to treatments (population)

σ_e^2= variance due to experimental error

The standard error of mean was computed using the formula**:**

S.E = $\sqrt{\frac{2Me}{r}(1+\frac{rqu}{q+1})}$

Here,

S. E = Standard error of mean

Me = Mean sum of square for error (Intra block)

r = Number of replications in the field

q = Number of population in each sub-block

u = Weightage factor

3.4.10.2 Estimation of Least Significant Differences (LSD)

According to of Gomez and Gomez (1984)

Least Significant Differences were estimated by the formula

$LSD_{\alpha} = t_a\sqrt{\frac{s^2}{r}}$

Where, α = Level of significance

t= tabulated t value with concerned df at same level of significance

s^2= Error Mean Sum of Square

r = Number of replication

3.4.10.3 Estimation of Phenotypic and Genotypic variance

Estimation of the variability among the populations for traits related to yield per plant in *Brassica rapa L.* were narrated by using the formula given bellow:

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

Here,

MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error

r = Number of replication

b. Phenotypic variance, $\sigma_p^2 = \sigma_g^2 + \sigma_e^2$

Here,

σ_p^2= Phenotypic variance

σ_g^2= Genotypic variance

σ_e^2= Environmental variance = Mean square of error

3.4.10.3.1 Estimation of genotypic and phenotypic coefficient of variation

Genotypic coefficient of variation (GCV) = $\frac{\sigma_g \times 100}{\bar{x}}$

Phenotypic coefficient of variation (PCV) = $\frac{\sigma_p \times 100}{\bar{x}}$

σ_g= Genotypic standard deviation

σ_p= Phenotypic standard deviation

$\bar{x}$= Population mean

Low (0-10%), Moderate (10-20%) and high (>20%) according to Sivasubramanian and Madhavamenon (1973).

3.4.10.3.2 Estimation of Heritability in Broad sense

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

Here, h_b^2=Heritability in broad sense

σ_g^2= Genotypic variance

σ_p^2= Phenotypic variance

Categories:

Low: 0-30%

Moderate: 30-60%

High: >60%

3.4.10.3.3 Estimation of Genetic Advance

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

Here,

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

σ_p= Phenotypic standard deviation

K= Standard selection differential which is 2.06 at 5% selection intensity.

Categories:

Low (<10%)

Moderate (10-20%)

High (>20%)

3.4.10.3.4 Estimation of Genetic Advance in Percentage of Mean

Genetic advance **(**GA) in percent of mean =$\frac{GA}{Grand\ mean} \times 100$

According to, Johnson *et al.* (1955) there are three categories of genetic advanced are given bellow:

Less than 10% - Low

10-20% -Moderate

More than 20% -High

3.4.10.4 Correlation Coefficient Analysis

Genotypic correlation coefficients (r_{gxy}) = $\frac{Cov_{gxy}}{\sqrt{\sigma_{gx}^2}\sqrt{\sigma_{gy}^2}}$

Phenotypic correlation coefficients (r_{pxy}) = $\frac{Cop_{gxy}}{\sqrt{\sigma^2_{Px}}\sqrt{\sigma^2_{py}}}$

Here,

$r_g(xy)$= Genotypic correlation coefficients of x and y

$r_p(xy)$ = phenotypic correlation coefficients of x and y

$Cov_{gxy=}$ Genotypic covariance of x and y

$Cov_{pxy\,=}$ Phenotypic covariance of x and y

σ^2_{gx}= Genotypic variance of the trait x

σ^2_{gy}= Genotypic variance of the trait y

σ^2_{px}= Phenotypic variance of the trait x

σ^2_{py}= Phenotypic variance of the trait y.

The calculated value of 'r' was compared with table 'r' value with n-2 degrees of freedom at 1% and level 5% of significance and n refers to number of pairs of observation.

3.4.10.5 Path Coefficient Analysis

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

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

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

Where,

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

r's denote simple correlation coefficient

P's denote path coefficient (unknown).

In order to estimate direct & indirect effect of the correlated characters, say x1, x2 and x3 yield y. After calculating the direct and indirect effect of the characters, residual effect (R) was calculated.

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

Here,

P_{RY}^2= (R^2)

Hence, residual effect, R = $\sqrt{P_{RY}^2}$

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

r_{iy}=Correlation of the character with yield

Categories:

Low (0.10 to 0.19)

Moderate (0.20 to 0.29)

High (0.30 to 1.0)

Very High (>1.00)

Negligible (0.00 to 0.09)

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted with a view to determine the variability among 39 F_2 populations of *Brassica rapa* 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 first flowering, days to 50% flowering, days to 80% flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, total siliqua, siliqua length (cm), number of seeds per siliqua, thousand seeds weight (g) and yield per plant (g). The data were statistically calculated and thus obtained results are described below under the following heads:

4.1 Variability study in *Brassica rapa*

4.1.1 Variability among the 39 F_2 populations of *Brassica rapa*

Considerable variations were observed for most of the characters among 39 F_2 materials of *Brassica rapa*. Table 4, Table 5, Table 6, Table 7 and Table 8 showed the analysis of variance, the values of mean, phenotypic variances, genotypic variances, phenotypic coefficient of variation, genotypic coefficient of variation and different yield related characters.

Table 4. Analysis of variance of 39 F_2 populations of mustard

Source of variance	DF	Mean sum of square												
		FF	D50% F	D80% F	80% M	PH	RL	PB	SB	TS	SL	SPS	1000 SW	TY
Replication	2	2.11	2.32	4.78	6.52	323.27	5.70	0.27	7.53	2197.73	0.12	10.66	5.49	7.05
Genotype	38	7.42**	6.75**	5.86**	7.70**	67.86**	3.07**	1.16*	1.87**	1032.81**	0.60**	25.41**	0.93**	2.12**
Error	76	0.76	0.47	0.48	1.54	35.60	1.42	0.68	1.02	505.26	0.27	6.03	0.35	0.80

FF= First flowering, PH = Plant height (cm), PB= primary branches, SB = secondary branches, D 80%F= Days to 80% flowering, D50%F = day to 50% flowering, 80%M = 80% Maturity, 1000 SW=1000 seed weight per plant, T Y= Total Yield, TS= Total siliqua, SL= Siliqua length, SPS= Seeds per siliqua.

* 5% level of significance , ** 1% level of significance

Table 5. Mean performance of 39 F_2 populations of mustard

Genotypes	FF	D50% F	D 80% F	80% M	PH	RH	PB	SB	TS	SL	SPS	1000 SW	TY
P2 ×P7	26.33gh	29.33gh	31.33hi	90.66 b-f	97.93 c-g	7.55 b-f	5.10 b-e	2.10 a-d	73.60 d-i	4.59 b-f	14.30f-j	3.81c-h	4.76 b-k
P3 × P7	29.33 a-c	31.66 b-d	33.66 c-e	90.33c-g	105.65 a-c	6.75c-f	5.06 b-e	1.73 b-f	61.07 i	4.75 b-e	15.82d-i	4.75bc	3.66 j-o
P5 × P1	29.667ab	31.66b-d	32.66e-g	85.33i	99.86 b-g	8.47 a-c	5.13 b-d	1.30c-g	67.03 g-i	4.57 b-f	23.30 a	4.07 b-g	4.49 c-n
P5× P3	30.00 ab	32.66 ab	35.00 ab	89.33d-g	105.60 a-c	8.54 a-c	4.16c-e	0.90c-g	79.77 c-i	4.27c-f	21.68 ab	4.60 b-e	5.55 a-e
P6 × P2	28.00c-f	31.66 b-d	33.00d-g	91.00 a -e	108.80 ab	7.73 b-f	4.94 c-e	1.16c-g	119.13 a	4.31c-f	10.98j	3.91 b-h	4.98 a-j
P1 × P2	27.33e-h	30.33 e-g	32.00g-i	90.33c-g	102.18 a-d	6.29 d-f	4.63c-e	1.86 a-e	98.27 a-h	4.82 b-e	14.25f-j	4.24 b-g	4.37 d-n
P1 × P4	26.33gh	30.33 e-g	32.33 f-h	91.00 a-e	101.12 a-e	8.43 a-c	4.30c-e	1.46 b-g	117.07 ab	4.19c-f	13.89f-j	3.67 e-h	4.88 a-j
P1× P3	27.66d-g	31.33 c-e	33.00d-g	91.66 a-c	104.34 a-d	6.05ef	4.33c-e	0.90c-g	84.90 a-i	4.48 b-f	14.18f-j	4.31 b-f	3.42k-o
P1×P6	29.33 a-c	31.66 b-d	33.00d-g	89.33d-g	92.08 e-g	6.21d-f	3.76e	1.73 b-f	59.80i	4.53 b-f	14.16f-j	4.35 b-f	3.27 l-o
P1×P7	29.66 ab	31.66 b-d	33.33c-f	89.33d-g	102.06 a-d	7.59 b-f	4.90 c-e	0.32e-g	80.80 b-i	5.25 b	18.64 b-d	4.48 b-f	4.21d-o
P2 × P4	24.00i	26.00i	29.00j	87.00hi	90.63 g	10.10 a	4.33 c-e	0.60d-g	71.13 f-i	5.03bc	15.70d-i	3.70e-h	2.88o
P2 ×P1	27.66d-g	31.00c-f	32.33f-h	91.33 a-d	100.25 b-g	7.24c-f	4.60 c-e	0.63c-g	110.10 a-d	4.09ef	13.60f-j	4.31 b-f	4.72 b-l
P2 ×P3	27.00f-h	31.00c-f	33.00d-g	91.00 a-e	104.73 a-c	7.17 c-f	5.23 b-d	0.83c-g	103.07 a-g	4.06ef	11.50 j	4.86 b	3.81i-o

P3 × P2	26.66f-h	30.66d-f	32.66 e-g	91.00 a-e	106.05 a-c	8.30 a-c	4.73 c-e	1.40 b-g	85.50 a-i	3.76f	14.27f-j	4.03 b-g	4.28 d-o
P3 × P6	28.66 b-e	32.00 a-c	34.00 b-d	90.33c-g	99.63 b-g	6.91c-f	4.16 c-e	1.06c-g	59.23i	4.07ef	14.58e-j	3.64e-h	3.08no
P3 ×P5	29.00 a-d	33.00 a	35.66 a	88.66f-h	101.16 a-e	7.39 c-f	5.03 b-e	0.63 c-g	72.10 f-i	4.81 b-e	20.42 a-c	3.58f-h	4.81 b-k
P3×P1	29.00 a-d	32.00 a-c	34.33bc	88.33gh	102.33 a-d	7.28c-f	4.00de	0.00 g	59.33 i	4.52 b-f	20.97 a-c	3.56 f-h	4.72 b-l
P3×P4	27.33 e-h	31.33 c-e	32.66e-g	90.33c-g	105.81 a-c	7.62 b-f	4.06de	1.06 c-g	85.10 a-i	4.46 b-f	13.90f-j	3.98 b-g	4.50 c-n
P4 × P6	26.66 f-h	30.33e-g	32.66e-g	91.33 a-d	103.83 a-d	7.11 c-f	4.40 c-e	1.76 a-f	93.07 a-i	4.36c-f	12.73g-j	3.55f-h	5.16 a-i
P4×P1	26.00h	30.33e-g	32.33 f-h	91.33 a-d	103.82 a-d	7.03 c-f	4.76c-e	1.43 b-g	82.00 b-i	4.31c-f	11.63 j	4.41 b-f	3.87 h-o
P4×P2	24.00i	26.00i	29.00j	88.33gh	94.96 d-g	8.39 a-c	4.33c-e	1.56 b-g	103.13 a-g	5.27 b	14.02f-j	6.17 a	4.65 b-m
P4×P3	27.00f-h	30.33e-g	32.33f-h	91.00 a-e	99.14 b-g	7.35c-f	5.46bc	3.03 ab	108.87 a-e	4.67 b-e	12.73g-j	3.32gh	5.93 a-c
P4×P5	26.33gh	29.33gh	31.33hi	91.00 a-e	90.99 fg	6.13d-f	4.13 c-e	1.43 b-g	93.70 a-i	4.00ef	12.26h-j	2.99h	5.96 ab
P4×P7	26.66f-h	30.33e-g	32.33 f-h	92.00 a-c	106.37 a-c	7.14c-f	5.00 b-e	0.93 c-g	121.00 a	4.62 b-e	13.54 f-j	4.31 b-f	5.27 a-h
P5 × P6	29.33 a-c	31.33 c-e	32.66e-g	89.00e-h	104.04 a-d	6.05ef	4.00 de	0.33 e-g	70.40 f-i	4.59 b-f	16.26d-g	4.67 b-d	3.22m-o
P5 ×P4	26.00h	29.00h	31.00i	92.00 a-c	99.22 b-g	7.63 b-f	4.50c-e	2.95 ab	102.13 a-g	4.46 b-f	11.97ij	3.59 f-h	6.30 a
P5×P2	26.66 f-h	30.66d-f	32.33f-h	88.33gh	104.76 a-c	10.12 a	6.33 ab	0.90c-g	91.60 a-i	4.69 b-e	18.36 b-e	3.65e-h	5.35 a-g
P5×P7	27.66d-g	31.66 b-d	33.66c-e	90.33c-g	104.20 a-d	7.86 b-e	4.53c-e	0.86c-g	75.00 d-i	4.62 b-e	15.88 d-i	4.24 b-g	4.63 b-m

P6 × P1	30.00 ab	32.00 a-c	33.00d-g	90.33c-g	104.09 a-d	6.72c-f	4.55c-e	0.56d-g	65.27 hi	4.09ef	15.88 d-i	4.21 b-g	3.99 f-o
P6 × P5	26.66 f-h	31.00c-f	32.66e-g	90.00c-g	102.87 a-d	7.23c-f	4.56c-e	0.56d-g	64.80 hi	4.00ef	15.98d-h	4.17 b-g	4.13 e-o
P6 × P7	28.00 c-f	31.33c-e	33.00d-g	92.66 ab	103.35 a-d	8.37 a-c	5.43bc	1.83 a-f	101.17 a-h	4.48 b-f	16.11d-h	3.67e-h	4.75 b-k
P6 × P4	27.33e-h	31.00c-f	32.33f-h	92.00 a-c	103.37 a-d	6.84 c-f	4.03de	3.40 a	115.40 a-c	4.16 d-f	11.10 j	3.96 b-g	4.01 f-o
P6× P3	30.33 a	32.66 ab	35.00 ab	88.66 f-h	100.41 b-f	6.65c-f	3.96de	2.26 a-c	69.60 g-i	4.28c-f	13.40 f-j	3.63f-h	3.90 g-o
P7×P1	27.66d-g	31.33c-e	33.00 d-g	91.33 a-d	102.17 a-d	7.31c-f	4.76c-e	0.76c-g	68.30 g-i	4.06ef	13.59f-j	4.78 b	4.35 d-n
P7×P2	29.00 a-d	31.66 b-d	33.00d-g	91.00 a-e	99.67 b-g	5.90f	4.56 c-e	0.56d-g	71.43 f-i	6.23 a	13.71 f-j	4.12 b-g	3.98 f-o
P7×P3	29.00 a-d	33.00 a	35.66 a	89.33d-g	110.40 a	7.98 b-e	4.13c-e	0.20fg	95.10 a-i	4.52 b-f	15.82 d-i	3.77d-h	5.63 a-d
P7×P4	26.33gh	30.00f-h	32.00g-i	91.33 a-d	94.73 d-g	7.93 b-e	6.83 a	1.93 a-e	106.33 a-f	4.96 b-d	14.08 f-j	4.36 b-f	5.38 a-f
P7×P5	29.66 ab	32.00 a-c	34.00 b-d	93.00 a	108.75 ab	8.05 b-d	4.56 c-e	0.70 c-g	72.90 e-i	4.52 b-f	17.16 c-f	4.70 b-d	4.34 d-n
P7×P6	29.00 a-d	32.00 a-c	34.00 b-d	93.00 a	110.34 a	9.48ab	4.73 c-e	0.43 e-g	88.83 a-i	4.04ef	12.30 g-j	4.50 b-f	3.16no

FF= First flowering, PH = Plant height (cm), PB= primary branches, SB = secondary branches, D 80%F= Days to 80% flowering, D50%F = day to 50% flowering, 80%M = 80% Maturity, 1000 SW=1000 seed weight, T Y= Total Yield, TS= Total siliqua, SL= Siliqua length, SPS= Seeds per siliqua.

Table 6. Range, mean, coefficient of variation and standard error for different characters

Trait	Range for individual characters		Mean	CV (%)	SE
	Min	Max			
First flowering	24.00	30.33	27.75	3.14	0.50
Days to 50% flowering	26.00	33.00	30.94	2.20	0.39
Days to 80% flowering	29.00	35.67	32.83	2.11	0.40
80% Maturity	85.33	93.00	90.35	1.37	0.72
Plant height	90.63	110.40	102.09	5.84	3.44
Root length	5.91	10.12	7.51	15.84	0.69
Primary branch	3.77	6.83	4.67	17.63	0.48
Secondary branch	0.00	3.40	1.24	81.92	0.58
Total siliqua	59.23	121.00	85.82	26.19	12.98
Siliqua length	3.77	6.23	4.51	11.54	0.30
Seeds per siliqua	10.98	23.30	14.99	16.37	1.42
1000 seed weight	2.99	6.17	4.12	14.27	0.34
Total yield	2.88	6.31	4.48	20.00	0.52

Table 7. Phenotypic, genotypic and environmental variance for different characters

Trait	Genotypic variance	Phenotypic variance	Environmental variance
First flowering	2.22	2.98	0.76
Days to 50% flowering	2.10	2.56	0.47
Days to 80% flowering	1.79	2.27	0.48
80% Maturity	2.05	3.59	1.54
Plant height	10.75	46.35	35.60
Root length	0.55	1.97	1.42
Primary branch	0.16	0.84	0.68
Secondary branch	0.28	1.31	1.02
Total siliqua	175.85	681.11	505.26
Siliqua length	0.11	0.38	0.27
Seeds per siliqua	6.46	12.49	6.03
1000 seed weight	0.19	0.54	0.35
Total yield	0.44	1.24	0.80

Table 8. Genotypic coefficient of variation, phenotypic coefficient of variation, heritability, genetic advance and genetic advance of percentage of mean for different characters

Characters	GCV	PCV	Heritability	GA	GA (%)
First flowering	5.37	6.22	74.48	2.65	9.54
Days to 50% flowering	4.68	5.17	81.83	2.70	8.72
Days to 80% flowering	4.08	4.59	78.90	2.45	7.46
80% Maturity	1.59	2.10	57.17	2.23	2.47
Plant height	3.21	6.67	23.20	3.25	3.19
Root length	9.88	18.67	28.02	0.81	10.78
Primary branch	8.55	19.60	19.03	0.36	7.68
Secondary branch	42.88	92.47	21.50	0.51	40.96
Total siliqua	15.45	30.41	25.82	13.88	16.17
Siliqua length	7.36	13.68	28.90	0.37	8.15
Seeds per siliqua	16.95	23.57	51.75	3.77	25.12
1000 seed weight	10.70	17.83	35.99	0.54	13.22
Total yield	14.82	24.89	35.44	0.81	18.17

4.1.1.1 Days to first flowering:

Significant variations were observed among the populations for days to first flowering (Table 4). The highest days to first flowering was taken in P6 × P3 (30.33 days) and the minimum days to first flowering was taken (24 days) in P4 × P2 and P2 × P4 followed by (26.00 days) in P4 × P1 and P5 × P4, (26.33 days) in P7 × P4, P4 × P5, P2 × P7 and P1 × P4 among the 39 F_2 populations. Mean value of 27.75 for days to first flowering was recorded (Table 6).

The phenotypic variance (2.98) was lower than genotypic variance (2.22) and variation between them was lower indicating that environment has little influence for the expression of this trait (Table 7). Generally, quantitative characters are highly influenced by the environment. The GCV (Genotypic coefficient of variation) and PCV (Phenotypic coefficient of variation) were low with 5.37 and 6.22 percent respectively (Table 8) (Figure 2). High heritability (74.48%) in association with low genetic advance (2.65) and low genetic advance in percentage of mean (9.54) were noted for this character is inappropriate for advancement through direct selection due to prevalence of additive and non-additive gene action (Table 8) (Figure 3). Similar result was also reported by Sikarwar *et al.* (2017).

4.1.1.2 Days to 50% flowering

Considerable variations were observed among 39 F_2 populations for days to 50% flowering. The days to 50% flowering were observed the lowest (26.00 days) in P4 × P2 and P2 × P4 followed by P5 × P4 (29.00 days) and (29.33 days) in P2 × P7 and P4 × P5. In P7 × P3 and P3 × P5 the highest (33.00 days) days to 50% flowering was observed (Table 5).The early days to 50% flowering was observed in F_2 populations of P4 × P2, P2 × P4, P5 × P4, P2 × P7 and P4 × P5.

Genotypic and phenotypic variance for days to 50 % flowering was observed 2.10 and 2.56 (Table 7), respectively with moderate differences between them indicating that they were moderate responsive to environmental factors for their phenotypic expression and values of GCV and PCV were 4.68% and 5.17%. respectively which indicated low variability present among the genotypes (Table 8). Sikarwar *et al.* (2017) found low GCV and PCV values among 46 genotypes of *B. juncea*. Islam *et al.* (2014) found significant genetic variability in days to 50% flowering in *B. rapa*.

Days to 50% flowering exhibited high heritability (81.33%) with reasonable genetic advance (2.70) and genetic advance in percentage of mean (8.72%) which revealed possibility of predominance of additive and non-additive gene action in the inheritance of this character (Table 8). For this, the characters could be improved through selection process. This results support the reports of Mahmud *et al.* (2008).

4.1.1.3 Days to 80% flowering:

Analysis of variance (Table 4) revealed significant differences among the populations for days to 80% flowering. The highest days to 80% flowering was recorded (35.67 days) inP7 × P3 and P3 × P5 whereas the minimum days to 80% flowering was recorded (29 days) P4 × P2 and P2 × P4 followed by P5 × P4 (31.00 days), (31.33 days) in P4 × P5 and P2 × P7 and the mean value is 32.83 (Table 5) (Table 6).

Phenotypic variance (2.27) was slightly higher from the genotypic variance (1.79) that indicated moderate environmental effect over the trait (Table 4). Low PCV (4.59%) and low GCV (4.08%) values indicated that less influence of environment on this character (Table 8).

High heritability (78.90 %) with low genetic advance of (2.45) (Table 8) and low genetic advance in percentage of mean (7.46) (Table 8) were recorded which revealed the possibility of predominance of both additive and non-additive gene action in the inheritance of this character which limit the scope of improvement by direct selection.

4.1.1.4 Days to maturity

From the ANOVA (Table 4), it was found that days to maturity showed significant variations among the populations. The minimum days to maturity was observed in P5 ×

P1 85.33 days followed by 88.33 days in P3 × P1, P4 × P2 and P5 × P2, 88.66 days in P3 × P5 and P6 × P3 and the highest days to maturity was observed in P7 × P5 and P7 × P6 93.00 days (Table 5). Mean value of 90.35 for days to maturity was recorded (Table 6)

Phenotypic and genotypic variance for days to maturity was observed 3.59 and 2.05 respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait (Table 7). The phenotypic coefficient of variation (2.10 %) was higher than the genotypic coefficient of variation (1.59 %) (Table 8), which suggested that environment has a significant role on the expression of this trait. Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Uddin *et al.* 2013).

Days to maturity exhibited moderate heritability (57.17%) with low genetic advance (2.23) and genetic advance in percentage of mean of (2.47%) revealed medium possibility of selecting genotypes that would mature earlier (Table 8). In some of the crosses the frequency of the segregating plants showing reduced maturity was comparatively higher than the other crosses.

4.1.1.5 Plant height (cm)

Highly significant variation was observed among the 39 F_2 populations for plant height. The highest plant height was observed in P7 × P3 (110.40 cm) followed by P7 × P6 (110.34 cm) whereas the minimum plant height was observed in P2 × P4 (90.63 cm) followed by P4 × P5 (90.99 cm) and P1 × P6 (92.08 cm). Mean value of 102.09 for plant height was recorded (Table 6).

The phenotypic variance and genotypic variance of plant height were observed 46.35 and 10.75. Respectively with relatively large differences between them indicating large environmental influences on these character as well as PCV (6.67%) and GCV (3.21 %)

indicating presence of considerable variability among the genotypes (Table 8). Tyagi *et al.* (2001) observed highest variation in plant height among parents and their hybrid.

Plant height showed low heritability (23.20%) with low genetic advance 3.25 and genetic advance in percentage of mean (3.19%) revealed that non-additive gene action in the inheritance of this trait (Table 8). For this the trait may not be improved through selection process.

4.1.1.6 Root length (cm):

Root length showed significant differences among the advanced populations (Table 4). Maximum length of root was found in P5 × P2 (10.12 cm) whereas minimum in P7 × P2 (5.91) (Table 5). Mean value was 7.51 (Table 6).

Phenotypic variance (1.97) was slightly higher than genotypic variance (0.55) having little difference between them indicated that there was less environment effect over genotypes for the expression of character (Table 7). Low genotypic coefficient of variation (GCV) and moderate phenotypic coefficient of variation (PCV) of 9.88%and 18.67% were observed, respectively (Table 8) (Figure 3).

Low heritability (28.02%) along with low genetic advance (0.81) and moderate genetic advance in percentage of mean (10.78%) were recorded indicating the presence of non-additive gene action which is responsible for the ineffectiveness of the selection for this trait. (Table 8)

4.1.1.7 Number of primary branches per plant

The mean square due to genotype was found significant for number of primary branches per plant indicating the presence of genotypic differences present among 39 genotypes (Table 4). Among the 39 populations the highest number of primary branches/plant was observed in P7 × P4 (6.83) whereas the minimum number of primary branches/plant was observed in P1 × P6 (3.77) (Table 5). Mean value was 4.67 (Table 6).

Number of primary branches per plant showed little differences between phenotypic variance (0.84) and genotypic variance (0.16) which indicated low environmental influence on these characters which might be due to their genetic control and relatively high difference between PCV (19.60 %) and GCV (8.55%) value indicating the apparent variation not only due to genotypes but also due to the large influence of environment (Table 8). Afrin *et al.* (2016) found significant differences for number of primary branches per plant.

Number of primary branches per plant exhibited low heritability (19.03%) with low genetic advance (0.36) and genetic advance in percentage of mean (7.68%) (Table 8). As a whole, the high heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes.

4.1.1.8 Number of secondary branches per plant

Significant variations were observed among the populations for number of secondary branches per plant (Table 4). The highest number of secondary branches/plant was observed (3 .40) in P6 × P4 whereas no number of secondary branches/plant was observed in P3 × P1 (0.00) (Table 5). Mean value of 1.24 for number of secondary branches per plant was recorded (Table 6).

Number of secondary branches per plant showed low difference between phenotypic variance (1.31) and genotypic variance (0.28) indicating little environmental influence on this character. The value of PCV (92.47 %) and GCV (42.88 %) indicating that the environment has significant role on the expression of this particular trait (Table 8). Halder *et al.* (2016) reported similar result.

Number of secondary branches per plant showed low heritability (21.50%) with low genetic advance (0.51) and high genetic advance in percentage of mean (40.96%) revealed the possibility of predominance of both additive and non-additive gene action in the inheritance of this character, for this limit scope of crop improvement by direct selection (Table 8). Kumari *et al.* (2017) reported low heritability for this trait.

4.1.1.9 Total siliqua

Analysis of variance (Table 4) revealed significant differences among the populations for total siliqua. The total siliqua was observed highest in P4 × P7 (121.00) followed by P6 × P2 (119.13) whereas the minimum total siliqua was observed in P3 × P6 (59.23) (Table 5). Mean value of 85.82 for total siliqua was recorded (Table 6).

Total siliqua showed highest phenotypic variance (681.11) and genotypic variance (175.85) with large environmental influence and the difference between the high PCV (30.41%) and moderate GCV (15.45 %) indicating existence of adequate variation among the populations (Table 8). Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Uddin *et al*. 2013)

Total siliqua exhibited low heritability (25.82%) with moderate genetic advance 13.88 and genetic advance in percentage of mean (16.17%) (Table 8). As a whole the low heritability and the consequent moderate genetic advance indicated the lower possibility of selecting genotypes.

4.1.1.10 Siliqua length (cm)

From the ANOVA (Table 4), it was found that siliqua length showed significant variations among the genotypes. Siliqua length was observed highest in P7 × P2 (6.23 cm) followed by P4 × P2 (5.27cm) whereas the minimum siliqua length was observed in P3 × P2 (3.77 cm) (Table 5). Mean value of 4.51 for siliqua length was recorded (Table 6).

Length of siliqua showed phenotypic (0.38) and genotypic variance (0.11) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively medium PCV (13.68%) and low GCV (7.36 %) indicating that the genotype has moderate variation for this trait (Table 8). Parveen *et al.* (2015) studied *B. campestris* population for siliqua length and observed high genetic variation on this trait. Naznin *et al.* (2015) found high genetic variability for this trait.

Length of siliqua showed 28.90% heritability with 0.37 genetic advance and genetic advance in percentage of mean 8.15% (Table 8).These results revealed that non-additive gene action in the inheritance of this trait. Yadava *et al*. *(1982),* Sharma (1984) and Kakroo and Kumar (1991) reported low to medium heritability for this trait.

4.1.1.11 Seeds per siliqua

Highly significant variation among 39 populations for seeds per siliqua (Table 4).The seeds per siliqua was observed the highest in P5 × P1 (23.30) and P5 × P3 (21.68) was found the second highest for seeds per siliqua whereas the minimum seeds per siliqua was observed in P6 × P2(10.98) (Table 5). Mean value of 14.99 for seeds per siliqua was recorded (Table 6).

The differences between phenotypic variances (12.49) and genotypic variances (6.46) were relatively high for number of seeds per siliqua indicating large environmental influence on these characters (Table 7). The value of PCV and GCV were 23.57 % and 16.95 %, respectively low for number of seeds per siliqua which indicating that medium variation exists among different genotypes (Table 8).

Number of seeds per siliqua showed 51.75% heritability coupled with low genetic advance (3.77) and genetic advance in percentage of mean 25.12% (Table 8) revealed possibility of predominance of additive gene action in the inheritance of this character and therefore, the characters could be improved through selection process. Afroz *et al.* (2004) reported high heritability for this trait.

4.1.1.12 Thousand seed weight (g)

Significant variations were observed among the genotypes for thousand seeds weight (Table 4). Thousand seeds weight was found maximum in P4 × P2 (6.17 g) followed by P2 × P3 (4.86 g) and P7 × P1 (4.78 g) where as the minimum was found in P4 × P5 (2.99 g) (Table 5). Mean value of 4.12 for thousand seeds weight was recorded (Table 6).

Thousand seed weight showed very low genotypic (0.19) and phenotypic (0.54) variance with minimum differences indicating that they were less responsive to environmental factors and the values of moderate GCV and PCV were 10.70 % and 17.83 % indicating that the genotype has moderate variation for this trait (Table 8). Sohail *et al.* (2017) reported values 11.8% and 18.9% of GCV and PCV for thousand seeds weight in *B.rapa.*

Thousand seed weight exhibited 35.99% heritability with genetic advance of 0.54 and genetic advance in percentage of mean 13.22% (Table 8) which revealed that this trait is governed by non-additive genes. Alam *et al*. (2010) reported that moderate values of heritability and low genetic advance may be due to non-additive gene action which includes dominance and epistasis. Johnson *et al. (1955)* reported that heritability estimates along with genetic gain were more useful in prediction selection of the best individual.

4.1.1.13 Seed yield per plant (g)

The mean square due to genotype was found significant at for yield per plant indicating the presence of genotypic differences present among 39 populations (Table 4). Yield is the most outstanding character and all the research work and objectives are dependent on yield. The highest amount of yield per plant was observed in P5 × P4 (6.31 g) followed by P4 × P5 (5.96 g) and P4 × P3 (5.93 g) whereas the minimum yield per plant was observed in P2 × P4 (2.88 g) (Table 2). Mean value of 4.88 for seed yield per plant was recorded (Table 6).

The phenotypic variance (1.24) appeared to be moderately higher than the genotypic variance (0.44) (Table 7) suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (24.89 %) was higher than the genotypic co-efficient of variation (14.82 %) which suggested that environment has a significant role on the on the expression of this trait (Table. 8). Rashid *et al.* (2013) reported high variability for this trait in different genotypes of *B. rapa*.

Seed yield per plant showed high heritability of 35.44% with genetic advance of 0.81 and genetic advance in percentage of mean 18.17% (Table 8). These results support the reports of Akter *et al.* (2010) but Iqbal *et al.* (2014) found high heritability for this trait.

4.2 Correlation coefficient

In mathematics, a correlation coefficient is a numerical value that indicates the direction and strength of a relationship between two or more variables relative movements. Between -1.0 and 1.0 is the range of values for the correlation coefficient. There was an error in the measurement of correlation if the calculated number was greater than 1, or smaller than -1, The perfect negative correlation is -1.0, whereas the perfect positive correlation is 1.0. There is no correlation between the two variables when the correlation is 0. In addition to polygene, the environment has a significant impact on yield. Selection based solely on yield is, therefore, ineffective. When a character that is highly correlated with yield is selected for development, it affects a number of other correlated characters at the same time. Knowledge of the relationship between character and yield, as well as between character and yield, provides a guide for plant breeders in making improvements through selection, as well as a clear understanding of the genetic and non-genetic factors that contribute to this association (Dewey and Lu, 1959).Each of the 39 populations of *Brassica rapa* L. is represented by its genotypic and phenotypical correlation coefficients in Tables 9 and 10. Genetic correlation coefficients were higher than phenotypic correlation coefficients, indicating that these traits were strongly correlated with one another and that their expression was less influenced by environmental factors. Parveen *et al*. also found a similar result (2015). There were many instances where the phenotypic correlation coefficient was higher than the genotypic correlation coefficient, indicating that both environmental and genotypic correlations worked together to maximize phenotypic manifestation.

Table 9. Genotypic correlation coefficient among yield and yield contributing characters of 39 F2 populations

Characters	FF	D 50% F	D80%F	80% M	PH	RL	PB	SB	TS	SL	SPS	1000SW	TY
First lowering													
Days to 50%flowering	0.921**												
Days to80% Flowering	0.867**	0.959**											
80% Maturity	-0.122^{NS}	0.115^{NS}	0.047^{NS}										
Plant height	0.572**	0.823**	0.806**	0.667**									
Root length	-0.444**	-0.405**	-0.274**	-0.361**	-0.040^{NS}								
Primary branch	-0.327**	-0.158^{NS}	-0.251**	0.158^{NS}	-0.293**	0.483**							
Secondary branch	-0.420**	-0.446**	-0.520**	0.396**	-0.786**	-0.396**	0.018^{NS}						
Total siliquea	-0.699**	-0.481**	-0.528**	0.772**	-0.342**	0.059^{NS}	0.073^{NS}	0.521**					
Siliquea length	-0.020^{NS}	-0.336**	-0.299**	-0.337**	-0.549**	0.057^{NS}	0.550**	-0.147^{NS}	-0.062^{NS}				
Seeds per siliquea	0.540**	0.380**	0.443**	-0.853**	0.203*	0.314**	0.203*	-0.655**	-0.679**	0.176^{NS}			
1000 seed weight	-0.008^{NS}	-0.180^{NS}	-0.198*	-0.045^{NS}	0.447**	0.024^{NS}	-0.066^{NS}	-0.282**	0.010^{NS}	0.264**	-0.034^{NS}		
Total yield	-0.228*	-0.120^{NS}	-0.070^{NS}	0.179^{NS}	-0.293**	-0.070^{NS}	0.314**	0.286**	0.565**	0.036^{NS}	-0.020^{NS}	-0.470**	

FF= First flowering, PH = Plant height (cm), PB= primary branches, SB = secondary branches, D 80%F= Days to 80% flowering, D50%F = day to 50% flowering, 80%M = 80% Maturity, 1000 SW=1000 seed weight, T Y= Total Yield ,TS= Total siliqua, SL= Siliqua length, SPS= Seeds per siliqua.

* 5% level of significance, ** 1% level of significance

Table 10. Phenotypic correlation coefficient among yield and yield contributing characters of 39 F2 populations

Characters	FF	D 50% F	D80%F	80% M	PH	RL	PB	SB	TS	SL	SPS	1000SW	TY
First flowering													
Days to 50% flowering	0.816**												
Days to 80% flowering	0.742**	0.930**											
80% Maturity	-0.060^{NS}	0.069^{NS}	0.044^{NS}										
Plant height	0.293**	0.447**	0.438**	0.114^{NS}									
Root length	-0.168^{NS}	-0.174^{NS}	-0.095^{NS}	-0.106^{NS}	0.178^{NS}								
Primary branch	-0.117^{NS}	-0.037^{NS}	-0.024^{NS}	0.067^{NS}	0.157^{NS}	0.307**							
Secondary branch	-0.221*	-0.186*	-0.188*	0.145^{NS}	-0.076^{NS}	-0.011^{NS}	0.168^{NS}						
Total siliquea	-0.293**	-0.146^{NS}	-0.132^{NS}	0.189*	0.342**	0.212*	0.379**	0.317**					
Siliquea length	-0.048^{NS}	-0.127^{NS}	-0.111^{NS}	-0.221*	-0.137^{NS}	-0.071^{NS}	0.025^{NS}	-0.038^{NS}	-0.084^{NS}				
Seeds per siliquea	0.340**	0.234*	0.254**	-0.406**	-0.051^{NS}	0.273**	-0.012^{NS}	-0.313**	-0.383**	0.222*			
1000 seed weight	-0.010^{NS}	-0.119^{NS}	-0.113^{NS}	0.051^{NS}	-0.030^{NS}	-0.003^{NS}	0.043^{NS}	-0.187*	-0.077^{NS}	0.143^{NS}	0.040^{NS}		
Total yield	-0.205*	-0.039^{NS}	0.013^{NS}	0.059^{NS}	0.159^{NS}	0.279**	0.304**	0.294**	0.488**	-0.030^{NS}	0.098^{NS}	-0.244**	

* 5% level of significance, ** 1% level of significanc

4.2.1 Days to first flowering

Days to first flowering exhibited significant and positive correlation with days to 50% flowering (r_g=0.921, r_p=0.816), days to 80% flowering (r_g=0.867, r_p=0.742), plant height (cm) (r_g=0.572, r_p=0.293) and seeds per siliqua (r_g=0.540, r_p=0.340) pointing out a possible increase in days to 50% flowering, plant height (cm) and seeds per siliqua by increasing days to first flowering. Correlation of days to first flowering with root length (cm) (r_g=-0.444), number of primary branches per plant (r_g=-0.327), number of secondary branches per plant (r_g=-0.420, r_p=-0.221), total siliqua (r_g=-0.699, r_p=-0.293) and yield per plant (g) (r_g=-0.228, r_p=-0.205) was significant and negative indicating a possible increase root length (cm), number of primary branches per plant, number of secondary branches per plant, total siliqua and yield per plant (g)by decreasing days to first flowering. It also showed non-significant and negative correlation with days to maturity (r_g=-0.122, r_p=-0.060), root length (cm) (r_p=-0.168), number of primary branches per plant (r_p=-0.117), siliqua length (cm) (r_g=-0.020, r_p=-0.048) and thousand seeds weight (g) (r_g=-0.008, r_p=-0.010). Non-significant association of these traits revealed that the combination between these traits was largely influenced by environmental factors.

4.2.2 Days to 50% flowering

Correlation of days to 50% flowering was significant and positive with days to 80% flowering (r_g=0.959, r_p=0.930), plant height (cm) (r_g=0.823, r_p=0.447) and seeds per siliqua (r_g=0.380, r_p=0.234) pointing out a possible increase in days to 80% flowering, plant height (cm) and seeds per siliqua by increasing days to 50% flowering. It exhibited Non-significant and positive correlation with days to maturity (r_g=0.11, r_p=0.069) showing very little contribution of this trait toward the increase in days to maturity. Significant and negative correlation was observed with root length (cm) (r_g=-0.405), number of secondary branches per plant (r_g=-0.446, r_p=-0.186), total siliqua (r_g=-0.481) and siliqua length (cm)(r_g=-0.336) indicating a possible decrease in root length (cm), number of secondary branches per plant, total siliqua and siliqua length (cm). Association of days to 50% flowering with root length (cm)(r_p=-0.174), number of primary branches per plant (r_g=-0.158, r_p=-0.037), total siliqua (r_p=-0.146), siliqua length (cm)(r_p=-0.127), thousand seeds weight (g)(r_g=-0.180, r_p=-0.119) and yield per plant (g)(r_g=-0.120, r_p=-

0.039) was non-significant and negative. Non-significant association of these traits suggested that the interrelationship between these traits was largely influenced by environmental factors.

4.2.3 Days to 80% flowering

Correlation of days to 80% flowering was significant and positive with plant height (cm)(r_g=0.806, r_p=0.438) and seeds per siliqua (r_g=0.443, r_p=0.254) pointing out a possible increase in plant height (cm) and seeds per siliqua by increasing days to 800% flowering. It exhibited Non-significant and positive correlation with days to maturity (r_g=0.047, r_p=0.044) and yield per plant (g)(r_p=0.013) showing very little contribution of this trait toward the increase in days to maturity and yield per plant (g). Significant and negative correlation was observed with root length (cm)(r_g=-0.274), number of primary branches per plant (r_g=-0.251), number of secondary branches per plant (r_g=-0.520, r_p=-0.188), total siliqua (r_g=-0.528), siliqua length (cm)(r_g=-0.299) and thousand seeds weight (g)(r_g=-0.198) indicating a possible decrease in root length (cm), number of primary branches per plant, number of secondary branches per plant, total siliquaa, siliqua length (cm), and thousand seeds weight (g) by increasing days to 80% flowering. Association of days to 80% flowering with root length (cm)(r_p=-0.095), number of primary branches per plant (r_p=-0.024), total siliqua (r_p=-0.132), siliqua length (cm)(r_p=-0.111), thousand seeds weight (g)(r_p=-0.113) and yield per plant (g)(r_g=-0.070) was non-significant and negative. Non-significant association of these traits suggested that the interrelationship between these traits was largely influenced by environmental factors.

4.2.4 Days to maturity

Correlation of days to maturity with plant height (cm)(r_g=0.667), number of secondary branches per plant (r_g=0.396) and total siliqua (r_g=0.772, r_p=0.189) was significant and positive enunciating a possible increase in plant height (cm), number of secondary branches per plant and total siliqua by increasing days to maturity. It showed non-significant and positive correlation with plant height (cm)(r_p=0.114),number of primary branches per plant (r_g=0.158, r_p=0.067), number of secondary branches per plant (r_p=0.145), thousand seeds weight (g)(r_p=0.051) and yield per plant (g)(r_g=0.179, r_p=0.059) indicating very little contribution of this trait toward the increase in plant height (cm), number of primary branches per plant, number of secondary branches per plant, thousand seeds weight (g)and yield per plant (g). Significant and negative correlation of days to maturity with was observed with root length (cm)(r_g=-0.361), siliqua length (cm)(r_g=-0.337, r_p=-0.221) and seeds per siliqua (r_g=-0.853, r_p=-0.406) stating that when days to maturity decreases, root length (cm), siliqua length (cm)and seeds per siliqua increases. Association of days to maturity with root length (cm)(r_p=-0.106) and thousand seeds weight (g)(r_g=-0.045) was non-significant and negative.

4.2.5 Plant height (cm)

Plant height exhibited significant and positive interaction with total siliqua (r_p=0.342), seeds per siliqua (r_g=0.203) and thousand seeds weight (g)(r_g=0.447) enunciating that increasing plant height results in an increase in total siliqua, seeds per siliqua and thousand seeds weight (g). Correlation of plant height with root length (cm)(r_p=0.178), number of secondary branches per plant (r_p=0.157) and yield per plant (g)(r_p=0.159) was non-significant and positive revealed that this trait had a very little contribution toward the increase in root length (cm), number of secondary branches per plant and yield per plant (g). Association of plant height (cm) was significant and negative with number of primary branches per plant (r_g=-0.293), number of secondary branches per plant (r_g=-0.786), total siliqua (r_g=-0.342), siliqua length (cm)(r_g=-0.549) and yield per plant (g)(r_g=-0.293) indicating that a possible decrease of plant height increases number of primary branches per plant, number of secondary branches per plant, total siliqua, siliqua length (cm)and yield per plant (g). Non-significant and negative correlation of plant height was observed with root length (cm)(r_g=-0.040),number of secondary branches per plant (r_p=-0.076), siliqua length (cm)(r_p=-0.137) and thousand seeds weight (g)(r_p=-0.030) indicated that environmental factors largely influenced on the association between these traits.

4.2.6 Root length (cm)

Significant and positive correlation of root length was observed with number of primary branches per plant (r_g=0.483, r_p=0.307), total siliqua (r_p=0.212), seeds per siliqua (r_g=0.314, r_p=0.273) and yield per plant (g)(r_p=0.279) indicating a possible increase in root length causes an increase in number of primary branches per plant, total siliqua, seeds per siliqua and yield per plant (g). Association of root length with total siliqua (r_g=0.059), siliqua length (cm)(r_g=0.057) and thousand seeds weight (g)(r_g=0.024) was non- significant and positive revealed that the trait showed a very little contribution toward the increase in total siliqua, siliqua length (cm)and thousand seeds weight (g). It also exhibited significant and negative correlation with number of secondary branches per plant (r_g=-0.396) enunciating that number of primary branches per plant increases by decreasing root length. Non-significant and negative correlation was also found with number of secondary branches per plant (r_p=-0.011), siliqua length (cm)(r_p=-0.071), thousand seeds weight (g)(r_p=-0.003) and yield per plant (g)(r_g=-0.070) indicated that environmental factors largely influenced on the association between these traits.

4.2.7 Number of primary branches per plant

Correlation of number of primary branches per plant with total siliqua (r_p=0.379), siliqua length (cm)(r_g=0.550), seeds per siliqua (r_g=0.203) and yield per plant (g)(r_g=0.314, r_p=0.304) was significant and positive pointing out a possible increase in siliqua length (cm), seeds per siliqua and yield per plant (g) by increasing number of primary branches per plant. Naznin *et al. (*2015) reported that seed yield/plant showed positive significant association with number of primary branches/plant at both genotypic and phenotypic level. Alam (2010) noticed significant and positive correlation of the number of primary branches per plant with the seed yield. The finding suggested that branching was an important contributor to increase seed yield/plant. It also showed non-significant and positive correlation with number of secondary branches per plant (r_g=0.018, r_p=0.168), total siliqua (r_g=0.073), siliqua length (cm)(r_p=0.025) and thousand seeds weight (g)(r_p=0.043) indicating that it had a very little contribution toward the increase in number of secondary branches per plant, total siliqua, siliqua length (cm)and thousand seeds weight (g). Non-significant and negative correlation was also observed with seeds per siliqua (r_p=-0.012) and thousand seeds weight (g) (r_g=-0.066) indicating a possible increase in seeds per siliqua and thousand seeds weight (g) by decreasing number of primary branches per plant.

4.2.8 Number of secondary branches per plant

Significant and positive correlation of number of secondary branches per plant was observed with total siliqua (r_g=0.521, r_p=0.317) and yield per plant (g)(r_g=0.286, r_p=0.294) enunciating that the traits are less influenced by environment. Naznin *et al*. (2015) reported that seed yield/plant had significant and positive correlation for number of secondary branches/plant (r_g = 0.5160, r_p= 0.4098) at both genotypic and phenotypic level. It also exhibited significant and negative correlation with seeds per siliqua (r_g=-0.655, r_p=-0.313) and thousand seeds weight (g)(r_g=-0.282, r_p=-0.187) whereas non-significant and negative correlation was observed with siliqua length (cm)(r_g=-0.147, r_p=-0.038) indicating a possible decrease in siliqua length (cm) by decreasing number of secondary branches per plant. Naznin (2013) found significant and positive correlation with yield while Akter (2010) found negative correlation with the yield.

4.2.9 Total siliqua

Correlation of total siliqua with yield per plant (g)(r_g=0.565, r_p=0.488) was significant and positive expressing that when total siliqua increases, yield per plant (g) increases. Ara (2010) reported that total siliqua had significant and positive effect on seed yield per plant. Naznin *et al*. (2015) also showed highly significant positive association of number of siliqua/plant with seed yield/plant. Rameeh (2011) also confirmed the same finding. Similar result was also discovered by Esmaeeli-Azadgoleh *et al*. (2009) and Marjanovic-Jeromela *et al.* (2007). It also showed non-significant and positive correlation with thousand seeds weight (g)(r_g=0.010) indicating that it had a very little contribution toward the increase in thousand seeds weight (g). Significant and negative correlation was observed with seeds per siliqua (r_g=-0.679, r_p=-0.383) stating that by decreasing total siliqua, seeds per siliqua increases. Non-significant and negative correlation was also observed with siliqua length (cm) (r_g=-0.062, r_p=-0.084) and thousand seeds weight (g)(r_p=-0.077) indicating a possible increase in siliqua length (cm)and thousand seeds weight (g) by decreasing total siliqua.

4.2.10 Length of siliqua

Length of siliqua exhibited significant and positive correlation with seeds per siliqua (r_p=0.222) and thousand seeds weight (g) (r_g=0.264) enunciating that a possible increase in length of siliqua increase sseeds per siliqua and thousand seeds weight (g). It also showed non-significant and positive correlation with seeds per siliqua (r_g=0.176), thousand seeds weight (g)(r_p=0.143) and yield per plant (g)(r_g=0.036) stated that it had a very little contribution toward the increase of seeds per siliqua, thousand seeds weight (g)and yield per plant (g). Non-significant and negative correlation was also observed with yield per plant (g) (r_p=-0.030).

4.2.11 Seeds per siliqua

Correlation of number of seeds per siliqua was non-significant and positive with thousand seeds weight (g) (r_p=0.040) and yield per plant (g)(r_p=0.098) enunciating that a decrease in seeds per siliqua results in an increase in thousand seeds weight (g)and yield per plant (g). It also exhibited non-significant and negative correlation with thousand seeds weight (g) (r_g=-0.034) and yield per plant (g) (r_g=-0.020) indicating the influence of environmental factors on the association between these traits.

4.2.12 Thousand seeds weight

Thousand seeds weight exhibited highly significant and negative correlation with yield per plant (g) (r_g=-0.470, r_p=-0.244) at both genotypic and phenotypic level indicating that an increase in thousand seed weight tends to little increasing yield per plant. The similar result was also reported by Parveen *et al.* (2015).

Plate 4: P3× P2

Plate 5: P3× P7

Plate 6: P3× P5

Plate 7: P6× P2

Plate 8: P1× P7

Plate 9: P4× P7

Plate 10: P2× P3

Plate 11: P7× P6

Plate 12: P5× P6

Plate 13: P5× P1

Plate 14: P5× P2

Plate 15: P6× P7

Plate 16: P1× P3

Plate 17: P7× P1

Plate 18: P2× P1

Plate 19: P5× P7

Plate 20: P7× P4

Plate 21: P6× P4

Plate 22: P5× P3

Plate 23: P5×P4

Plate 24: P4× P3

Plate 25: P3× P1

Plate 26: P1× P2

Plate 27: P1× P6

Plate 28: P1× P4

Plate 29: P6× P3

Plate 30: P4× P1

Plate 31: P2× P7

Plate 32: P4× P2

Plate 33: P4× P5

Plate 34: P3× P4

Plate 35: P7× P2

Plate 36: P7× P5

Plate 37: P6× P1

Plate 38: P3× P6

Plate 39: P7× P3

Plate 40: P6× P5

Plate 41: P2× P4

Plate 42: P4× P6

4.3 Path co-efficient analysis

The correlation coefficient can be used to determine the relative importance of direct and indirect influence of each yield component on the seed yield per plant by determining the association of characters. Phenotypic path analysis was used to determine the direct and indirect effects of seed yield per plant on other yield attributes as well as the relative importance of each component. Seed yield per plant is considered as dependent (resultant) variable and its attributes as independent variables (causal) such as days to first flowering, days to 50% flowering, days to 80% flowering, days to 80% maturity, plant height, root length, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, length of siliqua, number of seeds per siliqua, thousand seed weight. Partitioning of genotypic correlations into direct and indirect effects of important characters by path coefficient analysis of *Brassica rapa L.* is presented in Table 11. Residual effects of their independent variables have been denoted as ‘R’ which have influenced on seed yield per plant to a medium extent.

Table 11. Partitioning of genotypic correlations into direct and indirect effects of important characters by path coefficient analysis of *Brassica rapa* L.

Trait	First flowering	Days to 50% flowering	Days to 80% flowering	80% Maturity	Plant height	Root length	Primary branch	Secondary branch	Total siliqua	Siliqua length	Seeds per siliqua	1000 seed weight	Genotypic correlation with total yield
First flowering	**-0.491**	-2.034	0.589	-0.145	0.324	0.557	0.040	0.001	-0.365	-0.004	1.292	0.007	-0.228*
Days to 50% flowering	-0.452	**-2.208**	0.651	0.137	0.467	0.509	0.020	0.001	-0.252	-0.061	0.909	0.160	-0.120^{NS}
Days to 80% flowering	-0.426	-2.117	**0.679**	0.056	0.457	0.344	0.031	0.001	-0.276	-0.055	1.059	0.175	-0.070^{NS}
80% Maturity	0.060	-0.254	0.032	**1.188**	0.378	0.453	-0.019	-0.001	0.404	-0.062	-2.039	0.040	0.179^{NS}
Plant height	-0.281	-1.817	0.547	0.792	**0.567**	0.050	0.036	0.002	-0.179	-0.100	0.486	-0.396	-0.293**
Root length	0.218	0.895	-0.186	-0.428	-0.023	**-1.257**	-0.060	0.001	0.031	0.010	0.750	-0.022	-0.070^{NS}
Primary branch	0.161	0.349	-0.170	0.188	-0.166	-0.607	**-0.123**	-0.00005	0.038	0.100	0.485	0.059	0.314**
Secondary branch	0.206	0.985	-0.353	0.470	-0.446	0.497	-0.002	**-0.003**	0.272	-0.027	-1.566	0.250	0.286**
Total siliquea	0.343	1.063	-0.358	0.917	-0.194	-0.074	-0.009	-0.001	**0.522**	-0.011	-1.624	-0.009	0.565**
Siliquea length	0.010	0.743	-0.203	-0.400	-0.311	-0.072	-0.068	0.0004	-0.033	**0.182**	0.422	-0.234	0.036^{NS}
Seeds per siliquea	-0.265	-0.839	0.301	-1.013	0.115	-0.394	-0.025	0.002	-0.355	0.032	**2.391**	0.030	-0.020^{NS}
1000 seed weight	0.004	0.398	-0.134	-0.053	0.253	-0.031	0.008	0.001	0.005	0.048	-0.081	**-0.888**	-0.470**
	Residual effect 0.09												

* 5% level of significance, ** 1% level of significance

4.3.1 Days to first flowering

Path coefficient analysis revealed that days to first flowering had negative direct effect (-0.491) on seed yield per plant. The trait exhibited positive indirect effect on seed yield per plant via days to 80% flowering (0.589), plant height (0.324), root length (0.557), number of primary branches per plant (0.040), number of secondary branches per plant (0.001),seeds per siliqua (1.292) and thousand seeds weight (0.007) followed by negative indirect effect via days to 50% flowering (-2.034), days to maturity (-0.145), total siliqua (-0.365) and siliqua length (-0.004). Finally, the trait showed significant and negative genotypic correlation with seed yield/plant (-0.228) which was highly significant.

4.3.2 Days to 50% flowering

According to path coefficient analysis, days to 50% flowering exhibited direct negative effect (-2.208) towards seed yield per plant. Islam *et al*. (2016) showed that days to 50% flowering had the negative direct effect on seed yield per plant which was similar to the result. Zahan (2006) also reported the similar finding. The trait showed positive indirect effect on yield per plant through days to 80% flowering (0.651), days to maturity (0.137), plant height (0.467), root length (0.509), number of primary branches per plant (0.020), number of secondary branches per plant (0.001),seeds per siliqua (0.909) and thousand seeds weight (0.160) while negative indirect effect was found toward yield per plant days to first flowering (-0.452), total siliqua (-0.252) and siliqua length (-0.061). Finally, the trait had non-significant negative association with seed yield per plant that was pointed out by genotypic correlation of co-efficient (-0.120).

4.3.3 Days to 80% flowering

Days to 80% maturity had direct positive effect (0.679) on seed yield per plant. It showed positive indirect effect on seed yield per plant through days to maturity (0.056), plant height (0.457), root length (0.344), number of primary branches per plant (0.031), number of secondary branches per plant (0.001), seeds per siliqua (1.059) and thousand seeds weight (0.175) whereas negative indirect effect via days to first flowering (-0.426), days to 50% flowering (-2.117), total siliquae (-0.276) and siliqua length (-0.055). Finally, the trait had non-significant negative genotypic association with seed yield per plant (-0.070).

4.3.4 Days to 80% maturity

Days to 80% maturity had direct positive effect (1.188) on seed yield per plant. Naznin *et al*. (2015) reported positive direct effect of days to maturity towards yield per plant that was similar to the present finding. It showed positive indirect effect on seed yield per plant through days to first flowering (0.060), days to 80% flowering (0.032), plant height (0.378), root length (0.453), total siliqua (0.404) and thousand seeds weight (0.040) whereas negative indirect effect via days to 50% flowering (-0.254), number of primary branches per plant (-0.019), number of secondary branches per plant (-0.001), siliqua length (-0.062) and seeds per siliqua (-2.039). Finally, the trait had non-significant positive genotypic association with seed yield per plant (0.179).

4.3.5 Plant height (cm)

Plant height exhibited direct positive effect (0.567) on seed yield per plant. Uddin *et al*. (2013) demonstrated that plant height had the negative direct effect on yield per plant whereas Shakera (2014) showed positive direct effect of plant height on yield per plant. Positive indirect effect of the character was observed on seed yield per plant via days to 80% flowering (0.547), days to maturity (0.792), root length (0.050), number of primary branches per plant (0.036), number of secondary branches per plant (0.002) and seeds per siliqua (0.486) while indirect negative effect was found via days to first flowering (-0.281), days to 50% flowering (-1.817), total siliqua (-0.179), siliqua length (-0.100) and thousand seeds weight (-0.396). Finally, the trait showed significant and negative genotypic association with seed yield per plant that was marked by genotypic correlation of coefficient (-0.293).

4.3.6 Root length (cm)

According to path coefficient analysis, root length exhibited negative direct effect (-1.257) on seed yield per plant. Besides, positive indirect effect of the character was seen on seed yield/ plant via days to first flowering (0.218), days to 50% flowering (0.895), number of secondary branches per plant (0.001), total siliqua (0.031), siliqua length (0.010) and seeds per siliqua (0.750) while negative indirect effect on seed yield per plant via days to 80% flowering (-0.186), days to maturity (-0.428), plant height (-0.023), number of primary branches per plant (-0.060) and thousand seeds weight (-0.022). At last, the trait showed non-significant negative genotypic association (-.070) with seed yield per plant.

4.3.7 Number of primary branches per plant

Through path coefficient analysis, it was discovered that number of primary branches per plant had negative direct effect (-0.123) on seed yield per plant. Moreover, positive indirect effect was exhibited on seed yield per plant through days to first flowering (0.161), days to 50% flowering (0.349), days to maturity (0.188),total siliqua (0.038), siliqua length (0.100), seeds per siliqua (0.485) and thousand seeds weight (0.059) while negative indirect effect through days to 80% flowering (-0.170), plant height (-0.166), root length (-0.607) and number of secondary branches per plant (-0.00005). Eventually, the trait developed highly significant positive genotypic association with seed yield per plant that was marked by genotypic correlation of coefficient (0.314). This result suggested that correlation between yield and this trait was caused by both direct and indirect effects through other component traits.

4.3.8 Number of secondary branches per plant

According to path coefficient analysis, negative direct effect (-0.003) of number of secondary branches per plant was observed on seed yield per plant. Besides, positive indirect effect was noticed in seed yield per plant via days to first flowering (0.206), days to 50% flowering (0.985),days to maturity (0.470), root length (0.497), total siliqua (0.272) and thousand seeds weight (0.250) whereas negative indirect effect via days to 80% flowering (-0.353), plant height (-0.446), number of primary branches per plant (-0.002), siliqua length (-0.027) and seeds per siliqua (-1.566). In the end, the trait showed highly significant positive genotypic association with seed yield per plant that was marked by genotypic correlation of coefficient (0.286). This result suggested that correlation between yield and this trait was owing both direct and indirect effects through other component traits.

4.3.9 Number of siliqua per plant

Number of siliqua per plant exhibited positive direct effect (0.522) on seed yield per plant through path coefficient analysis. Besides this, positive indirect effect was noticed in seed yield per plant through days to first flowering (0.343), days to 50% flowering (1.063) and days to maturity (0.917) whereas days to 80% flowering (-0.358), plant height (-0.194), root length (-0.074), number of primary branches per plant (-0.009), number of secondary branches per plant (-0.001), siliqua length (-0.011), seeds per siliqua (-1.624) and thousand seeds weight (-0.009). At last, the trait showed highly significant positive genotypic association with seed yield per plant that was marked by genotypic correlation of co-efficient (0.565). This result suggested that correlation between yield and this trait was caused by both direct and indirect effects through other component traits.

4.3.10 Length of siliqua

Through path coefficient analysis, length of siliqua showed positive direct effect (0.182) on seed yield per plant. On the other hand, positive indirect effect was exhibited in seed yield per plant via days to first flowering (0.010), days to 50% flowering (0.743), number of secondary branches per plant (0.0004) and seeds per siliqua (0.422) followed by negative indirect effect via days to 80% flowering (-0.203), days to maturity (-0.400), plant height (-0.311), root length (-0.072), number of primary branches per plant (-0.068), total siliqua (-0.033) and thousand seeds weight (-0.234). In the end, the trait showed non-significant positive genotypic association with seed yield per plant that was marked by genotypic correlation of coefficient (.036). This result suggested that correlation between yield and this trait was caused by both direct and indirect effects through other component traits.

4.3.11 Number of seeds per siliqua

Number of seeds per siliqua had positive direct effect (2.391) on seed yield per plant. Besides, positive indirect effect was noticed in seed yield per plant through days to 80% flowering (0.301), plant height (0.115),number of secondary branches per plant (0.002), siliqua length (0.032) and thousand seeds weight (0.030) whereas negative indirect effect was found via days to first flowering (-0.265), days to 50% flowering (-0.839), days to maturity (-1.013), root length (-0.394), number of primary branches per plant (-0.025) and total siliqua (-0.355). Eventually, the trait showed non-significant and negative genotypic association (-0.020) with seed yield per plant.

4.3.12 Thousand seed weight

Thousand seed weight had negative direct effect (-0.888) on seed yield per plant. Moreover, positive indirect effect on yield per plant through days to first flowering (0.004), days to 50% flowering (0.398), plant height (cm) (0.253), number of primary branches per plant (0.008), number of secondary branches per plant (0.001), total siliqua (0.005) and siliqua length (0.048) followed by negative indirect effect via days to 80% flowering (-0.134), days to maturity (-0.053), root length (-0.031) and seeds per siliqua (-0.081). Eventually, the trait showed highly significant and negative genotypic relationship (-0.470) with seed yield per plant.

4.3.13 Residual effect

The residual effect (R) of path co-efficient analysis was noted as 0.09 which indicated that the characters under study contributed 91% to the seed yield per plant. There are some other factors which contribute 9% to the seed yield per plant. But those factors were not utilized in the present study which could have considerable effect on seed yield per plant.

4.4 SELECTION

The objectives of our study were to select short duration and high yielding population of *Brassica rapa L*. and it can fit well in the Aman-Mustard-Boro cropping system. Mean performance was observed for most of the characters of 39 F_2 populations and 12 populations such as P5×P1, P5×P3, P1×P2, P1×P7, P6×P5, P7×P3, P3×P5, P3×P1, P3×P4, P4×P2, P5×P2, P5×P7 were selected from those populations based on the variability, short duration and high yield. The minimum days to maturity was observed in P5 × P1 85.33 days followed by 88.33 days in P3 × P1, P4 × P2 and P5 × P2, 88.66 days in P3 × P5, 89.33 days in P5×P3, P1×P7 and P7×P3, 90.00 days in P6×P5, 90.33 days in P3×P4, P1×P2 and P5×P7. Seed yield per plant of P5×P1 (4.49g), P5×P3 (5.55g), P1×P2 (4.37g), P1×P7 (4.21g), P6×P5 (4.13g), P7×P3 (5.63g), P3×P5 (4.81g), P3×P1 (4.72g), P3×P4 (4.50g), P4×P2 (4.65g), P5×P2 (5.35g), P5×P7 (4.63g) were observed. Selection of most promising populations from different cross combinations of *Brassica rapa L.* based on mean performance is presented in Table 5.

CHAPTER V
SUMMARY AND CONCLUSION

An experiment was done in the Department of Genetics and Plant Breeding, Sher-e- Bangla Agricultural University, Dhaka-1207, from November 2019 to 2020. This study was carried out to determine the degree of character variations, variability and heritability, genetic advance, character associations, and the direct and indirect effect of different characters on yield in the F_2 populations of several inter-varietal crosses of the species *B. rapa*. The following is a summary of the study's findings:

According to the variability analysis, all genotypes differed significantly for all characters, indicating that there were significant differences between genotypes. The highest days to first flowering was taken in P6 × P3 (30.33 days) and the minimum days to first flowering was taken (24 days) in P4 × P2 and P2 × P4. The days to 50% flowering were observed the lowest (26.00 days) in P4 × P2 and P2 × P4 and in P7 × P3 and P3 × P5 highest (33.00 days) days to 50% flowering was observed. The highest days to 80% flowering was recorded (35.67 days) in P7 × P3 and P3 × P5 whereas the minimum days to 80% flowering was recorded (29 days) P4 × P2 and P2 × P4. The minimum days to maturity was observed in P5 × P1 (85.33 days) and the highest days to maturity was observed in P7 × P5 and P7 × P6 (93.00 days). The highest plant height was observed in P7 × P3 (110.40 cm) whereas the minimum plant height was observed in P2 × P4 (90.63 cm). Maximum length of root was found in P5 × P2 (10.12 cm) whereas minimum in P7 × P2 (5.91). the highest number of primary branches/plant was observed in P7 × P4 (6.83) whereas the minimum number of primary branches/plant was observed in P1 × P6 (3.77). The highest number of secondary branches/plant was observed (3.40) in P6 × P4 whereas no number of secondary branches/plant was observed in P3 × P1 (0.00). The total siliqua was observed highest in P4 × P7 (121.00) followed by P6 × P2 (119.13) whereas the minimum total siliqua was observed in P3 × P6 (59.23). Siliqua length was observed highest in P7 × P2 (6.23 cm) whereas the minimum siliqua length was observed in P3 × P2 (3.77 cm). The seeds per siliqua was observed highest in P5 × P1 (23.30) whereas the minimum seeds per siliqua was observed in P6 × P2 (10.98). Thousand seeds weight was found maximum in P4 × P2 (6.17 g) whereas the minimum was found in P4 × P5 (2.99 g). The highest amount of yield per plant was observed in P5 × P4 (6.31 g) whereas the minimum yield per plant was observed in P2 × P4 (2.88 g). For majority of the traits, a large range of variance was seen in the 39 F_2 progenies.

For all of the traits, the phenotypic variation were higher than the genotypic variation, showing that the expression of these characters are more influenced by the environment. The variations in genotypic and phenotypic variance in days to first flowering, days to 50% flowering, number of primary branches per plant, number of secondary branches/plant, siliqua length and thousand seeds weight were minimal, indicating modest environmental effect on these traits. On the other hand, days to maturity, days to 80% flowering, root length and yield per plant showed moderate environmental variance and plant height, total siliqua and seeds per siliqua showed large environmental variance. Days to first flowering, days to 50% flowering, days to 80% flowering, days to maturity, plant height and root length exhibited low genotypic and phenotypic coefficient of variance. Number of primary branches per plant, siliqua length, seeds per siliqua and thousand seeds weight showed moderate genotypic and phenotypic coefficient of variance. Number of secondary branches per plant, total siliqua and yield per plant showed high genotypic and phenotypic coefficient of variance. Days to first flowering, days to 50% flowering and days to 80% flowering showed high heritability coupled with low genetic advance and low genetic advance in percentage of mean where days to maturity, seeds per siliqua, thousand seeds weight and yield per plant showed moderate heritability coupled with low genetic advance and plant height, root length, number of primary branches/plant, number of secondary branches/plant and siliqua length showed low heritability and low genetic advance that revealed the possibility of predominance of non-additive gene action in the inheritance of this character, therefore, the characters could not be improved through selection process.

Study on correlation revealed that yield/plant had significant and positive association with number of primary branches per plant; number of secondary branches/plant and total siliqua but non-significant and negative association with days to first flowering and yield per plant at both phenotypic and genotypic level. Path co-efficient analysis revealed that number of seeds per siliqua showed the highest positive direct effect on yield/plant followed by, days to maturity, days to 80% flowering, plant height, total siliqua and siliqua length. On the other hand, number of primary branches/plant, number of secondary branches/plant, days to 50% flowering, root length and thousand seed weight had negative direct effect on yield per plant. Selection was conducted among 39 F_2 populations of *Brassica rapa L.* to find out the early maturing and the highest yielding populations. 12 populations such as P5×P1, P5×P3, P1×P2, P1×P7, P6×P5, P7×P3, P3×P5, P3×P1, P3×P4, P4×P2, P5×P2, P5×P7 were selected from the 39 populations based on short duration and high yield. Among the populations, the highest seed yield per plant (5.55g) was observed in P5XP3 with short days to 80% maturity.

CHAPTER VI
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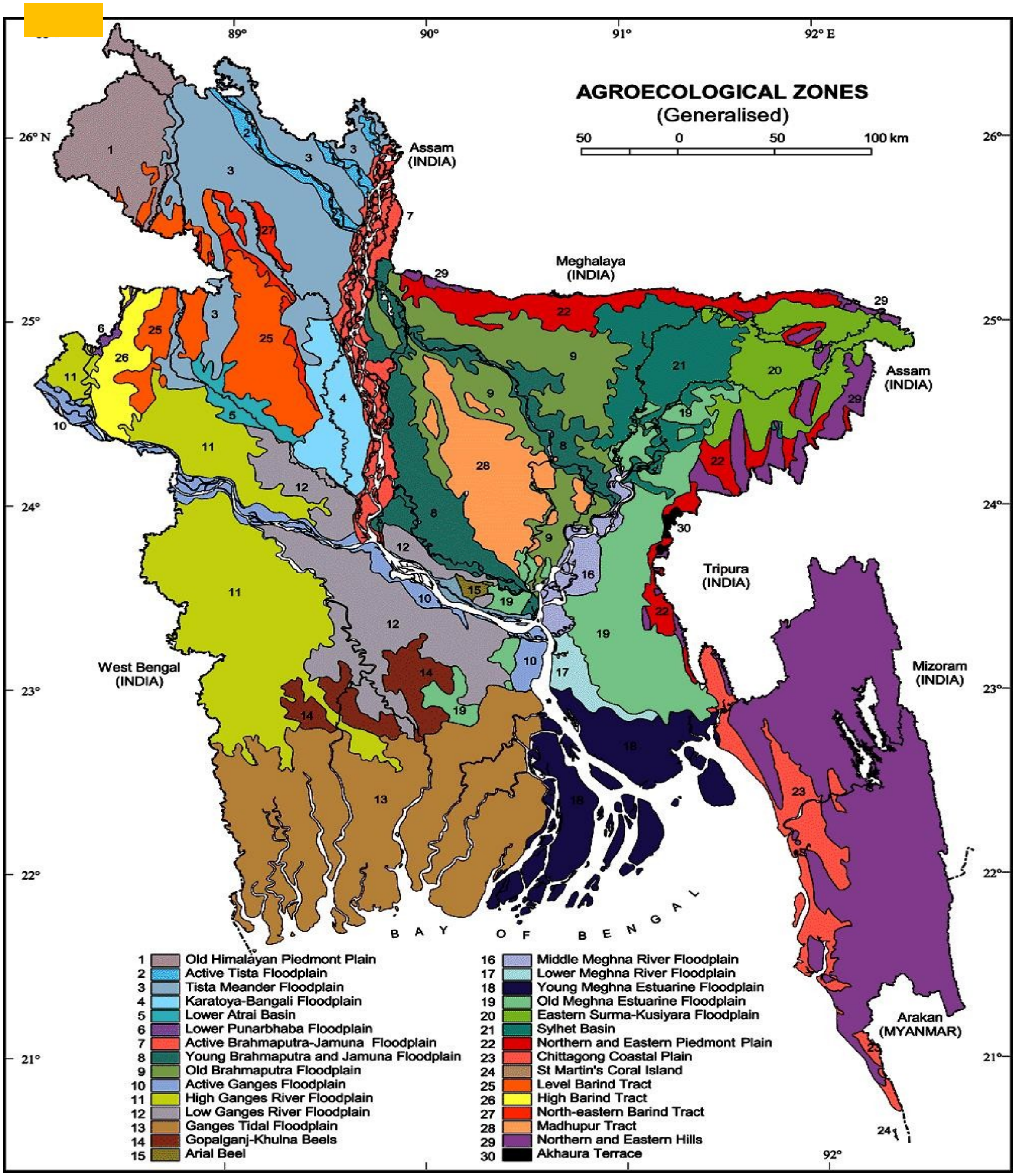
APPENDICES

Appendix I. Map showing the experimental site under the study



Yellow Legend showing the research site

Appendix II: Physical and chemical characteristics of initial soil depth of the experimental site.

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

A. Chemical composition of the soil:

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

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

Appendix III: Monthly average temperature, average relative humidity and total rainfall and total sunshine of the experimental site during the period from November, 2019 to February, 2020.

Month	Year	Monthly average dry-bulb temperature (° C)	Monthly average relative humidity (%)	Monthly average rainfall (mm)	Monthly average sea level pressure in milliber
November	2019	24.9	74	37	1011.5
December	2019	19.3	74	5	1015.2
January	2020	18.5	76	21	1014.7
February	2020	21.6.	59	1	1014.5
March	2020	26.4	57	30	1010.7
April	2020	27.9	72	127	1008.9

Source: https://www.timeanddate.com/weather/bangladesh/dhaka/climate

Appendix IV: The pictorial view of experimental plot during seed sowing stage.

Appendix V: The pictorial view of experimental field

Visit of research supervisor in the field