VARIABILITY STUDY IN F_2 PROGENIES OF THE INTER-VARIETAL CROSSES OF *Brassica rapa*

BY

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CERTIFICATE

This is to certify that thesis entitled, **"VARIABILITY STUDY IN F_2 PROGENIES OF THE INTER- VARIETAL CROSSES OF *Brassica rapa*"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by SHAHANAZ PARVEEN, Registration No. 26133/00432 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: November, 2007
Place: Dhaka, Bangladesh

....
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SOME COMMONLY USED ABBREVIATIONS

Abbreviations		Full word
%	=	Percent
°C	=	Degree Celsius
AEZ	=	Agro-Ecological Zone
Agric.	=	Agriculture
Agril.	=	Agricultural
Agron.	=	Agronomy
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
BD	=	Bangladesh
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
DM	=	Dry Matter
EC	=	Emulsifiable Concentrate
et al.	=	And others
etc.	=	Etcetera
F_2	=	The second generation of a cross between two dissimilar homozygous parents
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
G	=	Genotype
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	=	Metre
M.P.	=	Muriate of Potash
m^2	=	Meter Square
MOA	=	Ministry of Agriculture
NARS	=	National Agricultural Research Institute
No.	=	Number
NS	=	Not Significant
ppm	=	Parts Per Million
R	=	Residual effect
RCBD	=	Randomized Complete Block Design
Res.	=	Research
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
SE	=	Standard Error
T.S.P.	=	Triple Super Phosphate
t/ha	=	Tonnes per hectare
Univ.	=	University
var.	=	Variety

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(Shahanaz Parveen)

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ABSTRACT
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This research work was carried out by using the F_2 population of some inter-varietal crosses of the species *Brassica rapa* in the experimental farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during November 2005-March 2006 for estimating the magnitude of variations in characters, heritability, genetic advance, character associations, direct and indirect effect of different characters on seed yield. There were significant variations among the different genotypes used in the experiment. Genetic parameters, number of primary branches/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua, days to 50% flowering, 1000 seed weight and yield/plant showed least difference between genotypic and phenotypic variance. Plant height, length of siliqua, number of seeds/siliqua and days to 50% flowering showed low genotypic and phenotypic coefficient of variation. 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. However, the yield/plant, days to maturity and length of siliqua showed low heritability. Correlation co-efficient analysis revealed that yield/plant had non significant positive association with plant height, number of secondary branches/plant, days to 50% flowering, length of siliqua, number of siliquae/plant and number of seeds/siliqua. Path coefficient analysis revealed that number of seeds/siliqua showed highest direct effect on yield/plant followed by plant height, number of secondary branches/plant and number of siliquae/plant. Based on the variability study, some F_2 plants showing high heritability for yield contributing characters were selected from some of the cross combinations of the intervarietal crosses of *Brassica rapa*.

Chapter I

INTRODUCTION

Brassica oil is the world's third most important sources of edible vegetable oils (Downey, 1990). Oleiferous *Brassica* species can be classified into three groups viz; the cole, the rapeseed and the mustard. The mustard groups include species like *Brassica juncea* Czern and Coss, *Brassica nigra* Koch and *Brassica carinata* Braun; while the rapeseed groups includes *Brassica rapa* L. and *Brassica napus* L. (Yarnell,1956). The genomic constitutions of the three diploid elemental species of *Brassica* are AA for *Brassica campestris*, BB for *Brassica nigra* and CC for *Brassica oleracea* having diploid chromosome number of 20, 16 and 18 respectively. On the other hand the species *Brassica juncea* (AABB), *Brassica carinata* (BBCC) and *Brassica napus* (AACC) are the amphidiploids.

The coles are consumed as vegetables and the other two are the valuable sources of edible oils and proteins. The mustard oil is not used only for edible cooking purpose but also is used in hair dressing, body massing and in different types of pickles preparation. It has also several medicinal values. Oil cake is the most important feed for livestock and is also used as organic manure.

The important regions growing these crops include Canada, China, Northern Europe and the Indian subcontinent. In Bangladesh, local cultivars/varieties of *B. rapa* are widely grown and it gives moderate yield but late cultivars produce high yield. On the other hand, *B. juncea* gives low yield but it is drought/stress resistance. According to Kariya and Tsunada (1972, 1973, cited by Tsunada, 1980), *B. napus* has a physiological constitution that makes it more productive than *B. rapa*. The *B. napus* of the temperate regions remains constantly in the vegetative stage or is too late in maturing and also shattering habit is the major obstacle to be an oil crop.

In Bangladesh, *Brassica* is the most important oilseed crop. The country is facing huge shortage in edible oils. Almost one fourth of the total edible oil consumed annually are imported. The import cost was about 690 million US dollar in 2003 (BBS, 2004). On Recommended Dietary Allowance (RAD) basis, Bangladesh requires 0.29 million tons of oils which is equivalent to 0.8 million tons of oilseeds; but she produces only about 0.254 million tons, which covers only 40% of the domestic need (FAO, 2003). This crop covers the highest acreage which is 72% of the total oilseed acreage of Bangladesh (BBS, 2003).The average yield of *Brassica* oilseed in Bangladesh is around 733kg/hectare (FAO, 2003).

In Bangladesh there is limited scope to increase acreage due to pressure of other crops and to increase yield due to cultivation of the existing low yielding varieties with low inputs. *B. rapa* is the most popular cultivated species. Short duration variety Tori-7 of *B. rapa* is still popular in Bangladesh because it can fit well into the T.Aman-Mustard-Boro cropping pattern. No improved short duration variety of *B. rapa* is available to replace this short duration variety. There should be an attempt to develop short duration and high yielding varieties of mustard to meet the challenge of edible oils of the country by increasing the production. Segregating materials obtained through different inter-varietal crosses of the species *B. rapa* will give an opportunity to select the desired plant types to meet the existing demand. Therefore, this study will be carried out with following objectives mentioned below.

Objectives:

The present work, therefore, was planned with the following objectives:

1. To study the variability in F_2 segregating generations for selection of desired plant types
2. To select early maturity, high yielding and grey seeded plants
3. To select early maturity, high yielding and yellow seeded plants.

Chapter II

REVIEW OF LITERATURE

The review of literature concerning the studies presented and discussed in this thesis is outlined under the flowing heads:

1. Variability in *Brassica spp.*
2. Interrelationship among the characters.
3. Path coefficient Analysis.

2.1 Variability in *Brassica spp.*

Genetic variability is basic to rational plant breeding (Simmonds, 1983). The objectives of a plant breeder include selection, either from a natural population or from one generated by him and either for one or a few desirable characters.

Working on genetic variability and genetic advance of seed yield and its components in Indian mustard Katiyar *et al.* (1974); reported that high genetic coefficients 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 from flowering to maturity and number of primary branches.

Singh *et al.* (1991); found significant genetic variability in days to 50% flowering in *B. napus* and in *B. rapa*.

While working with 65 strains of *B. napus*, *B. rapa*, *B. juncea* and *B.carinata* Nanda *et al.* (1995); reported that days to first flowering varied both by genotypes and date of sowing. Kumar *et al.* (1996), Kumar and Singh (1994), Kakroo and Kumar (1991), Andrahennadi *et al.* (1991), Biswas (1989), Lebowitz (1989), Singh *et al.* (1987), Chauhan and Singh (1985), Yadava *et al.*

(1983), Thakral (1982) and many other researchers worked with different genotypes of *Brassica*. In general, according to them, significant variations were observed in this character.

Jain *et al.* (1988); observed that dominance gene action was important in the expression of days to flowering. Partial dominance was observed for this character (Kumar *et al.*, 1991).

Days to maturity are the most important character for oil seed crop, mustard and rapeseed in particular. The character is influenced by genotypes and various environmental factors. 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*. Yadava (1973), found GCV=7.6 among 29 strains of *B. juncea*; while in yellow sarson and toria, Tak and Patnaik (1977) found this value as 4.5 and 1.8 respectively.

Significant variation for days to 80% maturity was also found by Kumar and Singh (1994), Singh *et al.* (1991), Grosse and Geisler (1988), Khera and Singh (1988), Gupta *et al.* (1987), Chauhan and Singh (1985), Yadava (1983) and Thakral (1982).

Plant height is an important character which is largely influenced by genotype, soil, water availability and temperature etc. Highest Variation for plant height of parents and their hybrids was reported by Tyagi *et al.* (2001). The seed yield per plant exhibited the highest coefficient of variation (41.1%). 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 this character by many workers like Kumar *et al.* (1996), Malik *et al.* (1995), Kumar and Singh (1994), Singh *et al.* (1991), Yadava *et al.* (1993), Andrahennadi (1991), Gupta and Labana (1989), Lebowitz (1989), Chaturvedi *et al.* (1988), Gupta and Labana

(1988), Gupta *et al.* (1987), Chauhan and Singh (1985) and Sharma (1984) among different genotypes of *B. napus, B. rapa* and *B. juncea.*

Labana *et al.* (1987); studied 39 strains of Ethiopian mustard and found low genetic variation. But working with a number of strains of *B. napus, B. rapa* and *B. juncea,* Varshney *et al.* (1986) found high variability in plant height.

In a study, Lekh *et al.* (1998); reported that secondary branches showed highest genotypic co-efficient of variation. High genotypic and phenotypic co-efficient of variation was recorded for days to 50% flowering.

Siliqua length might have been influenced for the development of fruits in rape seed and mustard. Peduncle, beak as well as siliqua length varies due to difference in genotypes. High genetic variability was observed by Olsson (1990) in these characters. Lebowitz (1989), studied *B. rapa* population for siliqua length and found similar results. Selection for increased siliquae length is an effective strategy for yield improvement through raising seed weight/siliqua (Thurling, 1983).

Number of siliquae/plant is one of the most important traits of rape seed and mustard. In general, higher the siliqua number higher the seed yield. This trait has high variation and a considerable part of which appeared to be of environmental. High genetic variation was found by Yin (1989), for this character. Similar result was also found by Kumar *et al.* (1996), Kudla (1993), Andrahennadi *et al.* (1991), Singh *et al.* (1991), Biswas (1989), Jain *et al.* (1988), Chowdhury *et al.* (1987), Alam *et al.* (1986), Yadava *et al.* (1985) and Thakral, (1982).

In general, high number of seeds per siliqua is desirable. A good number of literatures are available on the variability of this character. Kumar *et al.* (1996); reported the presence of significant variability in the genotypes of *Brassica napus, Brassica rapa* and *Brassica juncea* they studied. Similar significant variability in 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).

Thousand seed weight is also an important trait of *Brassica* oil crops, where highest consideration is on the seed yield. This trait has been found to vary widely from genotype to genotype and from environment to environment including macro and micro environments. The coefficient of variation was high for thousand seed weight, pod length and number of seed per pod for both genotypic and phenotypic variability (Masood *et al.,* 1999).

Different degrees of significant variations of thousand seed weight due to variable genotypes were observed by Chowdhury *et al.* (1987), Yin (1989), Labowitz (1989), Biswas (1989) in *Brassica rapa*, Andrahennadi *et al.* (1991) in brown mustard, Kudla (1993) in sewede rape and Kumar and Singh, (1994) in *Brassica juncea*

Yield is the most important trait for all crops in every breeding program. This is a complex trait influenced largely by a number of component characters and factors of production. A good number of research works have been conducted on this character.

Shen *et al.* (2002); tested 66 F_1 hybrids of *Brassica rapa* and significant differences were found between F_1's and their parents for yield per plant and seed oil content.

A high degree of variation in yield was reported by Yin (1989) in *Brassica rapa;* Kudla (1993) in *Brassica napus* and Kumar *et al.* (1996) in *Brassica juncea*. Significant genetic variability in genotypes belonging to toria ecotype was reported by Thakral, (1982).

The heritability variation can be estimated with greater degree of accuracy when heritability in conjunction with genetic advance as percentage of mean (genetic gain) is studied. Johnson *et al.* (1955); suggested the necessity of estimating genetic advance along with heritability in orders to draw a more reliable conclusion in a selection programme. Many researchers investigated heritability and genetic advance of yield and yield component of rape seed and mustard. Some of them are reviewed here.

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, days to 50% flowering and oil content. They also found low heritability (h^2_b=<50%) for number of siliquae/plant, number of seeds/siliqua, plant height and seed yield. But Singh *et al.* (1991); found high heritability for all these characters studies with *B. napus.* Li *et al.* (1989); also observed similar results in studies with *B. napus* while in a study of 55 genotypes of *Brassica napus. B. rapa* and *B. Juncea.* Varshney *et al.* (1986) found high heritability and high genetic advance for plant height in all three species; but high heritabiliy 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 seed/siliqua.

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. 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 Malik *et al.* (1995), kumar *et al.* (1988), Yadava *et al.* (1985), Li *et al.* (1983), Chen *et al.* (1983) etc. However Singh (1986), found high heritability for this trait.

Low to medium heritability of siliqua length was observed by Kakroo and Kumar (1991), Sharma (1984) and Yadav *et al.*,(1982). But Kwon *et al.* (1989) and Rao (1977) observed high heritability (h^2_b=> 90%) for this trait.

In a study of 46 genotypes of *B. juncea*, Sharma (1984), 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 (h^2_b= 80%-95%) for oil content and yield/plant. The lowest heritability (34.9%) was observed for number of primary branches per plant.

Working with 104 mutants of Indian mustard *B. juncea* (Linn.) Czern and Coss Labana *et al.* (1980); found that plant height and number of seeds/siliqua were highly heritable where as siliqua length, number of primary branches and seed yield per plant were less heritable. The yield variation is thus principally pouring to the environmental influence, for which selection would not be more practicable for plant height and number of seeds/siliqua. This confirmed the finding of Chaudhari and Prasad (1968). In the same experiment the GA (expressed as percentage of mean) was highest for plant height (13.75%) followed by number of seeds/siliqua (12.43) and seed yield/plant (9.75). This offered scope for the improvement through selection.

Working with 30 varieties of *B. rapa* Chandola *et al.* (1977); found high estimates of 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.

It was reported by Thurling (1974), in *B. rapa* that the expected genetic advance in yield using a selection index technique based on simultaneous selection of several characters was significantly greater than that expected from selection for yield alone and several indices including measurement of both yield components and vegetable characters lower expected to promote a greater ratio of advance in yield than direct selection.

Chaudhary *et al.* (1987); studied variability and correlations in some varieties of brown season and reported high heritability was associated with high length, number of seeds per siliquae and 1000 seed weight.

Katiyar *et al.* (1974); studied in *Brassica rapa* L. var. sarson prain on ten characters in 54 plants from each of 40 varieties; seed yield per plant showed a high genotypic co-efficient of variation. Heritability in the broad sense was associated with high genetic advance for number of siliquae on the main shoot and for seed yield per plant.

Estimates of heritability in the broad sense and of genetic advance were high for plant height, maturity and number of nodes on the main shoot among the nine characters studied in 29 varieties (Yadava, 1973).

Katiyar *et al.* (1974); studied the genetic variability heritability and expected genetic advance in varieties of Indian mustard *B. juncea* (L.) Czern and Coss. Heritability value were high for yield per plant, plant height , days to first flowering and number of primary branches, moderate for the days from flowering to maturity but low for the number of secondary branches. High genetic advance was found for plant height, days to first flowering and yield per plant, where as low value was observed for number of primary branches.

Selection for yield in early segregating generations has been reported to be in effective in developing high yielding cultivars of self-pollinated crops (Knott, 1972; Seitzer and Evans, 1978; Whan *et al.*, 1982).

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. However, on theoretical grounds, selection for yield related characters in F_2 (or F_3) generation has been recommended to minimize the expected losses of valuable transgressive/productive segregants from the breeding population (Shebeski, 1967). This view point has prompted considerable research in the area of improving early generation selection for yield through either reduction of the effects of micro environmental variation in the breeding blocks (Fasoulas, 1973) or based on selection on yield related characters having a higher heritability than yield itself (Bhatt,1980).

Gupta and Labana (1985), observed that in Indian mustard, selection for bold seed size from F_2 to F_5 generations was highly effective. Teresa (1987), suggested that the most important feature in winter rape plant selection for seed yield was number of branches.

Stem diameter at the ground level and the number of branches on a plant were useful in preliminary selection for single plant seed yield because of their stronger correlation with yield and the number of siliquae on branches. Chatterjee and Bhattacharya (1986), reported 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. From the practical point of view, the index comprising plant height, 1000-seed weight and yield/plant was considered effective. In groundnut, there are reports both for early selection (Coffelt and Hammons, 1974; Kalesnikov, 1979; Kibite, 1981; Gebre-Mariam, 1982) and against (Wynne, 1976; Mcneal *et al.*, 1978; Whan *et al.*, 1982).

2.2 Interrelationships among the characters

Correlation coefficients among different characters are important in breeding programme. Many workers have reported their correlation among characters of *Brassica sp.* Some of this information is reviewed here.

Selection for plant height, for types where primary branches start at low heights from ground level and number of siliquae on the main raceme can result in yield increase (Zhau and Liu, 1987).

Plant height was found to be negatively correlated with siliqua length and seeds/siliqua by Labana *et al.*, (1980). Positive correlation of plant height with seeds/siliqua, number of siliqua/plant and negative correlation with 1000 seed weight were reported by Chowdhury *et al.*, (1987). Singh *et al.* (1987); found positive correlation of plant height with number of siliquae/plant, number of primary branches/plant, number of seeds/siliqua in 179 genotypes of Indian mustard. Banerzee *et al.* (1968); also found positive association of plant height with these three characters in 8 strains of yellow sarson.

In *B. rapa* Singh *et al.* (1987) and in *B. juncea*, Chowdhury *et al.* (1987), Lebowitz (1989) and Lodhi *et al.* (1979) reported that the siliqua length was positively correlated with both 1000 seed weight and number of seeds/siliqua. Several experiments were carried out by Chay and Thurling (1989) to study the inheritance of siliqua length among the tested lines of *B. napus.* It was observed that the siliqua length when increased there was an increase in the number of seeds/siliqua and 1000 seed weight.

1000 seed weight was positively and significantly correlated with seed yield/plant and number of siliqua/plant but negatively and significantly correlated with siliqua length and number of seeds/siliqua in *B. rapa* (Nasim *et al.*, 1994). Das *et al.* (1984); in F_3 population found that 1000 seed weight had highly significant genotypic and phenotypic correlation with seed yield in brown *sarson.*

1000 seed weight was found to be positively associated with days to 50% flowering and days to 80% maturity by Yadava *et al.* (1978) and Chowdhury *et al.* (1987) in *B. juncea* but Shivahare *et al.* (1975) and Singh *et al.* (1987) found negative correlation. Negative correlation of 1000 seed weight with plant height, number of primary branches/plant, and number of siliquae/plant was also reported by Chowdhury *et al.* (1987) and Yadava *et al.* (1978). Positive correlation with flowering time, days to maturity and 1000 seed weight was observed by Yadava *et al.* (1978) and Singh *et al.*, (1987).

Significant correlation between number of siliquae/plant and numbers of seeds/siliqua in yellow sarson (Banerjee, 1968). But Tak (1976), in a study with *B. rapa* found negative genotypic correlation between number of siliquae/plant and number of seeds/siliqua in brown sarson and *toria* varieties. On the contrary, Das *et al.* (1984); reported that number of siliquae/plant significantly and positively correlated with number of seeds/siliqua and 1000 seed weight. Nasim *et al.* (1994) and Kumar *et al.* (1984) in *B. rapa* found positive and significant correlation between seed yield/plant and 1000 seed weight in F_2 of *B. juncea* and Chowdhury *et al.* (1987); also found similar results in the same species.

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).

The significant partial correlation of number of secondary and tertiary racemes with seed yield indicated that branching was an important contributor to yield, independent of its association with plant size. Plants with high yields were also characterized by early maturity and early flowering (Thurling and Das, 1980).

Khulbe and Pant (1999), reported that number of siliquae/plant, siliqua length, number of seed/siliqua, 1000 seed weight were positively associated with seed yield. Kumar *et al.* (1999); studied 12 yield contributing characters in 15 genotypes of *B. juncea*, 3 of *B. napus*, 4 of *B. rapa* and one of *B. chinensis*. For more character studied, genotypic correlation coefficients were higher in magnitude than their corresponding phenotypic coefficient. Seed yield was positively correlated with plant height, siliqua number, number of siliqua/plant and 1000 seed weight.

Yield is a highly complex and variable character and the genes for yield per seed do not exist (Grafius, 1959). Therefore, direct selection for yield is not very effective. In selection for yield, recourse has then to be made to indirect selection.

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

In rape seed (*B. napus*), positive correlation between yield and yield components were generally found (Campbell and Kondra, 1978). Ramanujam and Rai (1963), found significant positive correlations between all the yield components and yield in *B. rapa* cv. yellow sarson. Similar results were reported by Zuberi and Ahmed (1973) for *B. rapa* cv. toria and by Thurling (1974) for three *B. rapa* and three *B. napus* cultivars. However, some negative associations were also found between the yield components in all studies. High yield per plant was found association with large plant size in *B. napus* (Campbell and Kondra, 1978).

Working with 65 strains of *B. juncea*, *B. rapa* and *B. napus*, Nanda *et al.* (1995); observed positive association between yield and siliqua filling period. Olsson (1990), found the similar result in *B. napus*. He also found positive correlation between siliqua density and yield.

Shivahare *et al.* (1975); found days to flowering were positively correlated with primary branches/ plant and height. But Kumar *et al.* (1996); working with 12 genotypes of *B. juncea* found flowering time and height negatively correlated with number of primary branches/plant. Labana *et al.* (1980); also found that number of primary branches was negatively correlated with plant height and siliqua length. Number of primary branches/plant was found negatively correlated with siliqua length and 1000 seed weight, but positively with number of siliqua/plant (Singh *et al.*, 1987).

Days to maturity showed insignificant correlation with seed yield both at phenotypic and genotypic levels. Number of branches/plant and number of siliquae/plant showed significant negative correlation with number of seed/siliqua and 1000 seed weight which indicated that genotypes having high number of branches as well as siliquae reduced the number of seeds/siliqua and seed size (Malek *et al.*, 2000).

2.3 Path coefficient Analysis

Partitioning the correlation coefficient into components of direct and indirect effects is necessary because correlation coefficients alone do not give a complete picture of the causal basis of association. It is established that as the number of contributing characters increased, the indirect association becomes more complex and important. Under such circumstances, path coefficient analysis is an effective tool in assigning the direct and indirect effects of different yield contributing characters.

Character association and path coefficient analysis were used to determine relationships between growth and yield parameters in 28 lines of yellow and brown sarson (*B. rapa*) by Saini and Sharma, (1995). Results revealed that seeds/siliqua and 1000 seed weight had direct positive effect on yield.

While working Kudla (1993), found that 1000 seed weight had positive direct effect on yield. Gupta *et al.* (1987); observed that the direct effect of primary branching and 1000 seed weight on seed yield.

Chaudhary *et al.* (1990); found, days to 50% flowering and plant height contributed to plant yield indirectly. Shabana *et al.* (1990); found the highest direct effect of no. of siliquae/plant on seed yield/plant.

Working with several strains of *B. juncea* Kakroo and Kumar (1991), found that 1000 seed weight had positive direct effect, but days to 50% flowering and primary branches had negative indirect effect via seeds/siliqua on seed yield. But Chauhan and Singh (1985), observed high positive direct effect of days to 50% flowering, plant height, primary branching, siliquae/plant, seeds/siliqua on yield. Kumar *et al.* (1988); observed the indirect positive effect of days to 50% flowering on yield. Again, Han (1990), working with *B. napus*, observed negative direct effect of no. of siliquae/plant, siliqua length and positive direct effect of seeds/siliqua and height on yield. Kumar *et al.* (1984) observed the negative indirect effect of days to flowering via plant height and siliqua length on yield in *B. juncea.* Singh *et al.* (1978) also found negative direct effect of these traits, but Dhillon *et al.* (1990); observed the highest positive direct effect of plant height on seed yield/plant.

The results of several experiments conducted by Das and Rahman (1989) in *B. rapa*, Ghosh and Chatarzee (1988) in *B. juncea*, Mishra *et al.* (1987) in *B. rapa,* Alam *et al.* (1986) in *B. juncea*, Singh *et al.* (1985) in *B. juncea*, Chen *et al.* (1983) in *B. napus*, Srivastava *et al.* (1983) in *B. juncea* and Yadava (1982) in *B. rapa*, revealed that plant height, days to maturity, 1000 seed weight, siliquae/plant and seeds/siliqua had positive direct effect and indirect effect on yield. But Varshney (1986), working with several strains of *B. rapa* found the negative direct effect of plant height, siliqua/plant, seeds/siliqua and 1000 seed weight on yield.

Chapter III

MATERIALS AND METHODS

3.1 Experimental Site

The present research work was carried out in the experimental farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during November 2005-March 2006.

3.2 Soil and Climate

The soil of the experimental plots were clay loam, land was medium high with medium fertility level. The site was suited in the subtropical climate zone, wet summer and dry winter is the general; climatic feature of this region. During the rabi season the rainfall generally is scant and temperature moderate with short day length. Meteorological data on rainfall, temperature, relative humidity from January 2005 to February 2006 were obtained from the Department of Meteorological centre, Dhaka-1207, Bangladesh (Appendix III). The experiment was conducted using twelve F_2 generation along with their five parental materials.

3.3 Materials

The cultivars were Tori-7, SS-75, BARIsarisha-6, BARIsarisha-9, SAUYC and F_2 progenies were Tori-7×SS-75, SS-75×Tori-7, BARIsarisha-6×BARIsarisha-9, BARIsarisha-9×BARIsarisha-6, Tori-7×SAUYC, SAUYC×Tori-7, BARIsarisha-9×SAUYC, SAUYC×BARIsarisha-9, BARIsarisha-6×Tori-7, Tori-7×BARIsarisha-6, SS-75×BARIsarisha-9, BARIsarisha-9×SS-75. The advanced line SAUYC and other parental materials and the F_2 materials were collected from *Brassica* Breeding Project of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. Twelve crosses including six reciprocals were done among parents in rabi season 2002-2003. In the rabi season of 2004-2005, the parents, F_1's and reciprocals were grown in the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh.

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 power tiller and country plough to bring about good tilth. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

3.4.2 Fertilizer application

Fertilizers such as urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and borax were applied at the rate shown in Table 1. Urea was applied by two installments. Total amount of TSP, MP, gypsum and borax along with half of the urea were applied at the time of final land preparation as a basal dose. The second half of the urea was top-dressed at the time of initiation of flowers.

Table 1. List of fertilizers with doses and application procedures

SL. No.	Fertilizer	Doses	Application Procedure
1.	Urea	250 Kg/ha	50% basal and 50% at the time of flower initiation
2.	TSP	170 Kg/ha	as basal
3.	MP	85 Kg/ha	as basal
4.	Gypsum	150 Kg/ha	as basal
5.	Borax	5 Kg/ha	as basal

3.4.3 Experimental design

Field lay out was done after final land preparation. The seeds of parents and F_2 materials were laid out in a Randomized complete block design (RCBD) with three replications. The size of the plot was 5m×25m. A distance of 1.5 m from block to block , 30 cm from row to row and 10 cm from plant to plant was maintained .Seeds were sown in lines in the experimental plots on 16 November, 2005. The seeds were placed at about 1.5 cm depth in the soil. Seed germination started after 3 days of sowing.

3.4.4 Intercultural operations

Intercultural operations, such as weeding, thinning, irrigation, pest management, etc. were done uniformly in all the plots. One post sowing irrigation was given by sprinkler after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. The first weeding was done after 15 days of sowing. During 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. The crop was protected from the attack of aphids by spraying Malathion-57 EC@ 2 ml/liter of water. The genotypes differed widely for days to flowering. The insecticide was applied for the first time approximately before one week of flower initiation and it was applied for another two times at an interval of 15 days. To protect the crop from the Alternaria leaf spot, Rovral-50 WP was sprayed at the rate of 2g/l at 50% flowering stage for the first time and it was again applied for two times at an interval of 15 days. Both the insecticide and fungicide were applied in the evening.

3.4.5. Harvesting

Harvesting was started from 15 February, 2006 depending upon the maturity of the plants. When 80% of the plants showed symptoms of maturity i.e.; straw colour of siliquae, leaves, stem and desirable seed colour in the matured siliquae, the crop was assessed to attain maturity. Ten plants were selected at random from parental line and 50 plants from F_2 progenies in each replication. The sample plants were harvested by uprooting and then they were tagged properly. Data were recorded from these plants.

3.4.6 Collection of data

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

3.4.7 Methods of collecting data

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

2. **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.

3. **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.

4. **Days to 50% flowering:** Difference between the dates of sowing to the date of 50% flowering of a line was counted as days to 50% flowering.

5. **Siliqua length (cm):** For this character measurement was taken in cm from the base to the tip of a siliqua without beak from the five representative siliquae.

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

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

8. **1000 seeds weight (gm):** Weight in grams of randomly counted thousand seeds was recorded.

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

10. **Days of maturity:** Number of days required from 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). Simple correlation coefficient was obtained using the formula suggested by Clarke (1973); Singh and Chaudhary (1985); and path co-efficient analysis were done following the method outlined by Dewey and Lu (1959).

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

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

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

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

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

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

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

Where, GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δ_g = Genotypic standard deviation

δ_p = Phenotypic standard deviation

$\overline{x}$ = Population mean

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

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

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

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

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

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

Where, GA = Genetic advance

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

δ_p = Phenotypic standard deviation

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

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

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

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

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

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 simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect of 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):

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

Where, $P^2RY = (R^2)$; and hence residual effect, $R = (P^2_{RY})$ ½

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

riy = Correlation of the character with yield.

Chapter IV

RESULTS AND DISCUSSION

4.1 Variability

4.1.1 Variability in parents and F_2 materials

Ten characters of *Brassica rapa* such as plant height, number of primary branches/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua, 1000 seed weight, yield/plant, days to 50% flowering and days to maturity were studied in five parental genotypes and their twelve F_2 progenies including reciprocals obtained from selective crosses. There were significant differences among the 12 F_2 materials for the different morphological characters studied (Appendix I and II). The mean performance, range and CV (%) over three replications for all the studied characters of 5 parental materials and the 12 F_2 materials are presented in Table 2 and 3 respectively.

The parents SS-75 and BARIsarisha-6 were the tallest with the average plant height of around 105cm. The shortest parent was improved Tori-7 with the plant height of 80.83cm. The parents BARIsarisha-9 was more or less similar to improved Tori-7 in height. However, SAUYC, a line derived from interspecific crosses was of moderate height (Table 2).

Branching has influenced on yield by providing opportunity of bearing siliqua. The parents SS-75, SAUYC and BARIsarisha-9 produced maximum number of primary branches per plant with an average of more or less 10. The lowest number of primary branches/plant was observed in the parent Tori-7. However, Tori-7 produced maximum number of secondary branches/plant, which was followed by the parent BARI sarisha-9. SAUYC had the moderate number of secondary branches per plant.

Table 2. Values of mean, range and CV (%) of seed and related characters of 5 Parents of *Brassica rapa*

Parents	Plant height (cm)	No. of primary branches/plant	No. of secondary branches/ plant	Length of siliqua (cm)	Seeds/ siliqua (no.)	No. of siliquae/ plant	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering	Days to maturity
Tori-7										
Mean	80.83	7	9	3.84	14	147	2.24	2.21	33	80
Range	67-95	4-12	4-15	2.92-5.7	8.6-19.8	47-238	1.6-3	0.94-3.81	------	79-85
CV (%)	8.48	35.14	31.41	14.75	27.14	38.73	12.39	25.72	------	2.21
SS-75										
Mean	106.77	10	1	3.59	16	289	2.49	4.64	41	95
Range	92-132	5-16	0-10	2.66-4.72	8.4-26	117-417	2-3.2	2.99-8.35	41-42	93-103
CV (%)	8.77	27.24	149.76	14.50	24.89	22.16	9.02	28.97	-------	4.51
BARI-6										
Mean	105.53	8	1	4.40	22	143	2.47	4.20	43	95
Range	90-121	5-10	0-3	3.54-5.16	5-30.4	104-215	1.9-3.5	1.45-7.43	42-43	85-103
CV (%)	8.31	22.08	180.33	11.24	23.79	17.52	16.13	29.40	-------	6.29
SAUYC										
Mean	95.3	11	5	4.65	18	211	2.24	3.50	30	83
Range	88-100	7-15	0-15	3.04-6.52	10-25	117-319	1.9-3.2	2.06-5.59	29-33	80-87
CV (%)	4.29	24.61	113.55	26.35	31.77	38.42	18.02	32.04	-------	3.14
BARI-9										
Mean	82.1	10	8	3.63	14	206	2.61	2.87	34	85
Range	62-110	5-15	0-20	2.46-4.72	10 -19.8	117-329	1.5-3.2	1.3-5.71	33-35	85-87
CV (%)	13.95	27.66	72.83	10.99	17.01	28.67	14.43	32.10	-------	0.72

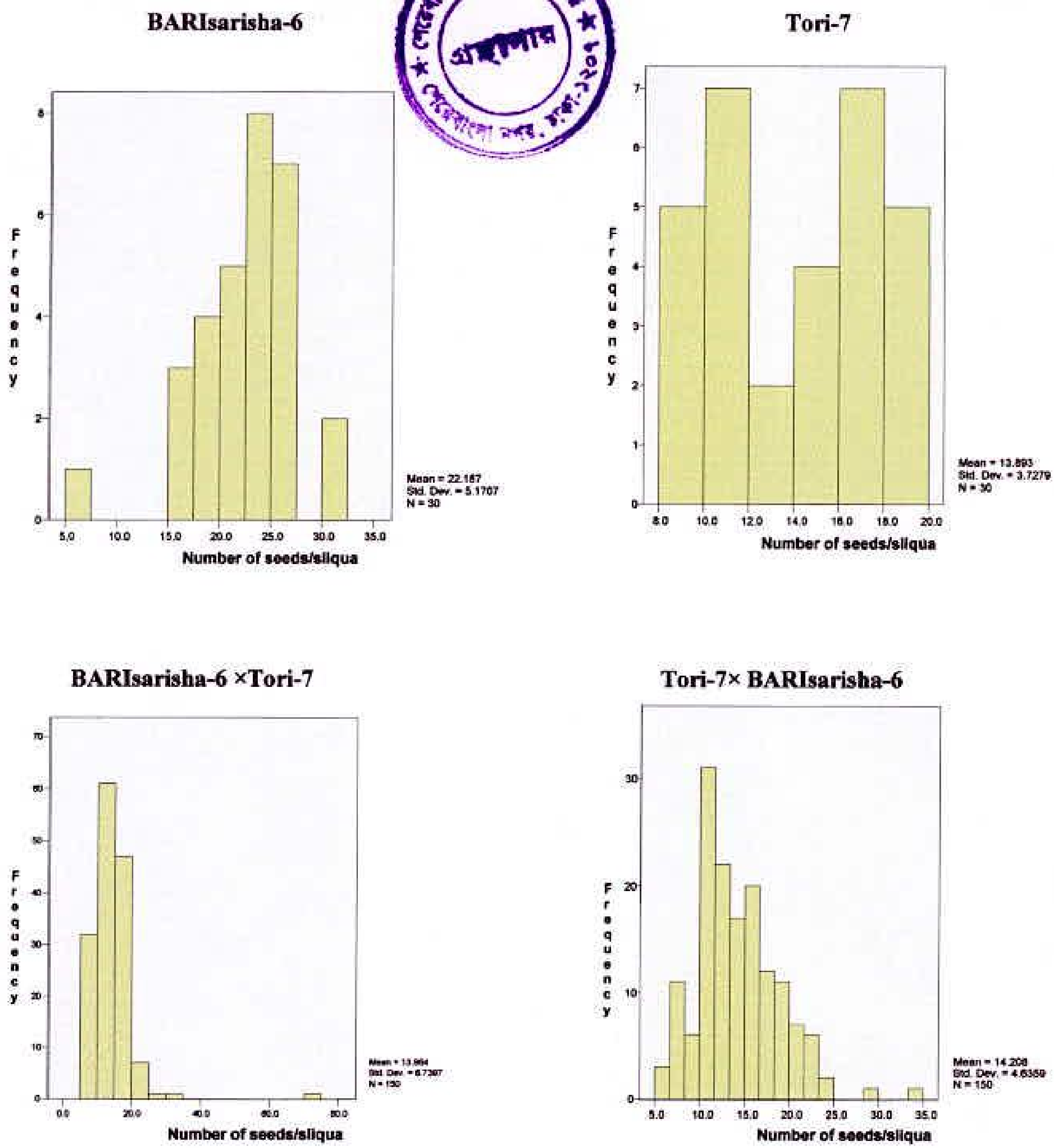

Figure 1. Histogram showing frequency distribution of plants for number of seeds/siliqua of parents and F_2 population of the cross BARIsarisha-6×Tori-7 and their reciprocals

Length of siliqua is an important yield contributing character. The length of siliqua was highest in SAUYC, which the line obtained from its parent *Brassica napus*. The average was 4.65cm which was followed by BARIsarisha-6 (4.4cm). The variation was large for the character number of seeds/siliqua. The parent BARIsarisha-6 produced on an average 22 seeds per siliqua (Fig. 1). The second lowest parent was SAUYC which produced (18.34) seeds/siliqua. The lowest number of seeds per siliqua was obtained in the variety Tori-7 followed by BARI sarisha-9.

The seed size was larger in the parent BARIsarisha-9 with an average of 2.61g for 1000 seed weight. The seed size of SS-75 and BARIsarisha-6 was of more or less similar type with moderate weight of 2.49g and 2.47g respectively (Table 2).

Larger variations were observed for number of siliqua per plant in different parental genotypes. The parent SS-75 had an average of (289) siliquae/plant which was the highest in number. BARIsarisha-9 was the second parent in terms of ranking for this character which an average of only 206.03. However, the lowest number of siliquae/plant was observed in BARIsarisha-6 (142.57) which was followed by Tori-7 (Fig. 2).

The yield was highest in the parent SS-75 which produced 4.64g of seeds per plant and BARIsarisha-6 produced 4.20g of seeds per plant and lowest was observed in Tori-7 produced only 2.21g of seeds (Fig. 3).

The line SAUYC started early flowering where days to 50% flowering was 30 days for this line. The variety Tori-7 started flowering on 33 days after sowing with the earliest average maturity period of 80 days. The line SAUYC was the second with average maturity period of 83 days. The high yielders SS-75 and BARIsarisha-6 were in the late maturing category of 95 days. Although the two varieties produced maximum yield/plant, yet they are not accepted largely by the farmers due to their long maturity period. On the other hand, low yielder Tori-7 and moderate

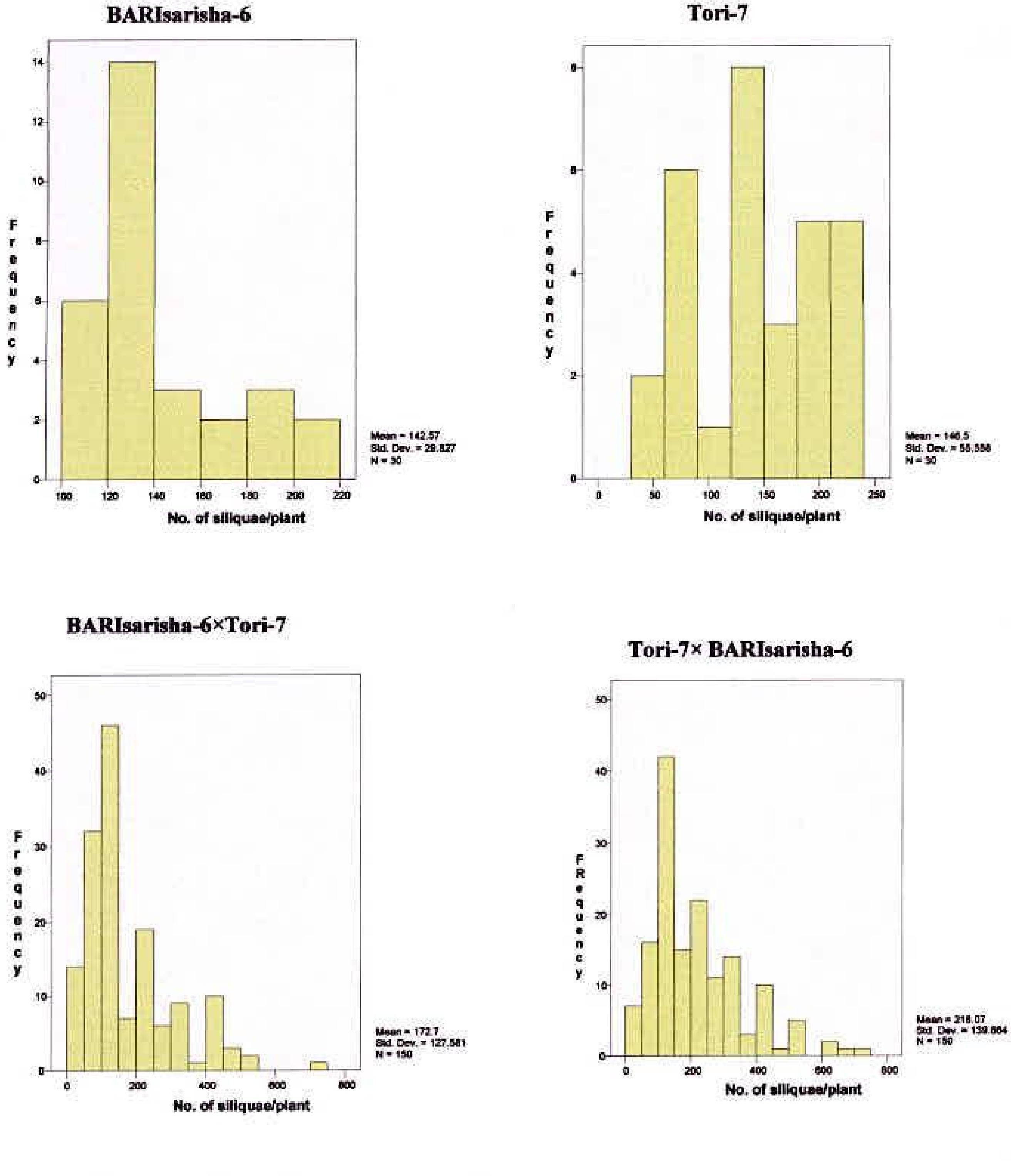

Figure 2. Histogram showing frequency distribution of plants for number of siliquae/plant of parents and F_2 population of the cross BARIsarisha-6×Tori-7 and their reciprocals

Table 3.Values of mean, range and CV (%) of seed and related characters of 12 F_2 materials of *Brassica rapa*

Crosses (F_2)	CHARACTERS									
	Plant height (cm)	No. of primary branches/plant	No. of Secondary branches/plant	Length of siliqua (cm)	No. of seeds/ siliqua	No. of siliquae/ plant	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering	Days to maturity
SS75×Tori-7										
Mean	80.54	8	4	3.61	14	156	1.90	2.06	30	87
Range	55-120	2-23	0-25	2.2-5.28	5.4-25.2	32-412	0.95-3.0	0.51-10.28	------	80-93
CV (%)	15.71	45.71	101.20	17.24	28.89	52.89	20.75	45.76	------	5.15
Tori-7×SS75										
Mean	89.79	5	5	3.43	13	150	2.21	2.86	36	89
Range	52-125	2-13	0-16	2.08-5.06	5.6-23.8	36-427	0.9-3.55	0.48-10.78	33-38	81-103
CV (%)	15.08	47.21	94.59	16.83	26.25	51.75	19.84	50.27	-----	7.90
SS-75× BARI-9										
Mean	96.99	6	3	3.63	14	171	2.04	2.05	33	94
Range	67-130	2-17	0-15	2.32-5.94	4.4-29	50-406	1.1-3.5	0.52-6.03	-----	80-103
CV (%)	13.70	40.56	120.50	17.78	31.23	47.00	20.15	45.68	-----	8.47
BARI-9 × SS-75										
Mean	97.67	6	3	3.89	13	148	2.25	2.21	39	90
Range	55-190	2-13	0-15	2.26-6.98	6.8-25	22-481	0.9-3.95	0.38-7.41	39-40	80-103
CV (%)	18.39	41.75	115.46	18.11	24.96	61.33	22.96	62.69	-----	8.12
Tori-7×BARI-6										
Mean	78.83	8	5	3.59	14	218	1.83	2.46	33	88
Range	43-521	2-26	0-29	2.3-5.92	5-33.4	31-712	1-3.1	0.43-7.89	-----	79-103
CV (%)	36.50	60.34	90.93	15.50	30.20	64.12	20.37	49.85	-----	9.25
BARI-6×Tori-7										
Mean	84.73	7	5	3.53	14	174	2.08	2.20	37	88.03
Range	50-121	2-39	0-43	2.14-7.24	5-75	35-717	0.15-4.4	0.37-8.01	35-38	80-93
CV (%)	18.66	62.71	94.95	16.78	45.20	68.92	30.25	74.23	------	5.75

Table 3 Continued

Crosses (F_2)	Plant height (cm)	No. of primary branches/plant	No. of Secondary branches/plant	Length of siliqua (cm)	No. of seeds/ siliqua	No. of siliquae/ plant	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering	Days to maturity
BARI-6×BARI-9										
Mean	93.26	5	5	3.914	16	177	1.99	2.93	38	87
Range	62-125	2-21	0-14	2.18-6.14	6.8-25.4	47-687	0.21-3.55	0.38-10.23	------	81-93
CV (%)	14.25	54.20	76.94	18.49	27.46	54.28	25.28	57.95	------	5.73
BARI-9×BARI-6										
Mean	99.12	6	3	3.90	14	188	2.105	2.89	40	95
Range	65-119	2-23	0-12	2.26-5.58	7.8-25.2	46-482	0.22-3.25	0.45-9.47	39-41	80-103
CV (%)	12.60	60.17	104.34	17.31	23.89	52.07	21.74	57.38	-----	7.64
SAUYC×Tori-7										
Mean	75.87	6	6	3.42	12	166	2.18	2.33	30	86
Range	50-118	2-22	0-23	2.2-9.8	6-37	146-567	1.25-3.3	0.69-7.59	-----	79-93
CV (%)	17.41	40.93	64.67	21.33	28.78	72.85	17.71	49.13	-----	6.24
Tori-7×SAUYC										
Mean	81.2	7	5	3.69	13	204	2.36	2.57	33	83
Range	55-130	2-25	0-15	2.16-6.82	3-39.6	11-704	0.8-5.1	0.76-7.09	-----	79-85
CV (%)	16.71	56.14	67.99	19.66	30.19	59.37	22.44	43.97	-----	3.02
BARI-9×SAUYC										
Mean	86.93	10	6	3.60	12	209	2.23	2.49	38	89
Range	51-124	2-39	0-43	1.92-5.5	3.8-33.6	31-706	0.18-4.35	0.46-9.68	-----	79-103
CV (%)	14.45	48.12	90.91	16.65	34.62	63.90	24.85	62.58	-----	8.17
SAUYC×BARI-9										
Mean	87.5	7	3	3.56	14	171	2.02	2.08	38	86
Range	10-127	1-26	0-17	2.2-5.44	6.2-24.8	29-517	0.5-3.9	0.31-9.67	38-39	79-103
CV (%)	15.22	51.35	134.02	18.67	27.15	57.36	23.55	66.24	------	8.21

yield producing variety BARIsarisha-9 are more acceptable to farmers as they can fit well in the existing cropping patterns (T. aman-mustard-boro) in Table 2.

Larger variations were observed in the different F_2 materials for most of the studied characters (Table 3). The F_2 materials SS-75×BARIsarisha-9, BARIsarisha-9×SS-75 and BARIsarisha-9×BARIsarisha-6 were found taller with the average plant height of more than 95cm. The shortest F_2 material was SAUYC×Tori-7 with the plant height of 76cm followed by Tori-7×BARIsarisha-6 (Table 3).

Branching has influenced on yield by providing opportunity of bearing siliqua. The cross BARI sarisha-9×SAUYC produced maximum number of primary branches per plant with an average of 10 which was followed by SS-75×Tori-7 (8). The lowest number of primary branches/plant was observed in the cross BARIsarisha-6×BARIsarisha-9. In the cross, SS-75×Tori-7 had the moderate number of secondary branches per plant. The coefficient of variation was higher for number of primary and secondary branches/plant in Tori-7×BARIsarisha-6 and SAUYC×BARIsarisha-9 respectively. This character might be taken into consideration while selecting a suitable line for releasing as a new variety.

Length of siliqua is an important yield contributing character. The highest siliqua length was found in three crosses viz; BARIsarisha-6×BARI sarisha-9, BARIsarisha-9×BARIsarisha-6 and BARI sarisha-9 ×SS-75 (3.89-3.91cm).

The variation was lower for the character number of seeds/siliqua. The range for seeds per siliqua was (12-16). On the other hand larger variations were observed for number of siliquae/plant in different F_2 materials. The F_2 material Tori-7×BARIsarisha-6 had an average of (218) siliquae/plant which was the highest in number (Figure 2). BARI sarisha-9×SAUYC was the second parent in terms of ranking for this character which an average of only 209. However,

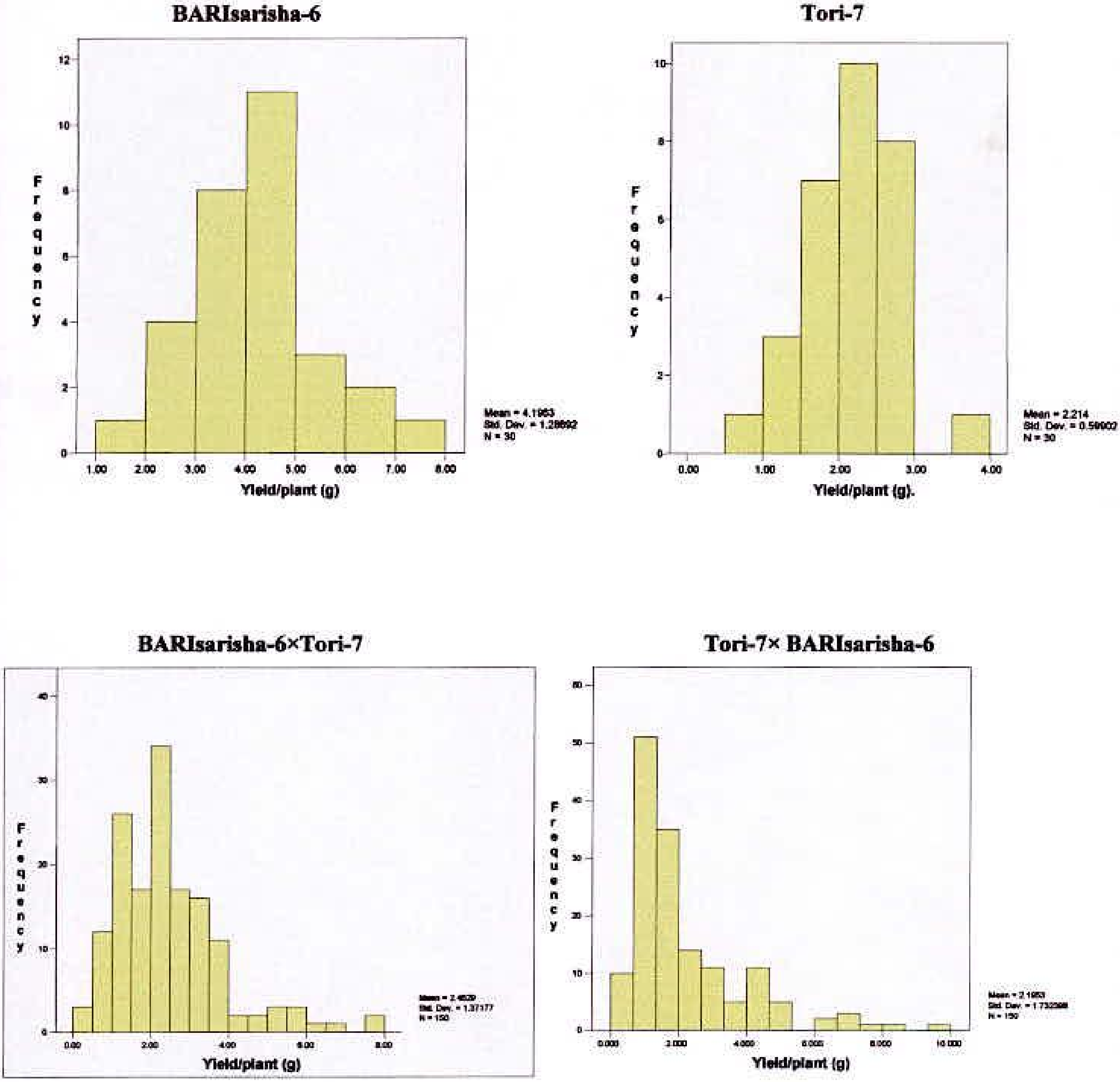

Figure 3. Histogram showing frequency distribution of plants for number of Yield/plant (g) of parents and F_2 population of BARIsarisha-6×Tori-7 and their reciprocals

Plate 1. Photograph showing flowering of Tori-7 and F_2 materials of the cross Tori-7×SS75

Plate 2. Photograph showing flowering of Tori-7 and F_2 materials of the cross Tori-7×BARIsarisha-6

Plate 3. Photograph showing flowering of SS75 and F_2 materials of the cross SS75×Tori-7

the lowest number of siliquae/plant was observed in BARI sarisha-9×SS-75 (148). The CV% (72.85%) was higher in SAUYC×Tori-7. So, selection can be made here for this character.

The larger variation in seed size was observed in the F_2 materials. The Tori-7×SAUYC had the highest number (2.36g) 1000 seed weight which was followed by BARI sarisha-9×SS-75. The lowest weight was (1.90g) in SS-75×Tori-7 and in BARIsarisha-6 × BARIsarisha-9 (1.99g).

The highest yield was recorded in the F_2 material BARI sarisha-6×BARIsarisha-9 which produced 2.93g of seeds per plant. SAUYC×BARIsarisha-9 and SS-75×Tori-7 produced 2.08g and 2.06g of seeds per plant respectively. Selection can be made for this character in BARI sarisha-6×Tori-7 because coefficient of variation was higher 74.23%.

The cross SAUYC×Tori-7 and SS-75×Tori-7 started early flowering where days to 50% flowering were 30days for these lines. The line Tori-7×SAUYC was the first with average maturity period of 82.52 days. The high yielders BARI sarisha-6×BARIsarisha-9 and Tori-7×SS-75 were in the late maturing category of above 86 days (Table 3). Different parents and F_2 materials showed variations in flowering time (plate 1, 2&3) and days to maturity (plate 4, 5&6).

The phenotypic variance of parent was considerably higher than the genotypic variance for all the characters studied in parents (Table 4). Deshmukh *et al.* (1986) also reported that phenotypic co-efficient of variation was higher than the genotypic co-efficient of variation.

Least difference between phenotypic variance and genotypic variance were observed in primary branches/plant, secondary branches/plant, length of siliqua, number of seeds/siliqua, days to 50% flowering, days to maturity, 1000 seed weight which indicated low environmental influence on these characters which might be due to their genetic control. Relatively high phenotypic variation was observed in plant height (180.91) and number of siliquae/plant (405.13) indicated large environmental influence on these characters. Characters like length of siliqua, 1000 seed weight

ble 4. Estimation of some genetic parameters of 5 parents of *Brassica rapa*

Parameters	Plant height (cm)	No. of primary branches/ plant	No. of secondary branches/ plant	Length of siliqua (cm)	Seeds/ siliqua (no.)	Siliquae/ plant (no.)	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering	Days to maturity
Genotypic variance	154.12	2.55	13.43	0.15	11.35	3741.43	0.02	0.93	27.82	49.63
Phenotypic variance	180.91	2.78	13.80	0.17	12.15	4050.13	0.06	1.91	28.60	51.15
Genotypic co-efficient of variation	13.03	17.47	80.72	9.82	20.19	29.96	5.75	27.70	14.49	8.03
Phenotypic co-efficient of variation	14.12	18.25	81.82	10.44	20.89	31.11	9.78	39.74	14.70	8.15

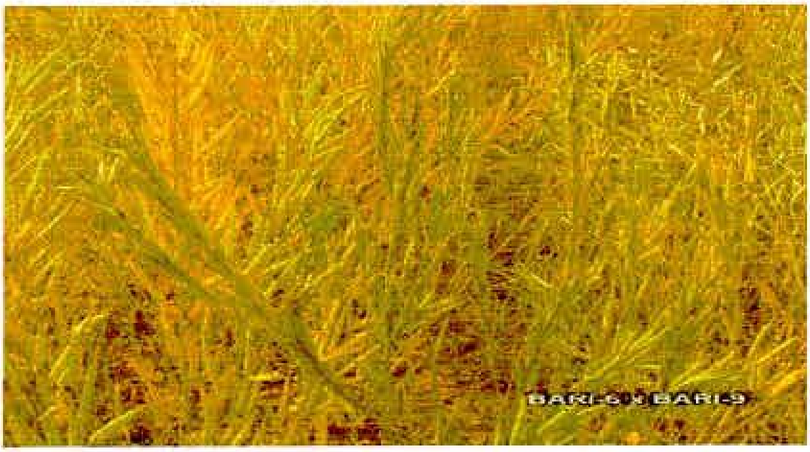

Plate 4. Photograph showing different maturity of F_2 materials of the cross BARIsarisha-6× BARIsarisha-9

Plate 5. Photograph showing different maturity of F_2 materials of the cross BARIsarisha-6×Tori-7

Plate 6. Photograph showing different maturity of F_2 materials of the cross Tori-7×BARIsarisha-6

and days to maturity showed low genotypic and phenotypic coefficient of variation indicated that the genotype has considerable variation for these traits. Moderate genotypic and phenotypic coefficient of variation was observed in plant height, number of primary branches/plant, number of seeds/siliqua, number of siliqua/plant, yield/plant and days to 50% flowering which indicated moderate variability were present among the genotype for these characters. Number of secondary branches/plant showed high genotypic and phenotypic coefficient of variation (80.72%) and (81.82%) respectively indicated that the genotype were highly variable for this trait (Table 4).

In the F_2 materials phenotypic variance was also higher than the genotypic variance for all the characters studied in Table 5. Number of primary branches/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua, days to 50% flowering, 1000 seed weight and yield/plant showed low difference between genotypic and phenotypic variance which indicated short of environmental influence on this character which might be due to their genetic control. Plant height, number of siliqua/plant and days to maturity showed higher difference between genotypic and phenotypic variance. Higher genotypic variances indicate the better transmissibility of a character from parent to offspring (Ushakumari *et al.* 1991).

Plant height, length of siliqua, number of seeds/siliqua and days to 50% flowering showed low genotypic and phenotypic coefficient of variation indicated that the genotype has considerable variation for these traits. Moderate genotypic and phenotypic coefficient of variation was observed in number of primary branches/plant, number of secondary branches/plant, number of siliqua/plant, yield/plant, 1000 seed weight and days to maturity which indicated moderate variability were present among the genotype for these characters (Table 4).

ble 5. Estimation of some genetic parameters of 12 F_2 materials of *Brassica rapa*

Parameters	Plant height (cm)	No. of primary branches/ plant	No. of secondary branches/ plant	Length of siliqua (cm)	Seeds/ siliqua (no.)	Siliquae/ plant (no.)	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering	Days to maturity
Genotypic variance	49.46	1.61	1.24	0.01	0.08	517.69	0.08	0.01	9.53	3.65
Phenotypic variance	84.94	2.03	1.49	0.07	1.55	633.31	0.16	0.22	10.49	31.16
Genotypic co-efficient of variation	8.02	18.54	27.48	2.07	6.51	12.77	13.27	3.99	8.54	2.16
Phenotypic co-efficient of variation	10.51	20.81	25.07	7.43	9.21	14.13	18.94	19.40	8.96	6.32
Heritability %	58.22	79.31	83.22	7.70	49.90	81.74	49.06	4.25	90.78	11.73
Genetic advance	12.61	34.01	47.11	1.18	9.47	23.79	19.14	1.70	16.76	1.53
Genetic advance in percentage of mean	14.38	496.86	560.56	32.35	70.05	13.35	409.41	70.36	46.38	1.73

4.1.2 Heritability, genetic advance and selection

The heritability estimates, genetic advance and genetic advance in percent of mean, selection of F_2 materials of *Brassica* rapa are presented in Table 5.

Days to 50% flowering showed high heritability 90.78% with genetic advance 16.76 and genetic advance in percentage of mean 46.38% revealed possibility of predominance of additive gene action in the inheritance of this character and therefore, the characters could be improved through selection process. The results obtained for heritability in this study showed close resemblance with the reports of Malik *et al.* (1995).

Days to maturity showed low heritability of 11.73% with genetic advance of 1.53 and genetic advance in percentage of mean 1.73%. As a whole the low heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes that would mature earlier. However, some of the individual plants showed quite a reasonable reduced maturity which were selected for further study in the next generation. In some of the crosses the frequency of the segregating plants showing reduced maturity was comparatively higher than the other crosses.

Heritability of 58.22% together with genetic advance 12.61 and genetic advance in percentage of mean 14.38% was found for plant height revealed the possibility of predominance of both additive and non additive gene action in the inheritance of this character which limit the scope of improvement by direct selection. Singh *et al.* (1987), Han (1990) and Malik *et al.* (1995) found high heritability (80%-95%), but Yadava *et al.* (1985) found moderate heritability for this character. Plant of moderate stature would be favorable for the farmers.

Number of primary branches/plant showed heritability of 79.31% coupled with genetic advance of 34.01 and very high genetic advance in percentage of mean 496.86%. These findings revealed the predominant action of additive gene effect on the expression of this character with a scope of improvement through selection. Similar findings were observed by Malik *et al.* (1995) and Singh *et al.* (1991) in *B. napus*.

High heritability 83.22% coupled with high genetic advance 47.11 and high genetic advance in percentage of mean 560.56% was found of the secondary branches/plant. As this trait possessed high variation, it is high potential for effective selection for further genetic improvement of this trait.

Length of siliqua showed heritability 7.70% connected with genetic advance 1.18 and genetic advance in percentage of mean 32.35%. The results revealed the possibility of predominance of both additive and non additive gene action in the inheritance of this character which limit the scope of improvement by direct selection. Low to medium heritability (<40%) of siliqua length was observed by Sharma (1984) and Kakroo and Kumar (1991).

The magnitude of moderate heritability in broad sense (h^2b) of seeds/siliqua was 49.90% and genetic advance of 9.47 and high genetic advance in percentage of mean 70.05%. It differs with the findings of Chaudhary and Prasad (1978).

Number of siliquae/plant showed high heritability 81.74% coupled with genetic advance 23.79 and genetic advance in percentage of mean 13.35%. It indicates the possibility of involvement of additive gene effects and suggested that moderate response might be obtained in selection for high number of siliqua/plant. The present findings have similarity with those of Singh *et al.* (1991). They found high heritability (80%-95%) for this character.

Heritability of 9.06% and genetic advance 19.14 was considerably high and genetic advance in percentage of mean 409.41% was very high of 1000 seed weight that offers a scope for improvement of the character through selection. It may provide a better indication of the amount of genetic process resulting from selection of the best individuals. Similar result was observed by

Singh (1986). He studied on 22 genotypes of *Brassica napus*, *B. rapa* and *B. juncea* and reported high heritability (>80%) and genetic advance for seed yield and thousand seed weight.

Yield/plant showed low heritability of 4.25% coupled with low genetic advance of 1.70 and genetic advance in percentage of mean 70.36%. The result indicates that this character might not be selected for improvement of the crop. In study of 46 genotypes of *Brassica juncea*, Sharma (1984) observed high heritability and genetic advance for yield/plant. In another study of 179 genotypes Singh *et al.* (1987) found high heritability (80%-95%) for this character. The result is in partial agreement with the above findings.

Variability was found for most of the studied characters in almost all the F_2 materials of different cross combinations. Selection was carried out among the F_2 materials as per objectives. Eighteen most promising plants with yellow seed and a short duration (80 days) were selected from the F_2 materials of the different cross combinations (Table 6). There were large variations for siliquae/plant in the 18 selected F_2 materials ranging from 32-419 siliquae. One of the selected plants of the cross produced as much as 4.4 g of 1000 seed weight.

Three plants of Tori-7×SAUYC produced more than 3g of 1000 seed weight. Yield/plant was more than 4.5g in a plant selected from BARIsarisha-6×BARIsarisha-9. Another selected plant of the same cross and one plant from its reciprocal cross and one from the cross BARIsarisha-6×Tori-7 produced more than 3g of seed per plant. One selected plant from the cross BARIsarisha-6×Tori-7 produced exceptionally high yield per plant (5.29g). Out of the 18 selected materials seven plants were of the Tori-7 type, five of BARIsarisha-6, four of SAUYC, one of SS-75 and one of BARIsarisha-9 type.

Table 6. Performance of selected yellow seeded short duration (80 days) plants from the F_2 materials of different cross combinations of *Brassica rapa*

Cross combinations	Plant no.	Siliquae/ Plant (no.)	1000 seed wt. (g)	Yield/ plant (g)	Type of plant
SS-75×Tori-7 (R-1)	5	32	1.90	2.00	SS-75
Tori-7×SS-75 (R-1)	7	69	2.05	2.01	Tori-7
BARIsar-6×BARI-9 (R-3)	9	298	2.75	4.60	BARIsar-6
	23	306	1.85	2.97	BARIsar-6
	24	291	2.85	3.45	BARIsar-6
BARIsar-9×BARsarI-6 (R-1)	4	127	1.90	3.22	BARIsar-9
BARIsar-6×Tori-7 (R-1)	1	419	1.85	5.29	BARIsar-6
	25	126	4.40	3.49	BARIsar-6
Tori-7×SAUYC (R-2)	4	161	1.90	2.36	Tori-7
	23	89	1.25	2.24	Tori-7
	24	76	2.25	2.03	Tori-7
Tori-7×SAUYC (R-3)	8	112	3.40	2.21	Tori-7
	9	114	3.10	2.33	Tori-7
	25	69	3.20	2.30	Tori-7
SAUYC×Tori-7 (R-2)	5	135	2.20	1.90	SAUYC
SAUYC×Tori-7 (R-3)	13	123	2.45	2.24	SAUYC
SAUYC×BARIsar-9 (R-2)	16	135	2.20	2.20	SAUYC
SAUYC×BARIsar-9 (R-3)	5	286	1.25	2.25	SAUYC

On the other hand, thirty one most promising plants with grey seeded and a short duration were selected from the F_2 materials of the different cross combinations (Table 7). There were also large variations for siliquae/plant in the 31 selected F_2 materials ranging from 67-507 siliquae. One of the selected plants of the cross SAUYC×BARIsarisha-9 produced as much as 3.80g of 1000 seed weight.

Table 7. Performance of selected grey seeded short duration (80 days) plants from the F_2 materials of different cross combinations of *Brassica rapa*

Cross combinations	Plant no.	Siliquae/ Plant (no.)	1000 seed wt. (g)	Yield/ plant (g)	Type of plant
Tori-7×SS-75 (R-2)	1	161	2.05	3.87	Tori-7
Tori-7×SAUYC (R-2)	2	345	1.65	4.33	Tori-7
	14	342	1.00	4.24	Tori-7
SAUYC×Tori-7 (R-1)	7	210	1.75	3.33	SAUYC
	8	210	2.05	3.28	SAUYC
BARIsar-6×BARIsar-9 (R-3)	12	341	2.20	5.60	BARIsar-6
	21	214	2.65	5.38	BARIsar-6
	22	319	1.65	6.28	BARIsar-6
	44	347	1.70	5.14	BARIsar-6
BARIsar-9×BARIsar-6 (R-3)	1	315	2.10	3.91	BARIsar-9
	5	398	1.85	4.77	BARIsar-9
BARIsar-6×Tori-7 (R-1)	19	314	2.65	4.07	BARIsar-6
	32	507	3.10	6.35	BARIsar-6
	34	138	3.00	4.39	BARIsar-6
BARIsar-6×Tori-7 (R-2)	2	417	2.50	7.20	BARIsar-6
	3	192	2.85	5.25	BARIsar-6
	12	497	1.70	4.99	BARIsar-6
BARIsar-6×Tori-7 (R-3)	7	430	1.95	5.32	BARIsar-6
	8	305	1.40	4.04	BARIsar-6
Tori-7×BARIsar-6 (R-1)	6	67	1.45	3.48	Tori-7
	7	297	2.65	5.95	Tori-7
	32	192	2.10	3.46	Tori-7
Tori-7×BARIsar-6 (R-2)	1	507	1.45	4.45	Tori-7
	14	421	2.25	4.90	Tori-7
BARIsar-9×SAUYC (R-3)	25	410	1.80	4.60	BARIsar-9
SAUYC×BARIsar-9 (R-1)	13	201	3.20	3.71	SAUYC
	40	321	3.80	3.61	SAUYC
SAUYC×BARIsar-9 (R-2)	5	315	2.15	5.03	SAUYC
SAUYC×BARIsar-9 (R-3)	10	231	2.55	4.17	SAUYC
	13	301	2.20	5.45	SAUYC
	23	267	2.10	4.25	SAUYC

Two plants of SAUYC×BARIsarisha-9 produced more than 3g and three plants of BARI sarisha-6×Tori-7 produced more than 2.5g of 1000 seed weight. Yield/plant was exceptionally high 7.20g in a plant selected from BARIsarisha-6×Tori-7 and more than 6.3g in another plant selected from its reciprocal cross. Other selected plants were four from the BARIsarisha-6×BARIsarisha-9, two from the BARIsarisha-6×Tori-7 and one plant from its reciprocal cross and one from the cross SAUYC×BARIsarisha-9 and one its reciprocal cross produced more than 5.00g of seed per plant. Out of the 31 selected materials twelve plants were of the BARIsarisha-6 type, eight plants were of SAUYC, eight plants were of the Tori-7 type, and three like BARIsarisha-9 type (Table 7).

4.2 Correlation co-efficient

Genotypic and phenotypic correlation coefficients between pairs of characters for F_2 materials of *Brassica rapa* were presented in Table 8.

Plant height showed highly significant positive association with days to 50% flowering (0.68) and significant positive association with length of siliqua (0.396). The results revealed that the tallest plant produced increased length of siliqua. Number of secondary branches/plant (-0.529) had highly significant negative association with plant height. On the other hand, plant height had non significant negative association with number of primary branches/plant (-0.315), number of siliquae/plant (-0.242) and thousand seed weight (-0.239). Number of seeds/siliqua (0.173) and yield/plant (0.255) had non significant correlation with plant height. Positive correlation of plant height with number of seeds/siliqua, number of siliquae/plant and negative correlation with 1000 seed weight were reported by Chowdhury *et al.* (1987). The present findings were in partial agreement with Chowdhury *et al.* (1987).

Table 6. Correlation co-efficient among different characters of the F_2 materials of the *Brassica rapa*

Characters	Plant height (cm)	No. of primary branches/ plant	No. of Secondary branches/ plant	Days to 50% flowering	Length of siliqua (cm)	Seeds/ siliqua (no.)	Siliquae/ plant (no.)	1000 seed weight (g)	Yield/ plant (g)
Plant height (cm)	**1.000**	-0.315	-0.529**	0.680**	0.396*	0.173	-0.242	-0.239	0.255
No. of primary branches/plant		**1.000**	0.225	-0.114	-0.144	-0.104	0.381*	0.136	-0.204
No. of secondary branches/plant			**1.000**	-0.429**	-0.239	-0.247	0.414*	0.207	0.167
Days to 50% Flowering				**1.000**	0.355*	0.319	-0.118	-0.021	0.060
Length of siliqua (cm)					**1.000**	0.360*	0.099	-0.319	0.243
Seeds/ siliqua (no.)						**1.000**	0.105	-0.208	0.042
Siliquae/plant (no.)							**1.000**	-0.058	0.236
1000 seed weight (g)								**1.000**	-0.072

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

Number of primary branches/plant had significant positive correlation with number of siliquae/plant (0.381) but non significant positive correlation with number of secondary branches/plant (0.225) and 1000 seed weight. But number of primary branches/plant had non significant negative correlation with days to 50% flowering (-0.114), length of siliqua (-0.144), number of seeds/siliqua (-0.104) and yield/plant (-0.204). Reddy (1991) and Singh et al. (1969) found the similar findings earlier in his experiment.

Number of secondary branches/plant showed negative correlation with length of siliqua (-0.239) and number of seeds/siliqua (-0.247). The results revealed that number secondary branches/plant might not be considered for the selection of number of seeds/siliqua.

Days to 50% flowering showed highly significant positive association with length of siliqua (0.355) and non significant negative association with number of siliquae/plant (-0.118) and 1000 seed weight (-0.021) in Table 8. The result revealed that early flowering type genotype might be selected for length of siliqua.

Positive significant association of length of siliqua with number of seeds/siliqua (0.360) and positive non significant association with yield/plant (0.243) and number of siliquae/plant (0.099) and non significant negative correlation with thousand seed weight (-0.319). Chaudhury *et al.* (1993) found that seed yield was positively correlated with siliqua length which is agreed with the present findings.

Number of Seeds/siliqua showed non significant positive correlation with number of siliquae/plant (0.105) and yield/plant (0.042) but non significant negative association with thousand seed weight (-0.208). Number of siliquae/plant had non significant positive association with yield/plant (0.236). Thousand seed weight (-0.058) showed non significant negative correlation with number of siliquae/plant. Thousand seed weight showed negative non significant correlation (-0.072) with yield/plant.

4.3 Path co-efficient analysis

Association of character determined by correlation co-efficient might not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on seed yield per plant. As a matter of fact, in order to find out a clear picture of the interrelationship between seed yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at genotypic 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/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua and 1000 seed weight were casual (independent) variables. The results of path co-efficient analysis using F_2 materials of *Brassica rapa* were presented in Table 9.

Plant height showed positive direct effect (0.766) on yield/plant and positive indirect effects through number of primary branches/plant and number of seeds/siliqua. On the other hand, plant height had negative indirect effect on number of secondary branches/plant, days to 50% flowering, length of siliqua, number of siliquae/plant and thousand seed weight. Han (1990) working with *Brassica napus*, observed negative direct effect of number of siliquae/plant (-0.808) and positive direct effect of number of seeds/siliqua (10.449) and plant height (0.321) on seed yield. There was disagreement of the present findings with that of Han (1990).

Path analysis showed that number of primary branches/plant had negative direct effect (-0.142) on yield/plant. It showed negative indirect effect through plant height (-0.241), number of seeds/siliqua (-5.726) and thousand seed weight (-4.426). Number of primary branches/plant

Table 7. Partitioning of genotypic correlation with seed yield per plant into direct and indirect components of F_2 materials of *Brassica rapa*

Characters	Plant height (cm)	No. of primary branches/ plant	No. of secondary branches/ plant	Days to 50% flowering	Length of siliqua (cm)	Seeds/ siliqua (no.)	Siliquae/ plant (no.)	1000 seed weight(g)	Yield/ plant (g)
Plant height (cm)	**0.766**	4.485	-0.245	-0.174	-2.735	9.526	-5.700	-7.778	0.255
No. of primary branches/plant	-0.241	**-0.142**	0.104	2.910	9.947	-5.726	8.974	-4.426	-0.204
No. of secondary branches/plant	-0.405	-3.204	**0.463**	0.110	1.651	-0.000	9.752	-0.067	0.167
Days to 50% flowering	0.521	1.623	-0.199	**-0.255**	-2.453	1.756	-2.780	6.833	0.06
Length of siliqua (cm)	0.303	2.050	-0.111	-9.063	**-6.908**	1.982	2.332	0.104	0.243
Seeds/ siliqua (no.)	0.132	1.480	-0.114	-0.081	-2.487	**5.506**	2.473	0.068	0.042
Siliquae/plant (no.)	-0.185	-5.425	0.192	3.013	-6.839	5.781	**0.236**	0.019	0.236
1000 seed weight (g)	0.183	-0.019	9.587	5.361	2.203	-1.145	-1.366	**-0.325**	-0.072

Residual effect: 0.63
Bold figures indicate direct effects

showed positive indirect effect through number of secondary branches/plant (0.104), days to 50% flowering 92.91), length of siliqua (9.947 and number of siliquae/plant (8.974). Kakroo and Kumar (1991) found that 1000 seed weight had positive direct effect (0.784) but number of branches/plant had negative indirect effect via number of seed/siliqua (-0.129) on seed yield.

Number of secondary branches/plant had positive direct effect (0.463) on yield/plant and negative indirect effects through plant height, number of primary branches/plant, number of seeds/siliqua and thousand seed weight. On the other hand, number of secondary branches/plant had positive contribution on days to 50% flowering, length of siliqua and number of siliquae/plant.

Path analysis revealed that days to 50% flowering had negative direct effect (-0.255) on yield/plant and positive indirect effects through plant height, number of primary branches/plant, number of seeds/siliqua and 1000 seed weight. Days to 50% flowering showed negative indirect effect through number of secondary branches/plant, length of siliqua and number of siliqua/plant. Chauhan and Singh (1985) observed high positive direct effect of days to 50% flowering, plant height, primary branching, siliqua/plant, seeds/siliqua on yield.

Length of siliqua (-6.908) had negative direct effect on yield/plant and negative indirect effect on number of secondary branches/plant and days to 50% flowering (Table 9). On the other hand, length of siliqua had positive contribution via plant height, number of primary branches/plant, number of seeds/siliqua, number of siliquae/plant and 1000 seed weight. Kumar *et al.* (1984) and Chen *et al.* (1983) found negative effect on plant height, days to maturity and siliqua length.

Path analysis revealed that number of seeds/siliqua had positive direct effect (5.506) on yield/plant and positive indirect effect on plant height, number of primary branches/plant, number of siliquae/plant and 1000 seed weight. It showed negative indirect effect on number of secondary branches/plant, days to 50% flowering and length of siliqua. Chen *et al.* (1983), Chauhan and Singh (1985) and Han (1990) found substantial direct effect of number of seeds/siliqua on seed yield.

Number of siliquae/plant had positive direct effect (0.236) on yield/plant. On the other hand, number of siliquae/plant had positive contribution via number of secondary branches/plant, days to 50% flowering, number of seeds/siliqua and 1000 seed weight. Number of siliquae/plant had negative indirect effect on plant height, number of primary branches/plant and length of siliqua. Chen *et al.* (1983) found that number of siliquae/plant had positive direct effect on yield/plant.

Path analysis showed that 1000 seed weight (-0.325) had negative direct effect on yield/plant (Table 9). It showed positive indirect effect on plant height, number of secondary branches/plant, days to 50% flowering and length of siliqua. 1000 seed weight had negative indirect effect on number of primary branches/plant, number of seeds/siliqua and number of siliquae/plant. Varshney (1986) working with several strains of *B. rapa* found the negative direct effect of plant height, number of siliquae/plant, number of seeds/siliqua and 1000 seed weight on yield.

Chapter V

SUMMARY AND CONCLUSION

This research work was carried out to study the F_2 population of some inter-varietal crosses of the species *Brassica rapa* for estimating the magnitude of variations in characters, variability and heritability, genetic advance, character associations, direct and indirect effect of different characters on yield.

All the genotypes varied significantly with each other for all the characters indicated the presence of considerably variations among the genotypes studied. The parents SS75 and BARIsarisha-6 were the tallest and the shortest parent was Tori-7. The parents SS75, SAUYC and BARIsarisha-9 produced maximum number of primary branches per plant and the lowest were observed in the parent Tori-7. However, Tori-7 produced maximum number of secondary branches/plant. The length of siliqua was highest in SAUYC. The parent BARIsarisha-6 found highest seeds per siliqua and the lowest number of seeds per siliqua were obtained in the variety Tori-7. The seed size was larger in the parent BARIsarisha-9 with an average of 2.61g for 1000 seed weight. The parent SS75 had the highest in number of siliquae/plant and the lowest was observed in BARI sarisha-6. The yield was highest in the parent SS75 and lowest was observed in Tori-7. The variety Tori-7 had the earliest average maturity period of 80days.

In the different F_2 materials, SS75×BARIsarisha-9, BARIsarisha-9×SS75 and BARIsarisha-9×BARIsarisha-6 were taller with the average plant height of more than 95cm and the shortest parent was SAUYC×Tori-7. BARIsarisha-9×SAUYC produced maximum number of primary branches per plant and the lowest primary branches were observed in the cross BARIsarisha-6×BARIsarisha-9. The co-efficient of variation was higher for number of primary branches per plant and number of secondary branches per plant in Tori-7×BARIsarisha-6 and

SAUYC×BARIsarisha-9 respectively. The length of siliqua was highest in BARIsarisha-6×BARIsarisha-9. The F_2 material Tori-7×BARIsarisha-6 had the highest number of siliquae/plant. However, the lowest number of siliquae/plant was observed in BARIsarisha-9×SS75 and the CV% (72.85%) was higher in SAUYC×Tori-7. So, selection can be made here for this character. The Tori-7×SAUYC had the highest 1000 seed weight and the lowest weight was in SS75×Tori-7(1.90g) and in BARI sarisha-6×BARIsarisha-9 (1.99g). The yield was highest in the cross BARI sarisha-6×BARIsarisha-9 which produced 2.93g of seeds per plant. The cross SAUYC×Tori-7 and SS75×Tori-7 showed the shortest days to 50% flowering. The line Tori-7×SAUYC showed the shortest maturity period of 82.52 days. The high yielders BARI sarisha-6×BARIsarisha-9 and Tori-7×SS75 were in the late maturing category of above 86 days.

The phenotypic variance of F_2 materials was considerably higher than the genotypic variance for all the characters studied. Number of primary branches/plant, number of secondary branches/plant, length of siliqua, number of seeds/siliqua, days to 50% flowering, 1000 seed weight and yield/plant showed minimum difference between genotypic and phenotypic variance which indicated low environmental influence on these characters. Plant height, number of siliqua/plant and days to maturity showed much difference between genotypic and phenotypic variance.

Plant height, length of siliqua, number of seeds/siliqua and days to 50% flowering showed low genotypic and phenotypic co-efficient of variation. Moderate genotypic and phenotypic co-efficient of variation was observed in number of primary branches/plant, number of secondary branches/plant, number of siliquae/plant, yield/plant, 1000 seed weight and days to maturity.

Number of primary branches/plant and number of secondary branches/plant showed high heritability coupled with high genetic advance and very high genetic advance in percentage of mean, where as days to 50% flowering, number of siliquae/plant, plant height, 1000 seed weight and number of seeds/siliqua showed high heritability with moderate genetic advance and genetic advance in percentage of mean that revealed the possibility of predominance of additive gene action in the inheritance of this character, therefore, the characters could be improved through selection process. Yield/plant, days to maturity, length of siliqua showed low heritability with low genetic advance and genetic advance in percentage of mean. As a whole, the low heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes for improvement of the crop.

Study on correlation revealed that yield/plant had non significant positive association with plant height, number of secondary branches/plant, days to 50% flowering, length of siliqua, number of siliquae/plant and number of seeds/siliqua but non significant negative association with number of primary branches/plant. Path co-efficient analysis revealed that number of seeds/siliqua showed highest direct effect on yield/plant followed by plant height, number of secondary branches/plant and number of siliquae/plant. On the other hand, number of primary branches/plant, days to 50% flowering, length of siliqua and thousand seed weight had negative direct effect. Based on the variability study, 18 plants of yellow seeded and 31 plants of grey seeded F_2 materials showing high heritability for yield contributing characters were selected from some of the cross combinations of the intervarietal crosses of *Brassica rapa*.

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Appendix I. Analysis of variances of 9 important characters of 5 parents of *Brassica rapa*

Source of variation	Degrees of freedom	Plant height (cm)	Number of primary branches/ plant	Number of secondary branches/ plant	Length of siliqua (cm)	Number of seeds/ siliqua	Number of siliquae/ plant	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering
Replication	2	3.07	0.03	0.29	0.03	0.72	374.22	0.04	0.09	3.20
Genotypes	4	489.15**	7.89**	40.66**	0.48**	34.86**	11533.95**	0.093*	2.87**	84.23**
Error	8	26.78	0.23	0.37	0.02	0.80	308.69	0.04	0.09	0.78
Co-efficient of variation		5.43	5.29	13.38	3.56	5.36	8.61	7.91	9.04	2.43

** Significant at 1% level
* Significant at 5% level

Appendix II. Analysis of variances of 9 important characters of 12 F_2 materials of *Brassica rapa*

Source of variation	Degrees of freedom	Plant height (cm)	Number of primary branches/ plant	Number of secondary branches/ plant	Length of siliqua (cm)	Number of seeds/ siliqua	Number of siliquae/ plant	1000 seed weight (g)	Yield/ plant (g)	Days to 50% flowering
Replication	2	38.71	0.35	0.43	0.06	0.99	56.70	0.02	0.39	1.03
Genotypes	11	183.86**	5.25**	3.96**	0.09*	3.10**	1668.69**	0.32**	0.24*	29.54**
Error	22	35.49	0.42	0.25	0.07	0.78	115.61	0.08	0.21	0.97
Co-efficient of variation		6.79	9.48	11.23	7.15	6.52	6.04	13.48	19.02	2.72

** Significant at 1% level
* Significant at 5% level

Appendix III. Monthly average of Temperature, Relative humidity, Total rainfall and Sunshine hour of the experimental site during the period from January'05 to February'06

Year	Month	*Air temperature (°c)			Relative humidity (%)	Rainfall (mm)	**Sunshine (hr)
		Maximum	Minimum	Mean			
2005	January	24.52	13.86	19.19	68.46	04	194.1
	February	28.88	17.98	23.43	61.04	03	221.5
	March	32.22	21.78	27.00	66.99	155	210.2
	October	30.6	24.6	27.60	77	326	142.20
	November	29.1	19.8	24.45	70	03	197.63
	December	27.1	15.7	21.4	64	Trace	217.03
2006	January	25.3	18.2	21.75	68	0	165.10
	February	31.3	19.4	25.35	61	0	171.01

* Monthly average
**Monthly total

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