VARIABILITY STUDY IN F_2 PROGENIES OF *Brassica rapa*

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REGISTRATION NO. 03-01105

A Thesis
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

SEMESTER: JULY-DECEMBER, 2008

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CERTIFICATE

This is to certify that thesis entitled, **"VARIABILITY STUDY IN F_2 PROGENIES 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. SALAH UDDIN**, Registration No. 03-01105 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, 2008
Place: Dhaka, Bangladesh

(Dr. Md. Shahidur Rashid Bhuiyan)
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Dedicated

to

My Beloved Parents

SOME COMMONLY USED ABBREVIATIONS AND SYMBOLS

Abbreviations	Full word
%	Percent
°C	Degree Celsius
@	At the rate
σ^2_p	Phenotypic variance
σ^2_e	Environmental variance
σ^2_g	Genotypic variance
h^2_b	Heritability in broad sense
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
BINA	Bangladesh Institute of Nuclear Agriculture
BSMRAU	Bangabundhu Sheikh Mujibur Rahaman Agricultural University
CEC	Cation Exchange Capacity
cm	Centi-meter
CV%	Percentage of Coefficient of Variation
cv.	Cultivar (s)
DAS	Days After Sowing
df	Degrees of Freedom
et al.	And others
etc.	Etcetera
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 fourth generation of a cross between two dissimilar homozygous parents
FAO	Food and Agricultural Organization
g	Gram (s)
G	Genotype
GA	Genetic advance
GCV	Genotypic Coefficient of Variation
GN.	Genotype Number
HI	Harvest Index
hr.	Hour (s)
IARI	Indian Agricultural Research Institute
ICARDA	International Centre for Agricultural Research in Dry Areas
j.	Journal
kg	kilogram (s)
m	Meter

Abbreviations	Full word
MoP	Muriate of Potash
m^2	Square meter
MOA	Ministry of Agriculture
MSG	Mean square of the genotypes
MSE	Mean square of the error
NARS	National Agricultural Research System
No.	Number
NPB/P	Number of primary branches per plant
NSB/P	Number of secondary branches per plant
NS	Not Significant
NSP	Number of siliquae per plant
PCV	Phenotypic Coefficient of Variation
PH	Plant height
ppm	Parts Per Million
R	Residual effect
RCBD	Randomized Complete Block Design
Rep.	Replication
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SE	Standard Error
SL	Siliqua length
S/S	Seeds per siliqua
t/ha	Tons per hectare
T.S.P.	Triple Super Phosphate
Univ.	University
var.	Variety
Via	By way of
Viz	Namely
WP	Wetable Powder
YPP	Yield per plant

ACKNOWLEDGEMENT

All the praises and gratitude are due to the omniscient, omnipresent and omnipotent Almighty Allah, who has kindly enabled the author to complete his research work and complete this thesis successfully for increasing knowledge and wisdom.

The author sincerely desires to express his deepest sense of gratitude, respect, profound appreciation and indebtedness to his research supervisor, Dr. Md. Shahidur Rashid Bhuiyan, Professor, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for his kind and scholastic guidance, untiring effort, valuable suggestions, inspiration, co-operation and constructive criticisms throughout the entire period of the research work and the preparation of the manuscript of this thesis.

The author expresses heartfelt gratitude and indebtedness to his Co-supervisor, Dr. Firoz Mahmud Associate-Professor & Chairman, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for his co-operation, criticisms on the manuscript and helpful suggestions for the successful completion of the research work.

Heartiest thanks to Professor Mohammad Hossain Bhuiyan, Co-ordinator (CASR) for providing necessary facilities and conductive atmosphere to accomplish his research work. Special thanks and indebtedness are also due to all the respective teachers of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, sympathetic co-operation and inspiration throughout the period of the study.

The author thankfully remembers the students of the Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for their cooperation in the entire period of study. The author also expends his thanks to all the staff of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for their help and co-operation during the research work also likes to give thanks to all of his friends for their support and inspiration throughout his study period in SAU, Dhaka.

The author also likes to give thanks to all of his friends for their support and inspiration throughout his study period in SAU, Dhaka. Special thanks to Abdullah vi, Kabir, Nayan, Laxmi, Borhan, Shazahan, Rasel, Musha, Tareque, Zakaria, Parvez and Nadim for their cordial support, co-operation and inspiration in preparing this thesis.

Finally, the author found no words to thank his parents and his younger brothers for their unquantifiable love and continuous support, their sacrifice, never ending affection, immense strength and untiring efforts for bringing his dream to proper shape. They were constant source of inspiration, zeal and enthusiasm in the critical moment of his studies.

Dated: December, 2008 The author

Place: SAU, Dhaka.

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VARIABILITY STUDY IN F_2 PROGENIES OF *Brassica rapa*

ABSTRACT

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The experiment was conducted with seven parental genotypes and their twenty one F_2 progenies of *Brassica rapa* at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during November, 2007 to March, 2008 to study the variability, correlation among different characters and direct and indirect effect of different characters on seed yield per plant. The phenotypic variances were higher than the genotypic variances. Least genotypic and phenotypic variance was observed among all the parental genotypes and their F_2 progenies for all the characters studied except for siliquae per plant. The high GCV value was observed for secondary branches per plant. The number of secondary branches per plant was also showed high heritability with high genetic advance in percent of mean. Based on the variability and as per our objectives nineteen most promising yellow seeded and thirty six most promising brown seeded plant with short duration were selected from the F_2 progenies. Seed yield per plant had significant positive association with number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant. Path co-efficient analysis revealed that days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, siliqua length, seeds per siliqua and thousand seed weight had the positive direct effect on seed yield per plant. And days to maturity and plant height had the negative direct effect on yield per plant.

Chapter I

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). 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 – rapeseed, mustard and cole. The rapeseed groups includes the diploid *Brassica rapa*, turnip rape (AA, 2n=20) and amphidiploid *Brassica napus* L, rape (AACC, 2n=38) while the mustard groups include species like *Brassica juncea* Czern and Coss; *Brassica nigra* Koch and *Brassica carinata* Braun (Yarnell, 1956). The genomic constitutions of the three elemental species of *Brassica* are as follows; "AA" for *Brassica campestris*, "BB" for *Brassica nigra* and "CC" for *Brassica oleracea* having diploid chromosome number 20, 16 and 18 respectively. The species *Brassica juncea* (AABB, 2n=36) *Brassica carinata* (BBCC, 2n=34) and *Brassica napus* (AACC, 2n=38) are the amphidiploid and originated by combination of the diploid elemental species. All these species have many cultivated varieties suited to different Agro-climatic conditions. In the oleiferous *Brassica* group in respect of different morphological characters, a considerable variation of genetic nature exists among different species and varieties within each species (Malik *et al*. 1995; Nanda *et al*. 1995; Kakroo and Kumar, 1991).

Brassica 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).

According to FAO (2005) the oil yielding crop *Brassica* hold the second position in the world oil seed production. In Bangladesh rapeseed and mustard are the major source of edible oil and more than 183 thousand metric ton of rape and mustard produced from total 216.92 thousand hectares of cultivable land in the year 2005-2006 (BBS, 2006). Its average yield per hectare was only 733 kg in Bangladesh compared to the world average of 1575 kg (FAO, 2005).

Bangladesh is in deficit of 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 rainfed conditions, pressure of other crops and the primitive crop husbandry method. Moreover, area of oilseed 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 *Brassica 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 of *B. rapa* is available to replace the existing Tori-7.

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. The improved variety also should well fit into T. Aman-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 progenies have been generated through different inter varietal crosses of *Brassica rapa* and the present study was conducted with the following objectives.

Objectives:

- To select short duration and high yielding genotype from the F_2 segregating progenies,
- To evaluate the performances of individual plants of the different crosses and
- To determine the nature of association, direct and indirect relationship between yield and yield contributing characters and their relative contribution towards seed yield in *Brassica rapa.*

Chapter II

Review of literature

CHAPTER II
REVIEW OF LITERATURE

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

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

2.2 Correlation among different characters

2.3 Path co-efficient analysis

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

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

A field experiment was conducted by Jahan (2008) to study on inter-genotypic variability and genetic diversity in ten F_4 lines obtained through intervarietal crosses along with eight 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 effective. 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 controlled by additive gene 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.

A study was conducted by Hosen (2008) using five parental genotypes of *Brassica rapa* and their ten F3 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.

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 viz. *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 eight 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 ten 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.

Pant and Singh (2001) studied genetic variability for nine traits in 25 genotypes. 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 ten 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%).

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

An experiment was conducted by Shalini *et al.* (2000) to study variability in *Brassica juncea* L. Different genetic parameters was estimated to assess the magnitude of genetic variation in 81 diverse Indian mustard genotypes. The analysis of variance indicated the prevalence of sufficient genetic variation among the genotypes for all ten 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), 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).

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

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

Diwakar and Singh (1993) studied heritability and genetic advance in segregating populations of yellow seeded Indian mustard (*Brassica juncea* L. Czern and Coss.). They used data on yield and five component traits in eight 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 Swede 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 eight 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*.

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 (1997) 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 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 F2 (or F_3) generation has been recommended to minimize the expected losses of transgrassive or productive segregates 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 F2 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.

Niraj and Srivastava (2004) conducted an experiment 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 jumea L.* Czern and Coss) for 10 characters in 24 strains of Indian mustard along with two 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 three 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 eight 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 seven 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 eight 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 eight 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 seven of *B. juncea,* two of *B. carinata* cultivars and one 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 eight 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 III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental site

The present experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during November, 2007 to March, 2008. The location of the experimental site was situated at **23^0 74'** N latitude and **90^0 35'** E longitude with an elevation of 8.6 meter from the sea level.

3.2 Climate and soil

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 II).

3.3 Plant materials

A total number of 28 materials were used in this experiment where seven were parents and remaining twenty one were F_2 segregating generations (Table 1). All the materials were collected from Department of Genetics and Pant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh.

Table 1: Materials used for the experiment

Sl. No.	Symbols	Descriptions
01	P_1	Agroni
02	P_2	Sofol
03	P_3	BARI Sar-6
04	P_4	BINA Sar-6
05	P_5	SS-75
06	P_6	Tori-7
07	P_7	BARI Sar-9
08	C_1	Agroni (P1) × Sofol (P2)
09	C_2	Agroni (P1) × BARI sar-6 (P3)
10	C_3	Agroni (P1) × BINA sar-6 (P4)
11	C_4	Agroni (P1) × SS-75 (P5)
12	C_5	Agroni (P1) × Tori-7 (P6)
13	C_6	Agroni (P1) × BARI sar-9 (P7)
14	C_7	Sofol (P2) × BARI sar-6 (P3)
15	C_8	Sofol (P2) × BINA sar-6 (P4)
16	C_9	Sofol (P2) × SS-75 (P5)
17	C_{10}	Sofol (P2) × Tori-7 (P6)
18	C_{11}	Sofol (P2) × BARI sar-9 (P7)
19	C_{12}	BARI sar-6 (P3) × BINA sar-6 (P4)
20	C_{13}	BARI sar-6 (P3) × SS-75 (P5)
21	C_{14}	BARI sar-6 (P3) × Tori-7 (P6)
22	C_{15}	BARI sar-6 (P3) × BARI sar-9 (P7)
23	C_{16}	BINA sar-6 (P4) × SS-75 (P5)
24	C_{17}	BINA sar-6 (P4) × Tori-7 (P6)
25	C_{18}	BINA sar-6 (P4) × BARI sar-9 (P7)
26	C_{19}	SS-75 (P5) × Tori-7 (P6)
27	C_{20}	SS-75 (P5) × BARI sar-9 (P7)
28	C_{21}	Tori-7 (P6) × BARI sar-9 (P7)

NB: BARI – Bangladesh Agricultural Research Institute

BINA – Bangladesh Institute of Nuclear Agriculture

SS – Sonali Sarisha

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), 150 kg Gypsum, 3 kg Zinc oxide and Boron 1 kg per hectare. The half amount of urea, total amount of Cowdung, TSP, MoP, Gypsum, Zinc Oxide and Boron was applied during final land preparation. The rest amount of urea was applied as top dressing after 25 days of sowing.

3.4.3 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experiment was 55m × 13m = 715 m^2. Each replication size was 55 m × 3 m, and the distance between replication to replication was 1 m. The spacing between row to row was 30 cm. Each parent was sown in five rows and each F_2 material was in six rows. Seeds were sown on 12 November, 2007. 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. To bring proper moisture condition of the soil one post sowing irrigation was given with cane after sowing of seeds 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 17th to 25th February, 2007 depending upon the maturity. When 80% of the plants of each entry 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 50 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 Collection of data

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

3.4.7 Methods of data collection

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

II. **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.

III. **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.

IV. **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.

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

VI. **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.

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

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

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

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

3.4.8 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). Genotypic and phenotypic correlation obtained using the formula suggested by 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, $\delta^2g = \frac{MSG - MSE}{r}$

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

Where, δ^2g = Genotypic variance,

δ^2e = Environmental variance = Mean square of error

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

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

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

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

Where, GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δ_g = Genotypic standard deviation

δ_p = Phenotypic standard deviation

$\overline{x}$ = Population mean

iii) Estimation of heritability:

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

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

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

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

iv) Estimation of genetic advance:

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

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

Where, GA = Genetic advance

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

δ_p = Phenotypic standard deviation

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

v) Estimation of genetic advance in percentage of mean:

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

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

vi) Estimation of simple correlation co-efficient:

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

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

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 genotypic 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 IV
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted with a view to determine the variability among seven parents and twenty one F_2 progenies 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 parents

Days to 50% flowering

Among the seven parents the lowest days to flowering was observed in BARI sar-9 (29.00 days) followed by Tori-7 (32 days). While the highest days to flowering was observed in Agrani (42.67 days) and Sofol (42.00 days) (Table 2). The phenotypic and genotypic variances for this trait were 26.36 and 19.97 respectively with minimum differences between them. The phenotypic variances appeared to be higher than the genotypic variance, suggested considerable influence of environment on the expression of the genes controlling this trait (Table 3).

Days to maturity

The lowest days to maturity was taken by BARI sar-9 (83.00 days) followed by Tori-7 (85 days). The varieties SS-75 and BARI sar-6 required 88.33 days and 89.33 days. Both the varieties Agrani and Sofol showed the maturity period of 90.33 days. The highest days to maturity was taken by BINA sar-6 (90.67 days) (Table 2). The phenotypic and genotypic variance for days to maturity was observed 8.46 and 6.35 respectively (Table 3). Although the variety BINA sar-6 produced higher yield per plant, due to longest maturity period it is not popular to the farmers. On the other hand, lower yielding Tori-7 is more acceptable to the farmers due to its short duration. It can fit well in the T. Aman-Mustard-Boro cropping pattern.

Table 2: Mean, range and CV (%) of seed yield and yield related characters of seven parents of *Brassica rapa*

Parents	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	Thousand seed weight (g)	Seed yield per plant (g)
Agrani										
Mean	42.67	90.33	126.50	7.67	0.73	123.07	4.22	19.64	2.64	6.02
Range	39-46	89-92	94-158	4-14	0-7	46-218	3.11- 4.88	2.32-28.60	1.0-3.9	1.58-16.33
CV%	4.83	0.99	8.05	26.35	149.66	28.22	7.63	25.37	15.58	37.08
Sofol										
Mean	42.00	90.33	144.10	10.67	0.47	165.37	3.43	19.90	2.82	6.36
Range	41-43	90-91	129-157	6-15	0.0-4	86-285	2.75- 4.47	13.90-27.30	1.0-1.5	1.69-11.65
CV%	1.40	0.38	3.96	17.87	176.76	26.63	7.37	12.45	73.03	28.13
BARI sar-6										
Mean	34.33	89.33	129.07	9.00	9.50	205.27	3.70	15.09	2.60	7.40
Range	34-35	88-90	98-197	3-19	0-29	28-553	2.82- 4.43	7.30-22.50	1.1-4.3	0.40-20.82
CV%	0.99	0.76	12.14	30.95	59.89	46.94	7.90	20.43	24.39	53.33
BINA sar-6										
Mean	38.00	90.67	131.10	8.20	1.90	142.13	3.69	19.19	2.63	7.21
Range	32-41	90-91	107-158	4-15	0-14	62-283	2.58-5.09	2.21-31.90	1.1-4.4	1.56-15.97
CV%	8.03	0.37	6.24	24.54	128.68	24.54	11.10	23.03	22.36	35.79
SS-75										
Mean	36.00	88.33	132.43	7.73	3.90	192.69	3.96	15.06	2.70	6.24
Range	35-37	86-90	110-161	4-12	0-20	57-385	3.31-5.07	4.40-31.60	0.9-3.8	1.70-10.60
CV%	1.63	1.38	5.96	19.65	88.36	28.58	8.37	23.41	31.30	30.83
Tori-7										
Mean	32.00	85.00	122.67	9.73	8.13	208.00	4.20	15.44	2.4	5.94
Range	31-33	83-87	93-147	5-17	0-20	32-397	3.37-5.28	6.50-21.20	1.0-4.3	1.94-13.05
CV%	6.92	1.75	8.36	19.45	47.00	29.91	7.65	18.90	21.00	34.37
BARI sar-9										
Mean	29.00	83.00	104.80	7.60	10.85	257.05	3.94	17.52	2.4	8.98
Range	29-29	82-84	80-135	5-12	6-19	97-639	3.12-5.22	11.90-22.70	0.9-4.3	3.04-21.87
CV%	0.00	0.87	8.37	19.66	27.43	38.99	10.34	11.00	25.71	32.54

Table 3: Estimates of genetic parameters for ten characters of seven parents of *Brassica rapa*

Parameters	Days to 50% flowering	Days to 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)	Seed yield / plant (g)
Genotypic variance	19.97	6.35	129.24	0.88	18.7	1656.56	0.07	3.59	0.0003	1.05
Phenotypic variance	26.36	8.46	168.75	2.47	19.52	2818.01	0.12	6.1	0.073	1.3
Heritability	75.75	75.05	76.59	35.76	95.79	58.78	56.53	58.88	0.45	80.72
Genetic Advance (5%)	8.01	4.5	20.5	1.16	8.72	64.28	0.4	3.0	0.003	1.89
Genetic Advance (5%) in % mean	21.8	5.07	16.11	13.37	171.99	34.76	10.29	17.31	0.1	26.86
Genotypic co-efficient of variation / GCV (%)	12.16	2.84	8.93	10.86	85.31	22.01	6.64	10.95	0.7	14.51
Phenotypic co-efficient of variation / PCV (%)	13.97	3.28	10.21	18.16	87.16	28.71	8.83	14.27	10.43	16.15
Environmental co-efficient of variation / ECV (%)	6.88	1.64	4.94	14.55	17.89	18.43	5.82	9.15	10.41	7.09

Plant height (cm):

The highest plant height was observed in Sofol (144.10 cm) where as the lowest plant height was observed in BARI sar-9 (104.80 cm). The plant height of Tori-7, Agrani, BARI sar-6, BINA sar-6 and SS-75 was observed 122.67 cm, 126.50 cm, 129.07 cm, 131.10 cm and 132.43 cm respectively (Table 2). Plant height showed phenotypic variance (168.75) and genotypic variance (129.24) with relatively high differences between them indicating large environmental influences on this trait (Table 3).

Number of primary branches per plant:

Among the seven parents highest number of primary branches/plant was observed in Sofol (10.67) where as the lowest number of primary branches/plant was observed in BARI sar-9 (7.60). The number of primary branches/plant in Tori-7, BARI sar-6, BINA sar-6, SS-75 and Agrani was observed 9.73, 9.00, 8.20, 7.73 and 7.67 respectively (Table 2). Number of primary branches per plant showed moderate differences between phenotypic variance (2.47) and genotypic variance (0.88) indicating low environmental influence on this character (Table 3).

Number of secondary branches per plant:

The highest number of secondary branches/plant was observed in BARI sar-9 (10.85) where as the lowest number of primary branches/plant was observed in Sofol (0.47). Number of secondary branches/plant in BARI sar-6, Tori-7, SS-75, BINA sar-6 and Agrani was 9.50, 8.13, 3.90, 1.90 and 0.73 (Table 2). Number of secondary branches showed low difference between phenotypic variance (19.52) and genotypic variance (18.70) indicating low environmental influence on this trait (Table 3).

Number of siliquae per plant:

In the present experiment the highest variation was found for this trait. The highest number of siliquae/plant was observed in BARI sar-9 (257.05) where as the lowest number of siliquae/plant was observed in Agrani (123.07). The number of siliquae/plant of Tori-7, BARI sar-6, SS-75, Sofol and BINA sar-6 were 208.00, 205.27, 192.69, 165.37 and 142.13 respectively (Table 2). The highest phenotypic variance (2818.01) and genotypic variance (1656.56) was observed for number of siliquae per plant with large environmental influence (Table 3).

Length of siliqua (cm):

The highest siliqua length was observed in Agrani (4.22 cm) where as the lowest siliqua length was observed in Sofol (3.43 cm) but maximum variation was also observed in BARI sar-9 (3.12-5.22 cm). The siliqua length of Tori-7, SS-75, BARI sar-9, BARI sar-6 and BINA sar-6 were 4.20 cm, 3.96 cm, 3.94 cm, 3.70 cm and 3.69 cm respectively (Table 2). Length of siliqua showed phenotypic variance (0.12) and genotypic variance (0.07) with very minimum difference between them indicating that they were less responsive to environmental factors for their phenotypic expression (Table 3).

Number of seeds per siliqua:

The highest number of seeds per siliqua was observed in Sofol (19.90) so close with Agrani (19.64) and BINA sar-6 (19.19) where as the minimum number of seeds per siliqua was observed in SS-75 (15.06) (Table 2). The phenotypic variances and genotypic variances for this trait were observed 6.10 and 3.59 respectively (Table 3).

Thousand seed weight (g):

Thousand seed weight was found maximum in Sofol (2.82 g) where as the minimum thousand seed weight was found in Tori-7 (2.40 g) and BARI sar-9 (2.40 g). The parent SS-75, Agrani, BINA sar-6 and BARI sar-6 were 2.70 g, 2.64 g, 2.63 g and 2.60 g respectively (Table 2). The phenotypic and genotypic variances for this trait were (0.073) and (0.0003) respectively (Table 3).

Seed yield per plant (g):

The highest seed yield per plant was observed in BARI sar-9 (8.98 g) followed by BARI sar-6 (7.40 g) and BINA sar-6 (7.21 g) where as the minimum yield per plant was observed in Tori-7 (5.94 g) (Table 2). The phenotypic variance and genotypic variance were 1.30 and 1.05 respectively (Table 3).

4.1.2 Variability among the 21 F_2 progenies of *Brassica rapa*

Wide range of variations were observed for most of the characters in 21 F_2 progenies of *Brassica rapa.* Table 4 and Table 5 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

Among the 21 F_2 progenies the lowest days to flowering was taken by Tori-7 × BARI sar-9 (30.00 days) where as the highest days to flowering was taken by both the cross Agrani × Sofol and Agrani × BINA sar-6 (42.33 days) (Table 4). The variations between F_2 progenies and their parents of Tori-7 × BARI sar-9 (Plate 1), Sofol × BARI sar-9 (Plate 2) and BARI sar-9 × BINA sar-6 (Plate 3) had been showed. The phenotypic and genotypic variances for this trait were (15.67) and (5.84) respectively. The phenotypic variances appeared to be much higher than the genotypic variance, suggesting that there is high influence of environment on the expression of the genes controlling this trait. The difference between phenotypic co-efficient of variation (11.30 %) and genotypic co-efficient of variation (6.90 %) was minimum (Table 5). Lekh *et al.* (1998) reported highest GCV and PCV for days to 50% flowering. Singh *et al.* (1991), found significant genetic variability in days to 50% flowering in *Brassica rapa.*

Days to maturity

The minimum days to maturity was observed in Tori-7 × BARI sar-9 (86.50 days) followed by BARI sar-6 × BARI sar-9 (89.85 days). And the highest days to maturity was observed in BINA sar-6 × SS-75 (92.11days) (Table 4). Plate 4 showed the variations in the maturity period of F_2 progenies of Agrani x SS-75 and Sofol x BARI sar-9. Phenotypic and genotypic variance for days to maturity was observed 1.36 and 0.17 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 (1.29 %) was higher than the genotypic coefficient of variation (0.45 %) (Table 5). 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.

Table 4: Mean, range and CV (%) of seed yield and yield related characters of 21 F_2 progenies of *Brassica rapa*

Crosses (F2)	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield /plant (g)
Agrani x Sofol										
Mean	40.33	90.86	128.95	6.65	1.30	136.25	3.55	19.56	2.90	5.38
Range	38-43	88-95	98-163	2-14	0-29	80-527.0	2.58-4.54	8.1-32.7	1.5-4.3	0.42-15.33
CV%	3.61	1.64	7.31	21.91	233.66	44.85	7.36	15.66	12.29	36.92
Agrani x BARI sar-6										
Mean	31.50	91.92	125.37	7.08	3.98	219.85	3.92	17.23	2.71	7.40
Range	31-32	88-95	96-198	2-15	0-18	64-530	2.82-6.36	8.70-9.20	1.4-5.0	1.58-17.63
CV%	0.92	1.28	8.10	23.56	69.19	28.86	10.83	17.18	19.45	30.01
Agrani x BINA sar-6										
Mean	40.33	90.89	132.31	6.81	1.24	144.10	3.71	21.53	3.39	6.67
Range	39-41	88-94	98-168	3-19	0-17	36-480	2.35-5.31	5.0-32.4	1.0-6.3	1.44-10.80
CV%	1.66	1.21	6.87	29.45	166.7	42.93	9.01	18.20	20.29	32.32
Agrani x SS-75										
Mean	38.67	90.60	136.63	6.49	1.53	118.16	3.78	20.65	3.68	5.88
Range	37-42	87-93	94-190	2-15	0-29	21-449	2.58-4.31	9.2-41.3	1.5-5.5	1.33-18.45
CV%	4.32	1.27	7.37	25.97	182.02	44.45	375.04	21.12	15.51	39.27
Agrani x Tori-7										
Mean	35.00	90.50	122.19	5.97	2.94	167.07	3.68	16.85	3.46	6.12
Range	34-36	87-94	96-191	2-12	0-24	21-706	2.45-5.51	7.4-50.2	1.2-5.7	0.74-19.97
CV%	1.66	1.44	8.99	22.11	87.99	37.64	11.65	22.10	13.36	39.29
Agrani x BARI sar-9										
Mean	32.33	91.36	125.74	6.94	6.97	190.97	3.78	14.98	3.50	7.29
Range	32-33	87-95	89-198	2-15	0-29	56-510	2.30-6.50	6.3-27.2	1.3-5.6	0.76-31.27
CV%	1.03	1.48	11.79	27.89	69.07	34.90	14.30	23.05	14.68	38.81

Table 4: "Continued"

Crosses (F2)	Days to 50% flowering	Days to 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)	Seed yield / plant (g)
Sofol x BARI sar-6										
Mean	38.00	90.47	121.89	5.90	2.41	153.77	3.81	17.03	3.18	5.43
Range	29-47	82-95	87-170	2-14	0-16	32-527	2.36-6.09	6.20-34.0	0.7-5.7	1.14-23.37
CV%	13.72	2.93	9.47	27.55	99.31	38.08	13.31	24.85	17.56	39.29
Sofol x BINA sar-6										
Mean	38.33	92.47	132.90	7.43	1.93	162.71	3.70	20.16	3.07	6.58
Range	34-42	88-96	104-163	1-18	0-22	45-570	2.48-5.21	2.7-34.3	0.9-5.0	1.00-18.71
CV%	6.11	1.63	6.33	28.13	144.76	37.87	10.42	21.55	18.85	32.70
Sofol x SS-75										
Mean	37.33	91.47	122.23	6.65	4.70	197.41	3.74	18.79	2.83	8.10
Range	34-41	89-94	84-164	2-17	0-43	27-1159	2.41-5.92	7.8-44.9	0.9-5.1	1.38-31.00
CV%	5.45	1.13	8.10	29.98	114.51	57.10	11.52	25.11	26.51	51.80
Sofol x Tori-7										
Mean	31.50	90.30	118.16	5.94	4.60	179.89	3.63	16.12	3.05	5.74
Range	31-32	87-93	92-156	2-11	0-29	59-517	2.27-5.33	7.9-27.5	1.0-5.2	1.73-15.91
CV%	0.92	1.37	6.87	18.86	63.34	28.15	11.53	18.12	17.28	29.19
Sofol x BARI sar-9										
Mean	34.33	90.53	124.33	6.53	4.74	175.95	3.78	18.65	2.83	6.96
Range	32-37	87-93	98-157	2-14	0-24	32-475	2.49-5.06	2.03-33.5	0.8-5.2	1.16-19.55
CV%	4.25	1.34	7.30	26.29	79.66	34.37	9.92	19.22	18.39	36.59
BARI sar-6 x BINA sar-6										
Mean	36.33	90.97	132.70	5.41	0.73	134.25	3.93	19.59	3.03	6.32
Range	29-40	88-94	105-190	1-12	0-19	39-437	2.19-6.32	5.2-30.4	1.0-5.5	0.69-15.62
CV%	10.13	1.20	6.28	27.11	225.73	29.81	12.34	21.48	21.41	33.36

Table 4: "Continued"

Crosses (F2)	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield /plant (g)
BARI sar-6 x SS-75										
Mean	35.67	90.91	129.73	5.75	3.25	166.88	3.88	17.71	3.33	6.93
Range	32-38	85-94	43-221	0-13	0-31	27-765	2.24-5.64	7.3-33.5	0.9-7.6	1.02-35.67
CV%	5.22	1.86	9.98	27.54	112.00	40.85	10.70	19.57	17.93	46.17
BARI sar-6 x Tori-7										
Mean	34.67	90.47	125.01	6.50	3.86	185.63	3.84	16.05	3.14	6.46
Range	34-36	83-95	93-229	3-12	0-37	43-665	2.43-5.68	3.35-32.8	1.0-5.9	0.20-28.11
CV%	1.93	2.32	9.13	21.38	96.02	32.51	12.69	20.87	21.06	38.62
BARI sar-6 x BARI sar-9										
Mean	32.00	89.85	124.38	5.86	3.65	152.76	3.67	15.92	3.52	5.62
Range	31-33	86-92	26-160	2-15	0-27	30-481	2.23-5.56	3.7-27.9	1.8-9.4	0.72-21.66
CV%	1.81	1.46	8.64	29.13	85.33	32.17	13.17	21.05	19.05	39.06
BINA sar-6 x SS-75										
Mean	36.00	92.11	124.24	5.42	2.58	148.63	4.54	21.42	3.43	6.43
Range	35-38	90-95	91-161	0-16	0-14	24-470	2.93-5.97	9.1-158.6	0.4-5.7	1.33-19.32
CV%	2.79	1.14	9.09	28.13	98.81	43.01	11.03	40.13	17.27	37.17
BINA sar-6 x Tori-7										
Mean	34.00	90.46	122.76	6.61	5.41	182.25	4.42	14.65	3.12	6.42
Range	33-35	88-93	87-163	2-13	0-27	49-435	2.34-21.7	2.79-28.6	1.1-5.8	0.30-16.82
CV%	1.70	1.07	9.13	24.67	77.90	31.91	43.29	26.28	17.53	36.36
BINA sar-6 x BARI sar-9										
Mean	32.33	90.36	123.63	6.21	3.09	149.42	3.71	16.15	3.05	5.57
Range	30-35	87-93	90-158	3-14	0-18	32-381	2.44-6.01	3.35-31.4	1.3-5.9	0.20-13.60
CV%	4.51	1.40	7.84	21.74	84.76	28.85	12.56	19.95	17.58	33.03

Table 4: "Continued"

Crosses (F2)	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield / plant (g)
SS-75 x Tori-7										
Mean	32.00	89.87	104.61	5.50	4.46	127.49	4.04	18.21	2.53	5.09
Range	30-35	84-95	78-153	2-12	0-24	28-388	2.63-29.9	7.3-29.4	0.4-5.6	0.63-18.23
CV%	4.79	2.21	8.76	22.77	68.33	31.82	38.51	16.55	30.37	42.26
SS-75 x BARI sar-9										
Mean	35.00	90.80	129.38	7.00	4.66	182.49	3.80	16.32	2.83	6.83
Range	34-37	88-93	97-161	4-13	0-24	71-487	2.32-5.64	8.3-31.2	0.2-5.0	1.17-16.69
CV%	2.87	1.08	7.59	21.67	70.75	25.50	13.78	21.12	21.32	35.23
Tori-7 x BARI sar-9										
Mean	30.00	86.50	102.34	5.71	11.17	212.49	3.70	15.59	2.72	8.44
Range	29-31	85-88	76-137	2-11	0-41	67-639	2.31-6.07	5.5-32.0	1.2-5.2	0.75-31.12
CV%	1.93	1.99	8.33	20.63	45.20	33.60	11.26	19.26	15.40	45.09

Table 5: Estimation of genetic parameters for ten characters of 21 F_2 progenies of *Brassica rapa*

Parameters	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield /plant (g)
Genotypic variance	5.84	0.17	50.63	0.20	4.01	401.82	0.03	2.93	0.02	0.45
Phenotypic variance	15.67	1.36	103.67	0.65	7.21	1437.87	0.24	7.33	0.26	1.51
Heritability	37.30	12.31	48.84	29.89	55.6	27.95	11.13	39.93	7.42	30.03
Genetic Advance (5%)	3.04	0.30	10.24	0.50	3.07	21.83	0.11	2.23	0.08	0.76
Genetic Advance (5%) in % mean	8.68	0.33	8.24	7.90	80.24	13.14	2.9	12.53	2.49	11.71
Genotypic co-efficient of variation	6.9	0.45	5.73	7.02	52.24	12.07	4.22	9.62	4.43	10.38
Phenotypic co-efficient of variation	11.3	1.29	8.19	12.84	70.06	22.83	12.65	15.23	16.27	18.94
Environmental co-efficient of variation	8.95	1.2	5.86	10.75	46.69	19.38	11.92	11.81	15.66	15.84

Tori-7

BARI sar-9

Tori-7and BARI sar-9

Plate 1: Photograph showing differences in flowering of parents Tori-7 & BARI sar-9 and F_2 progenies of the cross Tori-7 x BARI sar-9

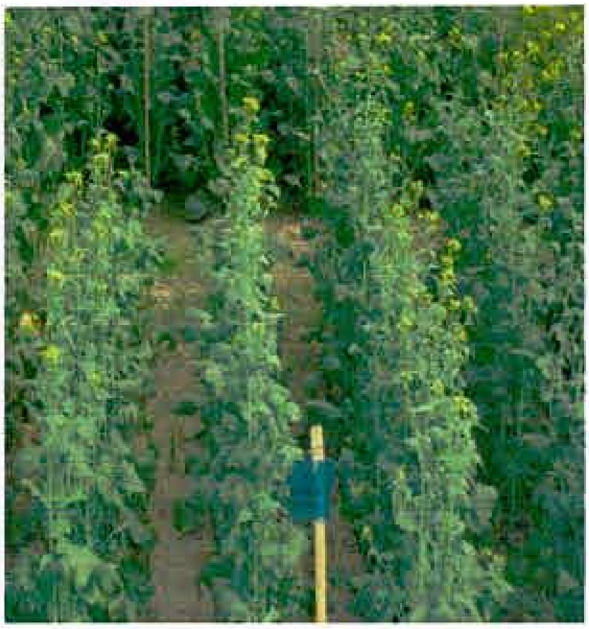
Sofol

BARI sar-9

Sofol x BARI sar-9

Plate 2: Photograph showing differences in flowering of parents Sofol & BARI sar-9 and F_2 progenies of the cross Sofol x BARI sar-9

BARI sar-6



BINA sar-6

BARI sar-6 x BINA sar-6

Plate 3: Photograph showing differences in flowering of parents BARI sar-6 and BINA sar-6 and F_2 progenies of the cross BARI sar-6 x BINA sar-6

Plate 4: The Photograph showing variation in the maturity period of F_2 progenies of the cross Agrani x SS-75

Plate 5: The Photograph showing variation in the maturity period of F_2 progenies of the cross Sofol x BARI sar-9

Plant height (cm):

The highest plant height was observed in Agrani × SS-75 (136.63 cm) where as the minimum plant height was observed in Tori-7 × BARI sar-9 (102.34 cm) (Table 4). Plant height showed The phenotypic variance and genotypic variance were observed 103.67 and 50.63 respectively with relatively high differences between them indicating large environmental influences on these character as well as PCV (8.19 %) and GCV (5.73 %) indicating presence of considerable variability among the genotypes (Table 5). Tyagi *et al.* (2001) observed highest variation in plant height among parent and their hybrid.

Number of primary branches per plant:

Among the 21 crosses the highest number of primary branches/plant was observed in Sofol × BINA sar-6 (7.43) followed by Agrani × BARI sar-6 (7.08) where as the minimum number of primary branches/plant was observed in BARI sar-6× BINA sar-6 (5.41) followed by BINA sar-6 × SS-75 (5.42) (Table 4). Number of primary branches per plant showed moderate differences between phenotypic variance (0.65) and genotypic variance (0.20) indicating moderate environmental influence on these character and relatively high difference between PCV (12.84 %) and GCV (7.02 %) value indicating the apparent variation not only due to genotypes but also due to the large influence of environment (Table 5). 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 in Tori-7 × BARI sar-9 (11.17) where as the minimum number of primary branches/plant was observed in BARI sar-6 × BINA sar-6 (0.73) (Table 4). Number of secondary branches showed moderate difference between phenotypic variance (7.21) and genotypic variance (4.01) indicating moderate environmental influence on this character. The value of PCV (70.06 %) and GCV (52.24 %) indicating that the environment have significant role on the expression of this particular trait (Table 5). Lekh *et al.* (1998) reported similar result.

Number of siliquae per plant:

The highest number of siliquae/plant was observed in Agrani × BARI sar-6 (219.85) followed by Tori-7 × BARI sar-9 (212.49). Higher variations for this trait in the F_2 progenies of Tori-7 × BARI sar-9 ranging 67-639 (Figure 1). Whereas the minimum number of siliquae/plant was observed in Agrani × SS-75 (118.16) (Table 4). Number of siliquae/plant showed highest phenotypic variance (1437.87) and genotypic variance (401.82) with large environmental influence and the difference between the PCV (22.83 %) and GCV (12.07 %) indicating existence of adequate variation among the genotype (Table 5). Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Ushakumari *et al.* 1991).

Length of siliqua (cm):

The highest siliqua length was observed in BINA sar-6 × SS-75 (4.54 cm) followed by BINA sar-6 × Tori-7 (4.42 cm) whereas the minimum length of siliqua was observed in Agrani × Sofol (3.55cm) (Table 4). Length of siliqua showed phenotypic (0.24) and genotypic variance (0.03) with very minimum difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively low PCV (12.65 %) and GCV (4.22 %) indicating that the genotype has less variation for this trait (Table 5). Labowitz (1989) studied *Brassica campestris* population for siliqua length and observed high genetic variation on this trait.

Number of seeds per siliqua:

The highest number of seeds per siliqua was observed in Agrani × BINA sar-6 (21.53). Variability for this trait in the F_2 progenies of Agrani × BINA sar-6 ranging 2.35 cm to 5.31 cm (Figure 2). BINA sar-6 × SS-75 (21.42) was found the second highest for number of seeds per siliqua where as the minimum number of seeds/siliqua was observed in BINA sar-6 × Tori-7 (14.65) (Table 4). The differences between phenotypic variances (7.33) and genotypic variances (2.93) was relatively high for number of seeds/siliqua indicating large environmental influence on these characters (Table 5). The value of PCV and GCV were 15.23 % and 9.62 % respectively for number of seeds/siliqua which indicating that significant variation exists among different genotypes. Bhardwaj and Singh (1969) observed 35.85 % GCV in *Brassica campestris*.

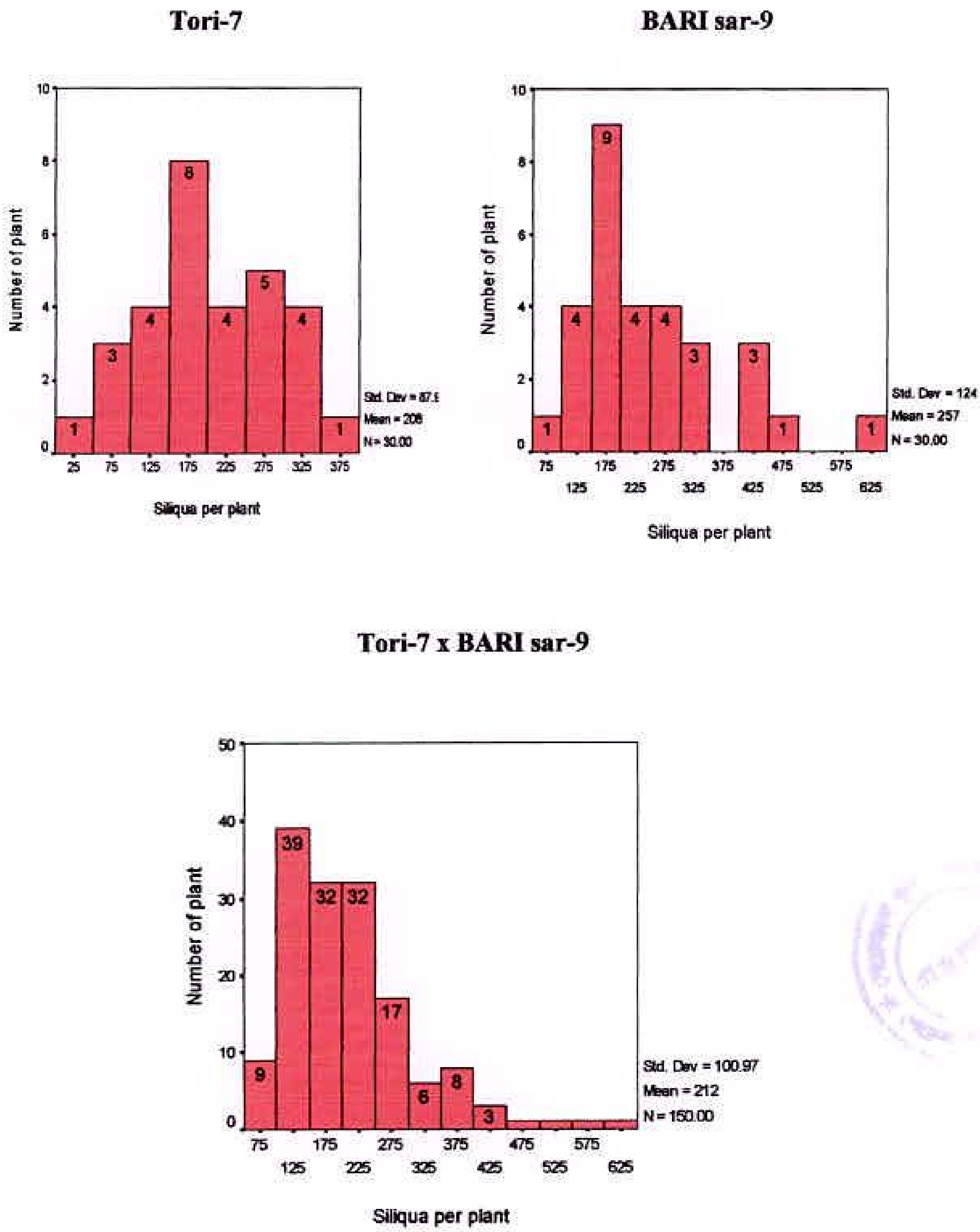


Figure 1: Frequency distribution of plants for number of siliquae per plant of parents and their F_2 progenies of Tori-7 x BARI sar-9

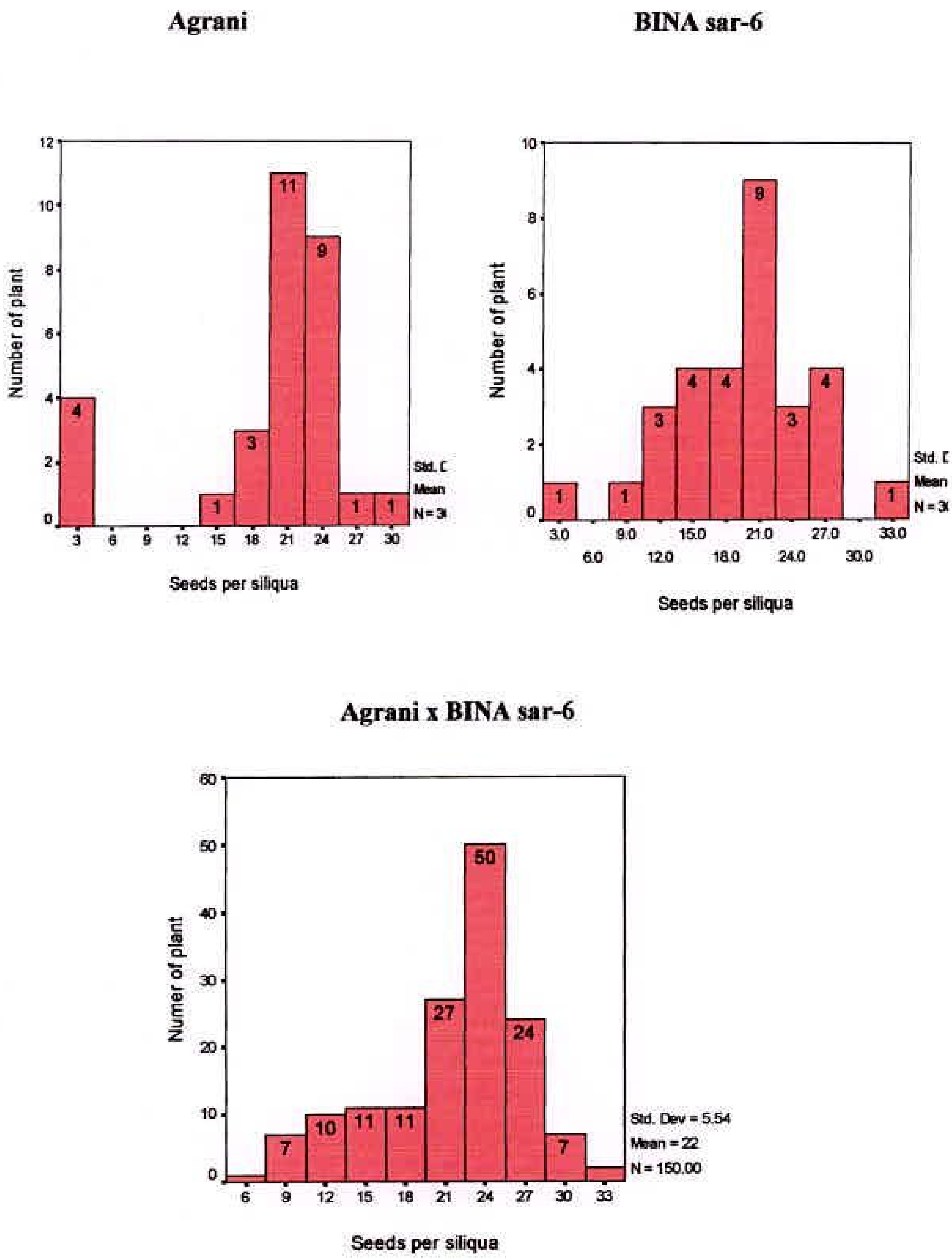


Figure 2: Frequency distribution of plants for seeds per siliqua of parents and their F_2 progenies of Agrani x BINA sar-6

Thousand seed weight (g):

Thousand seed weight was found maximum in Agrani × SS-75 (3.68 g) whereas the minimum thousand seed weight was found in SS-75 ×Tori-7 (2.53 g) (Table 4). The phenotypic and genotypic variances for this trait were (0.26) and (0.02) respectively. The phenotypic variance appeared to be much higher than the genotypic variance suggested considerable highly significant influences of environment on the expression of the genes controlling this trait. The difference between phenotypic coefficient of variation (16.27 %) and genotypic co-efficient of variation (4.43 %) indicating maximum influences by environment (Table 5). 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 Tori-7 × BARI sar-9 (8.44 g) followed by Sofol × SS-75 (Table 4). Higher variations for this trait in the F_2 progenies of Sofol × SS-75 ranging from 1.38 g to 31.00 g (Figure 3). Whereas the minimum yield per plant was observed in SS-75 × Tori-7 (5.09 g). The phenotypic variance (1.51) appeared to be moderately higher than the genotypic variance (0.45), suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic co-efficient of variation (18.94 %) was higher than the genotypic co-efficient of variation (10.38 %) which indicated that environment has a significant role on the expression of this trait.

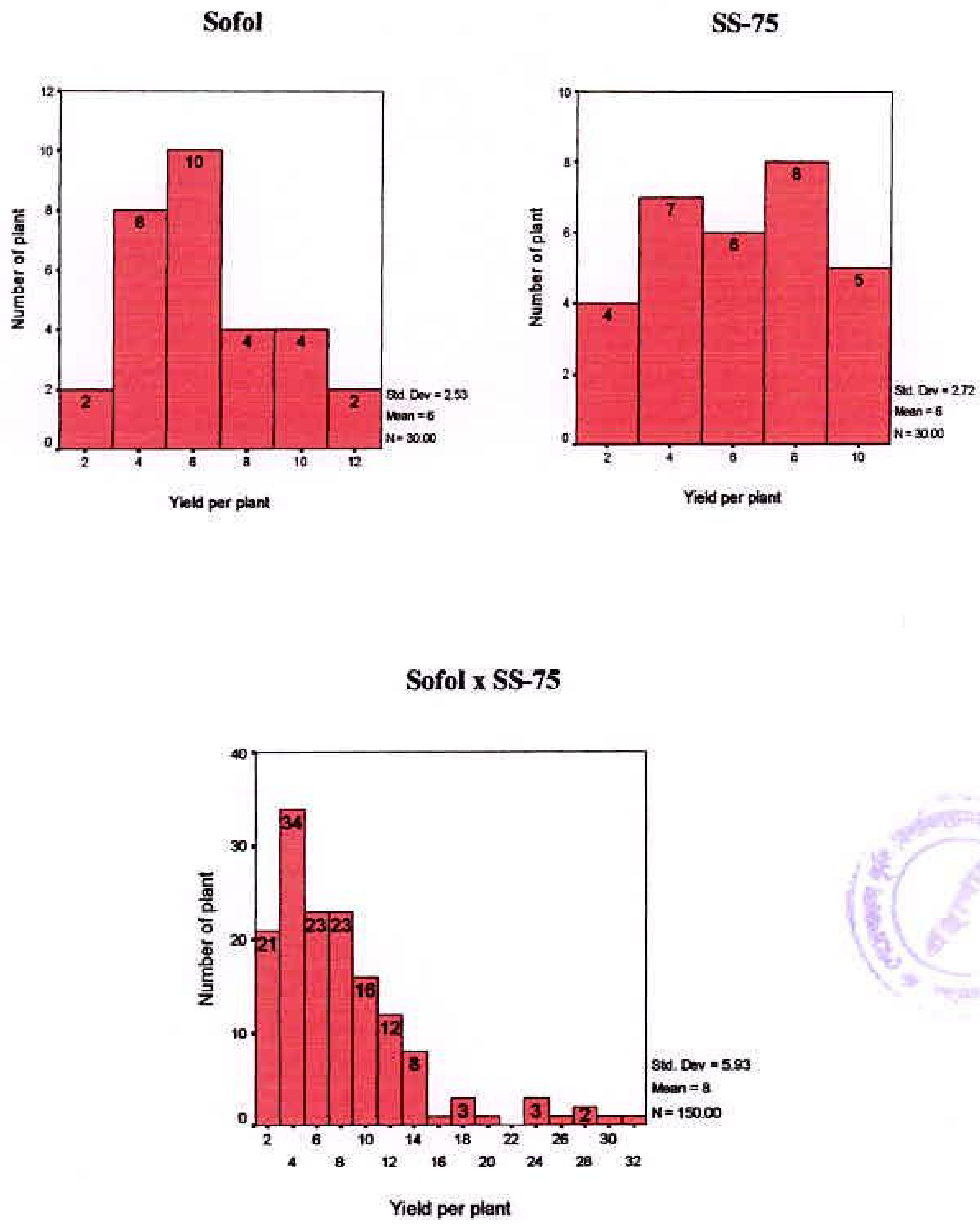


Figure 3: Frequency distribution of seed yield per plant of parents and their F_2 progenies of Sofol x SS-75

Heritability, genetic advance and selection

The extent of heritability, genetic advance, genetic advance in percentage of mean among the genotypes in respects of ten characters were studied have been presented in Table 5.

Days to 50% flowering

Days to 50% flowering exhibited moderate heritability (37.30 %) in broad sense (h^2_b) coupled with low genetic advance (3.04 %) and moderate genetic advance in percentage of mean (8.68 %) (Table 5) revealed that possibility of predominance of additive gene effect and selection might be effective for the development of varieties. Akanda *et al.* (1997) opined that the characters with high values of GCV and heritability accompanied by high genetic advance in percentage of mean indicated that they might transmit to their hybrid progenies and therefore, phenotypic selection based on these characters would be effective. Similar results were also reported by Afroz *et al.* (2004), Parveen (2007), Siddikee (2006), Kakroo and Kumar (1991) and Singh *et al.* (1987).

Days to maturity

The magnitude of heritability (12.31 %) in broad sense (h^2_b) for days to maturity was moderately high with low genetic advance (0.30 %) and low genetic advance in percentage of mean 0.33 % (Table 5) indicating this character is governed by non-additive gene and lower possibility of selecting genotypes.

Plant height (cm):

Plant height showed moderately high (48.84 %) heritability in broad sense (h^2_b) with medium genetic advance (10.24 %) and medium genetic advance in percentage of mean 8.24 % (Table 5), indicated the possibility of additive genes effect for the expression of this character. Therefore selection would be effective for producing varieties. Parveen (2007) found moderate h^2_b (58.22), medium genetic advance (12.61) and medium genetic advance in percentage of mean (14.38) which supported the present findings.

Number of primary branches per plant:

Number of primary branches per plant exhibited moderate heritability (29.89 %) in broad sense (h^2_b) coupled with low genetic advanced (0.50 %) and moderate genetic advanced in percentage of mean 7.9 % (Table 5), indicated the character were highly influenced by environmental effects and selection for such trait might not be rewarding. Li *et al.* (1989) and Singh *et al.* (1987) obtained similar type result.

Number of secondary branches per plant:

Number of secondary branches per plant exhibited high heritability (55.60 %) in broad sense (h^2_b) coupled with low genetic advance (3.07 %) and high genetic advanced in percentage of mean 80.24 % (Table 5) which revealed the possibility of predominance of both additive and non additive gene action in the inheritance of this characters. So direct selection is less effective for this character. Similar results were also reported by Parveen (2007).

Number of siliquae per plant:

The magnitude of heritability (27.95 %) in broad sense (h^2_b) for number of siliqua per plant was moderate with considerably high genetic advance (21.83 %) and medium genetic advance in percentage of mean 13.14 % (Table 5) indicated that the character was governed by additive gene and selection might be effective. Moderate h^2_b (54.97) was reported by Rashid (2007).

Length of siliqua (cm):

Length of siliqua exhibited moderately low heritability (11.13 %) in broad sense (h^2_b) with low (0.11 %) genetic advance and moderately low (2.90 %) genetic advance in percentage of mean (Table 5). In that case the high values of heritability are not always indication of high genetic advance i.e. this character is governed by non-additive gene. The low heritability was due to the favorable influence of environment rather than genotype and selection for such trait might not be effective. It differs with the findings of Rashid (2007) but similar with the findings of Singh *et al.* (1991), Kown *et al.* (1989) and Labana *et al.* (1980).

Number of seeds per siliqua:

Length of siliqua exhibited high heritability (39.93 %) in broad sense (h^2_b) with low (2.23 %) genetic advance and moderate (12.53 %) genetic advance in percentage of mean (Table 5). indicated that the character was governed by additive gene and selection might be effective. Malik *et* al. (1995) reported high heritability for this trait.

Thousand seed weight (g):

The magnitude of low heritability (7.42 %) in broad sense (h^2_b) with low (0.08 %) genetic advance and low (2.49 %) genetic advance in percentage of mean (Table 5) indicating that, the character was highly influenced by environmental effect and selection would not be in effective. Similar findings were observed by Singh *et al.* (1991), Li *et al.* (1989) and Yadav (1982).

Seed yield per plant (g):

Yield per plant exhibited moderately high heritability (30.03 %) in broad sense (h^2_b) with low (0.76 %) genetic advance and moderate (11.71 %) genetic advance in percentage of mean (Table 5) indicated the character were influenced by environmental effect and selection for such trait might not be rewarding. These results support the reports of Liang and Walter (1968) but Singh *et al.* (1987) found high heritability for this trait.

Plant selections:

Significant variability was found in almost all the F_2 progenies of *Brassica rapa* for most of the characters studied. As per objectives, selection was carried out among the F_2 progenies of different cross combinations. Nineteen most promising yellow seeded plant with short duration were selected from the F_2 progenies (Table 6). There were large variations in the nineteen selected F_2 plants for siliquae/plant ranging from 221 to 665 siliquae. One plant from BARI Sar-6 x SS-75 produced 4.5 g of thousand seed weight. Another two plants from BARI Sar-6 x Tori-7 and BINA Sar-6 x SS-75 both of which produced 4.0 g of thousand seed weight. One plant from BARI Sar-6 x Tori-7 which produced exceptionally high yield/plant (28.11 g) (Table 6).

Table 6: Performance of selected yellow seeded short duration plants from the F_2 progenies of different cross combinations of *Brassica rapa*

Cross combinations	Plant no.	Days to maturity	Siliquae per Plant	1000 seed weight (g)	Seed yield per plant (g)
Agroni x BARI sar-9	8 (R1)	87	421	2.4	13.27
	11 (R3)	90	468	3.4	18.68
Agroni x BINA sar-6	9 (R1)	88	294	3.7	12.39
Agroni x Sofol	1 (R1)	88	365	3.1	15.33
Agroni x SS-75	11 (R3)	90	311	3.9	17.83
BARI sar-6 x BARI sar-9	10 (R3)	87	221	3.6	10.17
BARI sar-6 x BINA sar-6	7 (R2)	89	437	3.7	8.93
	3 (R3)	91	282	2.8	13.79
BARI sar-6 x SS-75	9 (R2)	89	233	4.5	8.51
BARI sar-6 x Tori-7	28 (R1)	88	665	3.4	28.11
BINA sar-6 x SS-75	1 (R2)	90	470	4.0	12.44
	10 (R2)	90	378	4.0	11.43
	9 (R3)	91	381	2.6	15.24
BINA sar-6 x Tori-7	4 (R1)	88	285	2.9	10.35
Sofol x BARI sar-6	2 (R2)	90	397	3.7	15.35
Sofol x BARI sar-9	12 (R1)	84	295	3.3	11.78
	11 (R3)	90	323	2.9	13.56
Sofol x BINA sar-6	8 (R1)	88	230	3.7	14.95
Sofol x SS-75	3 (R2)	100	387	2.8	11.87

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Table 7: Performance of selected brown seeded short duration plants from the F_2 progenies of different cross combinations of *Brassica rapa*

Cross combinations	Plant no.	Days to maturity	Siliquae per plant	1000 seed weight (g)	Seed yield per plant (g)
Agroni x BARI sar-6	2 (R2)	88	221	2.5	11.43
	4 (R3)	91	477	3.2	14.96
Agroni x BARI sar-9	20 (R1)	90	313	2.9	19.02
	2 (R2)	90	286	4.0	11.56
Agroni x BINA sar-6	9 (R1)	88	294	3.7	12.39
Agroni x Sofol	1 (R1)	88	365	3.1	15.33
Agroni x SS-75	4 (R2)	89	227	3.1	15.3
	5 (R3)	89	327	2.9	16.58
Agroni x Tori-7	15 (R1)	89	370	3.4	14.26
	19 (R2)	89	218	3.9	11.86
	5 (R3)	90	344	3.5	14.97
BARI sar-6 x BARI sar-9	11 (R1)	90	225	3.7	10.11
	7 (R2)	87	223	2.8	11.55
	20 (R3)	89	424	3.4	21.66
BARI sar-6 x SS-75	4 (R1)	85	431	2.6	21.26
	7 (R3)	91	291	3.0	12.00
BARI sar-6 x Tori-7	4 (R1)	83	465	3.1	11.51
BINA sar-6 x SS-75	1 (R3)	91	320	2.5	15.23
	11 (R3)	92	340	3.0	19.32
BINA sar-6 x Tori-7	14 (R1)	90	221	2.7	11.96
	5 (R2)	89	219	2.8	13.52
	3 (R3)	90	307	2.3	12.68
Sofol x BARI sar-9	5 (R1)	89	211	2.7	8.75
	2 (R2)	87	228	1.9	15.29
	20 (R2)	88	475	2.5	19.55
Sofol x BINA sar-6	10 (R2)	91	212	1.9	12.45
Sofol x SS-75	2 (R1)	89	234	3.1	14.97
	8 (R2)	88	636	2.2	30.19
SS-75 x BARI sar-9	1 (R1)	88	221	2.8	12.59
	4 (R2)	90	487	2.0	15.9
	11 (R3)	90	262	2.4	13.32
SS-75 x Tori-7	20 (R2)	89	388	3.0	18.23
Tori-7 x BARI sar-9	5 (R1)	85	233	2.5	11.72
	11 (R1)	86	286	2.9	11.20
	1 (R2)	87	287	2.8	22.15
	22 (R3)	89	395	2.4	11.28

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On the other way, thirty six most promising brown seeded plant with short duration (83-92 days) were selected from the F_2 progenies *Brassica rapa* (Table 7). Large variations observed in the thirty six selected F_2 plants for siliquae per plant ranging from 211 to 636 siliquae. Plants selected from Agroni x BARI sar-9, Agroni x BINA sar-6, Agroni x Tori-7, BARI sar-6 x BARI sar-9, BINA sar-6 x SS-75, Sofol x SS-75 and SS-75 x Tori-7 75 produced more than 3.0 g of thousand seed weight. Plants selected from BARI sar-6 x BARI sar-9, BARI sar-6 x SS-75, Sofol x SS-75 and Tory-7 x BARI sar-9 produced more than 20.0 g seed yield/plant. And the several plants selected from Agroni x BARI Sar-9, Agroni x Sofol, Agroni x SS-75, BINA sar-6 x SS-75, Sofol x BARI sar-9 and SS-75 x Tori-7 produced more than 15.0 g seed yield per plant (Table 7).

4.2 Correlation co-efficient

Genotypic and phenotypic correlation co-efficient between pairs of characters for F_2 progenies of *Brassica rapa* are presented in the Table 8. It is evident that in most of the cases, the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient. This indicated a strong inherent association between the characters studied and suppressive effect of the environment modified the phenotypic expression of these characters by reducing phenotypic correlation values. In few cases, however, phenotypic correlation co-efficient were same with or higher than their corresponding genotypic correlation co-efficient suggesting that both environmental and genotypic correlation in these cases act in the same direction and finally maximize their expression at phenotypic level.

Days to 50% flowering

Days to flowering showed significant positive correlation with days to maturity (P = 0.402), plant height (G = 0.561, P = 0.423), number of primary branches per plant (G = 0.392), seeds per siliqua (G = 0.994, P = 0.564) and seed yield per plant (G = 0.348) followed by positive correlation with days to maturity (G = 0.185), number of primary branches per plant (P = 0..174), length of siliqua (P = 0.067), and thousand seed weight (G = 0.170, P = 0.221). Whereas significant negative correlation were found in number of secondary branches per plant (G = - 0.456, P = - 0.407) and siliquae per plant (G = - 0.651, P = - 0.301) followed by negative correlation was found in length of siliqua (G = -0.036) (Table 8). These findings are similar to the reports of Chowdhary *et al.* (1987) and Mahmud (2008).

Days to maturity:

Days to maturity showed significant positive correlation with plant height (G = 0.893), number of primary branches per plant (G = 0.928, P = 0.259), length of siliqua (G = 0.972), seeds per siliqua (G = 0.883, P = 0.319) and yield per plant (G = 0.511) followed by positive correlation with plant height (P = 0.169), siliquae per plant (G = 0.268, P = 0.104), length of siliqua (P = 0.141), thousand seed weight (P = 0.034) and yield per plant (P = 0.041). Whereas negative significant correlation were found in number of secondary branches per plant (G = - 0.583, P = - 0.242) and thousand seed weight (G = - 0.458) (Table 8). Ghosh and Chatterzee (1988), Chowdhury *et al.* (1987), Mishra *et al.* (1987) found the similar findings in their experiment.

Table 8: Genotypic and phenotypic correlation co-efficient among different characters of the F_2 progenies of *Brassica rapa*

Parameters		Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield /plant (g)
Days to flowering	G	0.185	0.561**	0.392**	-0.456**	-0.651**	-0.036	0.994**	0.170	0.348**
	P	0.402**	0.423**	0.174	-0.407**	-0.301*	0.067	0.564**	0.221	0.011
Days to maturity	G		0.893**	0.928**	-0.583**	0.268	0.972**	0.883**	-0.458**	0.511**
	P		0.169	0.259*	-0.242	0.104	0.141	0.319*	0.034	0.041
Plant height	G			0.485**	-0.864**	-0.490**	-0.117	0.477**	0.973**	-0.137
	P			0.366**	-0.510**	-0.160	0.142	0.370**	0.433**	094
No. of primary branches/plant	G				-0.156	0.206	0.941**	-0.130	0.063	0.712**
	P				0.133	0.413**	0.054	0.118	-0.152	0.350**
No. of secondary branches/plant	G					0.706**	-0.780**	-0.771**	-0.353**	0.448**
	P					0.686**	-0.01	-0.417**	-0.386**	0.598**
Siliquae /plant	G						-0.685**	-0.891**	-0.594**	0.318*
	P						-0.072	-0.332**	-0.237	0.649**
Length of siliqua	G							0.604**	0.792**	-0.130
	P							0.364**	0.138	0.078
Seeds /siliqua	G								0.510**	0.027
	P								0.127	0.087
Thousand seed weight	G									-0.238
	P									-0.136

** Significant at the 0.01 level of probability, * Significant at the 0.05 level of probability

G = Genotypic correlation co-efficients, P = Phenotypic correlation co-efficients

Plant height (cm):

Plant height showed significant positive correlation with number of primary branches per plant (G = 0.485, P = 0.366), seeds per siliqua (G = 0.477, P = 0.370) and thousand seed weight (G = 0.973, P = 0.433). Whereas negative significant correlation was found in number of secondary branches per plant (G = - 0.864, P = - 0.510) and number of siliquae per plant (G = - 0.490) followed by negative correlation was found in siliquae per plant (P = - 0.160), length of siliqua (G = - 0.117) and yield per plant (G = - 0.137) (Table 8). Similar findings were reported by Rashid (2007) and Siddikee (2006).

Number of primary branches per plant:

Number of primary branches per plant showed significant positive correlation with siliquae per plant (P = 0.413), length of siliqua (G = 0.941) and yield per plant (G = 0.712, P = 0.350) followed by positive correlation with number of secondary branches per plant (P = 0.133), siliquae per plant (G = 0.206), length of siliqua (P = 0.054), seeds per siliqua (P = 0.118) and thousand seed weight (G = 0.063). Whereas the negative interaction was found in number of secondary branches per plant (G = -0.156), seeds per siliqua (G = -0.130) and thousand seed weight (P = -0.152) (Table 8). 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 Varshney *et al.* (1986).

Number of secondary branches per plant:

Number of secondary branches per plant showed significant positive correlation with siliquae per plant (G = 0.706, P = 0.686) and yield per plant (G = 0.448, P = 0.598) followed by negative significant correlation with length of siliqua (G = - 0.780), seeds per siliqua (G = - 0.771, P = - 0.417) and thousand seed weight (G = - 0.353, P = - 0.386) followed by negative correlation with length of siliqua (P = - 0.101) (Table 8). Present findings were supported by Rashid (2007) and Siddikee (2006). Varshney *et al.* (1986) found negative correlation which does not supported present findings.

Number of siliquae per plant:

Siliqua per plant showed significant positive correlation with yield per plant (G = 0.318, P = 0.649) followed by negative significant correlation with length of siliqua (G = - 0.685), seeds per siliqua (G = - 0.891, P = - 0.332), and thousand seed weight (G = - 0.594) followed by negative correlation with length of siliqua (P = - 0.072) and thousand seed weight (P = - 0.237) (Table 8). Labana *et al.* (1980) found strong and negative correlation which does not supported present findings.

Length of siliqua (cm):

Length of siliqua showed significant positive correlation with seeds per siliqua (G = 0.604, P = 0.364) and thousand seed weight (G = 0.792) followed by positive correlation with thousand seed weight (P = 0.138) and yield per plant (P = 0.078). Length of siliqua showed negative correlation with yield per plant (G = -0.130) (Table 8). Similar result were obtained by Labana *et al.* (1980).

Seeds per siliqua:

Seeds per siliqua showed significant positive correlation with thousand seed weight at genotypic level (G = 0.510) and positive correlation at phenotypic level (P = 0.127) and yield per plant (G = 0.027, P = 0.087) (Table 8). Similar results were obtained by Varshney *et al.* (1986).

Thousand seed weight:

Thousand seed weight showed negative correlation with yield per plant (G = - 0.238, P = - 0.136) (Table 8). Saini and Sharma (1995), Kakroo and Kumar (1991) and Olsson (1990) found positive association which does not support the results.

4.3 Path co-efficient

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 9.

Path co-efficient analysis revealed that, number of siliquae per plant had the highest direct positive effect (0.998) on seed yield followed by days to 50% flowering (0.835), number of secondary branches per plant (0.400), seeds per siliqua (0.370), number of primary branches per plant (0.299), thousand seed weight (285) and length of siliqua (0.176) which indicating true relationship between them and direct selection for this trait would be effective for yield improvement. The present results are similar to the findings of Chen *et al.* (1983), Kumar *et al.* (1984) and Sabana *et al.* (1990) in rapeseed. Days to maturity (-0.047) and plant height (-0.307) showed negative direct effect on yield per plant.

Path co-efficient analysis revealed that days to flowering had positive direct effect (0.853) on yield per plant. Days to flowering had positive indirect effect on number of primary branches per plant (0.117), seeds/siliqua (.368) and thousand seed weight (0.48). And it showed negative indirect effect on days to maturity (- 0.009), plant height (-0.173), number of secondary branches per plant (- 0.182), number of siliquae per plant (- 0.650) and length of siliqua (- 0.006) (Table 9). Chauhan and Singh (1985) observed positive direct effect of days to 50% flowering and indirect effect of plant height, primary branches per plant and siliquae per plant on seed yield.

Table 9: Partitioning of genotypic correlations with seed yield per plant into direct and indirect components of F_2 progenies of *Brassica rapa*

Characters	Days to flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Genotypic correlation with seed yield
Days to flowering	**0.835**	-0.009	-0.173	0.117	-0.182	-0.650	-0.006	0.368	0.048	0.3476**
Days to maturity	0.154	**-0.047**	-0.274	0.278	-0.233	0.267	0.171	0.327	-0.131	0.5110**
Plant height	0.469	-0.042	**-0.307**	0.145	-0.346	-0.489	-0.021	0.176	0.278	-0.1374
No. of primary branches/plant	0.327	-0.043	-0.149	**0.299**	-0.063	0.206	0.165	-0.048	0.018	0.7122**
No. of secondary branches/plant	-0.380	0.027	0.266	-0.047	**0.400**	0.705	-0.137	-0.285	-0.101	0.4481**
Siliquae /plant	-0.544	-0.013	0.151	0.062	0.283	**0.998**	-0.121	-0.329	-0.169	0.3175*
Length of siliqua	-0.030	-0.045	0.036	0.281	-0.312	-0.684	**0.176**	0.223	0.226	-0.1296
Seeds /siliqua	0.830	-0.041	-0.147	-0.039	-0.309	-0.889	0.106	**0.370**	0.145	0.0266
Thousand seed weight	0.142	0.021	-0.299	0.019	-0.141	-0.593	0.139	0.189	**0.285**	-0.2383

Bold figures indicate direct effects

Residual effect (R) = 0.54

** Significant at 1% level of probability

* Significant at 5% level of probability

Path co-efficient analysis revealed that days to maturity had negative direct effect (- 0.047) on yield per plant and negative indirect effect through plant height (-0.247), number of secondary branches per plant (- 0.233) and thousand seed weight (-0.131). On the other hand days to maturity had positive indirect effect via days to flowering (0.469), number of primary branches per plant (0.278), number of siliqua per plant (0.257), length of siliqua (-0.171) and seeds per siliqua. Kumar *et al.* (1984) and Chen *et al.* (1983) found negative direct effect in days to maturity.

Path analysis revealed that plant height had negative direct effect (-0.307) on yield per plant followed by negative indirect effect on days to maturity (- 0.042), number of secondary branches per plant (- 0.346), number of siliqua per plant (-0.489) and siliqua length (-0.021). Positive indirect effect through days to flowering (0.469), number of primary branches per plant (0.145), seeds per siliqua (0.176) and thousand seed weight (0.278). 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 (0.299). This trait had positive indirect effect on days to flowering (0.327), number of siliquae per plant (0.206), length of siliqua (0.165) and thousand seed weight (0.278). On the other hand negative indirect effect was found on days to maturity (- 0.043), plant height (-0.149), number of secondary branches per plant (-0.063) and seeds per siliqua (-0.048). Rashid (2007) found number of primary branches had positive direct effect (0.145) on yield per plant.

Number of secondary branches per plant had positive direct effect (0.400) on yield per plant and positive indirect effect on days to maturity (0.027), plant height (0.266) and number of siliquae per plant (0.705). On the other hand this trait showed negative indirect effect on days to flowering (- 0.380), number of primary branches per plant (-0.047), length of siliqua (-0.137), seeds per siliqua (- 0.285) and thousand seed weight (-0.101). Siddikee (2006) found the number of secondary branches per plant had positive direct effect (0.295) on yield per plant.

Path co-efficient analysis revealed that, number of siliquae per plant had the highest positive direct effect (0.998) on seed yield while secondary branches per plant and plant height showed positive indirect effect (0.283, 0.151 respectively) on seed yield. Number of primary branches per plant (0.062) and number of And this trait had negative indirect effect on days to flowering (-0.544), days to maturity (-0.013), length of siliqua (-0.121), seeds per siliqua (-0.329), thousand seed weight (-0.169). Parveen (2007) found similar type result.

Path analysis also revealed that length of siliqua had direct positive effect (0.176) on seed yield per plant. This trait had also indirect positive effect on plant height (0.036), number of primary branches per plant (0.281), number of siliqua per plant (0.233) and thousand seed weight (0.226). On the other hand length of siliqua showed indirect negative effect on days to flowering (-0.030), days to maturity (- 0.045), number of secondary branches per plant (- 0.312) and siliquae per plant (-0.684). Siddikee (2006) found the same result.

Seeds per siliqua had positive direct effect (0.370) on yield per plant and positive indirect effect on days to flowering (0.830), siliqua length (0.106) and thousand seed weight (0.145). On the other hand this trait showed negative indirect effect on days to maturity (-0.041), plant height (- 0.147), number of primary branches per plant (- 0.039), number of secondary branches per plant (- 0.309) and number of siliqua per plant (- 0.889), Chen *et al.* (1983), Chuhan and Singh (1985) and Han (1990) found substantial direct effect of number of seeds per siliqua on seed yield (1.982) which agrees to the present findings.

Thousand seed weight had positive direct effect on yield per plant (0.285) and positive indirect effect on days to 50% flowering (0.142), days to maturity (0.021), number of primary branches per plant (0.019), length of siliqua (0.139) and number of seeds per siliqua (0.189) and plant height (- 0.229), number of secondary branches per plant (-0.141) and siliquae per plant (- 0.593). The finding of Chen *et al.* (1983), Gupta *et al.* (1987) and Kakroo and Kumar (1991) are more or less similar to the present findings.

Chapter V

Summary and Conclusion

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SUMMARY AND CONCLUSION

An experiment was conducted during the period of November, 2007 to March 2008, at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University using seven parental genotypes and their twenty one F_2 progenies of *Brassica rapa*. The experiment was carried out to study variability, heritability, genetic advance and genetic advance in percentage of mean, genetic diversity, character associations and direct and indirect effect of different traits on yield. All the parental genotypes and their twenty one F_2 progenies varied significantly with each other for all the characters studied.

Among the seven parents BARI sar-9 was found early in flowering and maturity followed by Tori-7. Agrani was late flowering and BINA sar-6 was late maturing. The plant height of the parent Sofol was highest and BARI sar-9 was shortest. The parent Sofol also produced highest number of primary branches/plant and BARI sar-9 produced lowest number of primary branches/plant. The highest number of secondary branches/plant was observed in BARI sar-9 where as the lowest number of primary branches/plant was observed in Sofol. The highest number of siliquae/plant was observed in BARI sar-9 where as the minimum number of siliquae/plant was observed in Agrani. The highest siliqua length was observed in Agrani and Sofol produced shortest siliqua. The highest number of seeds per siliqua was observed in Sofol where as the minimum number of siliquae/plant was observed in SS-75. Thousand seed weight was found maximum in Sofol where as the minimum thousand seed weight was found in Tori-7. The highest amount of yield per plant was observed in BARI sar-9 where as the minimum yield per plant was observed in Tori-7.

Wide range of variation observed for most of the characters. 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. Among the characters, days to 50% flowering, days to maturity, number of primary branches/plant, siliqua length and yield per plant showed least difference between phenotypic and genotypic variance which indicated additive gene action for the expression of the characters.

Among the 21 F_2 progenies Tori-7 × BARI sar-9 was early flowering and early maturing and both Agrani × Sofol and Agrani × BINA sar-6 were late flowering and BINA sar-6 × SS-75 was late maturing. The highest plant height was observed in Agrani × SS-75 and the lowest in Tori-7 × BARI sar-9. The highest number of primary branches/plant was observed in Sofol × BINA sar-6 the lowest in BINA sar-6 × BARI sar-6. The highest number of secondary branches/plant was observed in Tori-7 × BARI sar-9 where as the minimum number of primary branches/plant was observed in BARI sar-6 × BINA sar-6. The highest number of siliquae/plant was observed in Agrani × BARI sar-6 where as the minimum number of siliquae/plant was observed in Agrani × SS-75. The highest siliqua length was observed in Agrani × SS-75 and the lowest in Agrani × Sofol. The highest number of seeds per siliqua was observed in Agrani × BINA sar-6 where as the minimum number of seeds per siliqua was observed in BINA sar-6 × Tori-7. Thousand seed weight was found maximum in Agrani × SS-75 where as the minimum thousand seed weight was found in SS-75 ×Tori-7. The highest amount of yield per plant was observed in Tori-7 × BARI sar-9 and the lowest in SS-75 ×Tori-7.

Among the 21 F_2 progenies most of the characters showed wide range of variation. 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. Among the characters, days to 50% flowering, days to maturity, plant height, number of primary branches/plant, siliqua length and yield per plant showed moderate difference between phenotypic and genotypic variance which indicated additive gene action for the expression of the characters.

The entire characters showed moderate to high phenotypic and genotypic co-efficient of variation except days to maturity, plant height, number of primary branches per plant, seeds/siliqua. Amongst the characters the highest genotypic and phenotypic co-efficient of variation was recorded for number of secondary branches per plant followed by thousand seed weight, siliqua length and yield per plant. The highest estimated heritability coupled with high genetic advance in percent of mean was found for number of secondary branches per plant followed by plant height, seeds/siliqua and days to flowering. These results revealed that the possibility of predominance of additive gene action in the inheritance of these characters. Number of primary branches per plant and number of siliquae per plant showed moderate heritability indicating moderate possibility of selecting genotypes. Days to maturity, siliqua length, and thousand seed weight exhibited low heritability indicated there is little scope of selecting genotypes crop improvement. Based on the variability and as per our objectives nineteen most promising yellow seeded and thirty six most promising brown seeded plant with short duration were selected from the F_2 progenies.

Correlation revealed that seed yield per plant had significant positive association with number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant both at genotypic and phenotypic level. A significant positive correlation also observed for days to flowering, days to maturity and plant height at genotypic level.

Path co-efficient analysis revealed that days to 50% flowering, number of primary branches per plant, number of secondary 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 maturity and plant height had the negative direct effect on yield per plant.

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

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Appendices

Appendix I: Analysis of variances of ten important characters of seven parents of *Brassica rapa*

Sources of variation	Degrees of freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield /plant (g)
Replication	2	20.619	4.333	311.773	1.293	1.323	15039.853	0.033	14.638	0.170	14.503
Genotypes	6	66.302**	23.111**	370.454**	4.273	58.992**	8055.3.05*	0.265**	14.587	0.010	4.481**
Error	12	6.397	2.111	38.267	2.496	10.011	2253.720	0.058	6.451	0.070	5.868

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

Appendix II: Analysis of variances of ten important characters of 21 F_2 progenies of *Brassica rapa*

Sources of variation	Degrees of freedom	Days to 50% flowering	Days to maturity	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/plant	Siliquae /plant	Length of siliqua (cm)	Seeds /siliqua	1000 seed weight (g)	Seed yield /plant (g)
Replication	2	12.416	19.499	217.080	4.248	35.935	3377.255	1.620	5.368	0.040	6.539
Genotypes	20	27.894**	1.472	214.277**	1.234**	27.758	2419.221**	1.225	12.523**	0.030	2.479**
Error	40	10.059	1.139	50.116	0.433	23.195	971.125	1.497	4.509	0.020	1.845

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

Appendix III: Monthly record of temperature, rainfall, relative humidity and Sunshine of the experimental site during the period from October 2007 to March 2008

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	*Sunshine (hr)
		Maximum	Minimum	Mean			
2007	October	31.4	23.8	27.6	77	320	5.7
	November	29.0	19.9	24.45	69	111	5.5
	December	25.8	15.0	20.4	73	00	5.6
2008	January	24.7	12.5	18.6	67	00	5.8
	February	27.2	16.8	22	67	31	5.8
	March	31.5	19.7	25.6	55	12	8.3

*Monthly average

Source: Bangladesh Meteorological Department (Climate division) - Agargoan, Dhaka .

Appendix IV: Physical and chemical characteristics of initial soil (0-15 cm depth)

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

Appendix V: Total cultivated area and production of oil seed crops of Bangladesh from 2001-2002 to 2006-2007

Name of crops	2001-2002		2002-2003		2003-2004		2004-2005		2005-2006		2006-2007	
	Area	Prod^n.	Area	Prod^n.	Area	Prod^n.	Area	Prod^n.	Area	Prod^n.	Area	Prod^n.
Rape and mustard	**749**	**233**	**735**	**218**	**690**	**210**	**597**	**191**	**536**	**183**	-----	**188**
Til	**91**	**22**	**96**	**25**	**96**	**25**	**96**	**37**	**76**	**39**	-----	**29**
Linseed	**11**	**3**	**11**	**2**	**11**	**3**	**12**	**3**	**34**	**8**	-----	**8**
Groundnut	**64**	**30**	**66**	**34**	**64**	**34**	**71**	**39**	**73**	**38**	-----	**46**
Coconut	**76**	**87**	**77**	**88**	**96**	**133**	**13**	**907**	**22**	**325**	-----	-----

Note : Production of coconut (in weight) has been calculated at 40 cleaned coconut equal to one maund approximately.

*Area calculated in thousand hectares

*Prod^n (production) were in thousand metric ton

Source : Agricultural statistics, BBS (2008)

Statistical pocket book Bangladesh, 2008.