VARIABILITY CORRELATION AND PATH ANALYSIS IN SEGREGATING POPULATION OF *Brassica rapa* OBTAINED THROUGH INTERVARITAL CROSSES

BY

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CERTIFICATE

This is to certify that the thesis entitled ***"VARIABILITY CORRELATION & PATH ANALYSIS IN SEGREGATING POPULATION OF Brassica rapa OBTAINED THROUGH INTERVARITAL CROSSES"*** *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* ***Shifat Ara****, Registration Number:* ***03261*** *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 been duly acknowledged by her.

29/12/2011

Dated:june 2010
Place: Dhaka, Bangladesh

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Dedicated

to

My Beloved Parents

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June,2010 *The Author*

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VARIABILITY CORRELATION & PATH ANALYSIS IN SEGGREGATING POPULATION OF *Brassica rapa* OBTAINED THOUGH INTERVARIETAL CROSSES

ABSTRACT

BY

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A research was conducted by using eight F_2& eight F4 populations generated through inter-varietal crosses, along with three check varity of *Brassica rapa* and grown in the experimental farm of Sher-e-Bangla Agricultural Unriversity, Dhaka, during November 2009-March 20010 to study the variation in different characters, correlation between pairs of different characters and the direct and indirect effect of different characters on seed yield per plant of the F_2 & F4 materials to select the plants with higher potential. From the values of mean, range and CV (%) of seed yield and yield contributing characters it was confirmed that there were considerable variation present among all the genotypes used in the experiment . It was shown that more seggregation present in F2 material than F4 material. The values of phenotypic variances were higher than the corresponding genotypic variances. Days to 50% flowering, days to maturity, number of primary branches per plant, number of secondary branches per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and yield per plant showed least difference between phenotypic and genotypic variances. The values of GCV and PCV indicated that there was least variation present among most of the characters. The days to maturity, length of siliqua, seeds per siliqua, thousand seed weight showed high heritability with low genetic advance and genetic advance in percentage of mean. Yield per plant had significant and highest positive correlation with length of siliqua, seeds per siliqua and thousand seed weight. The path co-efficient analysis revealed that siliquae per plant had the highest positive direct effect followed by number of secondary branches per plant, days to 50% flowering, length of siliqua, and plant height. Sixteen most promising plants with short duration and higher yield were selected from eight crosses of the F_2 populations of *Brassica rapa* & forteen most promising plants with short duration and higher yield were selected from eight crosses of the F_4 populations

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Brassica rapa, commonly known as field mustard or turnip mustard is widely cultivated as an oil seed. In the 18th century the turnip and the oil seed producing variants were seen by Carolous Linneus as being different species and named them accordingly. However, 20th century taxonomists found that the plants were cross pollinated and thus belonged to the same genus *Brassica*, accounting for over 16% of the world's edible oil supply is an important genus of plant kingdom consisting of over 3200 species with high diverse morphology. *Brassica* is cross pollinated oil crops belonging to the family Brassiceae. *Brassica* have taproot system, with succulent, straight and cylindrical stem. The leaves are pinnati-divided. The inflorescence is racemose and flowering is indeterminate beginning at the lowest bud on the main raceme and blooming continues for two-three weeks. Stigma is receptive for about six days. The primary centre of origin for *Brassica campestris* is near the Himalayan region and the secondary centre of origin is located in the European –mediterranean area and Asia (Downey and Robelen, 1989). Major producing regions are China, the Indian subcontinent, Canada and Northern Europe (Ram and Hari, 1998).

. In Bangladesh more than 153.588 thousand metric ton of local rape and mustard produced from total 431.058 thousand acre of cultivable land and about 743.42 thousand metric ton of hybrid rape and mustard produced from total 146.18 thousand acre of cultivable land in the year 2009-20010 (BBS, 20010). The genus *Brassica* has generally been divided in to three groups namely –rape seed, mustard and cole. The rape seed groups includes the diploid *Brassica rapa*, turnip rape (AA, 2n=20) and amphidiploid *Brassica napus* L, rape (AACC, 2n=38) while the mustard groups include species like *Brassica juncea* Czern and Coss; *Brassica nigra* Koch and *Brassica carinata* Braun (Yarnell, 1956). The genomic constitutions of the three elemental species of *Brassica* are as follows; "AA" for *Brassica campestris*, "BB" for *Brassica nigra* and "CC" for *Brassica oleracea* having diploid chromosome number 20, 16 and 18 respectively. The species *Brassica juncea* (AABB, 2n=36) *Brassica* *carinata* (BBCC, 2n=34) and *Brassica napus* (AACC, 2n=38) are the amphidiploid and originated by combination of the diploid elemental species. All these species have many cultivated varieties suited to different Agro-climatic conditions. In the oleiferous *Brassica* group, a considerable variation of genetic nature exists among different species and varieties within each species in respect of different morphological characters (Malik *et al.* 1995; Nanda *et al.* 1995; Kakroo and Kumar, 1991).

As an agricultural country Bangladesh is faces increasing deficiency in oil seed production and consequently import cost is increasing. The causes are low yield potential of the varieties, insufficient precipitation when the crops are cultivated under rain fed conditions, pressure of other crops and the primitive crop husbandry method. Moreover, area of oil seed crops including mustard and rapeseed is also decreasing. On the other hand, high population growth rate is also putting increased pressure on the per capita consumption of oils.

In Bangladesh there is limited scope to increase acreage due to pressure of other crops. There is limited scope to increase yield because farmers usually cultivate the existing low yielding varieties with low input and management and almost all cultivars are brown seeded and smaller in size (2-2.5 g/1000 seeds). Short duration variety like Tori-7 of *B. rapa* is still popular in Bangladesh because it can fit well into the T. Aman - Mustard – Boro cropping pattern. There is no improved short duration variety *B. juncea* is available to replace this short duration but low yielding variety popular to farmers for its long duration. So we need to develop higher yielding short duration *Brassica rapa* variety.

Objectives

The present research work was undertaken with the following objectives:

- To study the variability in F_2 & F_4 segregating generations to select the desired plant types,
- To study the relationship among the different traits and their contribution to the yield and
- To select short duration and high yielding plantsfrom F_2 & F_4 populations .

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

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

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

2.2 Correlation among different characters

2.3 Path co-efficient analysis

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

Genetic variability is a prerequisite for initiating a successful breeding program aiming to develop high yielding varieties. A good number of literatures concerning the variability in the *Brassica species* are available. Some of those are presented here.

Richard (2010) studied self-compatible, rapid-cycling *brassica rapa* plants lacking inbreeding depression. The result revealed that the invention provides *Brassica rapa* plants and seeds thereof that are self-compatible, rapid-cycling and lack inbreeding depression. For instance, the invention provides plants and seeds of the *Brassica rapa* line designated B3. The invention thus relates to plants, seeds and tissue cultures of *Brassica rapa* plants that are self-compatible, rapid-cycling and lack inbreeding depression, such as *Brassica rapa* line B3, and methods to produce and propagate said plants by crossing such a *Brassica rapa* plant with itself, or another *Brassica rapa* plant. The invention further relates to seeds and plants produced by such crossing. Educational materials, such as a kit comprising said *Brassica rapa* plants are also provided by the invention.

Sheikh *et al.* (2009) studied the Induction of genetic variability in Ethiopian mustard (*Brassica carinata*) for quality traits through interspecific hybridization. The result revealed the Interspecific hybridization was used to enhance the spectrum of genetic variability in *Brassica carinata* (BBCC, 2n = 34) cv. PC5 for oil and meal quality traits from quality lines of *Brassica juncea* (AABB, 2n = 36).

Hasan *et al.* (2008) studied the association of gene-linked SSR markers to seed glucosinolate content in oilseed rape (*Brassica napus* ssp. *napus*) Breeding of oilseed rape (*Brassica napus* ssp. *napus*) has evoked a strong bottleneck selection towards double-low (00) seed quality with zero erucic acid and low seed glucosinolate content. The resulting reduction of genetic variability in elite 00-quality oilseed rape is particularly relevant with regard to the development of genetically diverse heterotic pools for hybrid breeding. In contrast, *B. napus* genotypes containing high levels of erucic acid and seed glucosinolates (++ quality) represent a comparatively genetically divergent source of germplasm. Seed glucosinolate content is a complex quantitative trait, however, meaning that the introgression of novel germplasm from this gene pool requires recurrent backcrossing to avoid linkagedrag for high glucosinolate content.

Abbas *et al.* (2008) studied the molecular and biochemical assessment of *brassica napus* and indigenous *campestris* species.The result revealed that the Parental lines along with five F2s were assessed for biochemical parameters using Near Infrared Reflectance Spectroscopy (NIRS). Parental lines contain more oil 45.85% as compared to F2s 42.26% while the F2s contain more protein 25.92% as compared to the parents 23.70%. Both parents and F2 contain high glucosinolate and fatty acids contents. Insulin Growth like Factor (IGF) primer sets were used to estimate genetic relationship among 5 F2 segregating population of *Brassica* along with 9 parental lines.

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

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

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

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

Tel-Zur and Goldman (2007) studied analysis of sub-populations of rapid-cycling *Brassica rapa* following recurrent bi-directional selection for cotyledon size. This study was conducted to determine the indirect effects of 10 cycles of bi-directional recurrent selection for cotyledon size in the model system of rapid-cycling *Brassica rapa*. Eight sub-populations (four large- and four small-cotyledon sizes) were phenotypically and cytologically evaluated. Each sub-population was measured by five phenotypic traits. Ploidy and pollen viability were studied and compared with the initial population.

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

Kelly (2006) Studied characterizing genotype specific differences in survival, growth, and reproduction for field grown, rapid cycling *Brassica rapa*. The result revealed that the rapid cycling *Brassica rapa* (RCBr) develops rapidly, and has both small adult size and a brief life cycle. This study is the first to describe the genotype specific variation in traits describing survival, growth, and reproduction for field grown; RCBr. Five genotypes of RCBr were used: standard, *anthocyaninless,* yellow-green, anthocyaninless and hairless, and *anthocyaninless* and yellow-green. Eight plant traits were measured: life span, height, growth rate, leaf size, number of flowers and fruits, fruit set, and fitness. All traits, except life span, differed significantly among the five plant genotypes.

Krumbein *et al.* (2005) studied Composition and contents of *phytochemicals (glucosinolates, carotenoids* and chlorophylls) and ascorbic acid in selected *Brassica species (B. juncea, B. rapa subsp. nipposinica var. chinoleifera, B. rapa subsp. chinensis and B. rapa subsp. rapa). Cultivars of selected Brassica species (B. juncea, B. rapa subsp. nipposinica var. chinoleifera, B. rapa subsp. chinensis [B. chinensis]* and B. rapa subsp. rapa) showed significant differences in their composition and contents of phytochemicals and ascorbic acid. B. *juncea* was characterized by a high proportion of alkenyl glucosinolates (85-96%) with a predominance of sinigrin; whereas in B. rapa subsp. nipposinica var. chinoleifera and B. rapa subsp. chinensis, the alkenyl glucosinolate proportion varied between 27 and 88% and consisted mainly of gluconapin, glucobrassicanapin and progoitrin. In B. *rapa* subsp. rapa, the main glucosinolate was the aryl glucosinolate gluconasturtiin (44-47%) with a relatively high level between 23.6 and 35.9 mg 100 g-1 FM. Distinct genotypic variations were also observed for lutein (3.4 to 8.9 mg 100 g-1 FM), beta -carotene (1.8 to 4.3 mg 100-1 FM) as well as chlorophyll a (35.7 to 96.8 mg 100 g-1 FM) and chlorophyll b (11.4 to 30.5 mg 100 g-1 FM).

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

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

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

Katiyar *et al.* (2004) studied on variability for the seed yield in ninety intervarietal crosses of *Brassica campestris*. Existence of significant variation among parents and crosses indicated the presence of adequate genetic variance between parents which reflected in differential performance of individual cross combinations.

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

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

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

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

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

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

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

In a study, Zhou *et al.* (1998) found significant variation in plant height in M_2 generation. Plant height was reported to be responsive to gamma rays, which decreased plant height substantially. Sengupta *et al.* (1998) also obtained similar results. Significant genetic variability was observed for plant height by many workers like Kumar *et al.* (1996), Malik *et al.* (1995), Kumar and Singh (1994), Yadava *et al.* (1993), Andrahennadi *et al.* (1991), Gupta and Labana (1989), Lebowitz (1989), Chaturvedi *et al.* (1988), Chauhan and Singh (1985), Sharma (1984) and many others among different genotypes of *B. napus*, *B. rapa* and *B. juncea*.

Lekh *et al.* (1998) reported that secondary branches per plant showed highest genotypic co-efficient of variation. High genotypic and phenotypic co-efficient of variation was recorded for days to 50% flowering in the same study. He found early flowering genotype will mature early and vice versa.

Yadava *et al.* (1996) studied 8×8 diallel analysis (excluding reciprocals). They found that both additive and dominance genetic component were important for seed yield and yield components in *B. rapa* var. toria. They reported higher heritability for days to maturity and 1000 seed weight.

In general, high number of seeds per siliqua is desirable. Kumar *et al.* (1996) reported the presence of significant variability for number of seeds per siliqua in the genotypes of *Brassica napus*, *Brassica rapa* and *Brassica juncea*. Similar significant variability for number of seeds per siliqua in oleiferous *Brassica* materials of diverse genetic base have also been observed by Kudla (1993) and Kumar and Singh (1994).

For days to maturity Biswas (1989) found high GCV and PCV among 18 genotypes of *B. napus*, while Sharma (1984) found low GCV and PCV values among 46 genotypes of *B. juncea.* Tak and Patnaik (1977) found these values as 4.5 % and 1.8 % respectively in yellow sarson and toria, while Yadava (1973) found GCV 7.6 % among 29 strains of *B. juncea*.

2.2 Heritability, genetic advance and selection

The variation of heritability can be estimated with greater degree of accuracy when heritability in conjunction with genetic advance as percentage of mean is studied. The necessity of estimating heritability along with genetic advance in order to draw a more reliable conclusion in selection program.

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

M. Portocarrero *et al.* (2006) studied effects of different pre-freezing blanching procedures on the physicochemical properties of *Brassica rapa* leaves (Turnip Greens, Grelos). The result revealed that the optimal freeze storage, green vegetables should first be blanched. The present study compared four different procedures for the blanching of grelos (leaves of *Brassica rapa* L.): steaming for 2 min, immersion in boiling water for 2 min, immersion in boiling water containing 1% citric acid for 1 min, and immersion in boiling water containing 5% citric acid for 1 min.

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

Working with different strains of *B. napus* Malik *et al.* (1995) observed very high broad sense heritability ($h^2_b > 90\%$) for number of primary branches per plant, days to 50% flowering and oil content and low heritability ($h^2_b = < 50\%$) for number of siliqua/plant, number of seeds/siliqua, plant height and seed yield. But Singh *et al.* (1991) found high heritability for all these character studied with *B. napus*. Li *et al.* (1989) also observed similar results while studied with *B. napus*.

In a study of 46 genotypes of *B. juncea*, Sharma *et al.* (1995) observed high heritability for plant height, days to flowering and low heritability for days to maturity. He also found low genetic advance for days to maturity and high genetic advance for yield/plant. In another study of 179 genotypes of Indian mustard Singh *et al.* (1987) observed high heritability for yield/plant and low heritability for number of primary branches/plant.

Diwakar and Singh (1993) studied heritability and genetic advance in segregating populations of yellow seeded Indian mustard (*Brassica juncea* L. Czern and Coss.). They used data on yield and 5 component traits in 8 cultivars and their 28 F_3 hybrids. They observed a wide range of phenotypic variation for most of the measured traits. They also reported that narrow sense heritability and genetic advance were high for days to flowering and plant height.

Singh *et al.* (1991) studied different morpho-physiological characters of 29 genotypes of *B. napus* and *B. campestris*. They found significant genetic variability in days to 50% flowering.

According to Labowitz (1989), Chowdhury *et al.* (1987), Biswas (1989) in *B. rapa*, Andrahennadi *et al.* (1991) in brown mustard, Kudla (1993) in seweden rape and Kumar and Singh (1994) in *Brassica juncea* reported different degrees of significant variations of 1000 seed weight due to variable genotypes.

Significant genetic variation for number of primary branches/plant was recorded by several researchers. Singh *et al.* (1989) studied this character under normal and stress conditions in 29 genotypes of *B. napus* and *B. rapa* and found significant variation among the genotypes. Similar result was reported earlier by Kumar and Singh (1994), Kakroo and Kumar (1991), Biswas (1989), Jain *et al.* (1988), Labana *et al.* (1987) and Gupta *et al.* (1987).

Working with 8 cultivars of *B. napus* Yin (1989) found the highest genotypic co-efficient of variation for secondary branches. High heritability estimates were observed for all the characters under all environments except harvest index and biological yield. Highest genetic advance and high genotypic and phenotypic co-efficient of variation was recorded for days to 50% flowering.

Thurling (1988) reported that selection for increased siliqua length is an effective strategy for yield improvement through raising seed weight/siliqua.

The most important feature in winter rape plant selection for seed yield was number of branches was reported by Teresa (1987).

Chatterjee and Bhattacharyya (1986) found higher efficiency with index selection than selection based on yield alone. The efficiency increased with an increase in the number of characters in the index. The index comprising plant height, thousand seed weight and yield per plant was considered effective from the practical point of view.

Singh (1986) studied 22 genotypes of *B. napus*, *B. rapa* and *B. juncea*. He observed high heritability and genetic advance in seed yield, 1000 seed weight and number of seeds/siliqua.

Vershney *et al.* (1986) found high heritability and high genetic advance for plant height in all three species; but high heritability and genetic advance were found for number of siliquae/plant only in *B. rapa* and in *B. juncea*. He reported high heritability and genetic advance in seed yield, 1000 seed weight and number of seeds/siliqua in *B. napus*.

Selection for bold seed size from F_2 to F_5 generations was highly effective was observed by Gupta and Labana (1985) in Indian mustard.

Working with 46 genotypes of *B. juncea* Sharma (1984) found low GCV and PCV values, while Biswas (1989) found high GCV and PCV among 18 genotypes of *B. napus*.

High heritability and genetic advance for flowering time, number of primary branches/plant and plant height was observed by Wan and Hu (1983). Low heritability of yield was reported by many researches like Malik *et al.* (1995), Kumar *et al.* (1988), Yadava *et al.* (1985), Li *et al.* (1989), Chen *et al.* (1983) etc. But Singh (1986) found high heritability for this trait. Low to medium heritability of siliqua length was observed by Kakroo and Kumar (1991), Sharma (1984) and Yadava *et al.* (1996).

Working with 30 varieties of *B. rapa* Chandola *et al.* (1977) found high genetic advance for plant height. Paul *et al.* (1976) observed in his study that a good genetic advance was expected from a selection index comprising seed yield, number of seeds/siliqua, number of siliquae/plant and number of primary branches/plant.

Working on genetic variability, heritability and genetic advance of seed yield and its components in Indian mustard Katiyar *et al.*(1974) reported that high genetic co-efficients of variation were observed for seed yield/plant, days to first flowering and plant height, whereas low values were observed for other characters like days to maturity and number of primary branches.

According to Yadava (1973) high heritability in the broad sense and genetic advance for days to maturity, plant height and number of node on the main shoot among the nine traits studied in 29 varieties.

Most breeders tend to suggest delaying selection until at least the F_4 generation, when yield comparisons might be based on reasonably large replicated plots. According to Shebeski (1967) selection for yield related traits in F_2 (or F_3) generation has been recommended to minimize the expected losses of transgressive or productive segregants from the breeding populations.

2.3 Correlation among different characters

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

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

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

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

Mondragon-Portocarrero *et al.* (2006) studied effects of different pre-freezing blanching procedures on the physicochemical properties of Brassica rapa leaves (Turnip Greens, Grelos). The result revealed that the blanching, the grelos were stored for up to 120 days at -18 degrees C, with sampling at two-weekly intervals for analysis of physicochemical properties (ash weight, vitamin C content, pH, acid value, moisture content and CIEL*a*b* colour variables). In almost all respects steam blanching gave the best results: notably, vitamin C losses were markedly lower, while moisture content and colour remained closer to those of the fresh product.

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

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

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

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

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

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

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

Pankaj *et al.* (2002) studied four parental cultivars and the 174 progenies of resultant crosses for correlation between yield and yield component traits. The genetic correlation was higher than the phenotypic correlation for the majority of the characters. The number of siliquae per plant, which had the strongest positive and significant correlation with yield per plant at both levels, was positively associated with the number of seeds per siliqua and test weight at both levels. The number seeds per siliqua were positively associated with siliqua length and yield per plant at both levels.

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

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

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

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

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

In a study of correlations in 8 Indian mustard *(Brassica juncea)* parents and their 28 F_1 hybrids Khulbe and Pant (1999) revealed that the number of siliquae per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and harvest index were positively associated with seed yield.

The number of siliquae per plant, number of seeds per siliqua and plant height was significantly positively correlated with seed yield was observed by Masood *et al.* (1999) while studied 7 genotypes of *B. campestris* and standard cultivar of *B.napus* to calculate correlation co-efficient.

Kumar *et al.* (1999) reported that genotypic correlation co-efficient were higher in magnitude than corresponding phenotypic correlation co-efficient for most characters. The plant height, siliquae on main shoot, siliquae per plant and thousand seed weight were positively correlated with seed yield.

Das *et al.* (1998) carried out an experiment with 8 genotypes of Indian mustard *(B. juncea)* and reported that the length of siliqua, seeds per siliqua had high positive genotypic correlated with seed yield per plant.

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

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

Plant height, siliquae per plant, siliqua length, seed weight, and seeds per siliqua had positive and significant effects on seed yield per plant was observed by Tyagi *et al.* (1996) while carried out an experiment with 6 yield components in 3 cultivars of mustard.

Gill and Narang (1995) studied correlation in gobhi sarson *(B. campestris* var. sarson) and observed that seed yield was positively correlated with number of primary branches and secondary branches per plant, number of siliquae per plant and thousand seed weight.

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

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

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

Siliqua length, number of siliquae per plant, number of seeds per siliqua and seed weight per siliqua was positively and linearly associated with seed yield per plant was observed by Ahmed (1993) while working with 8 cultivars of *B. campestris and B.juncea* for study of nature and degree of interrelationship among yield components.

Chaudhury *et al.* (1993) observed seed yield was positively correlated with siliqua length when evaluated 7 of *B. juncea, 2* of *B. carinata* cultivars and 1 cultivar each of *B, campestris* and B. *tournefortii.*

The number of seeds per siliqua negatively correlated with siliquae per plant was reported by Zaman *et al.* (1992) when they studied several yield contributing traits of Swedish advanced rape lines.

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

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

In F_3 population of brown sarson Das *et al.* (1984) observed 1000 seed weight had highly significant genotypic and phenotypic correlation with seed yield per plant.

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

Increasing the number of branches is a means of increasing yield, since the number of primary and secondary branches have a significant positive correlation with seed yield (Singh *et al.* 1969; Katiyar and Singh, 1974).

Banerjee, (1968) found significant correlation between number of siliqua/plant and numbers of seeds/siliqua in yellow sarson. But Tak and Patnaik (1977) found negative genotypic correlation between number of siliqua/plant and numbers of seeds/in brown sarson and toria varieties of *B. rapa*. On the contrary, Das *et al.* (1984) reported number of siliquae/plant showed significant and positive correlation with number of seeds/siliqua and 1000 seed weight. Chay and Thurling (1989) studied the inheritance of siliqua length among several lines of *B. napus* and reported that the siliqua length when increased there was an increase in the number of seeds per siliqua and thousand seed weight. The siliqua length was positively correlated with both number of seeds per siliqua and thousand seed weight was observed by Singh *et al.* (1987) in *B. rapa,* Chowdhury *et al.* (1987), Lebowitz (1989) and Lodhi *et al.* (1979) in *B. juncea.*

2.4 Path co-efficient analysis

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

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

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

Tel-Zur and Goldman (2007) studied analysis of sub-populations of rapid-cycling Brassica rapa following recurrent bi-directional selection for cotyledon size. This study was conducted total cell number exhibited statistically significant differences in broad and bottleneck-1 sub-populations, while cell number per unit area exhibited statistically significant differences in broad, bottleneck-2 and bottleneck-3 sub-populations. Decreases in pollen viability in comparison with the base population were observed in three sub-populations. Among the eight sub-populations studied, the most significant phenotypic differences were observed within broad sub-populations.

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

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

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

Kelly (2006) Studied characterizing genotype specific differences in survival, growth, and reproduction for field grown, rapid cycling Brassica rapa. The result revealed that the Correlation analysis revealed that fitness increased as each of these of seven plant traits increased. This study demonstrates that RCBr can serve as a model organism in ecological field studies

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

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

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

Khulbe and Pant (1999) studied path co-efficient analysis in 8 Indian mustard (*B.juncea*) parents and their 28 F_1 hybrids. The results revealed that harvest index, siliqua length, seeds per siliqua, siliquae per plant, thousand seed and days to initial flowering were the major traits influencing seed yield.

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

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

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

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

Saini and Kumar (1995) studied 28 lines of yellow and brown sarson *(B. campestris)* for path coefficient analysis. Results revealed that seeds per siliqua and 1000 seed weight had direct positive effect on yield.

Plant height, siliquae per plant and seeds per siliqua had high positive direct effect on seed yield was observed by Chauhan and Singh (1995).

Kudla (1993) reported that 1000 seed weight had positive direct effect on seed yield.

Kachroo and Kumar (1991) studied path co-efficient analysis in *B. juncea* and found that thousand seed weight had positive direct effect but days to flowering and number of primary branches had negative indirect effect via seeds per siliqua on seed yield.

Thousand seed weight had positive direct effect, but days to 50% flowering and primary branches had negative indirect effect via seeds per siliqua on seed yield was found by Kakroo and Kumar (1991) while working with several strains of *B. juncea.*

Han (1990) studied *B. napus* and observed negative direct effect of number of siliquae per plant, siliqua length and positive direct effect of seeds per siliqua and plant height on seed yield.

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

Siliqua length had highest positive direct effect and number of primary branches per plant had the highest negative direct effect on seed yield was observed by Chowdhury *et al.* (1987) while working with 42 strains of mustard.

Primary branches per plant and thousand seed weight had the direct effect on seed yield was observed by Gupta *et al*. (1987).

Chauhan and Singh (1985) found high positive direct effect of days to flowering, plant height, primary branches per plant, siliquae per plant and seeds per siliqua on seed yield while working with several strains *of B. juncea.*

Hari *et al.* (1985) studied 38 cultivars of *Brassica juncea* and observed that siliquae number per plant and thousand seed weight had considerable direct effect on yield.

In *B. juncea* Kumar *et al.* (1984) found the negative indirect effect of days to flowering via plant height and pod length, but negative direct effect of these traits was observed by Singh *et al.* (1987).

Negative indirect effect on seed yield of days to flowering via plant height and siliqua length on seed yield was observed by Kumar *et al.* (1984) while working with *B. juncea.*

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The present experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during November, 2009 to March, 2010. The location of the experimental site was situated at **23^0 74'** N latitude and **90^0 35'** E longitudes with an elevation of 8.6 meter from the sea level.

3.2 Soil and Climate

The experimental site was situated in the subtropical zone. The soil of the experimental site belongs to Agro ecological region of "Madhupur Tract" (AEZ No. 28). The soil was clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH was 5.47 to 5.63 and organic carbon content is 0.82% (Appendix I). The records of air temperature, humidity and rainfall during the period of experiment were noted from the Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix 2).

3.3 Plant materials

A total number of 19 (nineteen) materials were used in this experiment where eight were F_2 & eight F4segregating generations and three were checks varieties. All the Materials were collected from Department of Genetics and Pant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The materials used in that experiment is shown in Table -1.

Table 1: Materials used for the experiment

F_2 Populations	F_4 Populations	Check varieties
SS 75 × SAU 1	BINA 6 × **BARI 9 (Plant 1)**	BARI Sharisha 11
SS 75 × BARI 15	BINA 6 × BARI 9 **(Plant 2)**	BARI Sharisha15
BARI 15 × BARI 6	BINA 6 × BARI 9 **(Plant 3)**	SAU sarisha1
BARI 6 × R TORI 7	BARI 6 × BARI 9 (Plant 4)	
BARI 15 × SS 75	BARI 6 × BINA 6 (Plant 1)	
R TORI 7 × SAU 1	BARI 6 × BINA 6 (Plant 2)	
BARI 11 × R TORI 7	BARI 6 × BINA 6 (Plant 3)	
BARI 10 × BARI 15	AGRONY × BARI 9	

3.4 Methods

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

3.4.1 Land preparation

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

3.4.2 Application of manure and fertilizer

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

3.4.3 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experiment was 56m × 14m = 784 m^2. Each replication size was 56 m × 3.5 m, and the distance between replication to replication was 1 m. The spacing between lines to line was 30 cm. Seeds were sown in lines in the experimental plots on 4 November, 2009. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods were on the seeds.

3.4.4 Intercultural operations

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

3.4.5 Crop harvesting

Harvesting was done from 4^{th} to 20^{th} February, 2010 depending upon the maturity. When 80% of the plants showed symptoms of maturity i.e. straw color of siliqua, leaves, stems desirable seed color in the mature siliqua, the crop was assessed to attain maturity. Ten plants were selected at random from the parental line and 40 plants from F_2 & F_4 progenies in each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants.

3.4.6 Data collection

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

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

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

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

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

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

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

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

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

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

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

3.4.7 Statistical analysis

The data were analyzed for different components. Phenotypic and genotypic variance was estimated by the formula used by Johnson *et al.* (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhary (1985) and Allard (1960). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952). Simple correlation coefficient was obtained using the formula suggested by Clarke (1973); Singh and Chaudhary (1985) and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

i) Estimation of genotypic and phenotypic varianced:

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

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

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

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

ii) Estimation of genotypic and phenotypic co-efficient of variation:

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

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

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

Where, GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δ_g = Genotypic standard deviation

δ_p = Phenotypic standard deviation

$\overline{x}$ = Population mean

iii) Estimation of heritability:

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

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

Where, h^2_b = Heritability in broad sense.

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

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

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

Where, GA = Genetic advance

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

δ_p = Phenotypic standard deviation

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

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

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

vi) Estimation of simple correlation co-efficient: Simple correlation co-efficients (r) was estimated from the replicated data with the following formula (; Singh and Chaudhary, 1985).

$$r = \frac{Covxy}{\sqrt{Vx.Vy}}$$

Where, Vx=Variance of Character x

Vy= Variance of Character y

Covxy= covariance of x and y variable.

vii) Path co-efficient analysis:

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) and Dabholkar (1992), using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable.

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

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

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

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

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

Total correlation, say between x_1 and y is thus partitioned as follows:

P_{yx1} = The direct effect of x_1 on y.

$P_{yx2}r_{x1x2}$ = The indirect effect of x_1 via x_2 on y

$P_{yx3}r_{x1x3}$ = The indirect effect of $x_1$via x_3 on y

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

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

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

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

riy = Correlation of the character with yield.

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted with a view to determine the variability among twenty one F_2 materials of *Brassica rapa* genotypes and also to study the correlation and path co-efficient for seed yield and different yield contributing characters. The data were recorded on different characters such as plant height (cm), no. of primary branches per plant, no. of secondary branches per plant, days to 50% flowering, days to 50% maturity, pod/plant, length of pod (cm), number of seeds per pod, 1000 seed weight (g) and yield per plot (g). The data were statistically analyzed and thus obtained results are described below under the following heads:

4.1 Variability study in *Brassica rapa* of F_2

4.1.1 Variability among the 8 F_2 populations of *Brassica rapa* and three check varieties

In the study significant variations were observed for most of the characters among 8 F_2 materials of *Brassica rapa.* Table 2 and Table 3 showed the values of mean, range CV (%), phenotypic variances, genotypic variances, phenotypic coefficient of variation, genotypic coefficient of variation and different yield related characters.

Plant height (cm)

In this study the highest plant height was observed in BARI11 × TORI 7 (120.0 cm) where as the minimum plant height was observed in BARI 6 × TORI 7 (89.30 cm) (Table 2). Plant height observed in three check varieties 125cm in BARI Sharisha 11, 105.6 cm in BARI Sharisha 15 and 99.3 and in SAU 1 which was more than all the 8 F_2 populations (Table 6). Plant height showed the phenotypic variance and genotypic variance were observed 149.17 and 119.31, respectively with relatively large differences between them indicating large environmental influences on these character as well as PCV (11.38 %) and GCV (10.18 %) indicating presence of considerable variability among the genotypes (Table 3). Tyagi *et al.* (2001) observed highest variation in plant height among parents and their hybrid.

Number of primary branches per plant

Among the 8 F_2 populations the highest number of primary branches/plant was observed in SS75 × BARIsarisha 15 (10.13) where as the minimum number of primary branches/plant was observed in BARIsarisha 15 × SS75 (6.30) (Table 2). No. of primary branches per plant observed in three check varieties 6.0 in BARI Sharisha 11, 8.2 in BARI Sharisha 15 and 4.7 in SAUsarisha 1 (Table 6). Number of primary branches per plant showed little differences between phenotypic variance (1.39) and genotypic variance (0.46) indicating low environmental influence on these character and relatively high difference between PCV (12.93 %) and GCV (7.45 %) value indicating the apparent variation not only due to genotypes but also due to the large influence of environment (Table 3). Chowdhary *et al.* (1987) found significant differences for number of primary branches per plant.

Number of secondary branches per plant

The highest number of secondary branches/plant was observed (16.0) in BARI11 × TORI 7 where as the minimum number of primary branches/plant was observed in BARIshrisha 15 × SS 75 (3.93) (Table 2). Among the check varieties the number of secondary branches/plant was observed 36 in BARI Sharisha 11 1.5 in BARI Sharisha 15 and 11.1 in SAUsarisha 1 (Table 6). All the 11 F_2 populations produced less number of primary branches/plant than BARI Sharisha 11 but most of the crosses produced more secondary branches/plant than BARI Sharisha 15 (Table 2 Lekh *et al.* (1998) reported similar result.

Table 2. Mean, range and CV (%) of seed and other characters of 8 F2& 3Check

Genotypes	Plant height (cm)	Primary branches	Secondary branches	50% flowering	50% maturity	Siliqua/ plant	Siliqua length	Seed/ Siliqua	1000seed (w) gm	Total yield/ plant
SS75XSAU19										
Mean	110.89	8.61	13.25	44	97.33	315.75	5.51	13.77	3.50	10.72
SE	4.67	0.65	2.87	-	-	64.21	0.17	0.76	0.10	1.46
CV%	15.76	28.40	81.01	-	-	76.09	11.61	20.63	10.38	51.09
SS75XBARI15										
Mean	118.70	10.13	6.40	47.67	98.33	193.63	4.96	17.46	2.73	10.05
SE	2.57	0.59	1.68	-	-	21.78	0.13	1.00	0.17	0.69
CV%	8.40	22.42	101.41	-	-	43.57	9.82	22.21	24.79	26.40
BARI15XSS75										
Mean	107.43	6.30	3.93	43	95	158.43	5.20	16.77	3.31	6.51
SE	3.21	0.44	0.92	-	-	11.34	0.11	0.92	0.10	0.58
CV%	11.58	27.04	91.05	-	-	27.73	8.45	21.29	11.86	34.25
BARI15XBARI6										
Mean	114.17	9.83	5.23	45	99	166.60	5.56	18.78	3.08	10.05
SE	1.76	0.61	1.45	-	-	12.31	0.17	1.36	0.18	0.74
CV%	5.97	24.04	107.31	-	-	28.61	11.75	27.96	22.08	28.54
BARI16XBARI5										
Mean	104.35	8.70	13.45	39.67	101	266.00	5.02	16.19	3.43	9.72
SE	3.47	0.95	3.08	-	-	55.15	0.17	1.23	0.11	1.47
CV%	10.52	34.49	72.32	-	-	65.57	10.71	24.04	10.57	47.75
BARI6X.TORI7										
Mean	89.30	6.52	10.47	35.67	95.67	224.60	5.49	17.16	3.08	9.73
SE	1.82	0.48	1.58	-	-	17.08	0.11	0.79	0.13	1.09
CV%	7.88	28.36	58.57	-	-	29.45	7.60	17.90	16.64	43.35
.TORI7XSAU1										
Mean	89.86	6.95	15.09	45	97	303.09	5.36	14.49	2.22	10.19
SE	3.48	0.69	2.34	-	-	57.33	0.16	0.94	0.19	1.33
CV%	12.85	33.13	51.49	-	-	62.73	9.75	21.48	28.21	43.23

Genotypes	Plant height (cm)	Primary branches	Secondary branches	50% flowering	50% maturity	Siliqua/ plant	Siliqua length	Seed/ Siliqua	1000seed (w) gm	Total yield/ plant
BABRI 11X TORY 7										
Mean	120	9	16	42.67	96.33	427	3.96	10.2	1.7	3
SE	3.08	0.50	0.59	-	-	11.67	0.17	1.04	0.13	0.64
CV%	9.59	26.81	160.61	-	-	41.25	9.98	19.16	14.93	41.49
BARI sharisha 11										
Mean	125	6	36	39.67	105	975	4.28	13.6	18.2	3
SE	4.67	0.65	2.87	-	-	1.50	1.46	1.00	21.78	0.13
CV%	15.76	28.40	81.01	-	-	55.38	51.09	22.21	43.57	9.82
BARI sharisha 15										
Mean	105.6	8.2	1.5	40.33	102.33	138	5.9	16.9	3.5	11.98
SE	2.57	3.21	0.44	-	-	64.21	0.17	0.76	0.17	0.69
CV%	8.40	11.58	27.04	-	-	76.09	11.61	20.63	24.79	26.40
SAU1										
Mean	99.3	4.7	11.1	41	103	122.3	6.51	15	3.01	6
SE	0.59	0.68	0.92	-	-	0.92	0.10	11.34	0.11	0.58
CV%	22.42	21.41	91.05	-	-	21.29	11.86	27.73	8.45	14.25

Plate 1: Photograph Showing Flowering of F_4 materials of the cross SS 75 × BARI 15

Plate 2 Photograph Showing pod length of F_4 materials of the cross BARI SHARISHA 15 × BARI 16

Days to 50% flowering

Considerable variations were observed among 8 F_2 populations for days to 50% flowering. The days to 50% flowering were observed lowest (35.67 days) in BARI 6 × TORI 7 and highest (47.67 days) was observed in SS 75 × BARI 15 (Table 2). The days to 50% flowering were observed in three check varieties 39.67 days in BARI Sharisha 11, 40.33 days in BARI Sharisha 15 and 41 days in SAU-1. All the F_2 populations requires more flowering times than BARI Sharisha 11 except BARI 16 × TORY 7 but rest of the F_2 crosses requires more flowering time than BARI-15 and SAU-1 (Table 2). The check varieties BARI Sharisha 11 and BARI 16 × BARI 15 showed same result.

Days to 50% maturity

The minimum days to 50% maturity was observed in BARI 6 × Real TORI 7 935.67 days) and the highest days (101.0) to maturity was observed in BARI 16 × BARI 15 (Table 2). Among the check varieties the days to 50% maturity was observed in 105 days in BARI Sharisha 11, 102.33 days in BARI Sharisha 15, and 103.0 days in SAU 1 (Table 2). Phenotypic and genotypic variance for days to maturity was observed 6.36 and 2.48, respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (2.59 %) was higher than the genotypic coefficient of variation (1.62 %) (Table 3), 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 (Ushakumari *et al.* 1991). Working with 46 genotypes of *Brassica juncea* Sharma (1984) found low GCV and PCV values. Tak and Patnik (1977) found this value as GCV (1.8%) and PCV (4.5%) respectively.

Number of pod per plant

The number of pod per plant was observed highest in BARI 1 × TORI 7 (427.0) followed by SS 75 × SAU Sarisha 1 (315.75). Whereas the minimum number of pod per plant was observed in BARI 15 × SS 75 (158.43) (Table 2). Number of pod per plant observed in three check varieties 975 in BARI Sharisha 11, 138 in BARI Sharisha 15 and 122.3 in SAU 1 which was less than the cross BARI 15 × SS 75 (158.43). Besides all of the F_2 population produced more pod per plant than check varieties (Table 2). Number of pod per plant showed highest phenotypic variance (4312.20) and genotypic variance (3706.05) with large environmental influence and the difference between the PCV (28.90 %) and GCV (26.80 %) indicating existence of adequate variation among the genotype (Table 3). Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Ushakumari *et al.* 1991).

Length of pod (cm)

Length of pod was observed highest in BARI 15 × BARI 16 (5.56cm) followed by SS 75 × SAU 19 (5.51 cm) whereas the minimum length of pod was observed in BARI 1 × R TORI 7 (3.96 cm) (Table 2). Among the check varieties length of pod was observed 4.28 cm in BARI Sharisha, 5.9 cm in BARI Sharisha 15 and 6.51 cm in SAU 1 Check variety BARI Sharisha was less than most of the crosses (Table 6). Length of pod showed phenotypic (0.40) and genotypic variance (0.17) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively medium PCV (12.44 %) and GCV (8.07 %) indicating that the genotype has moderate variation for this trait (Table 3). Labowitz (1989) studied *Brassica campestris* population for pod length and observed high genetic variation on this trait. Olson (1990) found high genetic variability for this trait.

Number of seeds per pod

The number of seeds per pod was observed highest in BARI 15 × BARI 16 (18.78). SS 75 × BARI 15 (17.46) was found the second highest for number of seeds per pod. Whereas the minimum number of seeds per pod was observed in BARI 1 × R TORI 7 (10.2) (Table 2). The number of seeds per pod observed 13.6 in BARI Sharisha 11, 16.9 in BARI Sharisha 15 and 15.0 in SAU 1(Table 6). Crosses BARI 16 × R TORI 17 and SS 75 × BARI 15 produced more seeds per pod than check varieties (Table 3). The differences between phenotypic variances (12.04) and genotypic variances (11.08) were relatively low for number of seeds per pod indicating low environmental influence on these characters (Table 3). The value of PCV and GCV were 21.57 % and 20.69 % respectively for number of seeds per pod which indicating that medium variation exists among different genotypes. Bhardwaj and Singh (1969) observed 35.85 % GCV in *Brassica campestris*.

Thousand seed weight (g)

Thousand seed weight was found maximum in SS 75 × SAU Sarisha 1 (3.50 g) where as the minimum thousand seed weight was found in BARI 1 × TORI 7 (1.7 g) (Table 2). Thousand seed weight observed in three check varieties 18.2 g in BARI Sharisha, 3.5 g in BARI Sharisha 15 and 3.01 g in SAU 1 and which was more than most of the crosses (Table 6). Thousand seed weight showed very low genotypic (0.39 g) and phenotypic (0.44) variance with minimum differences indicating that they were less responsive to environmental factors and the values of GCV and PCV were 21.89 % and 23.40 % indicating that the genotype has considerable variation for this trait (Table 3). Bhardwaj and Singh (1969) reported values 11.8% and 18.9% of GCV and PCV for thousand seed weight in *Brassica campestris*. Similarly Tak and Patnaik (1977) reported values 13.1% and 16.5% of GCV and PCV for *Brassica campestris*.

Total yield per plant (g)

Yield is the most outstanding character and all the research work and objectives are dependent on yield. The highest amount of yield/plot was observed in SS 75 × SAU 19 (10.72 g) followed by. TORY 7 × SAU 1 (10.19). Whereas the minimum yield per plant was observed in BARI 1 × TORI 7 (3.0 g) (Table 2).The yield per plant of three check varieties were 3.0 in BARI Sharisha, 11.98 Bari Sharisha 15 and 6.0 in SAU 1 (Table 2) where as SS 75 × SAU 19 (10.72 g) cross produced higher yield per plant than check varieties BARI Sharisha 11 and SAU 1 and most of the crosses produced more yield/plant than check varieties but less than BARI Sharisha 15 (Table 3). The phenotypic variance (7.46) appeared to be moderately higher than the genotypic variance (6.69), suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (33.00 %) was higher than the genotypic co-efficient of variation (31.25 %) which suggested that environment has a significant role on the expression of this trait (Table. 3). Sharma *et al.* (1994) reported high variability for this trait in different genotypes of *Brassica rapa*.

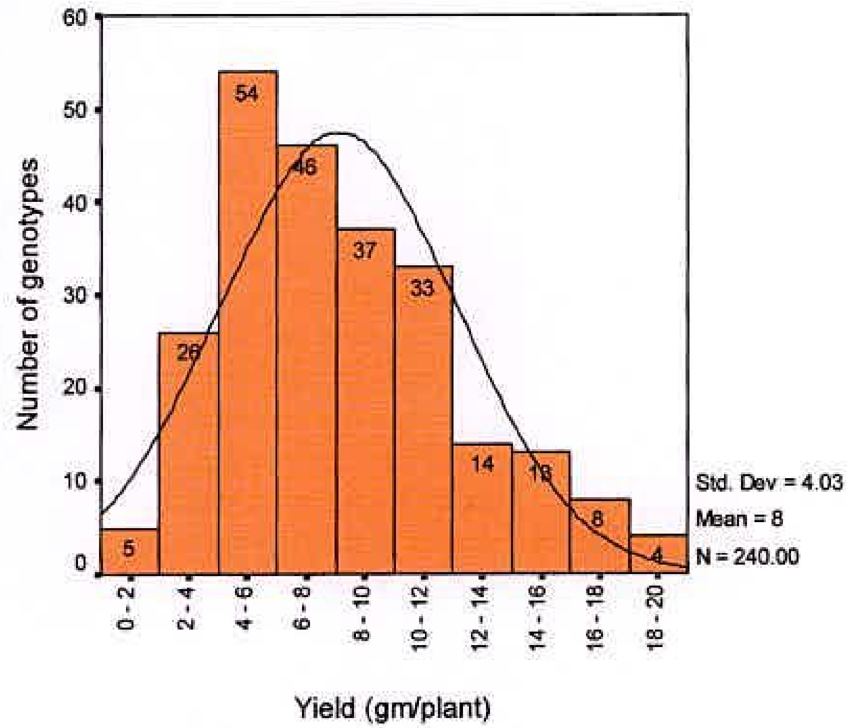

Plate 3a. Histogram showing frequency distribution for Yield of F_2 Progeny

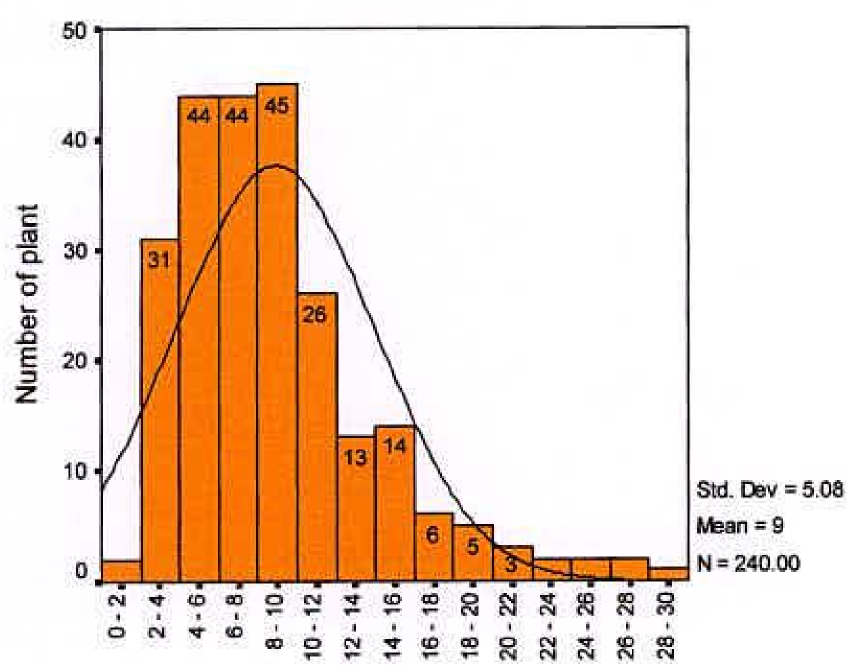

Plate 3b . Histogram showing frequency distribution for Yield of F_4 Progeny

4.1.2 Heritability, genetic advance and selection

Plant height showed high heritability 79.98% with genetic advance 20.12 and genetic advance in percentage of mean 18.75% revealed possibility of predominance of additive gene action in the inheritance of thus trait. For this the trait could be improved through selection process. Varshney *et al.* (1986) found high heritability for plant height.

Number of primary branches per plant exhibited high heritability 33.18% with low genetic advance 0.81 and genetic advance in percentage of mean 8.84%. As a whole, the high heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes. However, some of the individual plants showed quite a reasonable reduced maturity which were selected for further study in the next generation.

Days to 50% flowering exhibited high heritability (79.81%) with genetic advance 6.53 and genetic advance in percentage of mean 15.24% revealed possibility of predominance of additive gene action in the inheritance of this character. For this the characters could be improved through selection process. This results support the reports of Malik *et al.* (1995).

Table 3. Estimation of some genetic parameters in respect of F2 genotypes

Parameters	**Plant height (cm)**	**Primary branches**	**50%flowering**	**50%Maturity**	Siliqua /plant	Siliqua length	Seeds/ Siliqua	1000 seed wt.(gm)	Yield/plantt
MSSG	387.786	2.313	40.952	11.327	11724.30	0.732	34.189	1.213	20.827
MSSE	29.865	0.929	3.185	3.881	606.154	0.230	0.959	0.055	0.770
Genotypic variance	119.31	0.46	12.59	2.48	3706.05	0.17	11.08	0.39	6.69
Environmental variance	29.87	0.93	3.19	3.88	606.15	0.23	0.96	0.06	0.77
Phnotypic variance	149.17	1.39	15.77	6.36	4312.20	0.40	12.04	0.44	7.46
heritibility	79.98	33.18	79.81	39.01	85.94	42.11	92.03	87.53	89.67
Genetic advance(5%)	20.12	0.81	6.53	2.03	116.26	0.55	6.58	1.20	5.04
Genetic advance in percent of mean	18.75	8.84	15.24	2.08	51.17	10.79	40.89	42.19	60.95
GCV	10.18	7.45	8.28	1.62	26.80	8.07	20.69	21.89	31.25
PCV	11.38	12.93	9.27	2.59	28.90	12.44	21.57	23.40	33.00
ECV	5.09	10.57	4.17	2.02	10.84	9.47	6.09	8.26	10.60

Days to 50% maturity shows medium heritability (39.01%) with medium genetic advance (2.03) and genetic advance in percentage of mean (2.08%) revealed medium possibility of selecting genotypes that would mature earlier. In some of the crosses the frequency of the segregating plants showing reduced maturity was comparatively higher than the other crosses.

Number of pod per plant exhibited high heritability 85.94% with genetic advance 116.26 and genetic advance in percentage of mean 51.17%. These results revealed the possibility of predominance of additive gene action in the inheritance of this trait. This trait possessed high variation; it is high potential for effective selection for further genetic improvement of this character. This result supports the report of Paul *et al.* (1976).

Pod length showed 42.11% heritability with 0.55 genetic advance and genetic advance in percentage of mean 10.79%. These results revealed the possibility of predominance of both additive and 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.

Number of seeds per pod showed high heritability 92.03% coupled with genetic advance 6.58 and genetic advance in percentage of mean 40.89%. Malik *et al.* (1995) reported high heritability (h^2_b> 90%) for this trait.

1000 seed weight exhibited high heritability 87.53% with genetic advance 1.20 and genetic advance in percentage of mean 42.19%. This trait is governed by non additive gene. Liang and Walter (1968) 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.

Seed yield per plot showed high heritability 89.67% with genetic advance 5.04 and genetic advance in percentage of mean 60.95. These results support the reports of Liang and Walter (1968) but Singh *et al.* (1987) found high heritability for this trait.

Significant variability was found in almost all the F_2 materials *Brassica rapa* for most of the characters studied. The performance of the crosses also compared with the three check varieties BARI Sharisha 11, BARI Sharisha 15 and SAU-Sharisha -1 As per objectives, selection was carried out among the 8 F_2 materials of different cross combinations. 21 most promising plants with short duration and higher yield/plant were selected from the F_2 materials (Table 2). There were large variations in the thirty three selected F_2 materials for pod/plant ranging from 28 to 1389 pod. One plant from BARI 16 x BARI 15 produced 3.43 g of thousand seed weight. One plant from SS 75 x SAU 19 and BARI 15 x BARI 16 which produced exceptionally high yield/plant 10.72 g and 10.05 g, respectively (Table 2).

4.1.3 Correlation co-efficient

Seed yield is a complex product being influenced by several quantitative traits. Some of these traits are highly associated with seed yield. The analysis of the relationship among those traits and their association with seed yield is very much essential to establish selection criteria. Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait for F_2 materials of *B. rapa* are shown in Table 4.

Plant height (cm)

Plant height showed positive significant interaction with number of primary branches per plant (G = 0.591, P = 0.287), 50% flowering (G = 0.5222, P = 0.334) whereas negative interaction were found in 50% maturity (G = 0.125, p = -0.017), pod per plant (G = -0.812, P = -0.539), length of siliqua (G = -0.292, P = -0.252), seeds per pod (G = -0.458, P = 0.122), 1000 seed weight (G = -0.341, P = -0.065) and yield per plant (G = -0.678, P = -0.409). (Table 4). These findings are close resemblance to the reports of Chowdhury *et al.* (1987) and Yadava *et al.* (1978).

Number of primary branches per plant

Number of primary branches per plant showed positive significant interaction with days to 50% flowering (G = 0.933, P = 0.389), days to 50% maturity (G = 0.990, P = 0.401), pod length (G = 0.320, P = 0.144), seeds per pod (G = 0.590, P = 0.17), thousand seed weight (G = 0.263, P = 0.0.22) and yield (G = 0.572, P = 0.337). Whereas the negative interaction was found in pods per plant (G = -0.315, P = -0.021) (Table 4). Similar results were obtained by Afroz *et al.* (2004), Rashid (2007), Siddikee (2006), Kumar *et al.* (1996), and Shabana *et al.* (1990). Negative associations were found by Vershney *et al.* (1986).

Days to 50% flowering

Days to flowering showed positive significant interaction with days to maturity (G = 0.773, P= 0.651) and yield per pot (P = 0.162) followed by positive interactions with seeds per Siliqua (G = 0.107, P = 0.257). Whereas negative interactions were found in number of Siliqua per plant (G = -0.485, P = 0.07), pod length (G = -0.399, P=0.039), 1000 seed weight (G = 0.115, P = -0.014) and yield (G = -0.289) (Table 4). These findings are closing similar to the reports of Chowdhary *et al.* (1987) and Mahmud (2008).

Days to 50% maturity

Days to 50% maturity showed positive interaction with Siliqua per plant (G = 0.249, P = 0.298), Siliqua length (G = 0.384, P = 0.369), seeds per Siliqua (G = 0.649, P = 0.474), thousand seed weight (G = 0.495, P = 0.330) and yield per pot (G = 0.856, P = 0.671). In this case there was no negative interactions were found (Table 4).

Table 4. Genotypic and phenotypic Correlations co-efficient among different characters of F2 of *Brassica rapa*

Parameters		Primary branches(cm)	50% flowering	50% Maturity	Siliqua/plant	Siliqua length	Seeds/ Siliqua	1000 seed wt.(gm)	Yield
Plant height	r_g	0.591**	0.522*	0.125	-0.812**	-0.292	-0.458*	-0.341	-0.678**
	r_p	0.287	0.334	-0.017	-0.539*	-0.252	-0.122	-0.065	-0.409*
Primary branches	r_g		0.933**	0.990**	-0.315	0.320	0.590**	0.263	0.572**
	r_p		0.389	0.401*	-0.021	0.144	0.17	0.022	0.337
50%flowering	r_g			0.773**	-0.485*	-0.399*	0.107	0.115	-0.289
	r_p			0.651**	0.07	-0.039	0.257	-0.014	0.162
50%Maturity	r_g				0.249	0.384	0.649**	0.495*	0.856**
	r_p				0.298	0.369	0.474*	0.330	0.671**
Siliqua /**plant**	r_g					0.013	-0.073	-0.012	0.529*
	r_p					0.177	0.14	-0.049	0.528*
Siliqua **length**	r_g						0.999**	0.695**	0.703**
	r_p						0.741**	0.636**	0.605**
Seeds/ Siliqua	r_g							0.783**	0.619**
	r_p							0.724**	0.651**
1000 seed wt.	r_g								0.310
	r_p								0.428*

** Significant at the 1% level of probability

* Significant at the 5% level of probability

Number of pods per plant

Pods per plant showed positive significant interaction with yield per pot (G = 0.529, P = 0.528) followed by positive interaction with length of Siliqua (G = 0.013, P = 0.0.177) and seeds per pod (G = -0.073, P = 0.14). Whereas the negative interaction was found in thousand seed weight (G = -0.012, P = -0.049). (Table 4). Dileep *et al.* (1997) reported that number of siliquae per plant, thousand seed weight were positively correlated with seed yield. Tyagi *et al.* (1996) reported that no. of seeds per siliqua had positive and significant effects on seed yield per plant.

Length of siliqua (cm)

Length of siliqua showed positive significant interaction with yield per pot (G = 0.703, P = 605) followed by positive interaction with seeds per pod (G = 0.999, P = 0.741) and thousand seed weight (G = 0.695, P = 0.636) (Table 4). Das *et al.* (1998) reported that seed yield per plant positively correlated with length of siliqua and seeds per siliqua.

Seeds per Siliqua Seeds per pod showed positive interaction with thousand seed weight (G = 0.783, P = 0.724) and yield per pot (G = 0.619, P = 0.651) (Table 4). Dileep *et al.* (1997) reported that number of siliquae per plant, thousand seed weight were positively correlated with seed yield. Tyagi *et al.* (1996) reported that no. of seeds per siliqua had positive and significant effects on seed yield per plant.

Thousand seed weight

Thousand seed weight showed significant positive interaction with yield per pot (G = 0.31, P = 0.428) (Table 4). Saini and Sharma (1995), Kakroo and Kumar (1991) and Olsson (1990) found positive association which support the results.

4.1.4 Path co-efficient analysis

Association of character determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on seed yield per plant. In order to find out a clear picture of the inter-relationship between seed yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at phenotypic level which also measured the relative importance of each component. Seed yield per plant was considered as a resultant (dependent) variable and days to 50% flowering, days to 50% maturity, plant height, number of primary branches per plant, number of pod per plant, length of pod, number of seeds per pod and thousand seed weight were causal (independent) variables. Estimation of direct and indirect effect of path co-efficient analysis for *Brassica rapa* is presented in Table 5.

Path analysis revealed that plant height had positive direct effect (0.388) on yield per plant followed by negative indirect effect on number of primary branches per plant (-0.078), pods per plant (-0.802) and seeds per pod (-0.374). Positive indirect effect through days to 50% flowering (0.151), days to 50% maturity (0.001), and thousand seed weight (0.189) (Table 5). Mishra *et al.* (1987) and Shivahare *et al.* (1975) were found similar result.

Number of primary branches per plant had the negative direct effect on yield per plant (-0.132). This trait had positive indirect effect on plant height (0.229), days to 50% flowering (0.271), days to 50% maturity (0.010, pod length (0.168) and seeds per pod (0.482). On the other hand negative indirect effect was found on pods per plant (-0.311), and thousand seed weight (-0.146) (Table 5). Gupta *et al.* (1987) observed that primary branching and thousand seed weight had the direct effect on seed yield.

Table 5. Path coefficient analysis showing direct and indirect effect of yield components on seed yield in F_2

Characters	Plant height (cm)	Primary branches	50%flowering	50%Maturity	Siliqua /plant	Siliqua length (cm)	Seeds/ Siliqua	1000 seed wt.(gm)	Genotypic correlation with yield
Plant height	**0.388**	-0.078	0.151	0.001	-0.802	-0.153	-0.374	0.189	0.678**
Primary branches	0.229	**-0.132**	0.271	0.010	-0.311	0.168	0.482	-0.146	0.572**
50%flowering	0.202	-0.123	**0.290**	0.008	-0.479	-0.210	0.087	-0.064	-0.289
50%Maturity	0.049	-0.131	0.224	**0.010**	0.245	0.202	0.530	-0.274	0.856**
Siliqua **/plant**	-0.315	0.042	-0.141	0.002	**0.987**	0.007	-0.060	0.007	0.529*
Siliqua **length**	-0.113	-0.042	-0.116	0.004	0.013	**0.526**	0.817	-0.385	0.703**
Seeds Siliqua	-0.178	-0.078	0.031	0.006	-0.072	0.526	**0.817**	-0.434	0.619**
1000 seed wt.	-0.132	-0.035	0.033	0.005	-0.012	0.366	0.640	**-0.554**	0.310

Residual (R)=0.434

Path co-efficient analysis revealed that days to 50% flowering had positive direct effect (0.290) on yield per plant. Days to flowering had positive indirect effect on plant height 0.202), days to 50% maturity (0.008) and seeds per pod (0.087). And it showed negative indirect effect on number of primary branches per plant (-0.123), pods per plant (-0.479), pod length (-0.210) and thousand seed weight (-0.064) (Table 5). By path analysis, Zahan (2006) reported that, days to 50% flowering had negative direct effect on yield/plant.

Path co-efficient analysis revealed that days to 50% maturity had positive direct effect (0.010) on yield per plant and negative indirect effect through number of primary branches per plant (-0.131) and thousand seed weight (-0.274). On the other hand days to maturity had positive indirect effect via plant height (0.049), days to 50% flowering (0.224), pods per plant (0.245), pod length (0.202) and seeds per pod (0.530) (Table 5). Yadava (1982) revealed that days to maturity had positive direct effect on yield.

Path co-efficient analysis revealed that, number of Siliqua per plant had the positive direct effect (0.987) on seed yield followed by positive indirect effect on primary branches per plant (0.042), days to 50% maturity (0.002), length of Siliqua (0.007) and thousand seed weight (0.007). And this trait had negative indirect effect onnumber of primary branches per plant (-0.315), days to 50% flowering (-0.141), and seeds per pod (-0.060) (Table 5). Yadava *et al.* (1996) found the number of siliquae per plant had the highest positive direct effect on seed yield.

Path analysis revealed that length of Siliqua had direct positive effect (0.526) on yield per plant. This trait had also indirect positive effect on days to 50% maturity (0.004), pods per plant (0.013) and seeds per Siliqua (0.817). On the other hand length of pod showed indirect negative effect on plant height (-0.113), number of primary branches per plant(-0.042), days to 50% flowering (-0.116) and thousand seed weight (-0.385) (Table 5). Chaudhury *et al.* (1978) reported that siliqua length had highest positive direct effect on seed yield.

Seeds per pod had positive direct effect (0.817) on yield per plant and positive indirect effect on days to 50% flowering (0.031), days to 50% maturity (0.006) and pod length (0.526). On the other hand this trait showed negative indirect effect on plant height (-

0.178), number of primary branches per plant (-0.078) and number of pods per plant (-0.072) and thousand seed weight (-0.434) (Table 5). Uddin *et al.* (1995) reported that seeds per siliqua and thousand seed weight had high positive direct effect on seed yield per plant.

Thousand seed weight had negative direct effect on yield per plant (-0.554) and positive indirect effect on days to 50% flowering (0.033), days to 50% maturity (0.005), length of pod (0.366) and number of seeds per pod (0.640). On the other hand this trait showed negative indirect effect on plant height (- 0.132), number of primary branches per plant (-0.035) and pods per plant (-0.012) (Table 5). Kudla (1993) reported that 1000 seed weight had positive direct effect on seed yield.

Through path analysis the residual effect was observed. The residual effect (R) was 0.434, which indicating the character under study contributed of the seed yield per plant (Table 5). It is suggested that there were some others factors those contributed to the seed yield per plant not included in the present study may exert significant effect on seed yield.

4.2 Variability study in *Brassica rapa* of F_4

4.2.1 Variability among the 8 F_4 populations of *Brassica rapa* and three check varieties

In the study significant variations were observed for most of the characters among 8 F_4 materials of *Brassica rapa.* Table 6 & 7 showed the values of mean, range CV (%), phenotypic variances, genotypic variances, phenotypic coefficient of variation, genotypic coefficient of variation and different yield related characters.

Plant height (cm)

In this study the highest plant height was observed in BINA 6 × BARI 9 (Plant 2) (131.70 cm) where as the minimum plant height was observed in AGRONY × BARI 9 (108.12 cm). Plant height observed in three check varieties 125 cm in BARI Sharisha 11, 105.6 cm in BARI Sharisha 15 and 99.3 cm in SAU 1 which was less than all the 8 F_4 populations (Table 6 & 7). Plant height showed the phenotypic variance and genotypic variance were observed 77.93 and 37.78, respectively with relatively large differences between them indicating large environmental influences on these character as well as PCV (7.37 %) and GCV (5.13 %) indicating presence of considerable variability among the genotypes (Table 3). Tyagi *et al.* (2001) observed highest variation in plant height among parents and their hybrid.

Number of primary branches per plant

Among the 8 F_4 populations the highest number of primary branches/plant was observed in BINA 6 × BARI 9 (Plant 2) (9.53) where as the minimum number of primary branches/plant was observed in BINA 6 × BARI 9 (Plant 3) (7.17) (Table 7). No. of primary branches per plant observed in three check varieties 6.0 in BARI Sharisha 11, 8.2 in BARI Sharisha 15 and 4.7 in SAU 1 (Table 6). Number of primary branches per plant showed little differences between phenotypic variance (2.38) and genotypic variance (1.81) indicating low environmental influence on these character and relatively high difference between PCV (18.10 %) and GCV (15.78 %) value indicating the apparent variation not only due to genotypes but also due to the large influence of environment (Table 8). Chowdhary *et al.* (1987) found significant differences for number of primary branches per plant.

Table 6. Mean, range and CV (%) of seed and other characters of 8 F4 &-3 Check

Genotypes	Plant height (cm)	Primary branches	Secondary branches	50% flowering	50% maturity	Siliqua /plant	Siliqua length	Seed/ Siliqua	1000seed (w) (gm)	Total yield/ plant
BINA6XBARI9(Plant 1)										
Mean	113.10	7.37	8.00	46	97.33	188.40	5.22	15.05	3.48	9.90
SE	2.98	0.42	1.47	-	-	17.28	0.11	0.78	0.09	1.32
CV%	10.19	22.33	71.09	-	-	35.52	8.42	20.19	9.89	51.43
BINA6XBARI9(Plant 2)										
Mean	131.70	9.53	3.17	44.67	94.67	164.70	6.04	21.16	2.71	7.53
SE	3.29	0.81	0.77	-	-	12.87	0.22	0.96	0.14	0.58
CV%	9.67	32.93	94.75	-	-	30.27	13.99	17.61	19.92	29.97
BINA6XBARI9(Plant 3)										
Mean	124.30	7.17	1.43	42.67	96.33	109.57	6.41	21.05	3.29	5.97
SE	3.08	0.50	0.59	-	-	11.67	0.17	1.04	0.13	0.64
CV%	9.59	26.81	160.61	-	-	41.25	9.98	19.16	14.93	41.49
BINA6XBARI9(Plant 4)										
Mean	118.13	7.60	9.13	34.33	94.33	204.40	5.20	15.33	2.80	10.92
SE	2.82	0.40	1.90	-	-	18.42	0.17	1.40	0.13	0.91
CV%	9.24	20.53	80.50	-	-	34.91	12.78	35.33	18.54	32.31
BARI6XBINA6(Plant 1)										
Mean	117.60	9.40	4.52	39	102	179.88	5.14	19.01	3.61	7.62
SE	3.41	0.73	0.63	-	-	22.06	0.11	1.29	0.09	0.69
CV%	10.26	27.55	49.08	-	-	43.35	7.72	24.03	9.19	32.17
BARI6XBINA6(Plant 2)										
Mean	123.37	9.37	5.13	45	98	193.40	5.50	17.74	2.87	8.06
SE	1.91	0.70	1.11	-	-	19.87	0.08	1.36	0.14	0.78
CV%	6.00	28.97	83.96	-	-	39.80	5.79	29.61	18.51	37.40
BARI6XBINA6(Plant 3)										
Mean	119.10	8.73	4.63	43.67	99	148.10	5.71	22.65	3.38	7.61
SE	2.30	0.68	1.51	-	-	23.49	0.09	0.95	0.16	0.64
CV%	7.47	30.14	126.26	-	-	61.44	5.94	16.18	18.61	32.45

Genotypes	Plant height (cm)	Primary branches	Secondary branches	50% flowering	50% maturity	Siliqua /plant	Siliqua length	Seed/ Siliqua	1000seed (w) (gm)	Total yield/ plant
AGRONYXBARI9										
Mean	108.12	8.16	3.96	44	101.33	158.00	6.07	20.94	2.66	8.05
SE	3.07	0.50	0.79	-	-	17.35	0.16	1.11	0.12	0.60
CV%	10.03	21.76	70.20	-	-	38.82	9.52	18.73	16.40	26.53
BARI sharisha 11										
Mean	125	6	36	39.67	105	975	4.28	13.6	18.2	3
SE	4.67	0.65	2.87	-	-	1.50	1.46	1.00	21.78	0.13
CV%	15.76	28.40	81.01	-	-	55.38	51.09	22.21	43.57	9.82
BARI sharisha 15										
Mean	105.6	8.2	1.5	40.33	102.33	138	5.9	16.9	3.5	11.98
SE	2.57	3.21	0.44	-	-	64.21	0.17	0.76	0.17	0.69
CV%	8.40	11.58	27.04	-	-	76.09	11.61	20.63	24.79	26.40
SAU1										
Mean	99.3	4.7	11.1	41	103	122.3	6.51	15	3.01	6
SE	0.59	0.68	0.92	-	-	0.92	0.10	11.34	0.11	0.58
CV%	22.42	21.41	91.05	-	-	21.29	11.86	27.73	8.45	14.25

Days to 50% flowering

Considerable variations were observed among 8 F_4 populations for days to 50% flowering. The days to 50% flowering were observed lowest (42.67 days) in BINA 6 × BARI 9 (Plant 3) and highest (46.0 days) was observed in BINA 6 × BARI 9 (Plant 1) (Table 6). The days to 50% flowering were observed in three check varieties 39.67 days in BARI Sharisha 11, 40.33 days in BARI Sharisha 15 and 41 days in SAU-1 (Table 6). All the F_4 populations requires more flowering times than all the check varieties. Phenotypic and genotypic variance for days to maturity was observed 19.50 and 12.91, respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (10.41 %) was higher than the genotypic coefficient of variation (8.47 %) (Table 7), which suggested that environment has a significant role on the expression of this trait.

Days to 50% maturity

The highest days to 50% maturity was observed in BARI 6 × BINA 6 (Plant 1) (102.0 days) and the minimum days (94.33) to maturity was observed in BINA 6 × BARI 9 (Plant 4) (Table 6). Among the check varieties the days to 50% maturity was observed in 105 days in BARI Sharisha 11, 102.33 days in BARI Sharisha 15, and 103.0 days in SAU Sarisha 1 (Table 6). Phenotypic and genotypic variance for days to maturity was observed 10.83 and 6.54, respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (3.36 %) was higher than the genotypic coefficient of variation (2.61 %) (Table 7), 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 (Ushakumari *et al.* 1991). Working with 46 genotypes of *Brassica juncea* Sharma (1984) found low GCV and PCV values. Tak and Patnik (1977) found this value as GCV (1.8%) and PCV (4.5%) respectively.

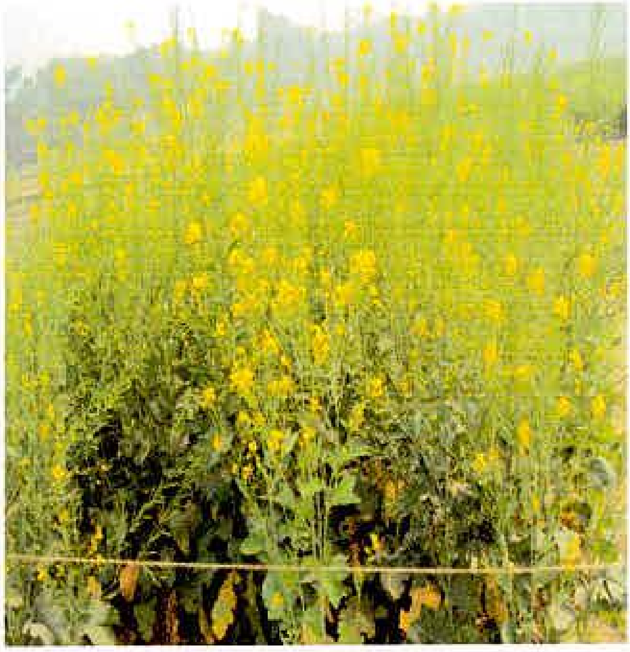

Plate 3. Photograph showing flowering of F_4 materials of the BINA 6 × BARI 9 (Plant 1)

Plate 4. Photograph showing yield per plant of F_4 materials of the BINA 6 × BARI 9 (Plant 4)

Number of pod per plant

The number of pod per plant was observed highest in BINA 6 × BARI 9 (Plant 4) (204.40) followed by BARI 6 × BINA 6 (Plant 2) (193.40). Whereas the minimum number of pod per plant was observed in BINA 6 × BARI 9 (Plant 3) (109.57) (Table 7). Number of pod per plant observed in three check varieties 975 in BARI Sharisha 11, 138 in BARI Sharisha 15 and 122.3 in SAU Sarisha 1 (Table 6). Number of pod per plant showed highest phenotypic variance (2201.17) and genotypic variance (1883.17) with large environmental influence and the difference between the PCV (29.11 %) and GCV (26.93 %) indicating existence of adequate variation among the genotype (Table 7). Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Ushakumari *et al.* 1991).

Length of pod (cm)

Length of pod was observed highest in BINA 6 × BARI 9 (Plant 3) (6.41 cm) followed by AGRONY × BARI 9 (6.07 cm) whereas the minimum length of pod was observed in BARI 6 × BINA 6 (Plant 1) (5.14 cm) (Table 6). Among the check varieties length of pod was observed 4.28 cm in BARI Sharisha 11, 5.9 cm in BARI Sharisha 15 and 6.51 cm in SAU Sarisha 1 (Table 6). Length of pod showed phenotypic (0.44) and genotypic variance (0.31) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively medium PCV (11.82 %) and GCV (9.89 %) indicating that the genotype has moderate variation for this trait (Table 7). Labowitz (1989) studied *Brassica campestris* population for pod length and observed high genetic variation on this trait. Olson (1990) found high genetic variability for this trait.

Number of seeds per pod

The number of seeds per pod was observed highest in BARI 6 × BINA 6 (Plant 3) (22.65). BINA 6 × BARI 9 (Plant 2) (21.16) was found the second highest for number of seeds per pod. Whereas the minimum number of seeds per pod was observed in BINA

6 × BARI 9 (Plant 1) (15.05) (Table 6). The number of seeds per pod observed 13.6 in BARI Sharisha 11, 16.9 in BARI Sharisha 15 and 15.0 in SAU 1. (Table 6). The differences between phenotypic variances (8.75) and genotypic variances (6.21) were relatively low for number of seeds per pod indicating low environmental influence on these characters. The value of PCV and GCV were 15.26 % and 12.86 % respectively for number of seeds per pod which indicating that medium variation exists among different genotypes (Table 7). Bhardwaj and Singh (1969) observed 35.85 % GCV in *Brassica campestris*.

Thousand seed weight (g)

Thousand seed weight was found maximum in BINA 6 × BARI 9 (Plant 1) (3.48 g) where as the minimum thousand seed weight was found in BINA 6 × BARI 9 (Plant 2) (2.71 g) (Table 7). Thousand seed weight observed in three check varieties 18.2 g in BARI Sharisha, 3.5 g in BARI Sharisha 15 and 3.01 g in SAU Sarisha 1 and which was more than most of the crosses (Table 6). Thousand seed weight showed very low genotypic (0.22 g) and phenotypic (0.0.29 g) variance with minimum differences indicating that they were less responsive to environmental factors and the values of GCV and PCV were 14.07 % and 15.90 % indicating that the genotype has considerable variation for this trait (Table 7). Bhardwaj and Singh (1969) reported values 11.8% and 18.9% of GCV and PCV for thousand seed weight in *Brassica campestris*. Similarly Tak and Patnaik (1977) reported values 13.1% and 16.5% of GCV and PCV for *Brassica campestris*.

Total yield per plant (g)

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 BINA 6 × BARI 9 (Plant 4) (10.92 g) followed by BINA 6 × BARI 9 (Plant 1) (9.90). Whereas the minimum yield per plant was observed in BINA 6 × BARI 9 (Plant 3) (5.97 g) (Table 7).The yield per plant of three check varieties were 3.0 in BARI Sharisha, 11.98 Bari Sharisha 15 and 6.0 SAU 1 where as all the crosses produced higher yield per plant than check varieties (Table 6). The phenotypic variance (2.82) appeared to be moderately higher than the genotypic variance (2.04), suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (19.97 %) was higher than the genotypic co-efficient of variation (16.96 %) which suggested that environment has a significant role on the expression of this trait (Table. 5). Sharma *et al.* (1994) reported high variability for this trait in different genotypes of *Brassica rapa.*

4.2.2 Heritability, genetic advance and selection.

Plant height of F_4 showed medium heritability 48.48% with genetic advance 8.82 and genetic advance in percentage of mean 7.36% revealed possibility of predominance of additive gene action in the inheritance of this trait. For this the trait could be improved through selection process. Varshney *et al.* (1986) found high heritability for plant height.

Number of primary branches per plant exhibited high heritability 76.00% with low genetic advance 2.42 and genetic advance in percentage of mean 28.34%. As a whole, the high heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes. However, some of the individual plants showed quite a reasonable reduced maturity which were selected for further study in the next generation.

Days to 50% flowering exhibited high heritability (66.18%) with genetic advance 6.02 and genetic advance in percentage of mean 14.19% revealed possibility of predominance of additive gene action in the inheritance of this character. For this the characters could be improved through selection process. This results support the reports of Malik *et al.* (1995).

Table 8. Estimation of some genetic parameters in respect of F_4 genotypes

Parameters	Plant height (cm)	Primary branches	50%flowering	50%Maturity	Siliqua/plant	Siliqua length	Seeds/ Siliqua	1000 seed w (gm).	Yield/plant
MSSG	153.489	6.007	45.310	23.899	5967.522	1.064	21.169	0.734	6.893
MSSE	40.144	0.572	6.595	4.292	317.999	0.133	2.534	0.062	0.786
Genotypic variance	37.78	1.81	12.91	6.54	1883.17	0.31	6.21	0.22	2.04
Envirnmental variance	40.14	0.57	6.60	4.29	318.00	0.13	2.53	0.06	0.79
Phnotypic variance	77.93	2.38	19.50	10.83	2201.17	0.44	8.75	0.29	2.82
heritability	48.48	76.00	66.18	60.36	85.55	70.00	71.03	78.32	72.14
G.Ad (5%)	8.82	2.42	6.02	4.09	82.69	0.96	4.33	0.86	2.50
G.Ad (5%) in % mean	7.36	28.34	14.19	4.18	51.31	17.05	22.33	25.65	29.68
GCV	5.13	15.78	8.47	2.61	26.93	9.89	12.86	14.07	16.96
PCV	7.37	18.10	10.41	3.36	29.11	11.82	15.26	15.90	19.97
ECV	5.29	8.87	6.05	2.12	11.07	6.48	8.21	7.40	10.54

Days to 50% maturity shows medium heritability (60.36%) with medium genetic advance (4.09) and genetic advance in percentage of mean (4.18%) revealed medium possibility of selecting genotypes that would mature earlier. In some of the crosses the frequency of the segregating plants showing reduced maturity was comparatively higher than the other crosses.

Number of Siliqua per plant exhibited high heritability 85.55% with genetic advance 82.69 and genetic advance in percentage of mean 51.31%. These results revealed the possibility of predominance of additive gene action in the inheritance of this trait. This trait possessed high variation; it is high potential for effective selection for further genetic improvement of this character. This result supports the report of Paul *et al.* (1976).

Siliqua length showed highr (70.00%) heritability with 0.96 genetic advance and genetic advance in percentage of mean 17.05%. These results revealed the possibility of predominance of both additive and 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.

Number of seeds per pod showed high heritability 71.03% coupled with genetic advance 4.33 and genetic advance in percentage of mean 22.33%. Malik *et al.* (1995) reported high heritability (h^2_b> 90%) for this trait.

1000 seed weight exhibited high heritability 78.32% with genetic advance 0.86 and genetic advance in percentage of mean 25.65%. This trait is governed by non additive gene. Liang and Walter (1968) 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.

Seed yield per plot showed high heritability 72.14% with genetic advance 2.50 and genetic advance in percentage of mean 29.68%. These results support the reports of Liang and Walter (1968) but Singh *et al.* (1987) found high heritability for this trait.

Significant variability was found in almost all the F_4 materials *Brassica rapa* for most of the characters studied. The performance of the crosses also compared with the three check varieties BARI Sharisha 11, BARI Sharisha 15 and SAU- Sharha 1 As per objectives, selection was carried out among the 8 F_4 materials of different cross combinations. 21 most promising plants with short duration and higher yield/plant were selected from the F_4 materials (Table 6). There were large variations in the thirty three selected F_4 materials for pod/plant ranging from 17 to 487 pod. One plant from BINA 6 x BARI 9 (Plant 1) produced 3.48 g of thousand seed weight. One plant from BINA 6 x BARI 9 (Plant 4) produced exceptionally high yield/plant 10.92 g (Table 6).

4.2.3 Correlation co-efficient

Seed yield is a complex product being influenced by several quantitative traits. Some of these traits are highly associated with seed yield. The analysis of the relationship among those traits and their association with seed yield is very much essential to establish selection criteria. Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait for F_4 materials of *B. rapa* are shown in Table 8.

Plant height (cm)

Plant height showed positive significant interaction with days to 50% flowering (G = 0.403, P = 0.0.426), number of Siliqua per plant (G =0.236, P = 0.147), length of pod (G = 0.089, P = -0.041), thousand seed weight (G =0.900, P =0.471) and yield (G =0.133, P =0.059) whereas negative interaction were found in number of primary branches per plant (G = -0.760, P = -0.306), days to 50% maturity (G = -0.918, P = -0.511) and seeds per pod (G = -0.580, P = 0.319). (Table 8). These findings are close resemblance to the reports of Chowdhury *et al*. (1987) and Yadava *et al*. (1978).

Number of primary branches per plant

Number of primary branches per plant showed positive significant interaction with days to 50% maturity (G = 0.369, P = 0.270), Siliqua length (G = 0.034, P = -0.024), and yield (G = 0.324, P = 0.234). Whereas the negative interaction was found in days to 50% flowering (G = -0.895, P = -0.589), length of Siliqua (G = -0.504, P = -0.435), number of seeds per Siliqua (G = -0.036, P = -0.122) and thousand seed weight (G = --0.262, P = -0,309) (Table 9). Similar results were obtained by Afroz *et al.* (2004), Rashid (2007), Siddikee (2006), Kumar *et al.* (1996), and Shabana *et al.* (1990). Negative associations were found by Vershney *et al.* (1986).

Days to 50% flowering

Days to flowering showed positive significant interaction with days to maturity (G = 0.104, P= 0.059), number of Siliqua per plant (G = -0.033, P = 0.053), length of Siliqua (G = 0.370, P = -0.062), seeds per Siliqua (G = 0.198, P = 0.110). Whereas negative interactions were found yield (G = -0.521 P = -0.173) (Table 9). These findings are closing similar to the reports of Chowdhary *et al.* (1987) and Mahmud (2008).

Days to 50% maturity

Days to 50% maturity showed positive interaction only with seeds per Siliqua (G = 0.901, P = 0.336) on the other hand negative interaction were found in pods per plant (G = -0.345, P = -0.326), pod length (G = -0.217, P = -0.082), thousand seed weight (G = -0.642, P = -0.259) and yield per plant (G = -0.388, P = -0.216). (Table 8).

Table 9. Genotypic and phenotypic Correlations co-efficient among different characters of F4 of *Brassica rapa*

Parameters		Primary branches(cm)	50% flowering	50% Maturity	Siliqua /plant	Siliqua length	Seeds/ Siliqua	1000 seed wt.(gm)	Yield
Plant height	r_g	-0.760**	0.403*	-0.918**	0.236	0.089	-0.580**	0.900**	0.113
	r_p	-0.306	0.246	-0.511*	0.147	-0.041	-0.319	0.471*	0.059
Primary branches	r_g		-0.895**	0.369	0.034	-0.504*	-0.036	-0.262	0.324
	r_p		-0.581**	0.270	-0.024	-0.435*	-0.122	-0.309	0.234
50%flowering	r_g			0.104	-0.033	0.370	0.781**	0.198	-0.521*
	r_p			0.059	0.053	-0.062	0.024	0.110	-0.173
50%Maturity	r_g				-0.345	-0.217	0.901**	-0.642**	-0.388
	r_p				-0.326	-0.082	0.336	-0.259	-0.216
Siliqua **/plant**	r_g					-0.309	-0.401*	0.464*	0.688**
	r_p					-0.225	-0.266	0.373	0.629**
Siliqua **length**	r_g						0.727	0.208	-0.510*
	r_p						0.511	0.161	-0.469*
Seeds/ Siliqua	r_g							-0.243	-0.928**
	r_p							-0.052	-0.440*
1000 seed wt.	r_g								0.058
	r_p								0.051

** Significant at the 1% level of probability

* Significant at the 5% level of probability

Number of Siliqua per plant

Pods per plant showed positive significant interaction with thousand seed weight (G = 0.464, P = 0.373) and yield per plant (G = 0.688, P = 0.629). Whereas the negative interaction was found in Siliqua length (G = -0.309, P = -0.225) and number of seeds per plant (G = -0.401, P = -0.266) (Table 9). Dileep *et al.* (1997) reported that number of siliquae per plant, thousand seed weight were positively correlated with seed yield. Tyagi *et al.* (1996) reported that no. of seeds per siliqua had positive and significant effects on seed yield per plant.

Length of Siliqua (cm)

Length of Siliqua showed positive significant interaction with number of seeds per plant (G = 0.727, P = 0.511) followed by positive interaction with thousand seed weight (G = 0.208, P = 0.161) and yield (G = -0.510, P = -0.469) showed negative interaction. (Table 9). Das *et al.* (1998) reported that seed yield per plant positively correlated with length of siliqua and seeds per siliqua.

Seeds per Siliqua

Seeds per Siliqua showed negative interaction with thousand seed weight (G = -0.243, P = -0.052) and yield per plant (G = -0.928, P = -0.440) (Table 9). Dileep *et al.* (1997) reported that number of siliquae per plant, thousand seed weight were positively correlated with seed yield. Tyagi *et al.* (1996) reported that no. of seeds per siliqua had positive and significant effects on seed yield per plant.

Thousand seed weight

Thousand seed weight showed significant positive interaction with yield per pot (G = 0.058, P = 0.051) (Table 8). Saini and Sharma (1995), Kakroo and Kumar (1991) and Olsson (1990) found positive association which support the results.

4.2.4 Path co-efficient analysis of F_4

Association of character determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on seed yield per plant. In order to find out a clear picture of the inter-relationship between seed yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at phenotypic level which also measured the relative importance of each component. Seed yield per plant was considered as a resultant (dependent) variable and days to 50% flowering, days to 50% maturity, plant height, number of primary branches per plant, number of pod per plant, length of pod, number of seeds per pod and thousand seed weight were causal (independent) variables. Estimation of direct and indirect effect of path co-efficient analysis for *Brassica rapa* is presented in Table 10.

Residual effects of their independent variables, which have influenced on yield to a medium extent, have been denoted as 'R' in the diagram. The results are discussed briefly as follows:

Path analysis revealed that plant height had negative direct effect (-0.190) on yield per plant followed by positive indirect effect on number of primary branches per plant (0.038), days to 50% maturity (0.471), number of pods per plant (0.138) and number of seeds per pod (0.039). Negative indirect effect through days to 50% flowering (-0.084), length of pod (-0.023) and thousand seed weight (-0.277) (Table 10). Mishra *et al.* (1987) and Shivahare *et al.* (1975) were found similar result.

Number of primary branches per plant had the negative direct effect on yield per plant (-0.050). This trait had positive indirect effect on plant height (0.144), days to 50% flowering (0.186), number of pods per plant (0.020), pod length (0.130), number of seeds per pod (0.002) and thousand seed weight (0.081). On the other hand negative indirect effect was found on days to 50% maturity (-0.189) (Table 10). Gupta *et al.* (1987) observed that primary branching and thousand seed weight had the direct effect on seed yield.

Table 9. Path coefficient analysis showing direct and indirect effect of yield components on seed yield in F_4

Characters	Plant height (cm)	Primary branches	50%flowering	50%Maturity	Siliqua /plant	Siliqua length	Seeds/ Siliqua	1000 seed wt.(gm)	Genotypic correlation with yield
Plant height	**-0.190**	0.038	-0.084	0.471	0.138	-0.023	0.039	-0.277	0.113
Primary branches	0.144	**-0.050**	0.186	-0.189	0.020	0.130	0.002	0.081	0.324
50%flowering	-0.076	0.045	**-0.208**	-0.054	-0.019	-0.096	-0.052	-0.061	-0.521*
50%Maturity	0.174	-0.018	-0.022	**-0.513**	-0.202	0.056	-0.060	0.197	-0.388*
Siliqua /plant	-0.045	-0.002	0.007	0.177	**0.586**	0.080	0.027	-0.143	0.688**
Siliqua length	-0.017	0.025	-0.077	0.111	-0.181	**-0.258**	-0.049	-0.064	-0.510*
Seeds/ Siliqua	0.110	0.002	-0.162	-0.462	-0.235	-0.188	**-0.067**	0.075	-0.928**
1000 seed wt.	-0.171	0.013	-0.041	0.329	0.272	-0.054	0.016	**-0.307**	0.058

Residual (R)=0.3887

Path co-efficient analysis revealed that day to 50% flowering had negative direct effect (-0.208) on yield per plant. Days to 50% flowering had negative indirect effect on plant height (-0.076), days to 50% maturity (-0.054), number of pods per plant (-0.019), length of pod (-0.096), seeds per pod (-0.052)and thousand seed weight (-0.521). And it showed positive indirect effect on number of primary branches per plant (0.045), (Table 9). By path analysis, Zahan (2006) reported that, days to 50% flowering had negative direct effect on yield/plant.

Path co-efficient analysis revealed that days to 50% maturity had negative direct effect (-0.513) on yield per plant and positive indirect effect through plant height (0.174), pod length (0.056) and thousand seed weight (0.197). On the other hand days to maturity had negative indirect effect via number of primary branches per plant (-0.018), days to 50% flowering (-0.022), pods per plant (-0.202), and seeds per pod (0.060) (Table 9). Yadava (1982) revealed that days to maturity had positive direct effect on yield.

Path co-efficient analysis revealed that, number of pods per plant had the positive direct effect (0.586) on seed yield followed by positive indirect effect on days to 50% flowering (0.007), days to 50% maturity (0.177), length of pod (0.080) and number of seeds per pod (0.027). And this trait had negative indirect effect on plant height (-0.045), number of primary branches per plant (-0.002) and thousand seed weight (-0.143) (Table 9). Yadava *et al.* (1996) found the number of siliquae per plant had the highest positive direct effect on seed yield.

Path analysis revealed that length of pod had direct negative effect (-0.258) on yield per plant. This trait had also indirect positive effect on number of primary branches per plant (0.025) and days to 50% maturity (0.111). On the other hand length of pod showed indirect negative effect on plant height (-0.017), days to 50% flowering (-0.077), number of pods per plant (-0.181), number of seeds per plant (-0.049) and thousand seed weight (-0.064) (Table 9). Chaudhury *et al.* (1978) reported that siliqua length had highest positive direct effect on seed yield.

Seeds per pod had negative direct effect (-0.067) on yield per plant and positive indirect effect on plant height (0.110), number of primary branches per plant (0.002) and thousand seed weight (0.075). On the other hand this trait showed negative indirect effect on days to 50% flowering (-0.162), days to 50% maturity (-0.462) and pod length (-0.235), pod length (-0.188) (Table 9). Uddin *et al.* (1995) reported that seeds per siliqua and thousand seed weight had high positive direct effect on seed yield per plant.

Thousand seed weight had negative direct effect on yield per plant (-0.307) and positive indirect effect on number of primary branches per plant (0.013), days to 50% maturity (0.329), pod per plant (0.272) and number of seeds per pod (0.016). On the other hand this trait showed negative indirect effect on plant height (- 0.171), days to 50% flowering (-0.041), pod length (-0.054) and thousand seed weight (-0.307) (Table 9). Kudla (1993) reported that 1000 seed weight had positive direct effect on seed yield.

Through path analysis the residual effect was observed. The residual effect (R) was 0.3887, which indicating the character under study contributed of the seed yield per plant (Table 9). It is suggested that there were some others factors those contributed to the seed yield per plant not included in the present study may exert significant effect on seed yield.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted during the period of 4th November, 2009 to March 2010, at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University using eight F_2, eight F_4 progenies of *Brassica rapa* and three check varieties. The experiment was carried out to study variability, heritability, genetic advance and genetic advance in percentage of mean, genetic diversity, character associations and direct and indirect effect of different traits on yield. All eight F_2, eight F_4 progenies varied significantly with each other for all the characters studied. The results of the present study are summarized as follows:

From variability analysis of F_2 progenies, it was observed that significant variation exist among all the genotypes used for most of the characters studied. Plant height exhibited highest in BARI 11 × TORI 7 and lowest in BARI 11 × TORI 7. The highest number of primary branches per plant was recorded in SS 75 × BARI Sharisha 15 and lowest number was recorded in BARI Sharisha 15 × SS 75. The maximum days to 50% flowering was found in SS 75 × BARI Sharisha 15 and the lowest in BARI 6 × TORI 7. The highest days to 50% maturity was observed in BARI 16 × BARI Sharisha 15 and lowest days were observed in BARI 6 × R TORI 7. The number of siliqua per plant showed highest in BARI 11 × TORI 7 and lowest in BARI 15 × SS 75. The lowest length of siliqua was recorded in BARI 11 × TORI 7 and the highest length of siliqua was observed in BARI Sharisha 15 × BARI 16. The number of seeds per siliqua was found highest in BARI Sharisha 15 × BARI 16 and lowest in BARI 1 × M TORI 7. The thousand seed weight exhibited highest in SS 75 × SAU Sharisha 1 and lowest in BARI 11 × TORI 7. The seed yield per plant was highest in SS 75 × SAU Sharisha 1 and lowest observed in BARI 11 × TORI 7.

From variability analysis of F_4 progenies, it was observed that significant variation exist among all the genotypes used for most of the characters studied. Plant height exhibited highest in BINA 6 × BARI 9 (Plant 9) and lowest in AGRONY × BARI 9. The highest number of primary branches per plant was recorded in BINA 6 × BARI 9

(Plant 2) and lowest number was recorded in BINA 6 × BARI 9 (Plant 3). The maximum days to 50% flowering was found in BINA 6 × BARI 9 (Plant 1) and the lowest in BINA 6 × BARI 9 (plant 3). The highest days to 50% maturity was observed in BARI 6 × BINA 6 (Plant 1) and lowest days were observed in BINA 6 × BARI 9 (Plant 4). The number of siliqua per plant showed highest in BINA 6 × BARI 9 (plant 4) and lowest in BINA 6 × BARI 9 (Plant 3). The lowest length of siliqua was recorded in BARI 6 × BINA 6 (Plant 1) and the highest length of siliqua was observed in BINA 6 × BARI 9 (Plant 3). The number of seeds per siliqua was found highest in BARI 6 × BINA 6 (Plant 3) and lowest in BINA 6 × BARI 9 (Plant 1). The thousand seed weight exhibited highest in BINA 6 × BARI 9 (Plant 1) and lowest in BINA 6 × BARI 9 (Plant 2). The seed yield per plant was highest in BINA 6 × BARI 9 (Plant 4) and lowest observed in BINA 6 × BARI 9 (Plant 3).

In the 16 F_2 & F_4 both progenies for most of the characters wide range of variation observed. The phenotypic variance was higher than the corresponding genotypic variance for all the characters indicating greater influence on environment for the expression of these characters. In F_2 & F_4 materials days to maturity, plant height, number of siliqua per plant showed moderate differences between genotypic and phenotypic variance. Days to 50% flowering, number of primary branches per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and yield per plant showed minimum differences between genotypic and phenotypic variance which indicated low environmental influence on these traits. Days to 50% flowering, days to maturity, plant height, length of siliqua, number of seeds per siliqua, thousand seed weight, exhibited low genotypic and phenotypic co-efficient of variation. Number of primary branches per plant, number of secondary branches per plant, and yield per plant and number of Siliqua per plant showed moderate genotypic and phenotypic co-efficient of variation. Plant height, and number of siliqua per plant showed high heritability with high genetic advance and genetic advance in percentage of mean. These results revealed the possibility of predominance of additive gene action in the inheritance of these traits. Therefore the traits could be improved through selection process. Days to 50% flowering, days to 50% maturity number of primary branches per plant, number of secondary branches per plant, length of siliqua, number of seeds per siliqua, 1000 seed weight and yield per plant showed high heritability with moderate genetic advance and genetic advance in percentage of mean indicated medium possibility of selecting genotypes .

Selection was carried out among the sixteen F_2 & F_4 materials of *Brassica rapa* for most promising plants with high yield and a short duration. The performance of the crosses also compared with three check varieties. Based on the variability and as per our objectives nineteen most promising plants with short duration and higher yield were selected from the F_2 & F_4 materials.

Correlation revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, number of siliqua per plant, thousand seed weight (Both genotypic & phenotypic level). A significant positive correlation also observed for days to 50 % flowering, siliqua length (genotypic level).

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

As the traits like, number of secondary branches per plant, plant height, seeds per siliqua and days to flowering showed high heritability coupled with high genetic advance in percent of mean, selection would be effective for those traits.

The selected lines can be further used for advance research or varietal improvement program. High yielding variety can be found from the selected line.

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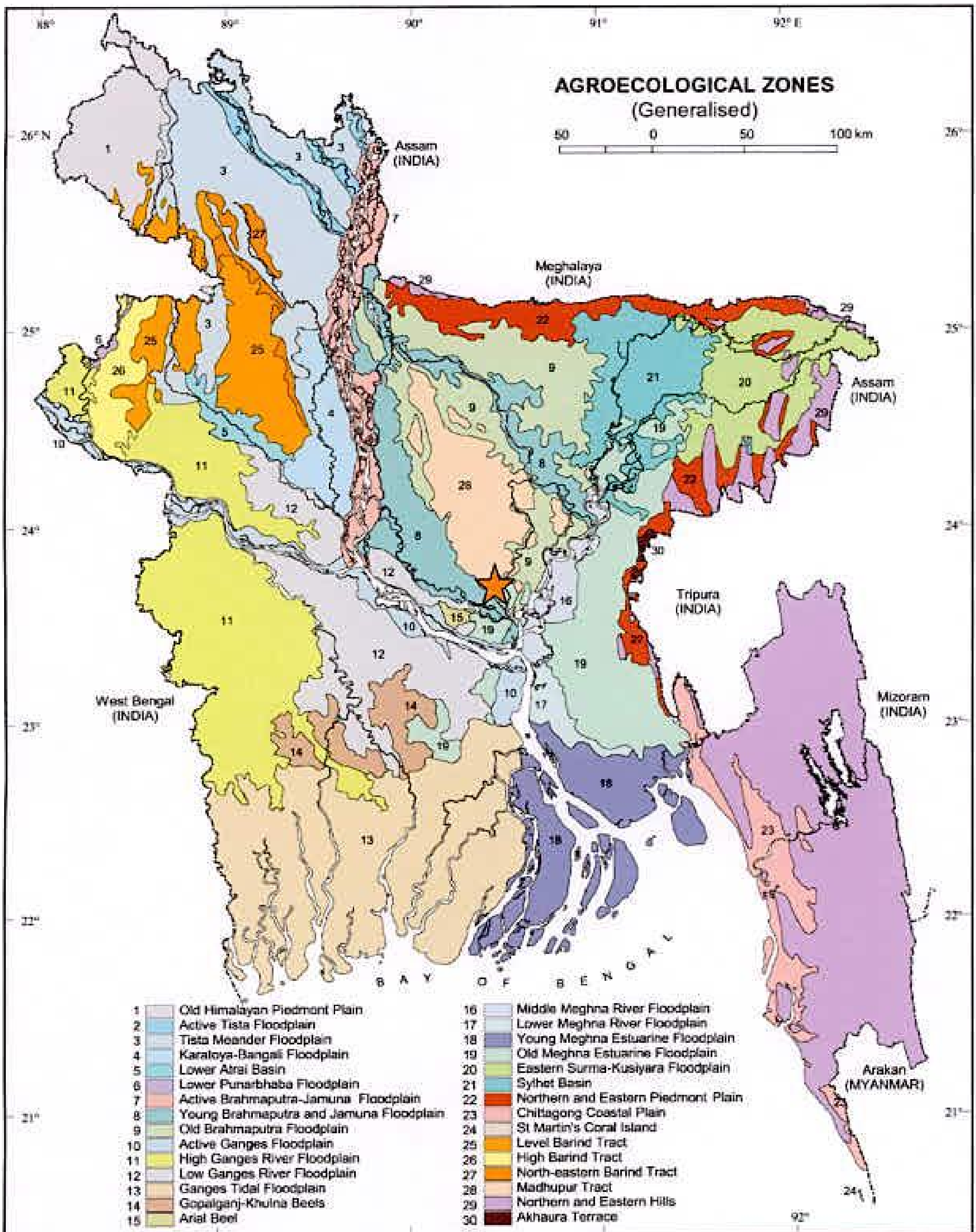
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



★ The experimental site under study

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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

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

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from October, 2009 to March, 2010

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2008	34.8	18.0	77	227	5.8
November, 2008	32.3	16.3	69	0	7.9
December, 2008	29.0	13.0	79	0	3.9
January, 2009	28.1	11.1	72	1	5.7
February, 2009	33.9	12.2	55	1	8.7
March, 2009	34.6	16.5	67	45	7.3
April, 2009	35.8	20.3	65	88	8.3

Source: Bangladesh Metrological Department (Climate division), Agargaon, Dhaka-1212.