VARIABILITY STUDY AMONG THE F_2 SEGREGANTS OF THE INTER VARIETAL CROSSES OF *Brassica rapa*

BY

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This is to certify that thesis entitled, **"VARIABILITY STUDY AMONG THE F_2 SEGREGANTS OF THE INTER VARIETAL CROSSES OF *Brassica rapa*"** 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 **MD. SAIFULLAH**, Registration No. 07-02642 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2009
Place: Dhaka, Bangladesh

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(Dr. Md. Shahidur Rashid Bhuiyan)
Professor
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Dedicated

to

My Beloved Parents

SOME COMMONLY USED ABBREVIATIONS

ABBREVIATION		FULL MEANING
AEZ	=	Agro – Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
cm	=	Centimeter
^{0}C	=	Degree celsius
CV	=	Co-efficient of variation
PCV	=	Phenotypic co-efficient of variation
GCV	=	Genotypic co- efficient of variation
et al.	=	and others
etc	=	Etcetera
e.g.	=	For example
FAO	=	Food and Agricultural Organization
g	=	gram
Kcal	=	Kilocalorie
NARS	=	National Agricultural Research System
G.A.	=	Genetic Advance
i.e.	=	That is
MoA	=	Ministry of Agriculture
ECV	=	Environmental co-efficient of variation
No.	=	Number
Var.	=	Variety
U.K.	=	United Kingdom
viz.	=	Namely
%	=	Percent
Agric.	=	Agriculture
Agril.	=	Agricultural
BBS	=	Bangladesh Bureau of Statistics
CEC	=	Cation Exchange Capacity
Univ.	=	University
SAU	=	Sher-e-Bangla Agricultural University
j	=	Journal
Sci	=	Science
F_1	=	The first generation of a cross between two dissimilar homozygous parents
F_2	=	The second generation of a cross between two dissimilar homozygous parents
F_3	=	The third generation of a cross between two dissimilar homozygous parents
F_4	=	The forth generation of a cross between two dissimilar homozygous parents

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Saifullah
The Author

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VARIABILITY STUDY AMONG THE F_2 SEGREGANTS OF THE INTER VARIETAL CROSSES OF *Brassica rapa*

ABSTRACT

BY

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A research was conducted by using 27 F_2 progenies of *Brassica rapa* and four check varieties in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2008-March 2009 to study the variation in different characters, correlation between pairs of characters and the direct and indirect effect of different characters on seed yield per plant of the F_2 materials. From the values of mean, range and CV (%) of seed yield and yield contributing characters it was confirmed that there were large variation present among all the genotypes used in the experiment. The phenotypic variances were higher than the genotypic variances. Minimum genotypic and phenotypic variances were observed among the F_2 progenies for all the characters studied except for siliquae per plant. The values of GCV and PCV indicated that there was considerable variation among all the characters except days to maturity. The high GCV value was observed for secondary branches per plant. The plant height and number of siliquae per plant showed high heritability with high genetic advance and genetic advance in percentage of mean. 33 most promising plants with short duration and higher yield were selected from 27 crosses of the F_2 populations of *Brassica rapa*. Yield per plant had significant positive association with plant height, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant and thousand seed weight. Path co-efficient analysis revealed that days to 50% maturity, number of primary branches per plant, number of siliquae per plant, siliqua length, seeds per siliqua and 1000 seed weight had the positive direct effect on yield per plant whereas days to 50% flowering, plant height had the negative direct effect on yield per plant.

Chapter 1

Introduction

CHAPTER I
INTRODUCTION

Brassica, belongs to the family Brassiceae is an important genera of plant kingdom consisting of 3200 species with high diverse morphology. It is mainly self-pollinated crop, although on an average 7.5 to 30% outcross does occur under natural field conditions (Abraham, 1994; Rakow & Woods, 1987).

B. rapa is popular in Bangladesh for it's high oil contents. Every year we have to import more than 70% edible oils from foreign country due to low production in our country. According to FAO (2005) the oil yielding crop *Brassica* hold the second position in the world oil seed production. In Bangladesh more than 134.875 thousand metric ton of local rape and mustard produced from total 392.900 thousand acre of cultivable land and about 540.005 thousand metric ton of hybrid rape and mustard produced from total 127.145 thousand acre of cultivable land in the year 2006-2007 (BBS, 2008). Its average yield per hectare was only 733 kg in Bangladesh compared to the world average of 1575 kg (FAO, 2005).

The primary center of origin for *Brassica rapa* is near the Himalayan region and the secondary center of origin is located in the European–Mediterranean area and Asia (Downey and Robelen, 1989). Major producing regions of this crop are China, Canada and Northern Europe and the Indian subcontinent (Ram and Hari, 1998).

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). 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).

Brassica rapa have great economic & commercial value and play a major role in our daily diet. Fat and oil are vital components of the human diet because they are important sources of energy and act as a carrier of fat soluble vitamins. Poor intake of fat and oil reduce the availability of fat soluble vitamins and caused dietary imbalance and food wastage. In a balanced diet 20-25% of calories should come from fats and oils and the average need of fats and oils is about 37 g/day (Rahman, 1981). The seeds of *Brassica rapa* contain 42% oil, 25% protein (Khaleque, 1985).

Though Bangladesh is an agricultural country the country is facing 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. And there is limited scope to increase yield because farmers usually cultivate the existing low yielding varieties with low input and management and almost all cultivars are brown seeded and smaller in size (2-2.5 g/1000 seeds). Short duration variety like Tori-7 of *B. rapa* is still popular in Bangladesh because it can fit well into the T. Aman - Mustard – Boro cropping pattern. There is no improved short duration variety *B. rapa* is available to replace this short duration but low yielding variety.

The above scenario indicates there should be an attempt to develop short duration and high yielding varieties of mustard with more oil percentage in seed, tolerant to biotic and abiotic stress to fulfill the requirement of edible oils of the country by increasing the production. The improved variety also should well fit into T. amon-Mustard-Boro cropping pattern.

Information on genetic variability is necessary for initiating a successful breeding program. Determination of correlation co-efficient between the characters has a considerable importance in selecting breeding materials. The path co-efficient analysis gives more specific information on the direct and indirect influence of each of the component characters upon seed yield (Behl, *et al.* 1992).

Thus F_2 materials have been generated through different inter varietal crosses of *Brassica rapa* and the present study was conducted to find out the variability, character association and the direct and indirect effect of different characters on yield per plant which will give an opportunity to select the desired plant types to meet the existing demand.

Conceiving the above idea the present study was undertaken with the following objectives:

- To study the variability in F_2 segregating materials for selection of desired plant types,
- To study the relationship among the different traits and their contribution to the yield and
- To select promising genotypes considering early maturing, high yielding plants from F_2 population

Chapter 2

Review of literature

CHAPTER 2

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.

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,

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 of mean.

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 studied 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 Pvariability, 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*.

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.

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.

Diwaker 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.

According to Knott (1972), Seitzer and Evans (1978) and Whan *et al.* (1982) selection for yield in early segregating generations was effective in developing high yielding cultivars of self pollinated crops.

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.

2.2 Correlation among different characters

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

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

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.

The number of siliquae/per plant, seed weight per plant and thousand seed weight were positively correlated with seed yield per plant was observed by Dileep *et al.* (1997).

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).*

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

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.

The number of siliquae per plant was the most important characters to yield were found by Swain (1990), when studied correlations of yield components in 15 genotypes of brown sarson *(B. campestris* var. dichotoma).

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.

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

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

2.3 Path co-efficient analysis

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

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

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

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

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

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

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

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

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

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 siliqua 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 3

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, 2008 to March, 2009. The location of the experimental site was situated at **23^0 74'** N latitude and **90^0 35'** E longitude with an elevation of 8.6 meter from the sea level. Photo graph showing experimental sites (Plate 1 and Plate 2).

3.2 Soil and Climate

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

3.3 Plant materials

A total number of 31 (thirty one) materials were used in this experiment where twenty seven were F_2 segregating generations and four were check varieties. All the Materials were collected from Department of Genetics and Pant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The materials used in that experiment is shown in Table -1.

Table 1: Materials used for the experiment

F_2 Populations			Check varieties
1. P-2 x P-10	10. P-5 x P-10	19. P-7 x P-3	1. Real tori-7
2. P-2 x P-11	11. P-5 x P-12	20. P-7 x P-5	2. BARI-15
3. P-2 x P-12	12. P-6 x P-2	21. P-7 x P-6	3. BARI-9
4. P-3 x P-2	13. P-6 x P-3	22. P-7 x P-10	4. SAU- 1
5. P-3 x P-10	14. P-6 x P-5	23. P-7 x P-11	
6. P-3 x P-11	15. P-6 x P-10	24. P-7x P-12	
7. P-3 x P-12	16. P-6 x P-11	25. P-10 x P-11	
8. P-5x P-2	17. P-6 x P-12	26. P-10 x P-12	
9. P-5x P-3	18. P-7 x P-2	27. P-11 x P-12	

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.

Plate 1. Photograph showing a field view of experimental site at flowering stage at SAU farm (Rabi 2008)

Plate 2. Photograph showing a field view of experimental site at maturity stage at SAU farm (Rabi 2008)

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 12 November, 2008. 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, 2009 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 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 variances:

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

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

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

$\delta^2 e$ = 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).

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

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

$$r = \frac{\sum xy - \dfrac{\sum x . \sum y}{N}}{\left[\left\{ \sum x2 - \dfrac{(\sum x)2}{N} \right\} \left\{ \sum y2 - \dfrac{(\sum y)2}{N} \right\} \right]}$$

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observations

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 4
RESULTS AND DISCUSSION

The present study was conducted with a view to determine the variability among twenty seven 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 days to 50% flowering, days to 80% maturity, plant height (cm), no. of primary branches per plant, no. of secondary branches per plant, total no. of siliquae/plant, length of siliqua (cm), number of seeds per siliqua, 1000 seed weight (g) and yield per plant (g). The data were statistically analyzed and thus obtained results are described below under the following heads:

4.1 Variability study in *Brassica rapa*

4.1.1 Variability among the 27 F_2 populations of *Brassica rapa* and four check varieties

In the study considerable variations were observed for most of the characters among 27 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.

Days to 50% flowering

Considerable variations were observed among 27 F_2 populations for days to 50% flowering. The days to 50% flowering were observed lowest (36.00 days) in P-3 × P-12, P-5 × P-2, P-5 × P-3, and P-7 × P-6. In P-11 × P-12 highest (40.00 days) days to 50% flowering was observed (Table 2). In case of check varieties the days to 50% flowering were observed 30.00 days in Real Tori-7, 33.57 days in BARI-9, 39 days in SAU-1 and 40.33 days in BARI-15. All the F_2 populations required more flowering times than check variety Real Tori-7 but most of the F_2 crosses required less flowering time than BARI-15, SAU-1 and BARI-9 (Table 2). The early days to 50% flowering was observed in F_2 population of P-7 × P-6 and P-11 × P-12 (Plate 3).

Table 2. Mean, range and CV (%) of yield and other yield contributing characters of 27 F_2 materials of *Brassica rapa* and four check varieties

Crosses (F_2)	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
P2×P10										
Mean	37.40	79.73	79.13	5.64	6.80	135.47	5.30	11.41	2.47	4.97
Range	37-38	78-81	66-96	3-8	0-16	65-264	4.65-5.80	8.50-13.50	2.44-2.52	3.10-6.20
SE	0.091	0.191	1.460	0.311	1.015	9.817	0.066	0.331	0.004	0.151
CV (%)	1.33	1.31	10.10	30.17	81.78	39.69	6.82	15.89	0.98	16.60
P2×P11										
Mean	38.00	85.00	80.07	3.63	4.17	130.50	4.64	14.21	2.50	3.42
Range	38-38	85-85	72-86	3-4	0-6	113-150	4.3-5.2	13.5-14.5	2.39-2.56	2.8-4.68
SE	0.000	0.000	0.877	0.089	0.387	2.126	0.046	0.058	0.006	0.094
CV (%)	0.00	0.00	6.00	13.49	50.85	8.92	5.48	2.25	1.23	15.05
P2×P12										
Mean	39.17	83.97	90.10	4.23	4.20	130.27	5.54	15.90	2.89	4.16
Range	38-40	83-84	74-104	3-6	2-7	110-167	5.2-5.75	14.0-17.2	2.84-2.95	2.64-7.82
SE	0.084	0.033	1.578	0.164	0.273	2.833	0.034	0.205	0.004	0.267
CV (%)	1.18	0.22	9.59	21.20	35.59	11.91	3.39	7.05	0.84	35.09
P3×P2										
Mean	37.33	82.00	71.97	4.60	5.73	158.87	4.70	14.79	2.57	4.88
Range	37-38	82-82	63-90	3-7	3-10	86-270	4.5-4.9	13.5-16.5	2.54-2.70	2.25-10.12
SE	0.088	0.000	1.443	0.177	0.455	10.646	0.020	0.131	0.007	0.428
CV (%)	1.28	0.00	10.98	21.05	43.44	36.70	2.37	4.87	1.55	48.06
P3×P10										
Mean	38.67	83.00	76.30	4.40	6.00	141.53	4.15	13.91	2.87	3.24
Range	38-39	83-83	62-95	3-7	2-11	83-217	3.6-4.7	12.0-15.5	2.83-2.94	2.36-4.90
SE	0.088	0.000	1.849	0.233	0.563	8.398	0.049	0.205	0.004	0.142
CV (%)	1.24	0.00	13.27	28.99	51.42	32.50	6.42	8.06	0.82	23.97

Cont'd

Crosses (F_2)	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
P3×P11										
Mean	38.00	81.00	79.37	4.69	2.67	125.40	4.71	13.47	2.97	4.40
Range	38-38	81-81	69-86	3-6	0-10	74-192	4.4-5.0	12.7-14.0	2.96-2.99	3.17-5.13
SE	0.000	0.000	1.099	0.204	0.519	7.502	0.039	0.075	0.002	0.123
CV (%)	0.00	0.00	7.59	23.84	66.67	32.77	4.56	3.03	0.29	15.35
P3×P12										
Mean	36.00	80.07	89.10	4.17	1.83	113.07	5.54	15.37	2.36	2.86
Range	36-36	78-81	76-100	3-7	0-10	67-211	4.8-6.20	13.0-18.0	2.34-2.39	2.18-4.11
SE	0.000	0.219	1.102	0.250	0.541	7.351	0.077	0.262	0.002	0.115
CV (%)	0.00	1.50	6.77	32.80	61.48	35.61	7.66	9.33	0.43	22.01
P5×P2										
Mean	36.00	81.00	81.63	4.40	4.50	127.43	5.62	14.77	2.96	3.96
Range	36-36	81-81	72-92	2-7	1-10	77-170	5.0-6.5	12.0-17.2	2.95-3.01	2.80-5.61
SE	0.000	0.000	1.123	0.238	0.486	6.030	0.072	0.282	0.003	0.146
CV (%)	0.00	0.00	7.53	29.60	59.16	25.92	7.03	10.44	0.63	20.22
P5×P3										
Mean	36.00	77.90	89.33	6.17	5.73	110.80	4.30	14.81	2.83	3.78
Range	36-36	77-78	76-100	2-9	4-7	72-187	3.6-4.5	11.0-17.0	2.80-2.85	2.50-5.57
SE	0.000	0.056	1.395	0.336	0.135	6.845	0.043	0.353	0.002	0.185
CV (%)	0.00	0.39	8.55	29.84	12.90	33.84	5.47	13.05	0.41	26.79
P5×P10										
Mean	38.10	82.80	77.97	3.80	1.60	92.53	5.32	16.18	2.80	4.58
Range	37-39	81-84	66-90	3-6	0-9	57-127	4.6-5.8	14.0-18.5	2.78-2.84	3.34-6.90
SE	0.175	0.273	1.028	0.147	0.479	4.261	0.069	0.279	0.003	0.188
CV (%)	2.52	1.81	7.22	21.19	63.80	25.22	7.11	9.45	0.65	22.42

Con'd

Crosses (F₂)	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
P5×P12										
Mean	37.00	80.00	70.67	3.37	3.67	125.90	4.51	13.85	2.36	2.59
Range	37-37	80-80	65-78	2-4	0-5	100-150	4.3-5.0	12.0-15.5	2.35-2.41	2.26-3.32
SE	0.000	0.000	0.739	0.102	0.251	2.048	0.032	0.178	0.003	0.056
CV (%)	0.00	0.00	5.73	16.52	37.44	8.91	3.93	7.04	0.66	11.96
P6×P2										
Mean	37.17	80.57	92.43	6.07	6.80	168.90	5.21	14.78	2.98	5.29
Range	37-38	80-82	73-104	4-10	0-12	118-232	4.4-5.6	13.0-16.0	2.85-3.11	3.76-7.21
SE	0.069	0.141	2.040	0.287	0.649	7.493	0.070	0.134	0.010	0.245
CV (%)	1.02	0.96	12.09	25.95	52.30	24.30	7.31	4.98	1.77	25.39
P6×P3										
Mean	37.00	79.00	86.50	4.33	6.30	219.30	5.03	13.50	2.61	4.16
Range	36-38	78-80	83-90	2-7	3-9	97-317	4.7-5.30	12.0-17.0	2.55-2.65	2.16-5.40
SE	0.083	0.083	0.345	0.255	0.399	12.035	0.038	0.279	0.006	0.194
CV (%)	1.23	0.58	2.18	32.26	34.66	30.06	4.11	11.30	1.18	25.50
P6×P5										
Mean	38.00	81.00	80.57	5.50	5.40	139.10	5.36	14.84	2.48	3.84
Range	38-38	81-81	72-85	5-6	2-12	118-204	3.9-6.5	13.0-23.0	2.44-2.64	2.73-5.97
SE	0.000	0.000	0.851	0.093	0.577	4.617	0.150	0.531	0.011	0.173
CV (%)	0.00	0.00	5.78	9.25	58.48	18.18	15.33	19.61	2.39	24.66
P6×P10										
Mean	39.00	85.00	79.47	3.60	3.17	116.87	4.53	15.35	2.53	2.67
Range	39-39	85-85	72-87	2-5	0-11	78-167	3.9-5.4	13.5-17.0	2.47-2.59	1.80-3.98
SE	0.000	0.000	0.803	0.149	0.576	5.485	0.086	0.205	0.004	0.101
CV (%)	0.00	0.00	5.54	22.60	59.55	25.71	10.34	7.30	0.82	20.72

Cont'd

Crosses (F_2)	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
P6×P11										
Mean	37.00	81.00	88.97	5.90	6.77	168.73	4.97	12.61	2.68	4.36
Range	37-37	81-81	75-105	2-11	2-13	73-320	4.1-6.40	8.2-19.0	2.58-2.79	2.20-6.46
SE	0.000	0.000	1.579	0.388	0.699	13.866	0.128	0.548	0.011	0.294
CV (%)	0.00	0.00	9.72	35.98	56.60	45.01	14.09	23.79	2.17	36.93
P6×P12										
Mean	37.00	78.00	74.90	3.20	1.37	85.67	5.01	14.42	2.45	2.17
Range	37-37	78-78	62-85	2-4	0-3	59-131	4.12-6.47	12.0-18.25	2.38-2.48	1.82-2.62
SE	0.000	0.000	1.164	0.139	0.217	4.036	0.110	0.323	0.006	0.040
CV (%)	0.00	0.00	8.51	23.79	86.97	25.81	12.06	12.28	1.44	10.04
P7×P2										
Mean	37.00	81.10	90.13	4.60	4.70	152.53	5.06	17.03	2.71	4.83
Range	37-37	81-82	58-103	4-6	3-8	110-186	4.5-6.1	13.5-19.0	2.61-2.75	3.12-6.43
SE	0.000	0.056	2.560	0.123	0.250	5.560	0.094	0.288	0.009	0.208
CV (%)	0.00	0.38	15.56	14.67	29.11	19.97	10.21	9.26	1.85	23.53
P7×P3										
Mean	38.00	84.00	95.83	4.37	5.53	170.40	5.14	14.47	2.52	4.44
Range	38-38	84-84	74-122	3-6	2-14	110-347	3.7-6.13	9.1-18.0	2.42-2.75	2.25-6.35
SE	0.000	0.000	2.299	0.176	0.573	10.583	0.183	0.487	0.022	0.235
CV (%)	0.00	0.00	13.14	22.08	56.70	34.02	19.49	18.46	4.71	29.00
P7×P5										
Mean	37.00	81.00	75.67	4.20	2.87	103.30	5.09	14.60	2.41	3.50
Range	37-37	81-81	60-83	2-7	1-4	63-132	4.6-5.4	13.0-17.0	2.35-2.57	2.80-4.90
SE	0.000	0.000	1.282	0.260	0.184	4.277	0.048	0.230	0.012	0.114
CV (%)	0.00	0.00	9.28	33.90	35.16	22.68	5.18	8.61	2.75	17.76

Cont'd

Crosses (F_2)	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
P7×P6										
Mean	36.00	80.00	79.10	3.43	2.17	99.07	5.25	14.77	2.58	3.59
Range	36-36	78-81	65-91	3-5	0-5	64-137	4.5-5.9	13.0-17.0	2.57-2.65	2.47-5.90
SE	0.000	0.235	1.364	0.124	0.304	4.106	0.084	0.253	0.004	0.167
CV (%)	0.00	1.61	9.45	19.77	76.74	22.70	8.74	9.40	0.79	25.50
P7×P10										
Mean	38.77	83.17	90.07	4.87	6.23	193.83	5.21	15.27	2.53	4.66
Range	38-40	82-84	77-110	2-6	1-11	144-327	4.1-5.60	13.0-16.5	2.47-2.91	2.56-8.10
SE	0.133	0.167	1.715	0.238	0.613	9.474	0.083	0.203	0.017	0.283
CV (%)	1.88	1.10	10.43	26.84	53.90	26.77	8.76	7.27	3.72	33.29
P7×P11										
Mean	39.00	83.97	99.07	5.47	4.47	196.53	5.74	16.67	2.84	6.79
Range	39-39	83-84	84-107	4-7	0-8	105-280	5.15-6.2	13.0-20.0	2.75-2.99	5.25-7.90
SE	0.000	0.033	1.123	0.142	0.351	10.038	0.066	0.356	0.015	0.136
CV (%)	0.00	0.22	6.21	14.20	43.10	27.98	6.28	11.70	2.96	10.95
P7×P12										
Mean	39.00	84.00	84.63	4.33	3.57	142.93	5.38	16.57	2.60	4.20
Range	39-39	84-84	77-100	2-8	0-7	82-197	4.2-5.9	14.0-19.5	2.39-2.71	2.34-6.60
SE	0.000	0.000	1.090	0.297	0.423	7.406	0.103	0.255	0.019	0.208
CV (%)	0.00	0.00	7.05	37.52	64.90	28.38	10.51	8.44	4.01	27.16
P10×P11										
Mean	38.20	82.00	81.23	3.50	4.60	124.80	5.08	14.37	2.57	3.81
Range	38-39	82-82	75-100	3-5	3-7	111-155	4.2-5.50	12.9-15.1	2.48-2.67	2.56-5.11
SE	0.074	0.000	0.963	0.125	0.163	2.315	0.067	0.136	0.007	0.133
CV (%)	1.07	0.000	6.50	19.49	19.44	10.16	7.25	5.17	1.54	19.10

Cont'd

Crosses (F_2)	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
P10×P12										
Mean	37.20	81.20	65.10	4.13	5.53	129.20	4.66	14.11	2.61	4.19
Range	37-38	81-82	58-75	3-5	0-14	73-172	3.5-6.1	11.2-17.0	2.40-2.88	2.74-6.10
SE	0.074	0.074	0.981	0.142	0.667	5.817	0.162	0.339	0.026	0.236
CV (%)	1.09	0.50	8.25	18.78	66.06	24.66	19.08	13.16	5.46	30.80
P11×P12										
Mean	40.00	84.00	78.57	4.93	8.60	190.47	4.93	13.86	3.03	6.16
Range	40-40	84-84	70-87	4-8	4-13	167-218	3.9-5.50	11.2-16.0	2.79-3.10	4.67-8.70
SE	0.000	0.000	1.018	0.230	0.471	3.710	0.105	0.252	0.016	0.225
CV (%)	0.00	0.00	7.10	25.49	30.01	10.67	11.73	9.94	2.94	19.97
Real Tory 7										
Mean	30	79	67.23	3.667	5.9	94	4.40	14.86	2.22	2.69
Range	28-32	78-80	45-81	2-9	2-11	40-137	3.9-5.2	12.5-19.5	1.9-2.54	1.46-4.7
SE	0.303	0.152	1.536	0.281	0.458	5.100	0.055	0.342	0.035	0.151
CV (%)	5.54	1.05	12.51	41.97	42.54	29.72	6.82	12.59	8.69	30.79
BARI-9										
Mean	33.57	86.23	87.17	4.9	6	157.4	4.78	12.83	2.62	4.32
Range	33-34	84-89	76-101	3-8	2-12	137-198	4.3-5.5	10.7-15.2	2.45-2.75	2.88-6.88
SE	0.092	0.233	1.339	0.211	0.439	2.935	0.081	0.308	0.012	0.211
CV (%)	1.50	1.48	8.41	23.58	40.11	10.21	9.32	13.15	2.61	26.74
BARI-15										
Mean	40.33	89.33	86.17	6.5	0	105.6	4.36	21.21	2.44	5.578
Range	40-41	88-91	8-107	5-10	-	67-188	4.1-4.65	19.2-22.2	2.15-2.9	3.13-9.58
SE	0.088	0.232	3.996	0.253	-	5.489	0.028	0.154	0.049	0.348
CV (%)	1.19	1.42	25.40	21.28	-	28.46	3.48	3.97	11.08	34.21
SAU-1										
Mean	39	83.67	105.9	7.833	8.833	215.87	4.98	11.75	3.09	6.46
Range	38-40	83-84	94-124	6-10	4-17	127-314	3.8-5.55	10-13.2	2.97-3.15	3.64-11.63
SE	0.152	0.088	1.412	0.220	0.599	11.377	0.088	0.188	0.010	0.411
CV (%)	2.13	0.57	7.31	15.39	37.1	28.87	9.72	8.78	1.74	34.81

Table 3. Estimation of some genetic parameters in respect of 27 F_2 materials of *Brassica rapa*

Parameter	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
Genotypic variance (σ^2g)	1.12	3.94	61.83	0.67	3.22	1094.20	0.14	1.45	0.04	1.04
Phenotypic variance (σ^2p)	1.27	4.26	66.86	0.79	3.59	1216.09	0.21	1.55	0.05	1.06
Environmental variance (σ^2e)	0.14	0.31	5.03	0.12	0.37	121.89	0.07	0.10	0.02	0.02
Heritability (h^2b)	88.86	92.62	92.48	84.47	89.65	89.98	67.10	93.54	65.03	98.02
Genetic advance (5%) GA (5%)	2.06	3.94	15.58	1.55	3.50	64.64	0.63	2.40	0.31	2.08
Genetic advance in percentage of mean (5%)	5.47	4.82	18.87	34.40	75.64	45.98	12.48	16.34	11.76	50.35
GCV	2.82	2.43	9.52	18.17	38.78	23.53	7.40	8.20	7.08	24.69
PCV	2.99	2.53	9.90	19.77	40.96	24.81	9.03	8.48	8.78	24.94
ECV	1.00	0.69	2.72	7.79	13.18	7.85	5.18	2.16	5.19	3.51

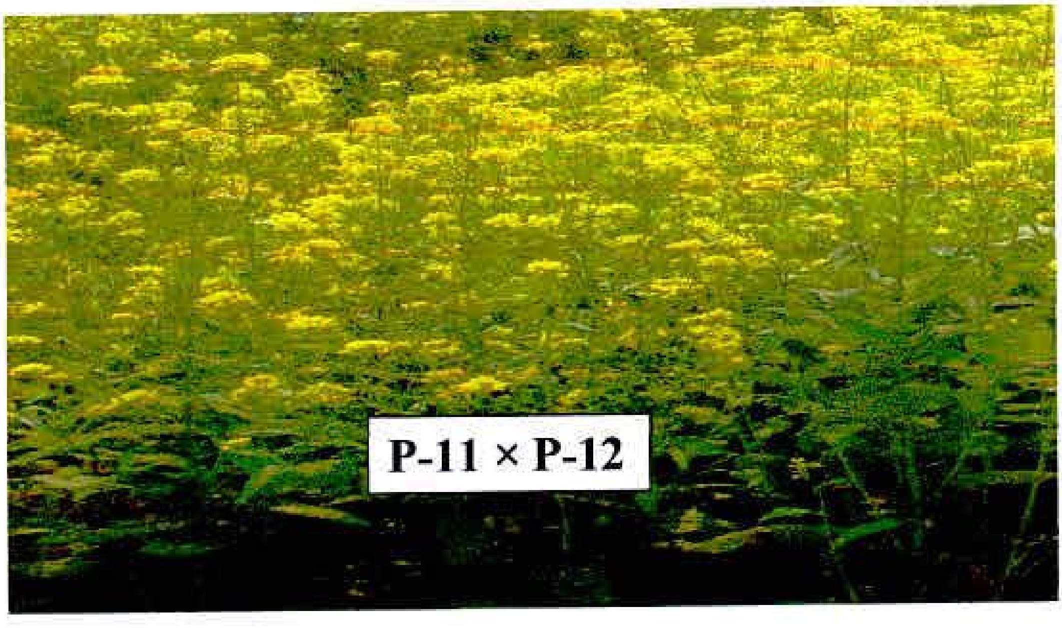

Plate 3. Photograph showing differences in flowering of F_2 materials of the cross P-7 × P-6 and P-11 × P-12 of *B. rapa* at SAU, 2009.

Genotypic and phenotypic variance of days to 50 % flowering was observed 1.12 and 1.27, respectively with moderate differences between them indicating that they were moderate responsive to environmental factors for their phenotypic expression and values of GCV and PCV were 2.82% and 2.99% , respectively which indicated moderate variability present among the genotypes (Table 3). Sharma (1984) found low GCV and PCV values among 46 genotypes of *B. juncea*. Singh *et al.* (1991) found significant genetic variability in days to 50% flowering in *Brassica rapa*.

Days to 80% maturity

The minimum days to 80% maturity was observed in P-5 × P-3 (77.90 days) and the highest days to maturity was observed in P-2 × P-11 and P-6 × P-10 (85.00 days) (Table 2). The days to 80% maturity of check varieties was observed in 79.00 days in Real Tori-7, 86.23 days in BARI-9, and 89.33 days in BARI-15 and83.67 days in SAU-1. Cross P-5 × P-3 showed short maturity period than all the check varieties and most of the F_2 populations required more time to mature than Real Tori-7 but most of the populations required less time than BARI-15, BARI-9 and SAU-1 (Table 2). Plate 5 and Plate 6 showed the variations in the maturity period of F_2 progenies of P-5 × P-3 and P-6 × P-10. Phenotypic and genotypic variance for days to maturity was observed 4.26 and 3.94, 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 (2.53 %) was higher than the genotypic coefficient of variation (2.43 %) (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.

Plate 4. Photographs showing variation in maturity of F_2 progenies of the crosses P-5 × P-3 of *B. rapa* at SAU, 2009.

Plate 5. Photographs showing variation in maturity of F_2 progenies of the crosses P-6 × P-10 of *B. rapa* at SAU, 2009.

Plant height (cm)

The highest plant height was observed in P-7 × P-11 (99.07 cm) where as the minimum plant height was observed in P-10 × P-12 (65.10 cm). Plant height of four check varieties was 67.23 cm in Real Tori-7 and 86.17 cm in BARI-15 which was less than all the 27 F_2 populations (Table 2). The phenotypic variance and genotypic variance of plant height showed were observed 22.36 and 3.124, respectively with relatively large differences between them indicating large environmental influences on these character as well as PCV (4.227 %) and GCV (1.580 %) 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 27 F_2 populations the highest number of primary branches/plant was observed in P-5 × P-3 (6.17) where as the minimum number of primary branches/plant was observed in P-6 × P-12 (3.12). No. of primary branches per plant observed in four check varieties were 3.67 in Real Tori-7 and 6.50 in BARI-15, 7.83 in SAU-1 and 4.9 in BARI-9. Most of the crosses produced more primary branches per plant than Real Tori-7 and BARI-9 but less than BARI-15 and SAU-1 (Table 2). Number of primary branches per plant showed little differences between phenotypic variance (0.79) and genotypic variance (0.67) indicating low environmental influence on these character and relatively high difference between PCV (19.77 %) and GCV (18.77 %) 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 (8.6) in P-11 × P-12 where as the minimum number of primary branches/plant was observed in P-6 × P-1 (1.37) (Table 2). In case of check varieties the number of secondary branches/plant was observed 8.83 in SAU-1, 6.00 in BARI-9, 5.90 in Real Tori-7 and 0.00 in BARI-15. All the 27 F_2 populations produced less number of primary branches/plant than SAU-1 but most of the crosses produced more secondary branches/plant than BARI-9, Real Tori-7 and BARI-15 (Table 2). Number of secondary branches per plant showed low difference between phenotypic variance (3.59) and genotypic variance (3.22) indicating little environmental influence on this character. The value of PCV (40.96 %) and GCV (38.78 %) indicating that the environment have significant role on the expression of this particular trait (Table 3). Lekh *et al.* (1998) reported similar result.

Number of siliquae per plant

The number of siliquae/plant was observed highest in P-6 × P-3 (219.30) followed by P-7 × P-11 (196.53) whereas the minimum number of siliquae/plant was observed in P-6 × P-12 (85.67). Number of siliquae/plant in four check varieties were 215.87 in SAU-1, 157.40 in BARI-9, 105.60 in BARI-15 and 94.00 in Real Tori-7 which was less than the cross P-6 × P-3 (219.30). Besides most of the F_2 population produced more siliqua/plant than check varieties but less than SAU-1 (Table 2). Number of siliquae/plant showed highest phenotypic variance (1216.09) and genotypic variance (1094.20) with large environmental influence and the difference between the PCV (24.81 %) and GCV (23.53 %) indicating existence of adequate variation among the genotypes (Table 3). Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Ushakumari *et al.* 1991)

Length of siliqua (cm)

Length of siliqua was observed highest in P-7 × P-11 (5.74cm) followed by P-5 × P-2 (5.62 cm) whereas the minimum length of siliqua was observed in P-3 × P-10 (4.15cm). Length of siliqua was observed 4.98 cm in SAU-1, 4.78 in BARI-9, 4.40 cm in Real Tori-7 and 4.36 in BARI-15 which was less than most of the crosses (Table 2). Length of siliqua showed phenotypic (0.21) and genotypic variance (0.14) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively medium PCV (9.03 %) and GCV (7.40 %) indicating that the genotype has moderate variation for this trait (Table 3). Labowitz (1989) studied *Brassica campestris* population for siliqua length and observed high genetic variation on this trait. Olson (1990) found high genetic variability for this trait.

Number of seeds per siliqua

The number of seeds per siliqua was observed highest in P-7 × P-2 (17.03). P-7 × P-11 (16.67) was found the second highest for number of seeds per siliqua whereas the minimum number of seeds/siliqua was observed in P-2 × P-10 (11.41). The no. of seeds per siliqua observed 21.21 in BARI-15, 14.86 in Real Tori-7, 12.83 in BARI-9 and 11.75 in SAU-1. Most of the crosses produced more seeds/siliqua than check varieties but less than BARI-15 (Table 2).The differences between phenotypic variances (1.55) and genotypic variances (1.45) were relatively low for number of seeds/siliqua indicating low environmental influence on these characters (Table 3). The value of PCV and GCV were 8.48 % and 8.20 %, respectively for number of seeds/siliqua 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 P-11 × P-12 (3.03 g) whereas the minimum was found in P-5 × P-12 (2.36 g). Thousand seed weight observed in four check varieties 3.09 in SAU-1, 2.62 in BARI-9, 2.44 g in

BARI-15 and 2.22 g in Real Tori-7 and which was more than most of the crosses but less than SAU-1 (Table 2). Thousand seed weight showed very low genotypic (0.04) and phenotypic (0.05) variance with minimum differences indicating that they were less responsive to environmental factors and the values of GCV and PCV were 7.08 % and 8.78 % 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*.

Seed 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/plant was observed in P-7 × P-11 (6.79 g) followed by P-11 × P-12 (6.16) whereas the minimum yield per plant was observed in P-6 × P-12 (2.17g).The yield per plant of four check varieties were 6.46 in SAU-1, 5.58 in BARI-15, 4.32 in BARI-9 and 2.69 g in Real Tori-7 where as P-7 × P-11 (6.79 g) crosse produced higher yield per plant than four check varieties and most of the crosses produced more yield/plant than check varieties but less than SAU-1 (Table 2). The phenotypic variance (1.06) appeared to be moderately higher than the genotypic variance (1.04), suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (24.94 %) was higher than the genotypic co-efficient of variation (24.69 %) which suggested that environment has a significant role on the on the expression of this trait (Table. 3). Sharma *et al*. (1994) reported high variability for this trait in different genotypes of *Brassica rapa*.

4.1.2 Heritability, genetic advance and selection.

Days to 50% flowering exhibited high heritability (88.86%) with reasonable genetic advance (2.06) and genetic advance in percentage of mean (5.47%) which revealed possibility of predominance of additive gene action in the inheritance of this character (Table 3). For this, the characters could be improved through selection process. This results support the reports of Malik *et al.* (1995).

Days to maturity exhibited high heritability (92.62%) with medium genetic advance (3.94) and genetic advance in percentage of mean (4.82%) revealed medium possibility of selecting genotypes that would mature earlier (Table 3). In some of the crosses the frequency of the segregating plants showing reduced maturity was comparatively higher than the other crosses.

Plant height showed high heritability (92.48%) with genetic advance 15.58 and genetic advance in percentage of mean (18.87%) revealed possibility of predominance of additive gene action in the inheritance of thus trait (Table 3). 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 (84.47%) with low genetic advance (1.55) and genetic advance in percentage of mean (34.40%) (Table 3). 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.

Number of secondary branches per plant showed high heritability (89.65%) with genetic advance (3.50) and genetic advance in percentage of mean (75.64%) revealed the possibility of predominance of both additive and non additive gene action in the inheritance of this character, for this limit scope of crop improvement by direct selection (Table 3). Katiyar *et al.* (1974) reported low heritability for this trait.

Number of siliquae per plant exhibited high heritability (89.98%) with genetic advance 64.64 and genetic advance in percentage of mean (45.98%) (Table 3). These results revealed the possibility of predominance of additive gene action in the inheritance of this trait. This trait possessed high variation; it is high potential for effective selection for further genetic improvement of this character. This result supports the report of Paul *et al.* (1976).

Length of siliqua showed 67.10% heritability with 0.63 genetic advance and genetic advance in percentage of mean 12.48% (Table 3).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 siliqua showed 93.54% heritability coupled with moderate genetic advance (2.40) and genetic advance in percentage of mean 16.34% (Table 3). Malik *et al.* (1995) reported high heritability (h^2_b> 90%) for this trait.

Thousand seed weight exhibited 65.03% heritability with genetic advance of 0.31 and genetic advance in percentage of mean 11.76% (Table 3) which revealed that this trait is governed by non additive genes. 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 plant showed high heritability of 98.02% with genetic advance of 2.08 and genetic advance in percentage of mean 50.35 (Table 3). 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 four check varieties SAU-1, BARI-9, Real Tori-7 and BARI-15. As per objectives, selection was carried out among the 27 F_2 materials of different cross combinations. Thirty three most promising plants with short duration and higher yield/plant were selected from the F_2 materials (Table 4). There were large variations in the thirty three selected F_2 materials for siliquae/plant ranging from 127 to 327 siliquae. One plant from P-11 x P-12 produced 3.10 g of thousand seed weight. Two plants from P-3 x P-2 which produced exceptionally high yield/plant was 10.12 g and 10.10 g respectively (Table 4).

Table 4. Performance of selected short duration and higher yield plants from the F_2 materials of different cross combinations of *Brassica rapa*

Cross combinations	Plant no.	Siliquae/ plant	1000 seed weight (g)	Yield/ plant (g)
P-1 x P-10	5 (R1)	260	2.50	6.10
	8(R3)	264	2.52	6.20
P-2 x P-11	3 (R3)	150	2.70	4.68
P-2 x P-12	8 (R1)	167	2.57	7.82
P-3 x P-2	10 (R2)	270	2.97	10.12
	6 (R1)	267	2.90	10.10
P-3x P-10	11 (R1)	185	2.85	4.90
P-3 x P-11	6 (R2)	180	2.67	5.10
P-3 x P-12	9 (R1)	205	2.35	4.11
P-5 x P-2	9 (R1)	169	2.80	5.61
P-5 x P-3	7 (R1)	160	2.75	5.57
P-5 x P-10	4 (R1)	127	2.70	6.90
P-5 x P-12	8 (R2)	150	2.35	3.32
P-6 x P-2	10 (R2)	232	2.80	7.21
	6 (R3)	210	2.70	6.50
P-6 x P-3	17 (R1)	212	2.60	5.40
P-6 x P-5	18 (R1)	190	2.50	5.97
P-6 x P-10	5 (R1)	140	2.55	3.84
P-6 x P-11	15 (R3)	278	2.54	6.46
P-6 x P-12	9 (R1)	131	2.45	2.62
P-7 x P-2	7 (R2)	186	2.65	6.43
P-7 x P-3	4 (R1)	268	2.30	6.35
P-7 x P-5	11(R1)	132	2.40	4.90
P-7 x P-6	6 (R3)	137	2.60	5.90
P-7 x P-10	10 (R2)	327	2.90	8.10
P-7 x P-11	12(R1)	280	2.85	7.90
	10 (R2)	270	2.75	7.50
	7 (R2)	245	2.80	7.10
P-7 x P-12	10 (R2)	197	2.50	6.60
P-10 x P-11	9(R2)	155	2.45	5.11
P-10 x P-12	10 (R1)	172	2.50	6.10
P-11 x P-12	6 (R2)	218	3.10	8.70
	5(R3)	198	2.90	7.10
Total no. of plant =	33	-	-	-
Range	-	127-327	2.30-3.10	2.62- 10.12

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 5.

Days to 50% flowering

Days to 50% flowering showed highly positive significant interaction with days to maturity (G = 0.808, P= 0.789) and yield per plant (G = 0.387) followed by positive interactions with plant height (G = 0.113, P = 0.099), number of secondary branches per plant (G = 0.240, P = 0.239), siliqua per plant (G = 0.369, P = 0.354), length of siliqua (G = 0.044, P = 0.016), seeds per siliqua (G = 0.210, P = 0.188) and thousand seed weight (G = 0.289, P = 0.252) (Table 5). Whereas negative interactions were found in number of primary branches per plant (G = -0.010, P = -0.012). These findings are more similar to the reports of Chowdhary *et al.* (1987) and Mahmud (2008).

Days to maturity

Days to maturity showed positive interaction with plant height (G = 0.176, P = 0.164), number of secondary branches per plant (G = 0.097, P = 0.097), siliquae per plant (G = 0.261, P = 0.257), length of siliqua (G = -0.090, P = 0.073), seeds per siliqua (G = 0.371, P = 0.351), thousand seed weight (G= 0.166, P = 0.165) and yield per plant (G = 0.298, P = 0.295). Whereas negative interactions were found in number of primary branches per plant (G = -0.147, P= -0.151) (Table 5.).

Table 5. Genotypic and phenotypic correlation co-efficients among different characters of the 27 F_2 materials of *Brassica rapa*

Parameters		Days to 80% maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliqua /plant	Length of Siliqua (cm)	Seeds /Siliqua	1000 seed weight (g)	Yield/plant (g)
Days to 50% flowering	r_g	0.808**	0.113	-0.010	0.240	0.369	0.044	0.210	0.289	0.387*
	r_p	0.789**	0.099	-0.012	0.239	0.354	0.016	0.188	0.252	0.376
Days to 80% maturity	r_g	–	0.176	-0.147	0.097	0.261	0.090	0.371	0.166	0.298
	r_p	–	0.164	-0.151	0.097	0.257	0.073	0.351	0.165	0.295
Plant height	r_g		–	0.495**	0.179	0.472*	0.527**	0.366	0.270	0.415*
	r_p		–	0.483*	0.189	0.478*	0.468*	0.354	0.25	0.419*
No. of primary branches/plant	r_g			–	0.676**	0.483*	0.111	-0.176	0.463*	0.619**
	r_p			–	0.647**	0.469*	0.102	-0.161	0.403*	0.599**
No. of secondary branches/plant	r_g				–	0.735**	-0.170	-0.405*	0.363	0.560**
	r_p				–	0.735**	-0.166	-0.390*	0.32	0.558**
No. of siliqua /plant	r_g					–	0.153	-0.060	0.269	0.659**
	r_p					–	0.125	-0.061	0.242	0.656**
Length of Siliqua	r_g						–	0.344	0.032	0.405*
	r_p						–	0.349	0.025	0.361
Seeds /siliqua	r_g							-	0.146	0.124
	r_p							-	0.125	0.118
Thousand seed weight	r_g								-	0.599**
	r_p								-	0.551**

** Significant at the 1% level of probability
* Significant at the 5% level of probability

Plant height (cm)

Plant height showed highly positive significant interaction with number of primary branches per plant (G = 0.495, P = 0.483), siliquae per plant (G = 0.472, P = 0.478), length of siliqua (G = 0.527, P = 0.468), and yield per plant (G = 0.415, P = 0.419) followed by positive interaction with number of secondary branches per plant (G = 0.179, P = 0.189), seeds per siliqua (G = 0.366, P = 0.354) and thousand seed weight (G = 0.270, P = 0.250) (Table 5). 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 highly positive significant interaction with number of secondary branches per plant (G = 0.676, P = 0.647), siliquae per plant (G = 0.483, P = 0.469), thousand seed weight (G = 0.463, P = 0.403) and yield per plant (G = 0.619, P = 0.599) followed by positive interaction with length of siliqua (G = 0.111, P = 0.102). Whereas the negative interaction was found in seeds per siliqua (G = -0.176, P = -0.161) (Table 5). 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).

Number of secondary branches per plant

Number of secondary branches per plant showed highly positive significant interaction with siliqua per plant (G = 0.735, P = 0.735) and yield per plant (G = 0.560, P = 0.558) followed by positive interaction with thousand seed weight (G = 0.363, P = 0.320) (Table 5) whereas the negative significant interaction was found in seeds per siliqua (G = -0.405, P = -0.390), followed by negetive interaction with length of siliqua (G =- 0.170, P =- 0.166). Present findings were supported by Rashid (2007) and Siddikee (2006). Vershney *et al.* (1986) found negative correlation which does not supported present findings.

Number of siliquae per plant

Siliquae per plant showed highly positive significant interaction with yield per plant (G = 0.659, P = 0.656) followed by positive interaction with length of siliqua (G = 0.153, P = 0.125) and thousand seed weight (G = 0.269, P = 0.242) (Table 5) whereas the negative interaction was found in seeds per siliqua (G = -0.060, P = -0.061). 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 plant (G = 0.405) followed by positive interaction with seeds per siliqua (G = 0.344, P = 0.349), thousand seed weight (G = 0.032, P = 0.025) and yield per plant (P = 0.361) (Table 5). Das *et al.* (1998) reported that seed yield per plant positively correlated with length of siliqua and seeds per siliqua.

Seeds per siliquae

Seeds per siliqua showed t positive interaction with thousand seed weight (G = 0.146, P = 0.125) and yield per plant (G = 0.124, P = 0.118) (Table 5). 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 plant (G = 0.599, P = 0.551) (Table 5). 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 maturity, plant height, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, length of siliqua, number of seeds per siliqua and thousand seed weight were causal (independent) variables. Estimation of direct and indirect effect of path co-efficient analysis for *Brassica rapa* is presented in Table 6.

The cause and effect relationship between seed yield per plant and yield contributing traits have been presented diagrammatically in Figure 1. 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:

Table 6. Path coefficient analysis showing direct and indirect effect of yield components on seed yield in 27 F_2 materials of *Brassica rapa*

Character	DF	DM	PH	NPB	NSB	NSP	SL	NSPS	TSW	Genotypic correlation with SYPP
DF	**-0.045**	0.194	-0.049	-0.005	-0.020	0.179	0.019	0.020	0.094	0.3866*
DM	-0.036	**0.240**	-0.077	-0.075	-0.008	0.127	0.039	0.035	0.054	0.2984
PH	-0.005	0.042	**-0.436**	0.253	-0.015	0.229	0.225	0.034	0.088	0.4154*
NPB	0.000	-0.035	-0.216	**0.511**	-0.057	0.234	0.047	-0.017	0.151	0.6191**
NSB	-0.011	0.023	-0.078	0.345	**-0.084**	0.357	-0.072	-0.038	0.118	0.5604**
NSP	-0.017	0.063	-0.206	0.246	-0.062	**0.486**	0.065	-0.006	0.088	0.6585**
SL	-0.002	0.022	-0.230	0.057	0.014	0.074	**0.427**	0.032	0.010	0.4047*
SS	-0.009	0.089	-0.159	-0.090	0.034	-0.029	0.147	**0.094**	0.048	0.1240
TSW	-0.013	0.040	-0.118	0.236	-0.030	0.131	0.014	0.014	**0.326**	0.5991**

Bold values are direct effect

Residual effect (R) = 0.398

DF = Days to 50% flowering, DM = Days to 80% maturity, PH = Plant height (cm), PB =No. of primary branches/plant, SB = No. of secondary branches/plant, NSP = No. of siliquae per plant, SL = Length of siliqua (cm), NSPS = No. of seeds per siliqua, TSW = 1000 seed weight (g) and SYPP = Seed yield per plant (g)

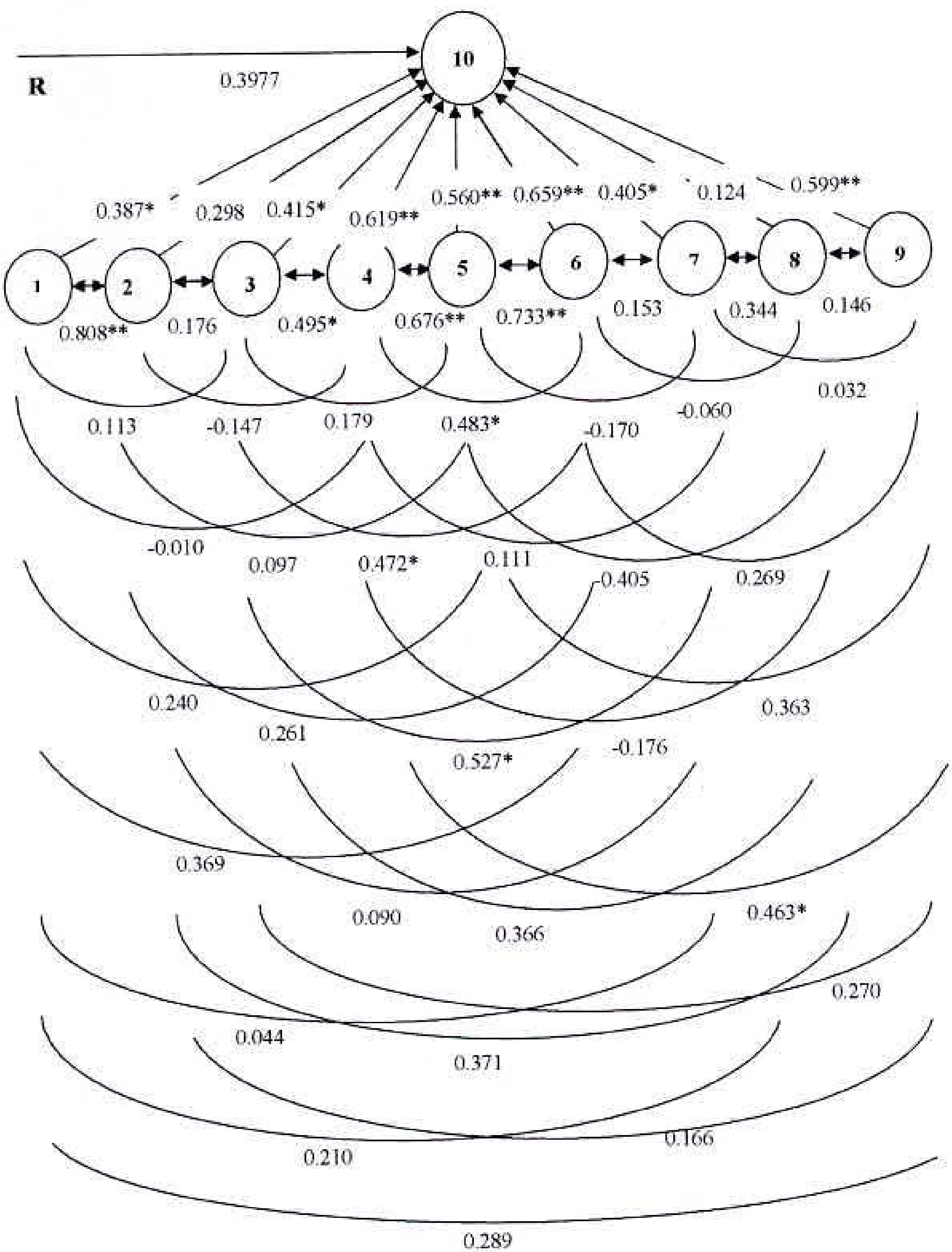

Fig. 1. Path diagram of yield contributing traits in 27 F_2 materials of *Brassica rapa*

1=Days to 1st flowering, 2=Days to maturity, 3=Plant height, 4=Number of primary branch, 5=Number of secondary branch, 6=siliquae per plant, 7= siliqua length, 8=seed per siliqua, 9=thousand seed weignt and 10= yield per plant
R= residual effect

Path co-efficient analysis revealed that days to 50% flowering had negetive direct effect (-0.045) on yield per plant (Table 6). Days to flowering had positive indirect effect on days to maturity 0.194), number of siliquae per plant (0.179), length of siliqua (0.019), seeds/siliqua (0.020) and thousand seed weight (0.094). And it showed negative indirect effect on plant height (-0.049), number of primary branches per plant (-0.005), and number of secondary branches per plant (-0.020). By path analysis, Zahan (2006) reported that, days to 50% flowering had negative direct effect on yield/plant.

Days to maturity had positive direct effect (0.240) on yield per plant and negative indirect effect through days to flowering (-0.036) , plant height (-0.077), number of primary branches per plant (-0.075), number of secondary branches per plant (- 0.008) (Table 6). On the other hand days to maturity had positive indirect effect via number of siliquae per plant (0.127), length of siliqua (0.039), seeds per siliqua (0.035) and thousand seed weight (0.054). Yadava (1982) revealed that days to maturity had positive direct effect on yield.

Plant height had negetive direct effect (-0.436) on yield per plant followed by negative indirect effect on days to flowering (-0.005), number of secondary branches per plant (- 0.015) (Table 6). Positive indirect effect through days to maturity (0.042), number of primary branches per plant (0.253), number of siliqua per plant (0.229) , length of siliqua (0.225), seeds per siliqua (0.034) and thousand seed weight (0.088). Mishra *et al.* (1987) and Shivahare *et al.* (1975) were found similar result.

Number of primary branches per plant had the highest positive direct effect on yield per plant (0.511). This trait had positive indirect effect on number of siliqua per plant (0.234), length of siliqua (0.04) and thousand seed weight (0.151). On the other hand negative indirect effect was found on days to maturity (-0.035), plant height (-0.216), number of secondary branches per plant (- 0.057) and seeds per siliqua (-0.017) (Table 6). Gupta *et al.* (1987) observed that primary branching and thousand seed weight had the direct effect on seed yield.

Number of secondary branches per plant had negetive direct effect (-0.084) on yield per plant and positive indirect effect on days to maturity (0.023), number of primary branches per plant (0.345), number of siliquae per plant (0.357) and thousand seed weight (0.118) (Table 6). On the other hand this trait showed negative indirect effect on days to flowering (- 0.017), plant height (-0.078), length of siliqua (-0.072) and seeds per siliqua (- 0.038).

Path co-efficient analysis revealed that, number of siliqua per plant had the positive direct effect (0.486) on seed yield followed by positive indirect effect on days to maturity (0.03), number of primary branches per plant (0.246), length of siliqua (0.065) and thousand seed weight (0.088) (Table 6). And this trait had negative indirect effect on days to flowering (-0.017), plant height (-0.206), number of secondary branches per plant (-0.062) and seeds per siliqua (-0.006). 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 (0.427) on yield per plant (Table 6). This trait had also indirect positive effect on days to maturity (0.022), number of primary branches per plant (0.057), number of secondary branches per plant (0.014), number of siliqua per plant (0.074), seeds per siliqua (0.032) and thousand seed weight (0.010). On the other hand length of siliqua showed indirect negative effect on days to flowering (-0.002), and plant height (-0.230). Chaudhury *et al.* (1978) reported that siliqua length had highest positive direct effect on seed yield.

Seeds per siliqua had positive direct effect (0.094) on yield per plant and positive indirect effect on days to maturity (0.089), number of secondary branches per plant (0.034), siliqua length (0.147) and thousand seed weight (0.048). On the other hand this trait showed negative indirect effect on days to flowering (-0.009), plant height (- 0.159), number of primary branches per plant (-0.090) and number of siliqua per plant (-0.029) (Table 6). 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 positive direct effect on yield per plant (0.326) and positive indirect effect on days to maturity (0.040), number of primary branches per plant (0.236), siliqua per plant (0.131), length of siliqua (0.014) and number of seeds per siliqua (0.014) (Table 6). On the other hand this trait showed negative indirect effect on days to 50% flowering (-0.013), plant height (- 0.118), number of secondary branches per plant (-0.030). Kudla (1993) reported that 1000 seed weight had positive direct effect on seed yield.

The residual effect (R) was 0.398, which indicated the characters under study contributed 60.20% of the seed yield per plant (Table 6). It thus meant that there were some other traits those contributed 39.8% to the seed yield per plant which are not included in the present study might be exert significant effect on seed yield.

Chapter 5
Summary and Conclusion

CHAPTER -V

SUMMARY AND CONCLUSION

An experiment was conducted during November, 2008 to March 2009, at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University using 27 F_2 progenies of *Brassica rapa* and four check varieties. The experiment was carried out to study variability, heritability, genetic advance and genetic advance in percentage of mean and direct and indirect effect of different traits on yield. All 27 F_2 progenies varied significantly with each other for all the characters studied. The results of the present study are summarized as follows:

From variability analysis, it was observed that significant variation exist among all the genotypes used for most of the characters studied. Days to 50% flowering exhibited highest in P-11 × P-12 and lowest in P-3 × P-12, P-5 × P-2, P-5 × P-3, and P-7 × P-6. The highest days to maturity was observed in both P-2 × P-11 and P-6 × P-10 and lowest were observed in P-5 × P-3. The plant height showed highest in P-7 × P-11 and lowest in P-10 × P-11. The highest number of primary branches per plant was recorded in P-5 × P-3 and lowest in P-6 × P-12. The number of secondary branches per plant showed highest in P-11 × P-12 and lowest in P-6 × P-12. The number of siliquae per plant showed highest in P-6 × P-3 and lowest in P-6 × P-12. The lowest length of siliqua was recorded in P-3 × P-10 and the highest in P-7 × P-11. The number of seeds per siliqua was found highest in P-7 × P-2 and lowest in P-2 × P-10. The thousand seed weight exhibited highest in P-11 × P-12 and lowest in P-5 × P-12. The seed yield per plant was observed highest in P-7 × P-11 and lowest in P-6 × P-12.

In the 27 F_2 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 materials days to maturity, plant height, number of siliquae per plant showed moderate differences between genotypic and phenotypic variance. Days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, length of siliquae, 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, yield per plant and number of siliquae per plant showed moderate genotypic and phenotypic co-efficient of variation. Plant height and number of siliquae 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 80% 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 27 F_2 materials of *Brassica rapa* for most promising plants with high yield and a short duration. The performance of the crosses also compared with four check varieties. Based on the variability and as per the objectives 33 most promising plants with short duration and higher yield were selected from the F_2 materials.

Correlation revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, 1000 seed weight both genotypic and phenotypic level. A significant genotypic positive correlation also observed for days to50 % flowering and length of siliqua.

Path co-efficient analysis revealed that days to 80% maturity, number of primary branches per plant, number of siliquae 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 and high yielding variety can be developed from the selected lines.

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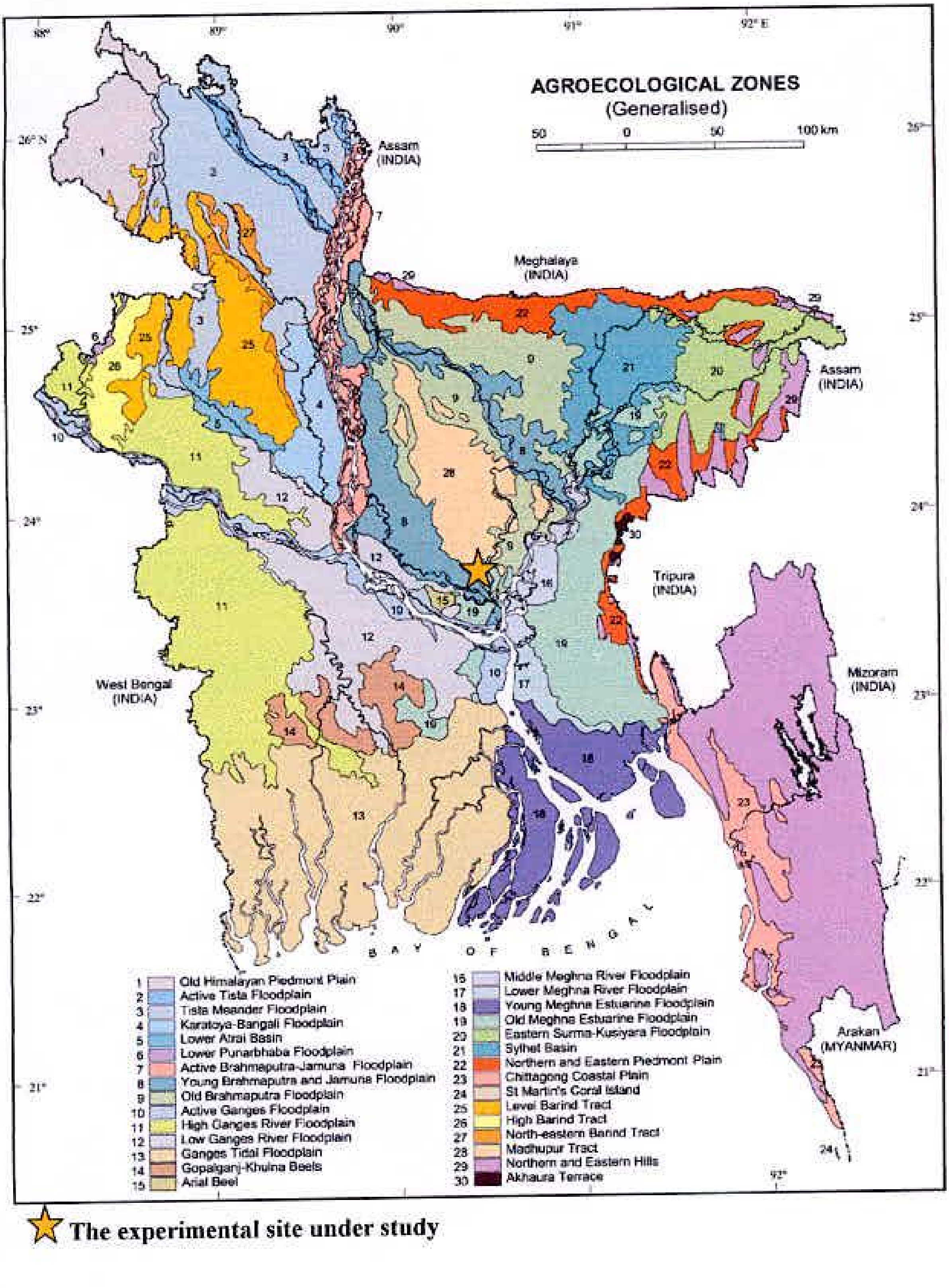
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



☆ The experimental site under study

Appendix II. Analysis of variances of 10 important characters of 27 F_2 materials of *Brassica rapa*

Source of variation	Degrees of freedom	Days to 50% flowering	Days to 80% maturity	Plant height (cm)	No. of primary branches /plant	No. of secondary branches /plant	No. of siliquae /plant	Length of siliqua (cm)	No. of seeds /siliqua	1000 seed wt. (g)	Yield /plant (g)
Replication	2	0.132	0.484	5.269	0.139	0.252	198.930	0.003	0.114	0.031	0.027
Genotypes	26	3.514**	12.142**	190.506**	2.130**	10.035**	3404.497**	0.484**	4.441**	0.125**	3.143**
Error	52	0.141	0.314	5.030	0.123	0.372	121.886	0.068	0.100	0.019	0.021

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

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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

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

Appendix IV. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from October, 2008 to April, 2009

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.