VARIABILITY AMONG ADVANCED LINES IN *Brassica rapa* L.

BY

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CERTIFICATE

This is to certify that thesis entitled,"VARIABILITY AMONG ADVANCED LINES IN Brassica rapa L." submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING, embodies the result of a piece of bonafide research work carried out by MD. SHAHIDUL ISLAM, Registration No. ***06-1889*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: JUNE, 2013
Place: Dhaka, Bangladesh

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TO

MY BELOVED PARENTS

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BY

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ABSTRACT

A research was conducted by using twenty one (21) F_9 populations derived from inter-varietal crosses of *Brassica rapa* L. and grown in the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2011 - March 2012 to study 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 in number of primary branches per plant, number of secondary branches per plant, number of silliqua per plant, days to 50% flowering, length of siliqua, number of seeds per siliqua, 1000 seed weight and yield per plant showed some differences between genotypic and phenotypic variances. Plant height, length of siliqua, number of silliqua per plant, days to 50% flowering showed low genotypic and phenotypic coefficient of variation. Plant height, number of primary branches per plant, number of secondary branches per plant and number of silliqua per plant showed high heritability coupled with high genetic advance and very high genetic advance in percentage of mean. However, length of siliqua showed low heritability. Correlation study revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, number of siliqua per plant, seeds per siliqua, and siliqua length (genotypic or phenotypic level). Path co-efficient analysis revealed that plant height, number of primary branches per plant, number of siliqua per plant, seeds per siliqua, and siliqua length had the positive direct effect on yield per plant and days to 50% flowering, number of secondary branches per plant, and thousand seed weight had the negative direct effect on yield per plant. Based on the variability study, some F_9 plants showed high heritability for short duration and yield contributing characters were selected from some of the cross combinations of the intervarital crosses of *Brassica rapa* for further selection.

LIST OF CONTENTS

LIST OF CONTENTS (Cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

SOME COMMONLY USED ABBREVIATIONS AND SYMBOLS

Abbreviations		Full word
AEZ	=	Agro-Ecological Zone
°C	=	Degree Celsius
@	=	At the rate
σ_p^2	=	Phenotypic variance
σ_e^2	=	Environmental variance
σ_g^2	=	Genotypic variance
h^2_b	=	Heritability in broad sense
Agric.	=	Agriculture
Agril.	=	Agricultural
Agron.	=	Agronomy
ANOVA	=	Analysis of variance
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
BD	=	Bangladesh
BSMRAU	=	Bangabundhu Sheikh Mujibur Rahaman Agricultural University
CEC	=	Cation Exchange Capacity
CV%	=	Percentage of Coefficient of Variation
CVA	=	Canonical Variate Analysis
cv.	=	Cultivar (s)
D 50% F	=	Days to 50% flowering
DAS	=	Days After Sowing
df	=	Degrees of Freedom
DM	=	Days to maturity
Dm	=	Dry-matter
DMRT	=	Duncan's Multiple Range Test
EC	=	Emulsifiable Concentrate
et al.	=	And others

Abbreviations		Full word
etc.	=	Etcetera
F_8	=	The eight generation of a cross between two dissimilar homozygous parents
FAO	=	Food and Agricultural Organization
G	=	Genotype
GA	=	Genetic advance
GCV	=	Genotypic Coefficient of Variation
GN.	=	Genotype Number
HI	=	Harvest Index
hr.	=	Hour (s)
HSW	=	Hundred seed weight
IARI	=	Indian Agricultural Research Institute
ICARDA	=	International Centre for Agricultural Research in Dry Areas
j.	=	Journal
kg	=	kilogram (s)
m	=	Meter
M.P.	=	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
PCA	=	Principal Component Analysis

Abbreviations		Full word
PCO	=	Principal Coordinate Analysis
PH	=	Plant height
PCV	=	Phenotypic Coefficient of Variation
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 lenght
S/S	=	Seeds per siliqua
T.S.P.	=	Triple Super Phosphate
t/ha	=	Tones per hectare
Univ.	=	University
var.	=	Variety
Via	=	By way of
Viz	=	Namely
WP	=	Wetable powder
YPP	=	Yield per plant

Chapter 1
Introduction

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 rapa,* 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 like *B.juncea* and *B. napus* are high yielding but not short durated .Thats why *B. rapa* are widely grown and it gives moderate yield but early cultivars produce high yield and it is drought and stress resistant. According to Kariya and Tsunada (1972, 1973, cited by T sunada, 1980), *B. rapa* has a physiological constitution that makes it more productive than *B. napus*. 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 is 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 45% of the domestic need (FAO, 2004).

This crop covers the highest acreage which is 78% of the total oilseed acreage of Bangladesh (BBS, 2004).The average yield of *Brassica* oilseed in Bangladesh is around 963 kg/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.Early maturity line (SAU sarisha 2 X SAU sarisha 1),combination SAU sarisha 2 X BARI sarisha 6 gave higher number of primary branches and number of siliquae / plant. No improved short duration variety of *B. napus* is available to replace this short duration variety. So *B. rapa* is the most popular variety to the farmers.There should be an attempt to develop short duration and high yielding varieties of rapeseed 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,

1. To study the variability among F_9 generation materials for selection of desired lines,

2. To study the inter-relationship and effect of characters on yield and

3. To select early maturing, high yielding lines for release.

Chapter 2

Review of literature

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 co-efficient 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 indays flowering in *B. napus* and in *B. rapa*.

While working with 65 strains *of B. napus, B. rapa, B. juncea and, B.cariuara* Nand a *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 tori 4 Tak and Patnaik (1997) 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, R'ater avilability and temperature etc. Highest Variation for plant height of parents and their hybrids was reported by Tyagi *et al.* (200l). 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 *et al* (1991) Gupta and Labana (1989) Lebowitz (1989) Chaturvedi *et al.* (1988) Gupta and Labana (1988) Gupta *et al.* (1987) Chauhan and Singh (1935) and Sharma (19Sa) among different Genotypes of *B. napas*, *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 lenglh 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.

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.* (199I) 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.* (1995) suggested the necessity of estimating genetic advance along 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 %) for number of primary branches, days to 50% flowering and oil content. They also found low heritability 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 (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.) Czem and Coss Labana *et al.* (1980) found that plant height and number of seeds/siliqua were highly heritable where as s iliqua 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 (13.7 5%) 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 siliqua/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 siliqua and 1000 seed weight.

Katiyar *et al.* (1974) studied in *Brassica rapa* L.var. sarson grain on ten characters in 54 plants from each of 40 varieties; seed yield per plant showed a high genotypic co-effecient 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 Whan *et al.*,(1982).

Most breeders tend to suggest delaying selection until at least the F_2 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 (Shebeskt, 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 rate as 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 (Zhat 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 siliqua/plant, number of primary branches/plant, number of seedsisiliqua in 179 genotypes of Indian mustard.

Banerzee *et al.* (1963) 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*, Chowdhry *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/seliqua 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 Shivah are *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 siliqua/plant and number of seeds/siliqua in yellow Sarson (Banerjee, 1968). But Tak (1976) in a study with *B. rapa* found negative genotypic correlation between number of siliqua/plant and number of seeds/siliqua in brown sarson and toria varieties. On the contrary, Das *et al.* (1980) reported that number of siliquae/plant significantly and positively correlated with number of seedsisiliqua 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.* (1957) also found similar results in the same species.

Increaseing 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 indicate 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 positively associated with seed yield. Kumar *et al.* (1999) studied 12 yield contributing characters in 15 genotypes of *B. juncea*, 3 of *B. napas* , 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 weigh 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 brances 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 Kondrq 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 Zubei 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. juncee, 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 rvith 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 seeeds/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 Sharna, (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 siliqua/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%o 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 siliqua/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 eflect 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*, Shing *et al.* (1985) in *B. juncea,* Chen *et al.* (1983) in *B. napas*.

Srivastava *et al.* (1983) in *B. juncea* and Yadava (1982) in *B. rapa,* revealed that plant height, days to maturity, 1000 seed weight siliqua/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 3

Materials and Methods

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 Rabi season 2011-2012, (Appendix I and Plate 1).

3.2 Soil and Climate

The soil of the experimental plots were clay loam, land was medium high with medium fertility level (Appendix II). 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 November 2011 to March 2012 were obtained from the Department of Meteorological centre, Dhaka-1207, Bangladesh. The experiment was conducted using twenty one F_9 generations progenies along with six testers (Table 1).

3.3 Materials

A total number of 21 (twenty one) materials were used in this experiment. where (21) were F_9 segregating generation materials and six check varieties (tester). All the materials were collected from Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The materials used in that experiment is shown in Table 1.

Table 1: Materials used for the experiment

F_9 Population	Check varieties (Tester)
BARI sarisha 15×BARI sarisha 6	BARI sarisha 15
BARI sarisha 15×Tori 7	BARI sarisha 6
BARI sarisha 15×SAU sarisha 3	Tori 7
BARI sarisha 15×SAU sarisha 1	SAU sarisha 3
BARI sarisha 15×SAU sarisha 1	SAU sarisha 2
Tori 7×BARI sarisha 6	SAU sarisha 1
Tori 7×SAU sarisha 1	
BARI sarisha 6×SAU sarisha 2	
BARI sarisha 6×SAU sarisha 3	
SAU sarisha 3×Tori 7	
SAU sarisha 3×SAU sarisha 1	
SAU sarisha 3×BARI sarisha 6	
SAU sarisha 2×BARI sarisha 6	
SAU sarisha 2× Tori 7	
SAU sarisha 2×SAU sarisha 1	
SAU sarisha 1×BARI sarisha 6	
SAU sarisha 1×SAU sarisha 2	
SAU sarisha 1× Tori 7	
SAU sarisha 1x SAU sarisha 3	
BARI sarisha 15×BARI sarisha 6	
BARI sarisha 15×Tori 7	

Plate 1: Photograph showing a field view of experimental site at seedling stage at SAU farm

Plate 2: Photograph showing a field view of experimental site at flowering stage at SAU farm

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 2. 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 2. 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 layout was done after final land preparation. The seeds of testers and F_9 materials were laid out in a Randomized complete block design (RCBD) with three replications. The size of plot was 5m x 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. The seeds were sown in separate line in the experimental field on 3 October 2011 by hand uniformly at a soil depth of 2.5 to 3.5 cm. The seeds were placed . 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, 2012 depending upon the maturity of the plants. When 80% of the plants showed symptoms of maturity i.e.; straw color of siliqua, leaves, stem and desirable seed color in the matured siliqua, the crop was assessed to attain maturity. Twenty (20) plants were selected at random from the row of each plot. The sample plants were harvested by uprooting and then they were tagged properly. Data were recorded from these ten 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 siliqua, which was considered as the number of seeds /siliqua.

8. 1000 seeds weight (gm): Weight in grarms 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 was calculated by the formula of Burton (1952). Simple correlation coefficient was obtained using the formula suggested by Clarke (1973) Singh and Chaudhary (1985) and path co-efficient analysis was done following the method outlined by Dewey and Lu (1959).

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

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

Where, MSG = Mean sum of square for genotypes

MSE= Mean sum of square for error, and

r = Number of replication

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

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

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

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

$$GCV = \frac{\delta g \times 100}{\bar{x}}$$

$$PCV - \frac{\delta p \times 100}{\bar{x}}$$

Where, GCV= Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δg = Genotypic standard deviation

δp = Phenotypic standard deviation

$\bar{x}$ = Population mean

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

$h^2b\ (\%) = (\delta^2 g / \delta^2 p) \times 100$

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

$\delta^2 g$ = Genotypic variance

$\delta^2 p$ = 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

$\delta^2 g$ = Genotypic variance

$\delta^2 p$ = Phenotypic variance

δp = 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).

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

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

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

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observations

vii) Path co-efficient analysis: Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singlr 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 and 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 blow;

$r_{yx1} = P_{yx1} + P_{yx2}r_{xlx2} + P_{yx3}r_{x1x3}$

$r_{yx2} = P_{yx1}\, r_{xlx2} + P_{yx2} + P_{yx3}r_{x2x3}$

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

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

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):

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

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

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

r_{iy} = Correlation of the character with yield.

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

4.1 Mean performance

Mean performance of nine agronomic and yield related traits of parents and hybrid combinations are presented in Table 3.

4.1.1 Plant height

For parent, the lowest plant height was observed in BARI sarisha15 (93.19) and for hybrid BARI sarisha 15 X SAU sarisha 3 (89.36). Whereas the parent Tori 7 (99.05) exhibited the highest plant height. The highest plant height was found from the hybrid Tori 7 X SAU sarisha 1 (108.70). The hybrids were approximately 8-15 cm higher than the parents.

4.1.2 Days to 80% maturity

Considering earliness, the parent Tori 7 (81) showed the lowest duration for maturation but the parent BARI sarisha 15 (82) had taken the highest duration. On the other hand, the hybrid combination SAU sarisha 3 X Tori 7 (80.33) matured with the lowest growth duration, which was earlier than its parents. The field view of different maturity stages are shown (plates 3, 4 and 5).

4.1.3 Number of primary branches per plant

For this character the parents showed the value ranging from 5.90 to 3.36. The parent BARI sarisha 15 (5.22) showed the highest value. In the hybrid, the highest value was provided by the combination SAU sarisha 2 X BARI sarisha 6 (5.90) which was higher than Tori 7 (Plates 6 & 7).

37779

Table 3: Mean performance for nine different characters in twenty one F_9's line of *Brassica rapa* L.

Treatments	Plant height(cm)	Days to 80% maturity	No. of Primary branches/plant	No. of secondary branches/plant	No. of siliquae/ plant	Siliqua Length (cm)	Seeds/ siliqua	Seed yield/ plant(gm)	1000 seed wt. (gm)
BARI sarisha15×BARI sarisha 6	103.1	84	5.9	4.63	99.68	4.47	11.75	4.54	3.24
BARI sarisha 15×Tori 7	93.06	81.67	3.36	1.75	87.9	4.17	9.79	3.46	2.64
BARI sarisha 15×SAU sarisha 3	89.36	80.67	4.53	1.23	72.9	3.48	13.2	3.62	3.14
BARI sarisha 15×SAU sarisha1	97.38	85.33	5.17	1.21	86.1	5.16	12.13	4.23	3.29
BARI sarisha 15×SAU sarisha 1	97.38	85.33	5.17	1.21	86.1	5.16	12.13	4.23	3.29
Tori 7×BARI sarisha 6	101.34	83.67	4.5	1.73	107.67	4.38	12.67	3.58	3.24
Tori 7×SAU sarisha 1	108.7	83	3.73	0.71	73.67	4.77	13.88	4.47	2.8
BARI sarisha 6×SAU sarisha 2	106.95	85	5.28	1.5	96.18	3.75	14.52	4.44	3.88
BARI sarisha 6×SAU sarisha 3	105.1	81.67	4.97	1.5	101.37	5.24	12.56	4.27	3.63
SAU sarisha 3× Tori 7	100.1	80.33	4.83	2.31	83.4	4.35	13.96	3.74	3.5
SAU sarisha 3×SAU sarisha 1	101.9	85.33	5.07	1.23	84.3	4.94	13.57	3.69	2.5
SAU sarisha 3×BARI sarisha 6	101.75	85	4.62	1.62	102.9	5.37	13.52	4.49	2.57
SAU sarisha 2×BARI sarisha 6	98.3	85	5.12	1.5	85	4.67	11.68	3.44	2.31
SAU sarisha 2× Tori 7	91.43	85	3.57	1.68	76.8	4.99	10.22	4.46	3.88
SAU sarisha 2×SAU sarisha 1	102.94	85.67	3.59	1.43	94.46	4.63	10.22	4.8	2.9
SAU sarisha 1×BARI sarisha6	99.21	86	5.58	1.6	75.02	5.71	14.35	4.36	3.87
SAU sarisha 1×SAU sarisha 2	98.12	84.33	4.21	1.75	85.15	3.51	12.92	3. 262	.99
SAU sarisha 1× Tori 7	94.73	85	3.88	1.57	64.33	4.74	12.3	5.7	3.07
SAU sarisha 1x SAU sarisha 3	93.15	82.32	3.42	1.53	67.33	4.23	11.35	4.13	3.14
BARI sarisha15	93.19	82	5.22	1.34	67.55	5.22	12.98	3.19	2.41
Tori 7	99.05	81	5	1.76	84.23	4.8	14.46	4.3	3.54
Grand mean	99.45	83.7	4.64	1.72	86.14	4.67	12.7	4.11	3.18

Plate 3: Photograph showing a field view of experimental site at maturity stage at SAU farm

Plate 4: Early maturity line (SAU sarisha 2 X SAU sarisha 1)

Plate 5: Late maturity line (SAU sarisha 3 X Tori 7)

Plate 4 &5 : Photograph showing variation between early (SAU sarisha 2 X SAU sarisha 1) and late (SAU sarisha 3 X Tori 7) line of *Brassica* rapa genotype.

Plate 6: SAU sarisha 2 X BARI sarisha 6

Plate 7: X BARI sarisha 15

Plate 6 & 7: Photograph showing variation for number of primary branches / plant between SAU sarisha 2 X BARI sarisha 6 (highest) and BARI sarisha 15 (Lowest) of *Brassica rapa* genotype.

Plate 8:Tori 7 X SAU sarisha 1

Plate 9: BARI sarisha 15 X BARI sarisha 6

Plate 8 & 9: Photograph showing variation for number of secondary branches / plant between Tori 7 X SAU sarisha 1 (lowest) and BARI sarisha 15 X BARI sarisha 6 (highest) of *Brassica rapa* genotype.

Plate10: SAU sarisha 2 X BARI sarisha 6 **Plate 11: BARI sarisha 15**

Plate 10 & 11: Photograph showing variation for number of siliquae / plant between SAU sarisha 2 XBARI sarisha 6 (highest) and BARI sarisha 15 (lowest) of *Brassica rapa* genotype.

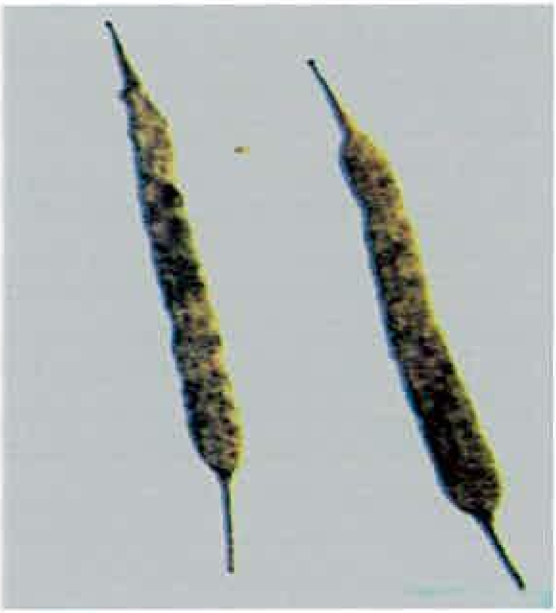

Plate 12: SAU sarisha 1 X BARI sarisha 6 **Plate 13: BARI sarisha 15 X Tori 7**

Plate 12 & 13: Photograph showing variation for siliqua length between SAU sarisha 1 X BARI sarisha 6 (highest) and BARI sarisha 15 X Tori 7 (lowest) of *Brassica rapa* genotype.

4.1.4 Number of secondary branches per plant

For the number of secondary branches per plant, the parent Tori 7 (1.76) showed the highest value. Similarly in the hybrid, the highest value of number of secondary branches per plant was provided by the combination BARI sarisha15 X BARI sarisha 6 (4.63) which was higher than Tori 7(Plates 8 & 9).

4.1.5 Number of siliqua per plant

Number of siliqua per plant varied from 64.33 to 110.00 where the parent BARI sarisha 15 produced the highest and Tori 7 produced the lowest number of siliqua per plant. Considering hybrid performance, it was ranged from 64.33 to 110.00. The hybrid combination SAU sarisha 2 X BARI sarisha 6 (110.00) provided the highest number which was higher than its parent (Plates 10 & 11).

4.1.6 Siliqua length

Siliqua length also varied from 3.48 to 5.71 cm in parents. The parent Tory 7 produced the shortest siliqua than the parent BARI sarisha 15. On the other hand, the values varied from 3.48 to 5.71 cm for hybrids. In this regard, the hybrid combination SAU sarisha 1 X BARI sarisha 6 (5.71cm) exhibited the highest length of siliqua and that was a little bit higher than that of it's either parent(Plates 12 & 13).

4.1.7 Seeds per siliqua

Seed per siliqua also varied from 12.98 to 14.46 in parents and from 9.79 to 14.52 in hybrids. The hybrid BARI sarisha 6 X SAU sarisha 2 (14.52) produced an excellent number of seeds and BARI sarisha 15 × Tori 7 is loest (9.79) per siliqua. (Table 3).

4.1.8 Seed yield per plant

Seed yield per plant was found to be diversed in different genotypes including parents and hybrids. Seed yield of the genotypes varied from 3.19 to 4.30 gm in parents and from 4.23 to 5.70 gm in hybrids. The highest seed yield of the parent was found in Tori 7 (4.30) whereas lowest in BARI sarisha 15 (3.19 gm). Similarly, the highest seed yield was also observed in the hybrid SAU sarisha 1× Tori 7 (5.70 gm) which was almost higher than both of its parents.

4.1.9 Thousand seed weight

Thousand seed weight in *B. rapa* varied with some extent i.e. from 2.41 to 3.54 gm in parent and from 2.31 to 4.21 gm in hybrid. However, the heaviest seeds were produced by the parent Tori 7 (3.54 gm) and also by the hybrid combination SAU sarisha 2 X BARI sarisha 6 (3.54 gm). The hybrid provided the highest weighted seeds which were higher than it's both parents (Table 3).

4.2 Correlation co-efficient

Seed yield is a complex product being influenced by several quantitative traits. Some of these traits are highly associated with seed yield. The analysis of the relationship among those traits and their association with seed yield is very much essential to establish selection criteria. Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait for F_9 materials of *B. rapa* are shown in Table 4. Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait for F_9 materials of *B. rapa* are shown in Table 4.

Plant height (cm)

Plant height showed positive significant interaction with number of siliqua per plant (G=0.516) and seeds per siliqua (G=0.329) followed by positive interaction with secondary branches per plant (G=0.085), length of siliqua (G= 0.032), days to 80% maturity (G= 0.247), 1000 seed weight (G=0.159) and seed yield per plant (G=0.263). Whereas positive significant interaction was found in number of primary branches per plant (P = 0.280), siliqua per plant (P=0.529) and seed yield per plant (P=0.292) followed by positive interaction was found in secondary branches per plant (P=0.156) , length of siliqua (P=0.208), seeds per siliqua (P=0.042), days to 80% maturity (P=0.118) and 1000 seed weight (P=0.160) (Table 4).These findings are close resemblance to the reports of Chowdhury *et al.* (1987) and Yadava *et al.* (1978).

Number of primary branches per plant

Number of primary branches per plant showed positive significant interaction with number of secondary branches per plant (G = 0.399) followed by positive interaction with seeds per siliqua (G= 0.548). Whereas the negative significant interaction was seed yield per plant (G=-0.343) but negative interaction was found in siliqua per plant (G = -0.078)(Table 4). Singh *et al.* (1987) reported number of primary branches per plant negatively correlated with siliqua length and 1000 seed weight positively correlated with number of siliqua per plant.

Number of secondary branches per plant

Number of secondary branches per plant showed negative significant interaction with length of siliqua (G= -0.122, P= -0.008) seeds per siliqua (G= -0.159, P= -0.066) and days to 80% maturity (P= -0.010) followed by positive interaction with siliqua per plant (G= 0.254), thousand seed weight (G = 0.194, P= 0.215) and yield per plant (G = 0.051, P=0.094)(Table 4).

Number of siliqua per plant

Siliqua per plant showed positive significant interaction with thousand seed weight (G = 0.318, P=0.285) followed by positive interaction with seed yield per plant (G = 0.061, P = 0.105). Whereas rest parameter the negative significant interaction (Table 4). Das *et al* (1984) reported number of siliquae/p showed significant and positive correlation with r of seeds/siliqua and 1000 seed weight.

Length of siliqua (cm)

Length of siliqua showed positive significant interaction days to 80% maturity (G = 0.480) (Table 4). Das *et al.* (1998) reported that seed yield per plant positively correlated with length of siliqua and seeds per siliqua.

Seeds per siliqua

Seeds per siliqua showed significant positive interaction with 1000 seed weight (G = 0.108, P=0.100) (Table 4). Dileep *et al* (1997) reported that number of siliqua per plant, thousand seed weight were positively correlated with seed yield. Tyagi *et at.* (1996) reported that no. of seeds per siliqua had positive and significant effects on seed yield per plant.

Thousand seed weight

Thousand seed weight showed significant positive interaction with yield per plant (Table 4).

Table 4: Correlation coefficients among different pairs of yield and yield contributing characters for different genotype of *Brassica rapa* L.

		Primary Branches Per Plant	Secondary branches per plant,	Siliqua per plant,	Length of Siliqua (cm),	Seeds per siliqua	Days to 80% maturity	1000 seed weight (gm	Seed yield per plant (gm)
Plant height (cm)	G	0.142	0.085	0.516**	0.032	0.329**	0.247	0.159	0.263
	P	0.280*	0.156	0.529**	0.208	0.042	0.118	0.16	0.292*
Primary Branches Per Plant	G		0.399**	-0.078	0.245	0.548**	0.21	0.005	-0.343**
	P		0.409**	0.021	0.397**	0.579**	0.104	0.055	0
Secondary branches per plant	G			0.254	-0.122	-0.159	0.009	0.194	0.051
	P			0.273	-0.008	-0.066	-0.01	0.215	0.094
Siliqua per plant	G				-0.237	-0.197	-0.069	0.318**	0.061
	P				-0.08	-0.11	-0.03	0.285*	0.105
Length of Siliqua (cm)	G					0.045	0.480**	-0.131	0.124
	P					0.178	0.227	-0.018	0.195
Seeds per siliqua	G						-0.114	0.108	-0.119
	P						-0.049	0.1	-0.018
Days to 80% maturity	G							-0.07	0.363**
	P							-0.166	0.191
1000 seed weight (gm	G								0.410**
	P								0.433**

** = Significant at 1%.

* = Significant at 5%.

4.3 Path co-efficient analysis

Association of character determined by correlation co-efficient may not provide an exact picture of the relative importance of direct and indirect influence of each of yield components on seed yield per plant. In order to find out a clear picture of the inter-relationship between seed yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at 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_9 materials of *Brassica rapa* were presented in Table 5.

Path analysis revealed that plant height had positive direct effect (0.347) on yield per plant followed by negative indirect effect on number of primary branches per plant (-0.146) and siliqua per plant (-0.110). Positive indirect effect through number of secondary branches per plant 0.038).

Length of siliqua (0.059), seeds per siliqua (0.026) ,days to 80% maturity (0.021) and 1000 seed weight (0.065)(Table 5). Chauhan and Singh (1995) reported plant height, siliquae per plant and seeds per siliqua had high positive direct effect on seed yield.

Number of primary branches per plant had negative direct effect on yield per plant (-**0**.502). This trait had positive indirect effect on seeds per siliqua (0.015). On the other hand negative indirect effect was found on number of number of siliqua per plant (-0.006)(Table 5). Number of primary braches 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.

plant (-0.057), seeds per siliqua (-0.004) and days to 80% maturity (-0.003). On the other hand this trait showed positive indirect effect on Plant height (0.057), length of siliqua (0.001) and 1000 seed weight (0.089) (Table 5). 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 siiqua per plant had negative direct effect (-0.208) on seed yield followed by positive indirect effect on plant height (0.184), secondary branches per plant (0.064) and thousand seed weight (0.120). And this trait had negative indirect effect on number of primary branches per plant (-0.016), length of siliqua (-0.020), seeds per siliqua (-0.007) and number days to 80% maturity (-0.007) (Table 5).Yadava *et al.* (1996) found the number of siliquae per plant had the highest positive direct effect on seed yield.

Path analysis revealed that length of siliqua had direct positive effect (0.273) on yield per plant. This trait had also indirect positive effect on seeds per siliqua (0.018). On the other hand length of siliqua showed indirect negative effect on number of primary branches per plant (-0.203), number of secondary branches per plant (-0.273), 1000 seed (-0.012) (Table 5). Siddikee (2006) found the same result.

Seeds per siliqua had positive direct effect (0.066) on yield per plant and positive indirect effect on number of plant height (0.137), siliqua per plant (0.021), siliqua length (0.073) and thousand seed weight (0.040). On the other hand this trait showed negative indirect effect on number of primary branches per plant (-0.293), secondary branches per plant (-0.013), days to 80% maturity (-0.011) and Pearson correlation with yield (-0.003) (Table 5).

Thousand seed weight had positive direct effect on yield per plant (0.428) and negative indirect effect on number of primary branches per plant (-0.022), siliqua per plant (-0.058), length of siliqua (-0.007) and days to 80% maturity (-0.030). On the other hand this trait showed positive indirect effect on number of plant height (0.053), secondary branches per plant (0.048) and seeds per siliqua (0.006) (Table 5).

Table 5. Path coefficient analysis showing direct and indirect effects of different characters on yield of *Brassica rapa* L.

Characters	Direct effect	Plant height (cm)	Primary branches per plant	Secondary branches per plant	Siliqua per plant	Length of siliqua	Seeds per siliqua	Days to 80% maturity	1000 seed weight	Pearson correlation with yield
Plant height (cm)	**0.347**		-0.146	0.038	-0.110	0.059	0.026	0.021	0.065	0.300**
Primary branches per plant	**-0.502**	0.101		0.097	-0.006	0.110	0.039	0.017	0.018	-0.126
Secondary branches per plant	**0.232**	0.057	-0.209		-0.057	0.001	-0.004	-0.003	0.089	0.106
Siliqua per plant	**-0.208**	0.184	-0.016	0.064		-0.020	-0.007	-0.007	0.120	0.112
Length of siliqua	**0.273**	0.075	-0.203	0.001	0.015		0.018	0.042	-0.012	0.204
Seeds per siliqua	**0.066**	0.137	-0.293	-0.013	0.021	0.073		-0.011	0.040	-0.003
Days to 80% maturity	**0.190**	0.038	-0.044	-0.004	0.007	0.060	-0.004		-0.069	0.175
1000 seed weight	**0.428**	0.053	-0.022	0.048	-0.058	-0.007	0.006	-0.030		0.418**

Residual effect: 0.430

** = Significant at 1%.
* = Significant at 5%.

.Genotypic and phenotypic coefficient of variation

The highest genotypic and phenotypic coefficient of variation number of secondary branches/plant was observed in (Table 6) whereas the minimum number of day to 80% maturity. Number of secondary branches showed moderate difference between phenotypic coefficient (45.57) and genotypic coefficient (42.83) indicating influence on this character (Fig. 1). Day to 80% maturity showed moderate difference between phenotypic coefficient (2.8) and genotypic coefficient (1.87) indicating influence on this character.Lekh *et al.* (1998) reported similar result.

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 6.

Plant height (cm):

Plant height showed moderately high (85.34 %) heritability in broad sense (h^2_b) with medium genetic advance (9.37 %) (Table 6), indicated the possibility of additive genes effect for the expression of this character. Therefore selection would be effective for producing varieties. Shahnaz (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 (73.35 %) in broad sense (h^2_b) coupled with moderate genetic advanced in percentage of mean 27.34 % (Table 6), 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.

Table 6. Estimation of genetic parameters among nine characters of twenty one genotypes in *Brassica rapa* L.

Parameters	Phenotypic coefficient of variation (PCV)	Genotypic coefficient of variation (GCV)	Heritability	Genetic advance (5%)	Genetic advance (% mean)
Plant Height (cm) (PH)	5.33	4.92	85.34	9.32	9.37
Primary Branches per Plant (PBP)	18.09	15.49	73.35	1.27	27.34
Secondary Branches per Plant (SBP)	45.57	42.83	88.32	1.42	82.71
Siliqua per Plant (SP)	15.76	15.25	93.63	26.19	30.40
Length of Siliqua(cm) (LS)	14.73	11.97	66.10	0.94	20.05
Seeds per Siliqua (SS)	11.51	10.66	85.83	2.58	20.34
Days to 80% Maturity (DM)	2.80	1.87	44.68	2.15	2.57
1000 Seed Weight(gm) (TSW)	19.57	15.90	66.05	0.85	26.65
Seed Yield per Plant(gm) (SYP)	15.56	14.02	81.12	1.07	26.04

PH = Plant Height (cm), PBP = Primary Branches per Plant, SBP = Secondary Branches per Plant, SP = Siliqua per Plant, LS =Length of Siliqua (cm), SS = Seeds per Siliqua, DM = Days to 80% Maturity, TSW = 1000 Seed Weight (gm), SYP = Seed Yield per Plant (gm), PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation.

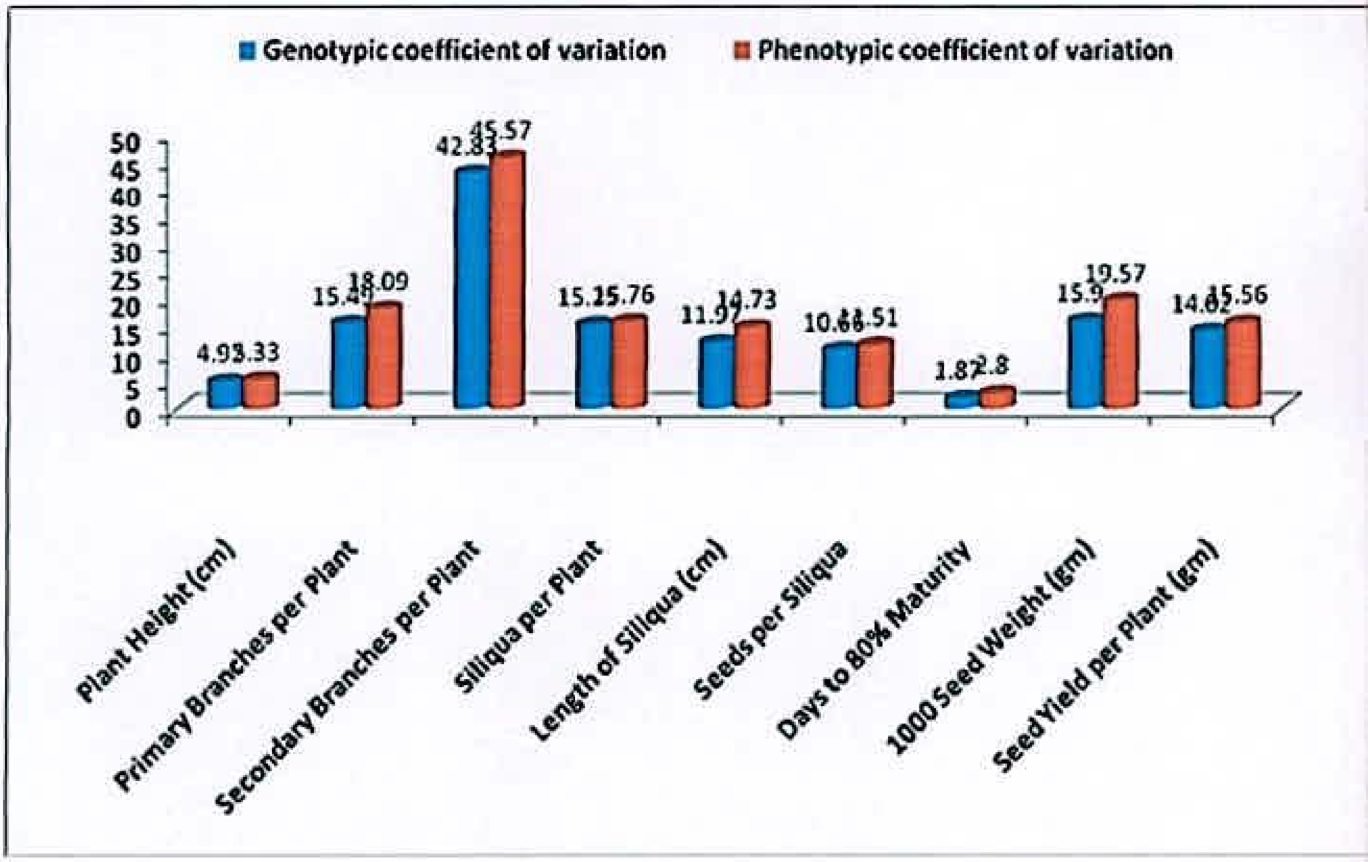

Fig 1: Genotypic and phenotypic coefficient of variation in *Brassica rapa* L.

Number of secondary branches per plant:

Number of secondary branches per plant exhibited high heritability (88.82 %) in broad sense (h^2_b) coupled high genetic advanced in percentage of mean 82.71 % (Table 6) 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.

Number of siliquae per plant:

The magnitude of heritability (93.63 %) in broad sense (h^2_b) for number of siliqua per plant was moderate medium genetic advance in percentage of mean 30.4 % (Table 6) indicated that the character was governed by additive gene and selection might be effective.

Length of siliqua (cm):

Length of siliqua exhibited moderately low heritability (66.1 %) in broad sense (h^2_b) with moderately (20.05 %) genetic advance in percentage of mean (Table 6). 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 (85.83 %) in broad sense (h^2_b) with moderate (20.34 %) genetic advance in percentage of mean (Table 6). indicated that the character was governed by additive gene and selection might be effective. Malik *et* al. (1995) reported high heritability for this trait.

Days to 80% maturity

The magnitude of heritability (44.68 %) in broad sense (h^2_b) for days to maturity was moderately high with low genetic advance in percentage of mean 2.57 % (Table 6) indicating this character is governed by non-additive gene and lower possibility of selecting genotypes.

Thousand seed weight (g):

The magnitude of low heritability (66.05 %) in broad sense (h^2_b) with moderately (26.65 %) genetic advance in percentage of mean (Table 6) 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 (81.12 %) in broad sense (h^2_b) with moderate (26.04 %) genetic advance in percentage of mean (Table 6) 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.

Genotypic and phenotypic correlation coefficient of yield

Plant height (cm):

Plant height showed positive the phenotypic correlation coefficient and Genotypic correlation coefficient were observed 0.263 and 0.292 respectively with relatively high differences between them indicating large environmental influences on these character (fig 2). Tyagi *et al.* (2001) observed highest variation in plant height among parent and their hybrid.

Number of primary branches per plant:

Number of primary branches per plant showed negative phenotypic correlation coefficient (-0.343) and genotypic correlation coefficient (0.00) (fig 2). Chowdhary *et al.* (1987) found significant differences for number of primary branches per plant.

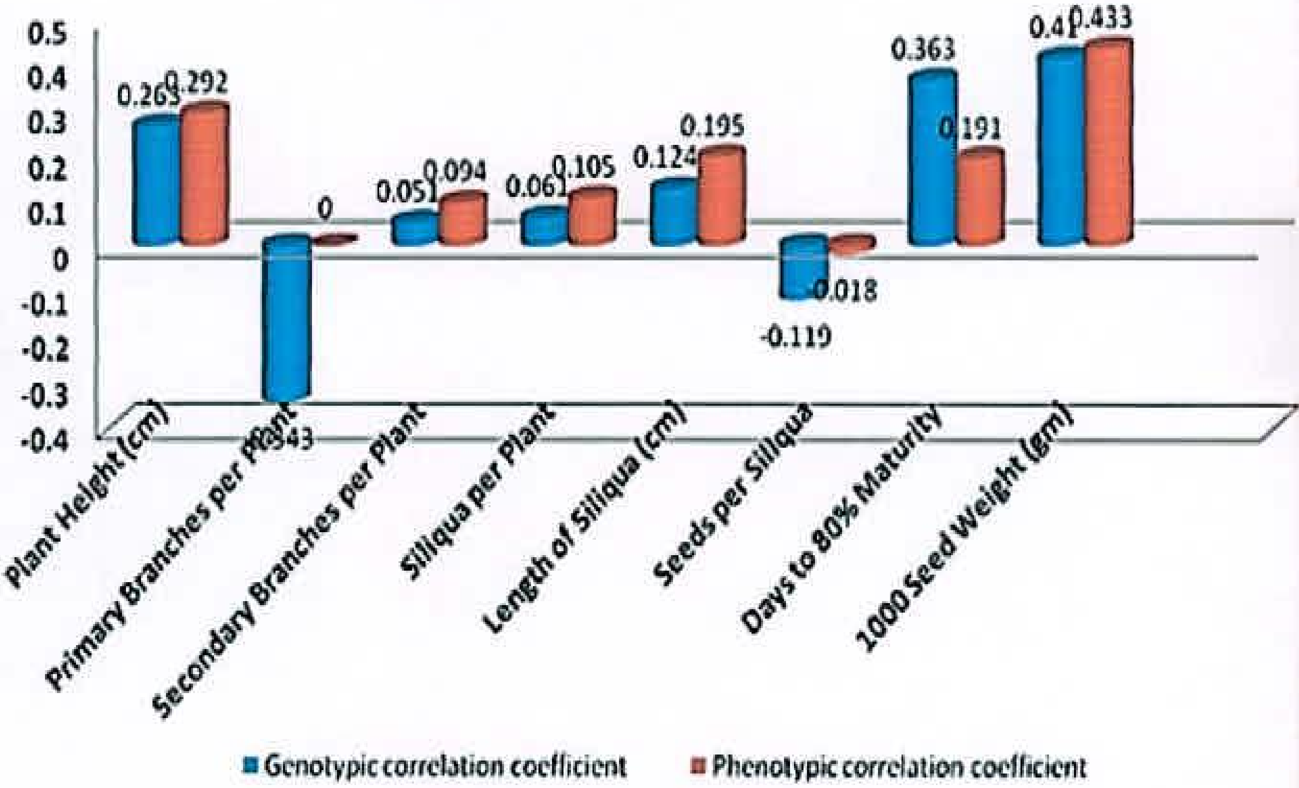

Fig 2: Genotypic and phenotypic correlation coefficient of yield with another character of *Brassica rapa* L.

Number of secondary branches per plant:

Number of secondary branches showed positive phenotypic correlation coefficient (0.051) and genotypic correlation coefficient (0.105) (fig 2). Lekh *et al.* (1998) reported similar result.

Number of siliquae per plant:

Number of siliquae/plant showed positive phenotypic correlation coefficient (0.061) and Genotypic correlation coefficient (0.105) (fig 2). Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring (Ushakumari *et al.* 1991).

Length of siliqua (cm):

Length of siliqua showed positive phenotypic (0.124) and Genotypic correlation coefficient (0.195) (fig 2). Labowitz (1989) studied *Brassica campestris* population for siliqua length and observed high genetic variation on this trait.

Number of seeds per siliqua:

Number of seeds per siliqua showed negative phenotypic correlation coefficient (-0.119) and genotypic correlation coefficient (-0.018) (fig 2). Bhardwaj and Singh (1969) observed 35.85 % GCV in *Brassica campestris*.

Days to 80% Maturity:

Days to 80% Maturity showed positive phenotypic (0.363) and genotypic correlation coefficient (0.191) (fig 2). Labowitz (1989) studied *Brassica campestris* population for days to 80% maturity and observed high genetic variation on this trait.

Thousand seed weight (g):

The phenotypic and genotypic correlation coefficients for this trait were (0.41) and (0.433) respectively. The phenotypic correlation coefficient appeared to be much higher than the genotypic correlation coefficient suggested considerable highly significant influences of environment on the expression of the genes controlling this trait. Bhardwaj and Singh (1969) reported values 11.8% and 18.9% of GCC and PCC for thousand seed weight in *Brassica campestris*. Similarly Tak and Patnaik (1977) reported values 13.1% and 16.5% of GCC and PCC for *Brassica campestris*.

Chapter 5
Summary and Conclusion

SUMMARY AND CONCLUSION

An experiment was conducted during the period of 12 November, 2011 to March 2012, at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University using twenty one segregated generation materials of *Brassica rapa* to study the variability, heritability, genetic advance, correlation co efficient, Path co-efficient analysis and direct and indirect influences of different characters on seed yield per plant. The twenty one F_9 materials varied considerably with each other for all the traits studied. The results of the present study are summarized as follows:

From variability analysis, it was observed that significant variation exist among all the genotypes used for most of the characters studied. Lowest plant height was observed in BARI sarisha15 (93.19) and for hybrid BARI sarisha 15 X SAU sarisha 3 (89.36). Days to 80% maturity were the parent Tori 7 (81) showed the lowest duration for maturation but the parent BARI sarisha 15 (82) and for hybrid combination SAU sarisha 3 X Tori 7 (80.33). Number of primary branches per plant were the parent BARI sarisha 15 (5.22) showed the highest value and for hybrid the highest value was provided by the combination BARI sarisha15 X BARI sarisha 6 (5.90). Number of secondary branches per plant were the parent Tori 7 (1.76) showed the highest value and hybrid the highest value combination BARI sarishab15 X BARI sarisha 6 (4.63). Number of siliqua per plant was the parent BARI sarisha 15 produced the highest and Tori 7 produced the lowest number of siliqua per plant. Considering hybrid performance, it was ranged from 64.33 to 110.00. The hybrid combination SAU sarisha 2 X BARI sarisha 6 (110.00). Siliqua length was parent Tori 7 produced the shortest siliqua than the parent BARI sarisha 15. On the other hand, the values varied from 3.48 to 5.71 cm for hybrids. In this regard, the hybrid combination SAU sarisha 1 X BARI sarisha 6 (5.71cm) Seeds per siliqua were varied from 12.98 to 14.46 in parents and from 9.79 to 14.52 in hybrids. The hybrid BARI sarisha 6 X SAU sarisha 2 (14.52) produced an excellent number of seeds per siliqua.

Seed yield of the genotypes varied from 3.19 to 4.30 gm in parents and from 4.23 to 5.70 gm in hybrids. The highest seed yield of the parent was found in Tori 7 (4.30) whereas lowest in BARI sarisha 15 (3.19 gm). Thousand seed weight were varied with some extent i.e. from 2.41 to 3.54 gm in parent and from 2.31 to 4.21 gm in hybrid. However, the heaviest seeds were produced by the parent Tori 7 (3.54 gm) and also by the hybrid combination SAU sarisha 2 X BARI sarisha 6 (3.54 gm)

The phenotypic variance of the twenty one materials was considerably higher than the genotypic variances for all the traits studied. Highest genotypic and phenotypic coefficient of variation number of secondary branches per plant was observed in the minimum number of day to 80% maturity. Number of secondary branches showed moderate difference between phenotypic coefficient (45.57) and genotypic coefficient (42.83) indicating influence on this character. Days to 80% maturity showed moderate difference between phenotypic coefficient (2.8) and genotypic coefficient (1.87) indicating influence on this character.

Plant height showed high heritability 85.34% with genetic advance 9.32 and genetic advance in percentage of mean 9.37%. Number of primary branches per plant exhibited high heritability 73.35% with low genetic advance 1.27 and genetic advance in percentage of mean 27.34%. Number of secondary branches per plant exhibited high heritability 88.32% with low genetic advance 1.42 and genetic advance in percentage of mean 82.71 %. Number of siliqua per plant exhibited high heritability 93.63% with genetic advance 26.19 and genetic advance in percentage of mean 30.40 %. Length of siliqua showed heritability 66.10% with 0.94 genetic advance and genetic advance in percentage of mean 20.05%. Number of seeds per siliqua showed heritability 85.83% coupled with genetic advance 2.58 and genetic advance in percentage of mean 20.34%. Days to 80% maturity exhibited high heritability (44.68%) with genetic advance 2.15 and genetic advance in percentage of mean 2.57%. 1000 seed weight exhibited heritability 66.05% with genetic advance 0.85 and genetic advance in percentage of mean 26.65%.

Selection was carried out among the twenty one materials of *Brassica rapa* for most promising plants with high yield and a short duration. Based on the variability and as per the objectives some most promising plants with short duration and higher yield were selected from the materials (lines).

Correlation revealed that yield per plant had significant positive association with plant height, number of primary branches per plant, secondary branches per plant, number of siliqua per plant, seeds per siliqua, and siliqua length (genotypic or phenotypic level).

Path co-efficient analysis revealed that days to plant height, number of secondary branches per plant, length of siliqua , seeds per siliqua, days to 80% maturity and thousand seed weight had the positive direct effect on yield per plant and primary branches per plant and siliqua per plant had the negative direct effect on yield per plant.

Finally I have realized from the conclusion that the cross SAU sarisha 3×Tori 7 showed the lowest 80% days of maturities(80.33) and the cross SAU sarisha 2×BARI sarisha 6 (4.21) gave the highest yield. So my suggestion is SAU sarisha 3×Tori 7 for early maturity or SAU sarisha 2× BARI sarisha 6 for best yield may use for further experiment.

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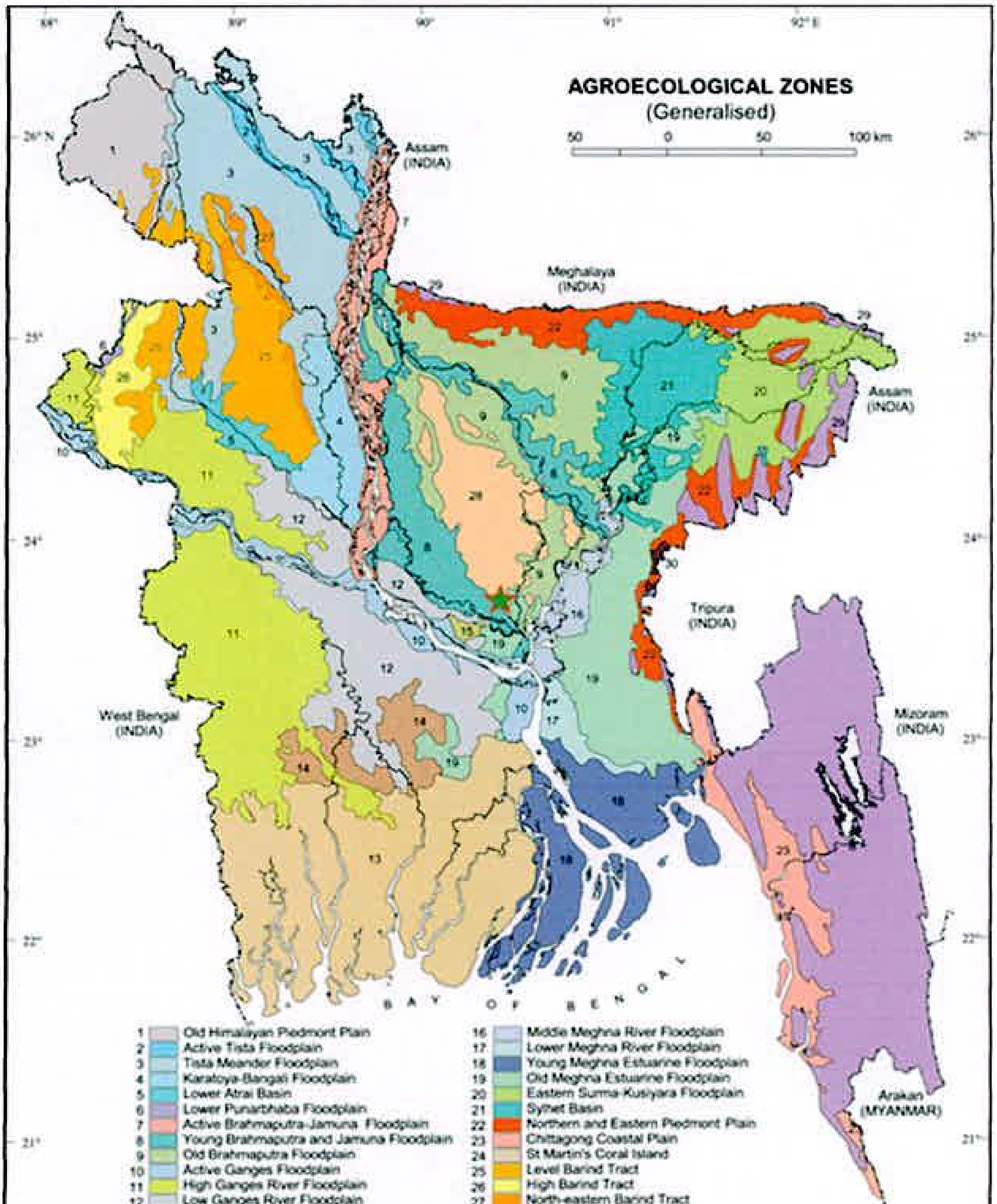
Appendices

APPENDICES

Appendix I: Location of the experimental field



★ The experimental site under study

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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix III. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from October, 2011 to April, 2012

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2011	34.8	18.0	77	227	5.8
November, 2011	32.3	16.3	69	0	7.9
December, 2011	29.0	13.0	79	0	3.9
January, 2012	28.1	11.1	72	1	5.7
February, 2012	33.9	12.2	55	1	8.7
March, 2012	34.6	16.5	67	45	7.3
April, 2012	35.8	20.3	65	88	8.3

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