VARIABILITY STUDIES IN F_4 PROGENIES OF *Brassica rapa* OBTAINED THROUGH INTERVARITAL CROSSES

BY

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This is to certify that thesis entitled, **"VARIABILITY STUDIES IN F_4 PROGENIES OF *Brassica rapa* OBTAINED THROUGH INTERVARITAL CROSSES."** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING,** embodies the result of a piece of *bonafide* research work carried out by **MD. FAYZUL ALAM**, Registration No. **08-03211** 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.

08/01/2012

Dated: JUNE, 2010

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TO

MY BELOVED FATHER AND

MOTHER

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LIST OF SYMBOLS AND ABBREVIATIONS

FULL WORDS	ABBRE VIATION
Percentage	%
Critical Difference	CD
Specific Combining Ability	sca, SCA
General Combining Ability	gca, GCA
Exempli gratia (by way of example)	e.g.
and others (at ell)	*et al.*
Food and Agricultural Organization	FAO
Centimeter	cm
Metric ton	Mt
Bangladesh Agriculture Research Institute	BARI
Sher-e-Bangla Agricultural University	SAU
Journal	*J.*
Number	No.
variety	var.
Namely	viz.
Degrees of freedom	df.

Mid parent	MP
The 1st generation of a cross between two dissimilar homozygous parents	F_1
The 2nd generation of a cross between two dissimilar homozygous parents	F_2
Better parent	BP
Triple Super Phosphate	TSP
Muriate of Potash	MP
Emulsifiable concentrate	EC
At the rate of	@
Milliliter	ml
Randomized Complete Block Design	RCBD
Mean of F_1 Individuals or Mean of reciprocal individuals	F_1
Mean of better parent values	$\overline{BP}$
Mean of the mid parent values	$\overline{MP}$
Gram	gm
Bangladesh Bureau of Statistics	BBS
Analysis of variances	ANOVA
Kilogram	Kg
Bangladesh Institute of Nuclear Agriculture	BINA
Error mean sum of square	EMS

Heterosis over better parent	HBP
Heterosis over mid parent	HMP
North	N
East	E
Negative logarithm of hydrogen ion concentration (-log [H+])	pH
High yielding varieties	HYV

VARIABILITY STUDIES IN F_4 PROGENIES OF *Brassica rapa* OBTAINED THROUGH INTERVARITAL CROSSES

BY

MD. FAYZUL ALAM

ABSTRACT

A research was conducted by using twenty six (26) F_4 populations of some inter-varietal crosses of *Brassica rapa* and grown in the experimental farm of Sher-e-Bangla Agricultural University. Dhaka, during November 2009 - March 2010 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 least difference 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_4 plants showing high heritability for short duration and yield contributing characters were selected from some of cross combinations of the intervarital crosses of *Brassica rapa* for further selection.

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 drough and stress resistance. According to Kariya and Tsunada (1972, 1973, cited by T sunada, 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 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 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 733 kg/hectare (FAO, 2003).

In Bangladesh there is limited scope to increase acreage due to pressure of other crops and to Increase y ield 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_4 segregating generations for selection of desired plant types,

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

3. To select early maturity, high yielding 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 coeffrcient 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. Similar result was also found by Kumar *et al.* (1996), Kudla (1993), Andrahennadi *et al.* (1991), Singh *et al.*(1991), Biswas(1989), Jain *at al* (1988), Chowdhuryer *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.* (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 confrrmed 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 grater 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 1978; 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 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.* (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 rvere 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 flou'ering 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 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 2009 - March 2010.

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 2009 to February 2010 were obtained from the Department of Meteorological centre, Dhaka-1207, Bangladesh. The experiment was conducted using twenty six F_4 generations progenies along with four testers.

3.3 Materials

A total number of 30 (thirty) materials were used in this experiment where twenty six (26) were F_4 segregating generations and four 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

Parents	F_4 Population		Check varieties (Tester)
1. P_1	1. P_5 x P_2	14. P_7 x P_{11}	1. Tori - 7
2. P_2	2. P_6x P_{11}	15. P_5 x P_1	2. BARI sharisa - 6
3. P_3	3. P_7 x P_2	16. P_5 x P_{10}	3. BARI sharisa - 14
4. P_5	4. P_3 x P_{10}	17. P_7 x P_{12}	4. SAU sharisa - 2
5. P_6	5. P_6 x P_2	18. P_2 x P_{11}	
6. P_7	6. P_7 x P_6	19. P_5 x P_{12}	
7. P_{10}	7. P_6 x P_{12}	20. P_7 x P_{10}	
8. P_{11}	8. P_3 x P_2	21. P_2 x P_{10}	
9. P_{12}	9. P_7 x P_3	22. P_2 x P_{12}	
	10. P_3 x P_{12}	23. P_5 x P_3	
	11. P_6 x P_3	24. P_6 x P_5	
	12. P_7 x P_5	25. P_{10} x P_{11}	
	13 P_3 x P_{11}	26. P_7 x P_1	

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 parents and F_4 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. Seeds were sown in lines in the experimental plots on 02 November, 2009. 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, 2010 depending upon the maturity of the plants. When 80% of the plants showed symptoms of maturity i.e.; straw colour of siliqua, 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_4 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 befween 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-effrcient 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-effrcient analysis was done following the method outlined by Dewey and Lu (1959).

i) Estimation of genofypic 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-efiicient 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).

$$h^2b\,(\%) = \frac{\delta^2 g}{\delta^2 p} \times 100$$

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).

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

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

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

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 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;

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

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

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

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

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

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

riy = Correlation of the character with yield.

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Variability

4.1.1 Variability among the 26 F_4 populations of *Brassica rapa*

In the study considerable variations were observed for most of the characters among 26 F_4 materials of *Brassica rapa.* Table 3 and Table 4 showed the values of mean, range, CV (%), phenotypic variances, genotypic variances, phenotypic coefficient of variation, genotypic coefficient of variation and different yield related characters.

Days to 50% flowering

Considerable variations were observed among 26 F_4 populations for days to 50% flowering. The days to 50% flowering were observed lowest (36 days) in P_5 x P_3. In P_7 x P_6 was observed highest (42.00 days) days to 50% flowering (Table 4). The days to 50% flowering was observed in four check varieties 39.00 days in BARI sharisa-6 and 40.67 days in BARI sharisa-14. Some of the F_4 populations requires more flowering times than BARI shaerisa-14 but some are less than BARI sharisa-6 (Table 3). Genotypic and phenotypic variance of days to 50 % flowering was observed 2.21 and 3.56, respectively with moderate differences between them indicating that they were moderate responsive to environmental factors for their phenotypic expression and values of GCV and PCV were 3.79 % and 4.81 % , respectively which indicated moderate variability present among the genotypes (Table 4).

Plant height (cm)

The highest plant height was observed in P_6 x P_{11} (103.97 cm) where as the minimum plant height was observed in P_2 x P_{10} (83.23 cm). Plant height observed among in four check varieties highest BARI sharisa-6 (116.70) which was greater than all the 26 F_4 populations (Table 4) and minimum plant height was observed in SAU sharisa-2 (95.97). Plant height showed the phenotypic variance and genotypic variance were observed 33.53 and 13.85, respectively with relatively large differences between them indicating large environmental influences on these character as well as PCV (6.06 %) and GCV (3.90 %) indicating presence of considerable variability among the genotypes (Table 4). Tyagi *et al.* (2001) observed highest variation in plant height among parents and their hybrid.

Table 3. Mean, range and CV (%) of seed and other characters of 26 crosses

Genotypes	Plant height (cm)	Primary branches/ plant	Secondary branches / plant	Days to 50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length (cm)	1000seed weight (gm)	Yield (gm)
1. P_5 x P_2									
Mean	98.03	6.20	15.73	42.33	254.60	18.97	5.53	2.00	6.83
SE	3.73	0.36	1.79	-	18.64	0.75	0.12	0.12	0.56
CV%	14.74	22.69	44.09	-	28.36	15.32	8.14	23.58	22.73
2. P_6x P_{11}									
Mean	103.97	7.33	15.43	39.00	219.30	23.90	6.11	2.97	8.69
SE	2.62	0.38	1.68	-	16.52	5.83	0.21	0.12	0.73
CV%	9.77	20.31	42.24	-	29.17	94.41	13.52	15.58	42.57
3.P_7XP_2									
Mean	100.27	5.93	11.00	38.00	201.47	18.43	5.70	3.29	8.60
SE	2.05	0.32	0.92	-	12.69	0.94	0.10	1.04	0.52
CV%	7.92	21.21	32.50	-	24.39	19.83	6.54	121.90	20.37
4.P_3XP_{10}									
Mean	95.53	5.97	11.57	40.67	259.27	17.57	5.41	2.15	7.67
SE	5.52	0.33	1.31	-	15.33	0.59	0.10	0.10	1.01
CV%	22.39	21.45	43.83	-	22.91	13.02	7.19	17.46	42.01
5.P6XP2									
Mean	97.86	5.77	8.80	39.33	214.03	17.50	5.54	2.12	8.87
SE	3.52	0.34	0.90	-	16.43	0.65	0.16	0.03	.32
CV%	13.91	22.70	39.57	-	29.74	14.38	10.86	5.08	14.32
6. P_7XP_6									
Mean	102.50	6.10	6.40	39.00	151.33	16.30	5.30	3.10	7.17
SE	2.43	0.48	1.06	-	9.29	0.80	0.12	0.09	0.39
CV%	9.19	30.19	63.96	-	23.77	18.97	9.10	10.93	30.37

Genotypes	Plant height (cm)	Primary branches/ plant	Secondary branches / plant	Days to 50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length (cm)	1000seed weight (gm)	Yield (gm)
7. P_6XP_{12}									
Mean	92.20	5.53	7.77	39.67	149.63	17.10	5.46	2.89	7.83
SE	1.93	0.32	0.97	-	11.78	0.85	0.17	0.21	0.54
CV%	8.09	22.45	48.58	-	30.49	19.31	12.18	27.95	23.41
8. P_3XP_2									
Mean	91.90	7.27	10.03	40.33	204.87	19.13	5.71	2.33	10.00
SE	2.22	0.37	0.97	-	11.42	0.61	0.13	0.12	0.84
CV%	9.36	19.62	37.57	-	21.59	12.34	8.96	19.43	38.72
9. P_7XP_3									
Mean	95.80	6.90	10.50	39.67	170.87	18.30	5.83	3.20	8.67
SE	1.84	0.33	1.32	-	9.77	0.77	0.15	0.10	0.37
CV%	7.43	18.52	48.56	-	22.14	16.19	10.03	12.12	19.62
10. P_3XP_{12}									
Mean	92.77	7.10	9.60	36.00	178.90	18.47	5.80	2.52	8.40
SE	1.82	0.45	0.91	-	12.18	0.74	0.13	0.20	0.79
CV%	7.60	24.44	36.87	-	26.38	15.44	8.40	30.13	34.58
11. P_6XP_3									
Mean	98.13	6.63	10.87	38.33	188.03	16.50	5.17	2.90	6.83
SE	2.54	0.27	1.34	-	13.92	0.71	0.14	0.05	0.80
CV%	10.03	15.96	47.78	-	28.67	16.71	10.22	6.26	45.23
12. P_7XP_5									
Mean	98.30	6.60	9.37	39.67	174.40	17.30	5.84	2.29	11.26
SE	2.32	0.30	1.22	-	11.17	0.57	0.13	0.11	2.57
CV%	9.15	17.48	50.33	-	24.82	12.81	8.51	18.94	88.30
13. P_3XP_{11}									
Mean	95.23	8.07	18.10	41.33	211.80	17.87	5.06	2.25	9.38
SE	3.78	0.64	1.89	-	14.93	0.68	0.12	0.05	0.55

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Genotypes	Plant height (cm)	Primary branches/ plant	Secondary branches / plant	Days to 50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length (cm)	1000seed weight (gm)	Yield (gm)
CV%	15.39	30.53	40.47	-	27.31	14.72	9.44	8.74	22.73
14. P_7XP_{11}									
Mean	98.60	6.57	12.33	42.00	167.80	20.80	5.87	3.29	8.88
SE	1.58	0.52	1.56	-	16.18	0.85	0.13	0.11	0.79
CV%	6.22	30.94	49.13	-	37.35	15.77	8.77	13.44	34.58
15. P_5XP_1									
Mean	88.37	5.53	8.93	38.00	166.57	19.07	6.39	3.21	8.01
SE	2.44	0.33	1.74	-	13.93	0.92	0.13	0.10	0.53
CV%	10.69	23.19	75.45	-	32.40	18.73	7.98	12.34	25.74
16. P_5XP_{10}									
Mean	94.43	6.63	14.23	36.67	167.00	17.30	5.93	3.38	7.52
SE	2.09	0.53	1.76	-	16.07	0.59	0.14	0.12	0.61
CV%	8.56	30.98	47.98	-	37.26	13.30	9.09	14.17	31.61
17. P_7XP_{12}									
Mean	103.60	7.37	13.13	38.33	224.40	19.57	5.64	2.82	9.76
SE	2.66	0.44	1.00	-	12.50	0.71	0.13	0.06	0.84
CV%	9.93	22.89	29.51	-	21.57	14.06	8.69	8.08	33.40
18. P_2XP_{11}									
Mean	89.13	6.37	12.93	38.00	191.50	18.07	5.59	2.64	8.56
SE	2.56	0.30	1.03	-	15.08	0.50	0.13	0.08	0.50
CV%	11.13	18.33	30.87	-	30.50	10.72	9.30	11.15	22.46
19. P_5XP_{12}									
Mean	93.30	6.03	13.20	40.33	181.27	17.40	5.37	2.15	7.99
SE	2.98	0.51	1.30	-	15.04	0.73	0.10	0.05	0.68
CV%	12.36	32.50	38.18	-	32.13	16.25	7.14	8.29	32.94
20. P_7XP_{10}									
Mean	94.03	6.17	13.13	39.67	194.53	16.33	5.71	2.91	10.66

Genotypes	Plant height (cm)	Primary branches/ plant	Secondary branches / plant	Days to 50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length (cm)	1000seed weight (gm)	Yield (gm)
SE	3.46	0.33	0.93	-	15.52	0.84	0.14	0.06	0.98
CV%	14.23	20.88	27.45	-	30.90	19.81	9.55	8.21	35.69
21. P_2XP_{10}									
Mean	83.23	7.43	15.67	39.00	263.30	16.40	5.42	2.40	9.13
SE	2.25	0.37	1.89	-	52.08	0.70	0.06	0.10	0.76
CV%	10.49	19.14	46.75	-	76.61	16.47	4.61	15.82	32.23
22. P_2XP_{12}									
Mean	99.77	7.73	17.93	37.67	242.33	15.83	5.43	3.07	9.57
SE	2.12	0.48	1.91	-	14.94	0.53	0.11	0.14	0.65
CV%	8.22	24.12	41.30	-	23.89	12.92	7.56	18.31	26.37
23. P_5XP_3									
Mean	90.43	6.77	12.20	36.00	196.10	17.40	5.68	2.60	8.72
SE	1.71	0.27	1.50	-	17.09	0.58	0.13	0.07	0.68
CV%	7.33	15.69	47.59	-	33.76	13.02	8.80	10.86	30.02
24. P_6XP_5									
Mean	103.97	7.00	11.43	40.67	204.60	16.33	6.15	2.52	7.87
SE	2.88	0.58	1.76	-	13.99	0.81	0.11	0.21	0.78
CV%	10.72	31.94	59.71	-	26.48	19.18	7.10	32.26	38.53
25. $P_{10}XP_{11}$									
Mean	97.37	7.43	9.37	40.33	237.67	19.13	5.54	3.36	7.85
SE	2.91	0.51	1.22	-	19.91	0.46	0.12	0.10	0.56
CV%	11.59	26.75	50.33	-	32.44	9.32	8.07	11.96	27.85
26. P_7XP_1									
Mean	94.03	6.80	13.13	39.00	163.33	18.40	5.56	2.72	8.39
SE	3.46	0.31	0.93	-	15.80	0.80	0.15	0.19	0.84
CV%	14.23	17.78	27.45	-	37.45	16.93	10.51	27.74	38.72

Table 4. Mean, range and CV (%) of seed and other characters of 4 Checks

Genotypes	Plant height (cm)	Primary branches/ plant	Secondary branches / plant	Days to 50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length (cm)	1000seed weight (gm)	Yield (gm)
1.Tori-7									
Mean	100.33	6.43	15.03	39.33	179.07	18.43	6.50	2.68	8.55
SE	1.95	0.41	1.02		8.12	0.52	0.21	0.06	0.45
CV%	7.53	24.44	26.31		17.55	10.84	12.50	9.23	20.51
2.BARI sharisa -6									
Mean	116.70	6.87	3.07	39.00	148.77	22.83	6.23	1.56	6.71
SE	2.18	0.43	0.56		10.64	0.80	0.11	0.06	0.56
CV%	7.24	24.45	70.92		27.70	13.51	6.91	14.54	32.06
3.BARI sharisa-14									
Mean	97.17	7.37	5.13	40.67	93.13	41.50	5.54	3.62	10.00
SE	1.76	0.40	0.99	-	2.96	0.68	0.09	0.08	0.39
CV%	7.02	21.01	74.58	-	12.32	6.31	6.05	8.21	15.24
4.SAU sharisa-2									
Mean	95.97	6.73	3.63	40.00	153.10	25.70	6.16	3.47	4.75
SE	2.24	0.43	0.76	-	7.77	0.63	0.27	0.11	0.30
CV%	9.06	24.96	81.42	-	19.66	9.50	17.17	12.06	24.84

Number of primary branches per plant

Among the 26 F_4 populations the highest number of primary branches/plant was observed in P_3 x P_{11} (8.07) where as the minimum number of primary branches/plant was observed in P_6 x P_{12} (5.53). No. of primary branches per plant observed in four check varieties highest BARI shaerisa-14 (7.37) and minimum primary branches per plant was observed in Tori-7 (6.43). Most of the crosses produced more primary branches per plant than Tori-7 (Table 3).

Number of primary branches per plant showed little differences between phenotypic variance (0.61) and genotypic variance (0.33) indicating low environmental influence on these character and relatively high difference between PCV (11.75 %) and GCV (8.68 %) value indicating the apparent variation not only due to genotypes but also due to the large influence of environment (Table 4). Chowdhary *et al.* (1987) found significant differences for number of primary branches per plant.

Number of secondary branches per plant

The highest number of secondary branches/plant was observed (18.10) in P_3 x P_{11} where as the minimum number of secondary branches/plant was observed in P_7 x P_6 (6.40) (Table 3). The number of secondary branches/plant was observed 15.03 in Tori-7 and 3.07 in BARI shaerisa-6. All the 26 F_4 populations produced less number of secondary branches/plant than check varieties Tori-7 (Table 4). Number of secondary Branches per plant showed little difference between phenotypic variance (6.24) and genotypic variance (4.97) indicating little environmental influence on this character. The value of PCV (11.75 %) and GCV (8.68 %) indicating that the environment have significant role on the expression of this particular trait (Table 4). Lekh *et al.* (1998) reported similar result.

Number of siliqua per plant

The number of siliqua was observed highest in P_2 x P_{10} (263.30).Whereas the minimum number of siliqua/plant was observed in P_6 x P_{12} (149.83). Number of siliqua/plant observed in four check varieties highest Tori-7 (179.07) and minimum was observed in BARI shaerisa-14 (93.13). (Table 3). Number of siliqua showed highest phenotypic variance (1285.91) and genotypic variance (977.28) with large environmental influence and the difference between the PCV (17.97 %) and GCV (15.66%) indicating existence of adequate variation among the genotype (Table 4) Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring Ushakumari *et al.* (1991).

Length of siliqua (cm)

Length of siliqua was observed highest in P_6 x P_5 (6.15 cm) followed by P_6 x P_{11} (6.11 cm) whereas the minimum length of siliqua was observed (5.06cm) in P_3 x P_{11}. Length of siliqua was observed 6.50 cm in Tori-7 which was higher than all the crosses (Table 3). Length of siliqua showed phenotypic variance (0.22) and genotypic variance (0.08) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively low PCV (8.35%) and GCV (5.08%) indicating that the genotypehas less variation for this trait (Table 4). Labowitz (1989) studied *Brassica campestris* population for siliqua length and observed high genetic variation on this trait. Olson (1990) found high genetic variability for this trait.

Number of seeds per siliqua

The highest number of seeds per siliqua was observed in P_6 x P_{11} (23.90). Where as the minimum number of seeds/siliqua was observed in P_7 x P_6 (16.30). Number of seeds per siliqua observed in four check varieties highest BARI shaerisa-14 (41.50) and minimum was observed in Tori-7 (18.43). (Table 3). The differences between phenotypic variances (4.08) and genotypic variances (2.28) were relatively low for number of seeds/siliqua indicating low environmental influence on these characters (Table 4). The value of PCV and GCV were 11.31 % and 8.47 % respectively for number of seeds per siliqua which indicating that less variation exists among different genotypes.

Thousand seed weight (g)

Thousand seed weight was found maximum in P_5 x P_{10} (3.38 g) where as the minimum thousand seed weight was found in P_5 x P_2 (2.00 g). Thousand seed weight observed in check varieties 3.62 g in BARI shaerisa-14 and 2.68 g in Tori-7 which was near about most of the crosses (Table 3). Thousand seed weight showed very low genotypic (0.56) and phenotypic (0.71) variance with minimum differences indicating that they were less responsive to environmental factors and the values of GCV and PCV were 27.10 % and 30.65 % indicating that the genotype has considerable variation for this trait (Table 4).

Seed yield per plant (g)

Yield is the most outstanding character and all the research work and objectives are dependent on yield. The highest amount of yield/plant was observed in P_7 x P_5 (11.26

g).Where as the minimum yield per plant was observed in P_5 x P_2 (6.83 g).The yield per plant of check varieties were 10.00 g in BARI shaerisa-14 and 4.75 g in Tori-7 whereas most of crosses produced higher yield per plant than both two check varieties (Table 3). The phenotypic variance (1.95) appeared to be moderately than the genotypic variance (1.50). Suggested moderate environmental influence on these characters (Table 4). The phenotypic co-efficient of variation (16.69 %) was higher than the genotypic co-efficient of variation (14.64 %) which suggested that environment has a significant role on the on the expression of this trait (Table. 4).

4.1.2. Heritability, genetic advance and selection

Days to 50% flowering exhibited high heritability (62.09%) with genetic advance 2.41 and genetic advance in percentage of mean 6.16% (Table. 5). As a whole, the high heritability and the consequent low genetic advance indicated the lower possibility of selected genotypes. This results support the reports of Malik *et al.* (1995).

Plant height showed high heritability 41.30% with genetic advance 4.93 and genetic advance in percentage of mean 5.16% (Table. 5). As a whole, the high heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes. Varshney et al. (1986) found high heritability for plant height.

Number of primary branches per plant exhibited high heritability 54.58 % with low genetic advance 0.88 and genetic advance in percentage of mean 13.21% (Table.5). As a whole, the low heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes.

Number of secondary branches per plant exhibited high heritability 79.67% with low genetic advance 4.10 and genetic advance in percentage of mean 35.72% (Table. 5). As a whole, the low heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes. Katiyar *et al.* (1974) reported low heritability for this trait.

Number of siliqua per plant exhibited high heritability 76.00% with genetic advance 56.14 and genetic advance in percentage of mean 28.13% (Table. 5). As a whole, the high heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes. This result supports the report of Paul *et al.* (1976).

Length of siliqua showed heritability 37.04% with 0.35 genetic advance and genetic advance in percentage of mean 6.37% (Table. 5).These results revealed the possibility of predominance of both additive and non additive gene action in the inheritance of this trait. Kwon *et al.* (1989) and Rac (1977) reported high heritability for this trait. Yadava *et al.* (1982), Sharma (1984) and Kakroo and Kumar (1991) reported low to medium heritability for this trait.

Number of seeds per siliqua showed heritability 56.06% coupled with genetic advance 2.33 and genetic advance in percentage of mean 13.06% (Table. 5). Malik *et al.* (1995) reported high heritability (h^2b> 90%) for this trait.

1000 seed weight exhibited heritability 78.14% with genetic advance 1.36 and genetic advance in percentage of mean 49.34% (Table. 5). This trait is governed by non additive gene. Liang and Walter (1968) reported that moderate values of heritability and low genetic advance may be due to non additive gene action which includes dominance and epistasis. Johnson *et al.* (1955) reported that heritability estimates along with genetic gain were more useful in prediction selection of the best individual.

Seed yield per plant showed heritability 77.00% with low genetic advance 2.22 and medium genetic advance in percentage of mean 26.47% (Table.5).These results support the reports of Liang and Walter (1968) but Singh *et al.* (1987) found high heritability for this trait.

Significant variability was found in almost all the F_4 materials *Brassica rapa* for most of the characters studied. The performance of the crosses also compared with the four check varieties (Table. 6). As per objectives, selection was carried out among the F_4 materials of different cross combinations. Some of the promising cross with short duration and higher yield/plant were selected from the F_4 materials.

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_4 materials of *B. rapa* are shown in Table 7.

Table 5. Estimation of some genetic parameters in respect of 26 Crosses

Parameters	Plant height	Primary branches	Secondary branch	50%flowering	Siliqua/plant	Seeds/Siliqua	Siliqua length	1000 seed wt.	Yield
Genotypic variance	13.85	0.33	4.97	2.21	977.28	2.28	0.08	0.56	1.50
Phenotypic variance	33.53	0.61	6.24	3.56	1285.91	4.08	0.22	0.71	1.95
Heritability %	41.30	54.58	79.67	62.09	76.00	56.06	37.04	78.14	77.00
Genetic advance (5%)	4.93	0.88	4.10	2.41	56.14	2.33	0.35	1.36	2.22
G.Ad (5%) in % mean	5.16	13.21	35.72	6.16	28.13	13.06	6.37	49.34	26.47
Genotypic co-efficient of variation	3.90	8.68	19.43	3.79	15.66	8.47	5.08	27.10	14.64
Phenotypic co-efficient of variation	6.06	11.75	21.77	4.81	17.97	11.31	8.35	30.65	16.69

Table 6. Estimation of some genetic parameters in respect of 4 checks

Parameters	Plant height	Primary branches	Secondary branch	50%flowering	Siliqua/plant	Seeds/Siliqua	Siliqua length	1000 seed wt.	Yield
Genotypic variance	68.89	0.37	3.14	0.36	1245.48	42.30	0.10	0.84	2.54
Phenotypic variance	98.62	0.42	5.37	0.92	1430.73	47.45	0.23	0.87	2.96
Heritability %	69.85	87.77	58.46	39.37	87.05	89.14	42.16	97.01	85.78
Genetic advance (5%)	14.29	1.17	2.79	0.78	67.83	12.65	0.42	1.86	3.04
G.Ad (5%) in % mean	14.10	18.24	45.86	1.95	47.26	49.25	7.02	67.12	35.67
Genotypic co-efficient of variation	8.19	9.45	29.12	1.51	24.59	25.32	5.25	33.08	18.69
Phenotypic co-efficient of variation	9.80	10.09	38.08	2.41	26.36	26.82	8.08	33.59	20.18

Table 7. Genotypic and phenotypic Correlations co-efficient among different characters of 26 crosses

Parameters		Primary branches	Secondary branch	50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length	1000 seed wt.	Yield
Plant height (cm)	r_g	-0.304**	-0.068	0.486**	0.059	-0.023	-0.069	0.354**	0.043
	r_p	-0.081	-0.065	0.226*	0.118	-0.114	0.073	0.168	0.076
P. branches	r_g		0.432**	-0.377**	-0.016	0.069	-0.012	0.038	0.020
	r_p		0.261*	-0.236*	0.042	0.168	0.012	-0.014	-0.035
S. branches	r_g			-0.050	0.161	0.450**	0.468**	0.176	0.032
	r_p			-0.075	0.096	0.361**	0.324**	0.114	0.056
50%flowering	r_g				0.050	0.249*	0.079	-0.321**	0.098
	r_p				-0.045	0.157	-0.062	-0.238*	-0.001
Siliqua per plant	r_g					-0.024	-0.185	-0.211*	0.428**
	r_p					0.033	0.062	-0.071	0.184
Seeds per siliqua	r_g						0.365**	-0.045	0.196*
	r_p						0.286*	-0.070	0.076
Siliqua length	r_g							0.431**	0.261*
	r_p							0.186	0.242*
1000 seed wt.	r_g								-0.104
	r_p								0.006

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

Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait for F_4 materials of *B. rapa* are shown in Table 7.

Days to 50% flowering

Days to flowering showed positive significant interaction with seeds per siliqua (G = 0.079) and yield per plant (G = 0.098) followed by positive interactions with seeds per siliqua (P = 0.157). Whereas negative significant interactions were found in number thousand seed weight (G = -0.321) followed by negative interaction was found in siliqua per plant (P = -0.045), length of siliqua(P = -0.062), thousand seed weight (P = -0.238) and yield per plant (P = -.001) Singh *et al.* (1987) and Shivahare *et al.* (1975) reported that days to 50% flowering negatively correlated with thousand seed weight.

Plant height (cm)

Plant height showed positive significant interaction with number of thousand seed weight (0.354) and yield per plant (0.043) followed by positive interaction with siliqua per plant (0.118), length of siliqua (P =0.073), thousand seed weight (0.168) and yield per plant (0.076). Whereas negative significant interaction was found in number of primary branches per plant (G = - 0.304), Seeds per siliqua (-0.023) and length of siliqua(-0.069) followed by negative interaction was found in primary branches per plant (P= - 0.081), Seeds per siliqua (G = -0.114), (Tabie 7).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 = 0.432) followed by positive interaction with seeds per siliqua (G= 0.069), thousand seed weight (G = 0.038) and yield per plant (G= 0.020). Whereas the negative significant interaction was not found but negative interaction was found in siliqua per plant (G = - 0.016), length of siliqua (- 0.012 (Table 7). 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 siliquae per plant.

Number of secondary branches per plant

Number of secondary branches per plant showed positive significant interaction with seeds per siliqua (G= 0.450) and siliqua length (G = 0.0.468) followed by positive interaction with siliqua per plant (G= 0.161), thousand seed weight (G = 0.176, P= 0.114) and yield per plant (G = 0.170). Whereas the negative significant interaction was found in number of siliqua per plant (G= 0.032, P = 0.056) (Table 7).

Number of siliqua per plant

Siliquae per plant showed positive significant interaction with thousand seedweight (P = 0.404) and yield per plant (P = 0.457) followed by positive interaction with length of siliqua (G = 0.030, P = 0.075), seeds per siliqua (0 =0.119, P = 0.278), thousand seed weight (0 = 0.333) and yield per plant (0 =0.345) (Table 7). 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 yield per plant (G = 0.428) (Table 7). 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 length of siliqua (G = 0.431) and yield per plant (G = 0.261, P = 0.242)(Table 7). 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 no significant positive interaction with yield per plant

(Table 7).

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 primarybranches/plant, number of secondary branches/plant, lenglh of siliqu4 number of seeds/siliquaand 1000 seed weight were casual (independent) variables. The results of path co-efficient analysis using F_4 materials of *Brassi ca rapa* were presented in Table 8.

Path co-efficient analysis revealed those days to flowering had negative direct effect (-0.431) on yield per plant. Days to flowering had positive indirect effect on plant height (0.268) and number of secondary branches per plant (0.029), number of siliqua per plant (0.028), length of siliqua (0.070) and thousand seed weight (0.194), seeds/siliqua (0.054). And it showed negative indirect effect on number of primary branches per plant (-0.115) (Table 8). Chauhan and Singh (1985) observed positive direct effect of days to 50% flowering and indirect effect of plant height, primary branches per plant and siliqua per plant on seed yield.

Path analysis revealed that plant height had positive direct effect (0.552) on yield per plant followed by negative indirect effect on number of primary branches per plant (-0.093), seeds per siliqua (-0.005), and thousand seed weight (-0.214). Positive indirect effect through number of secondary branches per plant 0.040), number of siliqua per plant (0.033) (Table 8). 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 positive direct effect on yield per plant (0.305). This trait had positive indirect effect on days to flowering (0.163), seeds per siliqua (0.015). On the other hand negative indirect effect was found on number of secondary branches per plant (- 0.252), number of siliqua per plant (-0.009), length of siliqua (-0.011) and thousand seed weight (-0.023) (Table 8). No. 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.

Table 8. Path coefficient analysis showing direct and indirect effect of yield components on seed yield in F_4

Characters	Plant height (cm)	Primary branches	Secondary branch	50% flowering	Siliqua per plant	Seeds per siliqua	Siliqua length	1000 seed wt.	Genotypic correlation with yield
Plant height	**0.552**	-0.093	0.040	-0.209	0.033	-0.005	-0.061	-0.214	0.043
P. branches	-0.168	**0.305**	-0.252	0.163	-0.009	0.015	-0.011	-0.023	0.020
S. branches	-0.038	0.132	**-0.583**	0.022	0.090	0.097	0.418	-0.106	0.032
50%flowering	0.268	-0.115	0.029	**-0.431**	0.028	0.054	0.070	0.194	0.098
Siliqua per plant	0.033	-0.005	-0.094	-0.022	**0.559**	-0.005	-0.165	0.127	0.428**
Seeds per siliqua	-0.013	0.021	-0.262	-0.108	-0.014	**0.217**	0.327	0.027	0.196*
Siliqua length	-0.038	-0.004	-0.273	-0.034	-0.103	0.079	**0.894**	-0.260	0.261*
1000 seed wt. (g)	0.195	0.012	-0.103	0.139	-0.118	-0.010	0.385	**-0.604**	-0.104

Residual (R) = 0.551

Number of secondary branches per plant had negative direct effect (-0.538) on yield per plant and negative indirect effect on plant height (-0.038), and thousand seed weight (-0.106). On the other hand this trait showed positive indirect effect on days to flowering (0.022), number of siliqua per plant (0.090) and seeds per siliqua (0.097) and length of siliqua (0.418) (Table 8). 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 positive direct effect (0.559) on seed yield followed by positive indirect effect on plant height (0.033) and thousand seed weight (0.127). And this trait had negative indirect effect on number of primary branches per plant (-0.005), days to flowering (-0.022) and number of secondary branches per plant (-0.094 (Table 8). 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 the highest direct positive effect (0.894) on yield per plant. This trait had also indirect positive effect on seeds per siliqua (0.079). On the other hand length of siliqua showed indirect negative effect on number of primary branches per plant (-0.004), number of secondary branches per plant (-0.273), number of siliqua per plant (-0.103) and thousand seed weight (-0.260) and days to flowering (-0.034), and (Table 8). Siddikee (2006) found the same result.

Seeds per siliqua had positive direct effect (0.217) on yield per plant and positive indirect effect on number of primary branches per plant (0.021), siliqua length (0.327) and thousand seed weight (0.027). On the other band this trait showed negative indirect effect on number of secondary branches per plant (-0.262), number of siliqua per plant (-0.014), days to flowering (-0.108) and plant height (- 0.013) (Table 8).

Thousand seed weight had negative direct effect on yield per plant (-0.604) and negative indirect effect on number of secondary branches per plant (-0.103) and siliqua per plant (-0.118). On the other hand this trait showed positive indirect effect on number of primary branches per plant (0.012), length of siliqua (0.385. days to 50% flowering (0.139), and plant height (0.195) (Table 8).

Through path analysis the residual effect was observed. The residual effect (R) was 0.551, which indicating the character under study contributed 44.1% of the seed yield per plant (Table 8). It is suggested that there were some others factors those contributed 55.1% to the seed yield per plant not included in the present study may exert significant effect on seed yield.

CHAPTER 5

SUMMARY AND CONCLUSION

An experiment was conducted during the period of 12 November, 2009 to March 2010, at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University using nine parental genotypes, their twenty six F_4 progenies of *Brassica rapa* and four check varieties to study the variability, heritability, genetic advance, correlation co efficient and direct and indirect influences of different characters on seed yield per plant. The twenty six F_4 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. Days to 50% flowering were highest in plants P_7 x P_{11} (42.00 days) and lowest in P_5 x P_3 (36.00 days). The plants of where the tallest (103.97 cm) at P_6 x P_{11} and the plants of P_2 x P_{10} were the shortest plant height (83.23 cm). The plants P_3 x P_{11} produced maximum number of primary branches per plant (8.07) and P_6 x P_{12} produced lowest number of primary branches per plant (5.53). Number of secondary branches per plant was highest in parents P_3 x P_{11} (18.10) and lowest in P_7 x P_6 (6.40). Number of siliqua per plant showed highest in P_2 x P_{10} (263.30) and lowest in P_6 x P_{12} (149.83). The length of siliqua of showed P_6 x P_5 (6.15 cm) highest and P_3 x P_{11} (5.06 cm) in was observed lowest. The highest number of seeds per siliqua (23.90) was observed in P_6 x P_{11} and lowest in P_7 x P_6 (16.30). The seed size was largest in the P_5 x P_{10} with an average of (3.38 g) for 1000 seed weight. The smallest seed size showed in P_5 x P_2 with an average of (2.00 g) for 1000 seed weight. The highest yield per plant was recorded in the parents P_7 x P_5 (11.26 gm) and lowest yield per plant was observed in P_5 x P_2 (6.83 gm).

The phenotypic variance of the twenty six F_4 materials was considerably higher than the genotypic variances for all the traits studied. In F_4 materials, plant height, and number of siliquae per plant showed moderate differences between genotypic and phenotypic variances. Days to 50% flowering, days to maturity number of primary branches per plant, number of secondary branches per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and yield per plant showed minimum differences between genotypic and phenotypic variances which indicate low environmental influence on these traits. Days to 50% flowering, days to maturity. Plant height, number of primary branches per plant, number of secondary branches per plant number of seeds per siliqua, length of siliqua, thousand seed weight, and yield per plant exhibited genotypic or phenotypic co-efficient of variation. Siliqua per plant showed moderate genotypic and phenotypic co-efficient of variation.

Days to 50% flowering, plant height, number of primary branches per plant, number of secondary branches per plant and number of siliqua per plant and showed high heritability with high genetic advance and genetic advance in percentage of mean indicated little possibility of selecting genotype. Length of siliqua, seeds per siliqua and thousand seed weight showed low heritability with low genetic advance and genetic advance in percentage of mean that indicate lower possibility of selecting genotypes. Yield per plant exhibited high heritability with low genetic advance and medium genetic advance in percentage of mean that indicate medium possibility of selecting genotypes for improvement of the crop.

Selection was carried out among the twenty six F_4 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 F_4 materials.

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

Path co-efficient analysis revealed that days to 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.

REFERENCES

Alam, M.S., Rahman, A.R.II,S. and Khair. A.B.N{.A. (1986). Genetic variability and character association in groundnut (*Arachis hypogaeaL.*). *Bangladesh J. Agron.*l0(4): 9-16.

Allard. R.W. (1960). Principles of Plant Breeding. John Willey and Sons. Inc. New York. p. 36.

Andrahennadi, C.P., Weerasena L.A. and Aberyrantne, M.D.R.S" (1991). Evaluation of brow mustard germplasms in Srilank a. *Cruciferae newsletter*. l4(I 5): 62-63.

Banerzee. H.T., Bhattacharjee, H. and Das, M. (1968). A note on the relationship between growth and yield of the yellow sarson var. Prain. *Indian J. Agron.* 13:203-204.

BBS. (2003). Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistic Division, Ministry of Planning, Gol't. of the People's Republic of Bangladesh. p. 92.

BBS (2004). Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistic Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. p. 96.

Bhatt, G.M. (1980). Early generation selection criteria for yield in wheat. *J. Aust. Inst. Agric. Sci.* 48. p. 14.

Biswas, K.P. (1989). Performance evaluation of 18 genotype of oleiferous *Brassica.* Proceedings of the 4th Annual Bangladesh Sci. Conf. p.70.

Burton, G.W. (1952). Quaniitative inheritance in grass pea. Proc. 6 th Grassl. Cong. 1:277-283.

Campbell, D.C. and Kondra, Z.P. (1978). A genetic study of growth characters and yield characters of rape. *Euphytica.* 27 : 177 -183.

Campbell, D.C. and Kondra, Z.P. (1978). Relationship among growth patterns, yield components and yield of rapeseed. *Can. J. Plant Sci.* 58: 87-93.

Chandola, R.F., Dixit, P.K., Sharina, K.N., Saxena, D.K. (1977). Variability in *B. juncea* under three environments. *Indian J. Agric. Sci*. 47(9):680-683.

Chafterjee, S.D. and Bhatiacharya, B. (1986). Selection index in Indian mustard. *Indian J. Agric. Sci.* 56: 208-209.

Chaturvedi, G.S., Singh, B.B. and Chauhan, Y.S. (1988). Physiological analysis of yield in Indian mustard under irrigated condition. *Indian J. of plant physiology*. 38 (1): 38-44.

Chaudhari, L.B. and Prasad, B. (1968). Genetic variation and heritability of quantitative characters in Indian mustard. *Indian J. Agric. Sci.* 38(5): 820-825.

Chaudhary, L.B. and Prasad, B. (1987). Genetic variation and heritability of quantitativ characters in Indian mustard. *Indian J. Agric. Sci.* 38(5): 820-825.

Chaudhury, P.K., Singh,P. and Kumar, A. (1990). Association and lnterdependence of morpho- physiological characters under moisture stress in *Brassica. Beitrage Zar TropichenLanduirt shaft.* l8(l): 43 -47 .

Chauhan, J. and Singh, P. (1985). Association of some morpho-physiological determinants with seed yield in toria (*B. campestris* L. var. toria). Thesis Abstract XI-l: 42-43.

Chay, P. and Thurling, N. (1989). Identification of Genus controlling siliqua length in spring rapeseed and their utilization for yield improvement. *Plant Breeding.* l03(l): 54-62.

Chen, C., Hwu, K.K., Liu, C.P. and Lin, M.S. (1983). Selection criteria for yield improvement in rape. *J Agric. Asso. China.* l24: 63-73.

Chowdhury, B.D., Thakural, S.K., Singh, D.P. and Singh, P. (1987). Genetics of yield and its components in Indian mustard. *Narenda Deva J. Agril. Res.* 3(1): 37-43.

Clarke, G.M. (1973). Statistics and Experimental Design. Edward Amold. London.

Coffelt, T.A. and Hammons, R.O. (1974). Early generation yield trials of peanuts. *Peanut Sci.* 1:3-6.

Comstock, K. and Robinson, P.R. (1952). Estimation of genetic advance. *Indian J. Hilt.* 6(2): 17l-174.

Dabholkar, A.R. (1992). Elements of Biometrical Genetics. Concept publishing, New Dhelhi, India.

Das, M.L. and Rahmffi, A. (1994). Evaluation of mutants of rapeseed for earliness, seed yield and response to change environments in M_2 generation. *Bangladesh J. Nuclear Agri.* l0: 71-80.

Das, M.L. and Rahmil, A. (1989). Correlated response and path analysis in mustards (*B.*

campestris). Bangladesh J. Sci. Res. 7(1): 37- 41.

Das, M.L., Rahman, A., Khan, M.H.R. and Miah, A.J. (1984). Conelation and path coefficient studies in soybean, *Bangladesh J. Bot.* 7(1): 1-5.

Das, M.L., Malek, M.A. and Rahman, A. (1999). Performance of gamma irradiated M5 mutants of rapeseed in different locations of Bangladesh. *Bangladesh J. Agri.*24(1): I 15- 1 19.

Das, M.L., Rahman, A., Malek, M.A. and Pathan A.J. (1995). Stability and fatty acid analysis for selecting promising mutants of rapeseed. *Bangladesh J. Nuclear Agric.*11: l- 8.

Degby, P., Galway, N and Lame, P. (1939). Genstat 5A second course. Oxford Science

Publications, Oxford. pp. 103-108.

Deshmukh, S.N., Basu, M.S. and Reddi, P.S. (1936). Genetic variability, character association and path coefficient of quantitative traits in Virginia bunch varieties of groundnut. *Indian J. Agric.* 56(12): 8 l6-821.

Dewey, D.R. and Lu, K.H. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* 5l :515-518.

Dhillon, S.S., Laban4 K.S. and Ahuja, K.L. (1990). Association analysis in Indian Mustard.

Journal of Research. 27 (3): 3 85-3 88.

Dhillon, S.S., Labana, K.S., Ahujq K.L. and Bangra, S.K. (1984). Pod intensity, yield potential and oil content of exotic collections of rape and mustard. *Cruciferae Newsletter*.9:48-49

Downey, R.K. (1990). Brassica oilseed breeding- achievements and oppurtunities. plant Breeding Abstracts. 60: I 165-1 170.

FAO. (2003). Production Year Book, Food and Agricultural Organization of United Nations,

Rome 00108, Italy. Vol. 57.pp. 115-133.

Fasoulas, A. (1973). A new approach to breeding superior yielding varieties. Arist. Univ.,

Thessaloniki. Publ. 3. p. 42.

Gebre-Mariam, M. (1982). Index selection for genetic improvement of yield, kernel weight and protein content in wheat. Dissertation Abstracts International.B42 (121) 4679 B.

Ghosh, R.K. (1998). Path analysis of important growth functions of Indian mustard. *Indian J.*

Agron. and Crop Sci. 160(2): 116-121.

Ghosh, R.K. and Chatterjee, B.N. (1988). Path analysis of important growth fi.rnctions of Indian mustard. *Journal of Agron. Crop Sci.*160(2): 112-l18.

Grafius, J.E. (1959). Heterosis in barley. *Agron.* J. 5l: 515-518.

Grosse, C. and Geisler, G. (1988). Variability in the physiological yield characteristics and

assortment of water rape cultivars yield components.

Gupta M.L. and Laban4 K.S. (1985). Effect of selection for seed size and its correlatedresponses in Indian mustard. *Crop Improv*.12: 193-194.

Gupta, M.L., Labana, K.S. and Badwal, S.S. (1987). Conelation and path coefficient o tilari'rtraits contributing towards oil yield in Indian mustard. Intemational rapseed congress, Poznan, Poland.p.107 .

Poznan, Poland. p. 107.

Gupta, S. K. and Labana K.S. (1988). Genetics of oil content in oilseed rape. *Cruciferae Newsletter*.13: 48.

Gupta, S.K. and Labana K.S. (1989). Triple test cross analysis for some physiomorphological trait in oil yield in Indian mustard. Proceedings of the 7m International Rapeseed Congress. Poland. May 1987. pp. 11-14.

Han, J.X. (1990). Genetic analysis of oil content in rape *Brassica napus*. *Oil crops Chaina*.2:1-6

Jain, A.K., Tiwari, A.S. and Kushwah, V.S. (1988). Genetics of quantitative traits in Indian mustard. *Indian J. Genet. Pl. Breed*.: 117-119.

Jatasra, D.S. and Paroda, R.S. (1978). Genetic divergence in wheat under different environmental conditions. *Cereal Res. Comm*. 6: 307 - 317 .

Johnson, Herbert, W. Robinson, H.F. and Comstock, R.E. (1955). Estimates of genetic and environmental variability in soyabeans. *Agron*. J. 47 : 3 14-3 1 8.

Kakroo, P. and Kumar, S. (1991). Genetic determination of seed yield through it's components in Indian mustard. Thesis Abstract xvii-i: 82.

Kalesnikov, I.M. (1979). The possibility of early prediction of the breeding value of hybrids and the effectiveness of selection in the F_2 *Tidskr*.65: 178.

Katiyar, A.P. and Singh, B. (1974). Inter-relationship among yield and its components in Indian mustard. *Indian J. Agric. Sci*. 44: 287-290.

Katiyar, B.S., Lee, J. I. and Chae, Y.A. (1974). Genetic studies on some agronomic characters in rapeseed. *Korean J. Breeding*. 21(1): 22-27 .

Kaul, A.K. and Das, M.L. (1986). Oilseeds in Bangladesh. Bangladesh-Canada Agric. Sector Team-MOA, Bangladesh. p. 323.

Khera M.K. and Singh, P. (1988). Sensitivity and performance of some Brassica napus enotypes in stress and non-stress environments. *Crop Improv*. 15(2): 209-211.

Khulbe, R.K. and Pant, D.P. (1999). Correlation and path coefficient analysis of yield and it-. components in Indian mustard. *Crop Res. Hisar.IT*(3):371-375.

Kibite, S. (1981). Genetic studies on the simultaneous improvement of grain yield and grai-rprotein content in wheat (*Triticum aestivum* L. em. Thell). Dissertation Abstracr Intemational B. 41(9): 3263 B.

Knott, D.R. (1972). Effects of selection for Fz plant yield on subsequent generations in u'hea *Can. J. Pl.* Sci. 52: 721-726.

Kudla, M. (1993). Comperative analysis of winter swede rape genotypes. Biulefy-n Insryru; *Hodowli Roslin*. 9A: 99-107 .

Kumar, C.H.M.V., Arunachalam, V. and Rao, P.S.K. (1996). Ideotype and relationship benre, morpho-physiological characters and yield in Indian mustard (*B. juncea*). *Indian J. Agri-Sc*i. 66(1): 14-17.

Kumar, N., Bisht, J.K. and Joshi, M.C. (i988). Conelation and discriminant function anatrl sisIndian mustard. *Indian J. Agric. Sci*. 58(1): 5l-52.

Kumar, P., Yadava T.P. and Yadav, A.K. (1984). Association of seed yield and its comr',r- :traits in the F_2 generation of Indian mustard. *Indian J. Agric. Sci*. 54(7): 604-607 .

Kumar, S., Sangwan, R. S. and Yadava I. S. (1999). Path coefficient analysis in *-Brassica* species under rainfed conditions. *Cruciferae newsletter*. 24: 59-60; 3 ref.

Kumar, V. and Singh, D. (1994). Genetics of yield and its components in Indian mustard (*Brassica juncea* L. Czern and Coss). *Crop Res*. 7(2): 243-246.

Kwon" B.S., Lee, J.I. and Chae, Y. A. (1989). Genetic studies on some agronomic characters in rapeseed. *Korean J. Breeding*. 2l(l): 22-27 .

Labana K.S., Ahuja K.L. and Banga, S.S. (1987). Evaluation of some Ethiopian mustard (*Brassica carinata*) genotype under Indian conditions. In 7th International rapeseed congress, Poznan, Poland. p. l15.

Labanq K.S., Chaurasia B.D. and Singh, B. (1980). Genetic variability and inter-character associations in the mutants of Indian mustard. *Indian J. Agric Sci.* 50(1): 803-806.

Lebowitz, R.J. (1989). Image analysis measurements and repeatability estimates of siliquamorphological traits in *B. campestris L. Euphytica*.43(I-2): 113-116.

Lekh, R., Hari, S., Singh, V.P., Raj, L. and Singh, H. (1998) Variability studies in rapeseed and mustard. *Ann. Agril. Res.* 19(1): 87-88.

Li. J.N., Qiu, J. and Tang, Z.L. (1989). Analysis of variability of some genetic parameters in egregating hybrid generations of *B. napus. Heriditus Beijing*. ll(6): 4-7.

Lodhi, G.P., Singh, R.K. and Sharma S.C. (1979). Conelated response in brown sarson. *Indian J. Genet*. 39: 373-377.

Malek, M.A., Das, M.L. and Rahman, A. (2000). Genetic variability, character association and path analysis in rapeseed. *Bangladesh J. Agric. Sci.* 27(l): 25-59.

Malik, V., Singh, H. and Singh, D. (1995). Gene action of seed yield and other desirable characters in rapeseed. *Analysis Biol. (Ludhiana*). ll(ll2): 94-97.

Masood, T., Gilani, M.M. and Khan, F.A. (1999). Path analysis of the major yield and qualitycharacters in *Brassica campestris. J. Ani. Pl. Sci.* 9(4): 69-72.

Mcneal, F.H., Qualset, C.O., Baldridge, D.E. and Stewart, V.R. (1978). Selection for yield and yield components in wheat. *Crop Sci.* 18: 795-798.

Mishra R.M., Kouth, G.K. and Bilaiya S.K. (1987). D_2 and metrogylph analysis in soybean. I *Oilseeds Res*. 4(1): 103-107.

Nanda, R., Bhargava, S.C. and Tomar, D.P. S. (1995). Rate and duration of siliqua and seed filling and their rotation to seed yield in Brqssica species. *Indian J. Agric. Sci.* 64(4):227-232.

Nasim, M., Rahman, L., Quddus, M.A. and Shah-E-Alam, M. (1994). Conelation and path analysis in Brassica campestrisL. *Bangladesh J. Aril. Sci.*21(10): 15-23.

Olsson, G. (1990). Rape yield-production components. Sversft Fortidning. 59(9): 194-197. *Cited from P/. Br. Abs.* 61(5): 588, 1991 .

Panse V.G. (1957). Genetics of quantitative characters in relation to plant breeding. *Indian J.Genet. PL Breed.lT*: 318-328.

Paul, N.K., Joarder, O.I. and Eunus, A.M. (1976). Genotypic and phenotypic variabilify andcorrelation studies o*n B. junceaL. Zeitschriflfur pflazenzuchtung*. TT(2): 145-154.

Ramanujam, S. and Rai, B. (1963). Analysis of yield components in.Brassica campestris var.yellow sarson. *Indian J. Genet.* 23: 312-319.

Rao, C. R. (1952). Advance Statistical Methods in Biometrical Research. John Wiley and Sons. New York.

Rao, T.S. (1977). Genetics of yield components in brown sarson. *Genetica lberica.*2g (314): 219- 227.

Sachan, K.S. and Sharma, J.R. 1971. Multivariate analvsis of genetic divergence in tomato. *Indian J. Gene*t. 3l: 86-93.

Saini, H.C. and Sharma R.P. (1995). Model plant architecture through association and pathcoefficient analysis in Indian colza. *Indian J. Agric. Res*. 29(3): 109-1 15.

Seitzer, J.F. and Evans, L.E. (1978). Yield gains in wheat by pedigree method of selection and two early yield tests. *Z. P flaruenntchtg*. 80: 1-10.

Sengupta U.K., Pal, M. and Jain, V. (1998). Inlluence of enhanced UV radiation on mustard cultivar response, *Indian J. Pl. Physiol.* 3(3): I 88-193.

Shabana, R., Shrief, S.A. and Geister. G. (1990). Correlation and path analysis for some newrelease spring rapeseed cultivars grown under different competitive systems. *J. Agron. Crop Sci.* 65(2-3): 138-143.

Sharma S.K. (1984). Variation and correlation studies in Indian mustard (*B. juncea). Thesis Abstract* 10(2): 146-147 .

Shebeski, L.H. (1967). Wheet breeding. In : Canadian Centennual wheat symposium. (ed. F.Nielsen). *Modem Press. pp.* 249-277 .

Shen, J.X., Fu, T.D., Yang, G.S., Shen, J.X., Fu, T.D. and Y*9, G.S. (2002). Heterosis of double low self incompatibility in oilseed rape (.Broşsica rapa L.). *Agril. Sci. China.* 7(i): 732-737.

Shivahare, M.D., Singh, A.B., Chauhan, Y.S. and Singh, P. (i975). Path coefficient analysis of yield component in Indian mustard. *Indian J. Agric. Sci.* 45(9): 422-425.

Simmonds, N.W.(1953). Plant Breeding : The state of the art. In: Genetic engineering of plants- An Agricultural Perspective. (eds., T. Kosuge, C.P. Meredith and A. Hollaender). *Plenum press, New York, London.* pp. 5-26.

Singh B.D. (1990). Plant Breeding in Biometrical Tecniques. In Plant Breeding. Kalyani Publishers. pp. 100- 1 25.

Singh, A., Yadava, T.P., Asawa B. M. and Gupta, V.P. (1978). Note on path coefficient analysis in Indian mustard. *Indian J. Agri.Sci.* 48(10): 622-623.

Singh, B.D. (2000). Plant Breeding. Kalyani Publishers, New Delhi. pp.574-597.

Singh, D.P., Singh, D., Singh, S.P., Singh, A.B. and Mishra" S.N. (1969)" Relationship among some important agronomic characters in Indian mustard. *Indian J. Agric. Sci.* 39: 362-365.

Singh, H. (1986). Genetic variability, heritability and drought indices analysis in *Brassica pecies. J. Oilseeds Res.* 3(2): 170'177.

Singh, H. and Singh, D. (1987). A note on transfer of resistance to white rust from Ethiopian mustard to Indian mustard. *Cruciferae Newsletter.*12:95.

Singh, H., Yadav, A.K. and Yadava, T.P. (1985). Morphophysiological attributes in relation to seed yield in Indian mustard. Haryana *Agric. UnL J. Res.* 15(3): 295-299.

Singh, P. (1983). Studies on genetic variability and diversity of nce. *Madras Agric. J.* 70(7): 436-440.

Singh, R.K. and Chaudhary, B.D. (1985). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, India. p. 56.

Singh, R.P., Khera, M.K. and Gupta, V.P. (1991). Variability and correlation studies for oil and seed yield in gobhi sarson. *Crop Improv.* l8(2): 99-102.

Singh, R.P., Malik, B.P.S. and Singh, D.P. (1987). Variation for morphological characters ingenotypes of Indian mustard. *Indian J. Agric. Sci.* 57(4): 225-230.

Singh, R.P., Singh, D.P. and Chaudhry, B.D. (1987). Morpho-physiological variation in Indian mustard. *Annals of Biology*.3(1): 26-31.

Singh, R.S., Singh, P. and Dixit, R.K. (1987). Combining ability analysis sf yhM I developmental traits in Indian canola *(Brassica campestris L. var. yellou- s.amm d Farm Sci.* J. 2(2): 170-17 4.

Srivastava, P. P. Salara" B.S. and Gowda, M.V.C. (1983). Variability and correlation mrdiknr groundnut (Arachis hypogaea). *Crop Improvement*. 25(l): 122-123.

Tak, G.M. (1976). Correlation and path analysis of the yield component in the three formns *Brassica campestris L. Crop Improvement*.: 43-52.

Tak, G. M. and Patnaik, M.C. (1977). Genetic variation and heritability on the 3 forms *Brassica campestris. Indian J. Agril. Res.* ll(2): 89-93.

Teresa, W. (1987). Selection criteria of winter rape single plant and its seed yield. In: *'International Rapeseed congress. Poland*.I I-I4, May. pp. 284-289.

Thakral, N.K. (1982). To study the association of some morphophysiological attributes rr'iyield in toria. *Thesis Abstract*. 8(11): 66-67.

Thurling, N. (1974). An evalution of an index method of selection for high yield in turnip rag *B. campestr s L. spp. Euphytica*. 23 (2): 321 -33 1 .

Thurling, N. (1983). Variation in pod length in spring rape *(B. napus)* and its relationship yield. In proceedings, Australian Plant Breeding conference, *Adelaide, South Australia*. pp.14-18.

Thurling, N. and Das, L.D.V. (1980). The relationship between pre-anthesis development ar seed yield of spring rape (Brassica napus L.). *Aust. J. Agric. Res.* 3l: 25-36.

Tyagi, M.K., Chauhan, J.S., Kumar, P. R. and Singla K.H. (2001). Estimation of heterosis *Indian mustard. Annals Agri. Bio. Res*.6 (20): 193-200.

Ushakumari, R.M., Subramani&, M. and Subramaniam. (1991). Studies on coefficient variation and heritable components of some quantitative characters of Brinjal. *Indian Hort*. 48(1): 75-78.

Varshney, S.K., Rai, B. and Singh, B. (1986). Component analysis of harvest index in Brassica oilseeds. *Indian J. Agric. Res.* 20(3): 129-134.

Ventatramana, P., Sheriff, R.A. and Janakiraman, N. (2001). Assessment of groundngermplasms and isolation of elite genotypes for improvement. *J. Soils* and *Crops*. 11;156-160.

Wan, Y.L. and Hu, G.C. (1983). Studies on heritability, genetic correlations and generadvances of the major characters in rape. *Chinese oil crops*. l: l-7.

Whan, B.R., Knight, R. and Rathijen, A. (1982). Response to selection for grain yieid a: harvest index in Fz, Fg and Fa derived lines of wheat crosses. *Euphytica.* 3l: 139-150.

Wynne, J.C. (1976). Evaluation of early generation testing in peanuts. *Peanut Sci* .3: 62-66.

Yadava, C.K. (1983). Studies on genetics of yield and its components in Indian musta

(Brassica junceaL. Czem & Coss). *Thesis Abstract*. 9(2): 186-187.

Yadav4 O.P., Yadav, T.P. and Kumar, P. (1996).Combining ability studies for seed yield. i components characters and oil content in Indian mustard (*Brassica juncea* L. Czern zu Coss.). *J. Oil seed Res.* 9(1): 4-20.

Yadava, T.P. (1973). Variability and correlation studies rn Brassica junceaL. Czem and Co: *Madras Agric.* . 60: 1508- I 5l1.

Yadava T.P., Kumtr, P. and Thakral, S.K. (1982). Association of pod yield with some characters in groundnut. Haryana. *Agric. Univ. J. Res.* 14(1): 75-88.

Yarnell, S.H. (1956). Cytogenetics of vegetable crops. Crucifers Bot. Rev. 22(2): 81-166

Zahu, Y. M., Tan, Y.L., Liu, M., Wei, Z. L., Yao, L. and Shi, S.W. (1998). Studies on irradiation induced mutation in rapeseed (*B. nupus* L.). *Chinise J. Oil Crop Sci.* 20(4): 1-5

APPENDIX

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

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2009	34.8	18.0	77	227	5.8
November, 2009	32.3	16.3	69	0	7.9
December, 2009	29.0	13.0	79	0	3.9
January, 2010	28.1	11.1	72	1	5.7
February, 2010	33.9	12.2	55	1	8.7
March, 2010	34.6	16.5	67	45	7.3
April, 2010	35.8	20.3	65	88	8.3

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