VARIABILITY, CORRELATION AND PATH COEFFICIENT ANALYSIS IN BC_1F_1 GENERATION OF *Brassica napus* L.

BY

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*This is to certify that thesis entitled, **"Variability, Correlation and Path Co-efficient Analysis in BC_1F_1 Generation of Brassica napus L"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **Mir Asaduzzaman,** Registration No. **10-04234** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2012
Place: Dhaka, Bangladesh

(Prof. Abu Akbar Mia)
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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted with thirty four BC_1F_1 progenies of *Brassica napus* and one check variety at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during november, 2010 to March, 2011 to study the variability, correlation and path analaysis in BC_1F_1 generation of *Brassica napus*. Comparatively phenotypic variances were higher than the genotypic variances for all the characters studied. The high GCV value was observed for number of secondary branches per plant. High heritability with low genetic advance in percent of mean was observed for number of seeds per siliqua, siliqua length and thousand seed weight indicating that non-additive gene effects were involved for the expression of these characters and selection for such traits might not be rewarding. High heritability with high genetic advance in percent of mean was observed for number of siliqua per plant and seed yield per plant indicating that these traits were under additive gene control and selection for genetic improvement for these traits would be effective. The results of correlation revealed that yield per plant had positive association with plant height, days to 50% flowering and days to maturity. Path co-efficient analysis revealed that plant height, days to 50% flowering, days to maturity and thousand seed weight had the positive direct effect on yield per plant. Whereas, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua and siliqua length had the negative direct effect on yield per plant.

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SOME COMMONLY USED ABBREVIATIONS AND SYMBOLS

Abbreviations	Full word
%	Percent
°C	Degree Celsius
@	At the rate
σ^2_p	Phenotypic variance
σ^2_e	Environmental variance
σ^2_g	Genotypic variance
h^2_b	Heritability in broad sense
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BD	Bangladesh
Cm	Centi-meter
CV%	Percentage of Coefficient of Variation
cv.	Cultivar (s)
Df	Degrees of Freedom
et al.	And others
etc.	Etcetera
F_2	The second generation of a cross between two dissimilar homozygous parents
FAO	Food and Agricultural Organization
G	Gram (s)
G	Genotype
GA	Genetic advance
GCV	Genotypic Coefficient of Variation
GN.	Genotype Number
HI	Harvest Index
IARI	Indian Agricultural Research Institute
ICARDA	International Centre for Agricultural Research in Dry Areas
j.	Journal
Kg	kilogram (s)
M	Meter
M.P.	Muriate of Potash
m^2	Square meter
MOA	Ministry of Agriculture

Abbreviations	Full word
MSG	Mean square of the genotypes
MSE	Mean square of the error
NARS	National Agricultural Research System
No.	Number
NPB/P	Number of primary branches per plant
NSB/P	Number of secondary branches per plant
NS	Not Significant
NSP	Number of siliquae per plant
PCA	Principal Component Analysis
PCO	Principal Coordinate Analysis
PCV	Phenotypic Coefficient of Variation
PH	Plant height
Ppm	Parts Per Million
R	Residual effect
RCBD	Randomized Complete Block Design
Rep.	Replication
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SE	Standard Error
SL	Siliquae length
S/S	Seeds per siliquae
t/ha	Tons per hectare
T.S.P.	Triple Super Phosphate
Univ.	University
var.	Variety
Via	By way of
Viz	Namely
YPP	Yield per plant

Chapter I

Introduction

CHAPTER I
INTRODUCTION

Brassica oil is the world's third most important sources of edible vegetable oils. Oleiferous *Brassica* species can be classified into three groups viz; the cole, the rapeseed and the mustard. The cole group is grown for vegetables and others two group the mustard and the rape are grown for the valuable sources of edible oils.

Brassica napus, Brassica campestris and Brassica napoBrassica are the component species of rapeseed. But Yarnell (1956) has classed *Brassica campestris* under mustard group which is usually composed of *Brassica juncea* (Indian mustard/Rai), *Brassica nigra* (black mustard), *Brassica hirta, Brassica carinata* (Ethiopian mustard) and *Brassica arvensis*.

In Bangladesh various species of *Brassica* are grown. 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.

B. napus (rape seed) is high yielding species recently adopted but shattering is occurred at ripening while *B. campestris* is comparatively low yielding but very familiar in Bangladesh. *B. juncea* has comparatively high yield potentiality and stable yield when it is late planted. It is also non shattering type and can tolerate drought and salinity but it is long duration species. Morphophysiological traits and their associations influence yield, resistance or tolerance to biotic and abiotic stresses under varied environmental conditions.

Brassica oil crops are the most important group of species that supply major edible oils in Bangladesh (BBS, 2000). Rape seed and mustard is the third highest source of edible oils supply in the world after soybean and palm (FAO 2000).

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 per capita consumption of edible oil in our country is 8 g/day as compared to a need of 40 g /day (Kaul and Das, 1978). The shortage of edible oil has become a chronic problem for the nation. Bangladesh requires 0.29 million tons of oil equivalent to 0.8 million tons of oil seeds for nourishing her people but oil seed production is about 0.254 million tons. This covers only 40% of the domestic need (FAQ, 2001). One third of the total requirements of oil are meeting by local production of rape seed and mustard (BBS, 2004). In Bangladesh two third of the total annually consumed edible oil are imported. In 2003, for the import cost was 690 million U.S. dollar (BBS, 2004).

In Bangladesh the average production of rape seed and mustard is 183 thousand metric ton from an area of 216.92 thousand hectares of land (BBS, 2006). Productivity of oilseed crops in this country is comparatively lower than the oil seed growing countries of the world. The major reasons for such poor yield in Bangladesh may be attributed due to lack of improved varieties and poor management practices. The average per hectare yield of oilseed crops in Bangladesh was 733 kg and world average production was 1575 kg (FAO, 2005).

There is plenty of scope to increase yield per unit of area through breeding superior varieties. Information on genetic variability and character association is a prerequisite for initiating a successful breeding program aiming to develop high yielding varieties.

Determination of correlation co-efficient between the characters has a considerable importance in selecting breeding materials. The path co-efficient analysis has been found to give more specific information on the direct and indirect influence of each of the component characters upon seed yield (Behl *et al.* 1992).

Therefore, the present research work was undertaken with the following objectives:

Objectives:

1. To study the variability in BC_1F_1 generation for selection of desired plant types,
2. To study the relationship among the different traits and their contribution to the yield and
3. To select promising genotypes considering early maturity, high yielding plants.

Chapter 2

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

In undertaking the present piece of research work on BC_1F_1 materials of *Brassica napus*, a number of literatures on *Brassica* had to be studied. For development of high yielding varieties, the important prerequisites are identification of superior parents, promising cross combination(s) and suitable breeding methodology. The estimation of different genetic parameters with variability, characters association and magnitude of direct and indirect effect on yield is an important factor in developing an efficient breeding programme. The review of literatures concerning the studies is outlined under the following points:

2.1 Studies on variability in *Brassica* spp.

2.2 Studies on correlation analysis

2.3 Studies on path co-efficient analysis

2.1 Studies on variability in *Brassica* spp.

A good number of literatures concerning the variability in the *Brassica spp.* are available. These literatures are outlined here. Nanda *et al.* (1995) observed that days to first flowering varied both by genotypes and date of sowing, while working with 65 strains of *B. napus, B. juncea, B. carinata and B. rapa*. Many other researchers like Kumar and Singh (1994), Kumar *et al.* (1996), Kakroo and Kumar (1991), Andrahermadi (1991), Lebowitz (1989), Biswas (1989), Singh *et al.* (1987), Chauhan and Singh (1985), Yadava (1983) and Thakral (1982) found significant variations for this character while working with different genotypes of *Brassica*.

Dominance gene action was important in the expression of days to flowering was found by Jam *et al.* (1988). Kumar *et al.* (1991) observed partial dominance for this character. Significant genetic variability in days to 50% flowering in *B. napus* and *B. rapa* was observed by Singh *et al.* (1991).

Katiyar *et al.* (1974) observed high genetic co-efficient of variation for days to first flowering, plant height (cm) and seed yield per plant (g) where as low values were observed for other characters like days to maturity and number of primary branches per plant, while working on genetic variability and genetic advance of seed yield and its components in Indian mustard.

Varshney *et al.* (1986) worked with a number of strains of *B. juncea, B. rapa* and *B. napus* and observed high variability in plant height.

Chandola *et al.* (1977) worked on 30 varieties of *B. campestris* and reported that the varietal differences were highly significant for plant height, due to varieties and growing conditions. They also found highly significant varietal differences for yield and six other yield components.

According to Tyagi *et al.* (2001) variation was highest in parents and their hybrids for plant height. The seed yield per plant exhibited the highest co-efficient of variation (41.1%). Significant genetic variability was observed for this character by many workers like Kumar *et al.* (1991), Andarhennadi *et al.* (1991), Gupta and Labana (1989), Malik *et al.* (1995), Kumar and Singh (1994), Yadava *et al.* (1993), Lebowitz (1989), Chaturvedi *et al.* (1988), Gupta *et al.* (1987), Chauhan and Singh & 1985) and Sharma (1988) among different genotypes of *B. napus, B. rapa and B. juncea.*

The highest genotypic co-efficient of variation was calculated for secondary branches. High genotypic and phenotypic co-efficient of variation was recorded for days to 50% flowering among 10 genotypes for each of *Brassica campestris*, *Brassica carinata* and *Brassica napus* and 24 genotypes of *Brassica juncea* by Lekh *et al.* (1998).

Generally high number of seeds per siliqua is desirable. On the variability of this trait a good number of literatures are available. Significant variability in number of seeds/siliqua in oleiferous *Brassica* materials of diverse genetic base was observed by Kudla (1993) and Kumar and Singh (1994). Similar significant variability in the genotypes of *Brassica napus*, *B. campestris* and *B. juncea* were studied by them. Bhardwaj and Singh (1969) observed GCV value of 35.85% in case of *Brassica campestris* genotypes.

High co-efficient of variation for thousand seed weight, pod length and number of seeds per pod for both genotypic and phenotypic level was found by Masood *et al.* (1999) while working with seven genotypes of *Brassica campestris* and standard cultivar of *Brassica napus* to study genetic variability.

Higher seed yield is the result of higher number of siliqua. Large variation is involved for this trait. High genetic variation in number of siliqua was observed by Yin (1989) while working with 8 cultivars of *Brassica napus*. Kumar *et al.* (1996) also observed and reported similar results of high variation for this trait. Genotypic co-efficient of variation GCV (%) and phenotypic co-efficient of variation PCV (%) of this trait in yellow sarson were as high as 55.4% and 53.2%, respectively (Tak and Patnaik,1977), but in toria the values were 27.1% and 23.5%, respectively.

Singh *et al.* (1987) observed variable results of GCV (25.41%) and PCV (29.15%) in *Brassica campestris* for siliquae number higher and the seed yield, GCV was reported to be also as 18.85% by Yadava (1973) and Bhardwaj and Singh (1969) reported 97.3% of GCV. Number of siliquae per plant is one of the most important traits of *Brassica* spp. This trait has high variation and a considerable part of which appeared to be environmental. High genetic variation was found by Kudla (1993). Similar results was also found by Andraherinadi *et al.* (1991), Biswas (1989), Jain *et al.* (1988) Chowdhury *et al.* (1987), Alam *et al.* (1986) and Thakral (1982).

Siliqua length is another important character for the development of fruits in oil seed crops like mustard and rape seed. Peduncle, beak as well as siliqua length varies due to difference in genotypes. High genetic variability was found by Olsson (1990) for this character. Lebowitz (1989) found similar results while working with *B. rapa* for siliqua length.

Thurling (1983) reported that selection for increased siliqua length is an effective strategy for yield improvement through raising seed weight per siliqua.

Thousand seed weight is a very important character of rape seed and mustard, where highest consideration is on the seed yield. This character has been found to vary widely from genotypes to genotypes and from environment to environment. A good number of literatures are available on the variability of this trait.

According to Kumar and Singh (1994) in *B. juncea*, Kudla (1993) in sewede rape, Andarhennadi *et al.* (1991) in brown mustard, Biswas (1989) in *Brassica campestris*, Lebowitz (1989) in *B. rapa*, Yin (1989) in *B. rapa* and Chowdhury *et al.* (1987) in *B. rapa* found different degrees of significant variations among the genotypes for thousand seed weight.

In every breeding program yield is the most important character among various traits for oil crops. It is a complex trait which is influenced by various factors of production. A good number of literatures are available on the variability of this trait. High variability in different genotypes of *B. rapa* was reported by Sharma *et al.* (1994). Thakral (1982) also reported significant genetic variability in genotypes of B. napus. Similar high variability in different genotypes of *B. napus* was found by Khera and Singh (1988).

High degrees of variation for seed yield per plant in *B. rapa* was observed by Yin (1989) and Kudla (1993) in *B. napus* and Kumar *et al.* (1996) in *B. juncea*. Bhardwaj and Singh (1969) found GCV value of 96.99% among different strains of *B. rapa*. Yadava (1973) found 48.76% GCV value among 29 strains of *B. juncea*. While Singh *et al.* (1987) found GCV and PCV values of 44.04% and 46.9% in *juncea*.

Heritability, genetic advance and selection

The variation of heritability can be estimated with greater degree of accuracy when heritability in conjunction with genetic advance as percentage of mean is studied. The necessity of estimating heritability along with genetic advance in order to draw a more reliable conclusion in selection program.

High heritability coupled with high genetic advance for seed yield per plant, number of secondary branches per plant, siliqua per plant, 1000 seed weight (g) and number of primary branches per plant was observed by Sheikh *et al.* (1999) while working with 24 genotypes of toria.

Lekh *et al.* (1998) carried out an experiment with 24 genotypes of *B. juncea* and 10 genotypes each of *B. campestris, B. carinata* and *B. napus* and observed highest genetic advance and high genotypic and phenotypic co-efficient of variation for days to 50% flowering and high heritability for other yield contributing characters.

Both additive and dominance genetic components were important for seed yield and yield components in *B. campestris var. toria*, and higher heritability for days to maturity and thousand seed weight while studied 8x8 diallel analysis (excluding reciprocals) was reported by Yadava *et al*. (1993).

Malik *et al.* (1995) observed very high broad sense heritability (h^2_b>90%) for number of primary branches per plant, days to 50% flowering and oil content while working with different strains of *B. napus.* They also observed low heritability (h^2_l, 50%) for plant height, number of siliqua/ plant, number of seedsl siliqua and seed yield. But high heritability for all these characters were found by Lie *et al.* (1989) while working with 55 genotypes of *B. napus*, *B. rapa* and *B. juncea*.

High heritability and genetic advance for number of siliqual plant in *B. rapa* and *B. juncea* were observed by Varshney *et al.* (1986), but they found high heritability and genetic advance for plant height in all the three species.

High narrow sense heritability and genetic advance for days to flowering and plant height were reported by Diwakar and Singh (1993) while working with segregating populations of yellow seeded Indian mustard (*B.juncea* L. Czern and Coss).

High heritability and genetic advance for number of seeds per siliqua and seed yield per plant was reported by Singh (1986) while working with 22 genotypes of *B. napus, B. campestris* and *B. juncea.*

Low heritability for yield per plant was observed by Malik *et al.* (1995), Kumar *et al.* (1988) and Yadava *et al.* (1985). Lie *et al.* (1989), Chen *et al.* (1983) and Wan and Hu (1983) found high heritability and genetic advance for days to flowering, number of primary branches per plant and plant height.

Sharma (1984) studied 46 genotypes of *B. juncea* and reported high heritability for days to flowering and plant height and low heritability and genetic advance for days to maturity and high genetic advance for yield per plant.

Singh *et al.* (1987) studied 179 genotypes of Indian mustard and found high heritability (h_b= 80% - 95%) for seed yield per plant and oil content and the lowest heritability for number of primary branches per plant.

In a study of variability and correlations in some varieties of brown sarson, reported high heritability for siliqua length, number of seeds per siliqua and thousand seed weight was observed by Chaudhury *et al.* (1989).

Kwon *et al.* (1989) and Rao (1977) reported high heritability ($h > 90\%$) for siliqua length, but Kakroo and Kumar (1991), Sharma (1984) and Yadava *et al.* (1984) reported low to medium for this trait.

Plant height and number of seeds per siliqua were highly heritable where as siliqua length, number of primary branches per plant were less heritable was observed by Labana *et al.* (1980) while working with 104 mutants of Indian mustard *B. juncea* (linn.) Czern and Coss. Chandola (1977) observed high genetic advance for plant height while working with 30 varieties of *B. rapa*.

Paul *et al.* (1976) found in his study that a good genetic advance was expected from a selection index comprising seed yield, number of seeds per siliqua, number of primary branches per plant and number of siliquae per plant.

Katiyar *et al.* (1974) reported heritability in the broad sense was associated with high genetic advance for number of siliquae on the main shoot and seed yield per plant while working with *B. campestris L. var. sarson.* In a study of genetic variability, heritability and genetic advance of Indian mustard Katiyar *et al.* (1974) reported high heritability for days to flowering, plant height, number of primary branches and seed yield per plant, moderate for days to maturity and low for the number of secondary branches. He also reported low genetic advance for number of primary branches and high values for days to flowering, plant height and seed yield per plant.

According to Yadava (1973) high heritability in the broad sense and genetic advance for days to maturity, plant height and number of node on the main shoot among the nine traits studied in 29 varieties.

The most important feature in winter rape plant selection for seed yield was number of branches was reported by Teresa (1987).

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

Selection for bold seed size from F_2 to F_5 generations was highly effective was observed by Gupta and Labana (1985) in Indian mustard.

Chatterjee and Bhattacharyya (1986) found higher efficiency with index selection than selection based on yield alone. The efficiency increased with an increase in the number of characters in the index. The index comprising plant height, thousand seed weight and yield per plant was considered effective from the practical point of view. In ground nut, there are reports both for early selection (Gebre-Mariam, 1982; Kibite, 1981; Kalesnikov, 1979; Coffelt and Hammons, 1974) and against (Whan *et al.* 1982; Mcneal *et al.* 1978 and Wynne, 1976).

Most breeders tend to suggest delaying selection until at least the F_4 generation, when yield comparisons might be based on reasonably large replicated plots. According to Shebeski (1967) selection for yield related traits in F_2 (or F_3) generation has been recommended to minimize the expected losses of transgressive or productive segregants from the breeding population.

2.2 Studies on correlation analysis

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

Rashid (2007) carried out an experiment with 40 oleiferous *Brassica* species to estimate correlation and observed that, highly significant positive association of yield per plant with number of primary branches per plant, number of secondary branches per plant, number of seeds per siliqua and number of siliquae per plant.

An experiment was conducted by Parveen (2007) with F_2 population of *Brassica rapa* to study the correlation and observed that yield per plant had non significant positive association with plant height, number of secondary branches per plant, number of seeds per siliqua and number of siliquae per plant, days to 50% flowering and length of siliqua.

An experiment on oleiferous *Brassica campestris L.* was conducted by Siddikee, (2006) to study the correlation analysis. The results revealed that yield per plant highest significant positive correlation with number of siliquae per plant.

Pankaj *et al.* (2002) studied four parental cultivars and the F_4 progenies of resultant crosses for correlation between yield and yield component traits. The genetic correlation was higher than the phenotypic correlation for the majority of the characters. The number of siliquae per plant, which had the strongest positive and significant correlation with yield per plant at both levels, was positively associated with the number of seeds per siliqua and test weight at both levels. The number of seeds per siliqua was positively associated with siliqua length and yield per plant at both levels.

Srivastava and Singh (2002) studied correlation in Indian mustard [*Brassica juncea* L. Czern and Coss] for 10 characters was conducted with 24 strains of Indian mustard along with 2 varieties. Results revealed that number of primary branches per plant, number of secondary branches per plant, 1000 seed weight (g) and oil percent were positively associated with seed yield.

Shalini *et al.* (2000) evaluated 81 genotypes of Indian mustard for the magnitude of association between their quantitative characters of secondary branches, plant height, number of siliquae and seeds per siliquae were highly associated with seed yield.

Khulbe and Pant (1999) carried out a study of correlations in 8 Indian mustard (*Brassica* juncea) parents and their 28 F_1 hybrids and revealed that the number of siliqua per plant, length of siliqua, number of seeds per siliqua, thousand seed weight and harvest index were positively associated with seed yield.

The number of siliquae per plant, number of seeds per siliqua and plant height was significantly positively correlated with seed yield was observed by Masood *et al.* (1999) while studied 7 genotypes of *B. campestris* and standard cultivar of *B.napus* to calculate correlation co-efficient.

Thakaral *et al.* (1999) studied correlation co-efficient on seed yield and yield contributing characters in 8 Indian mustard (*Brassica juncea*) parents and their 28 F_1 hybrids grown at Hisar. The data indicated that higher seed yield could be obtained by selecting for increased plant height.

According to Kumar *et al.* (1999) genotypic correlation co-efficient were higher in magnitude than corresponding phenotypic correlation co-efficient for most characters. The plant height, siliquae on main shoot, siliquae per plant and thousand seed weight were positively correlated with seed yield. Gurdial and Hardip (1998) carried out an experiment with gobhi sarson (*B. nigra*) and reported that dwarf plant gave higher yield.

Zagac *et al.* (1998) studied phenotypic correlation between yield and its component and reported that strong positive correlation occured between seeds per siliqua and actual yield. Positive but a weaker correlation was observed between seed yield and siliquae per plant. The number of seeds per siliqua had the greatest influence and siliquae number per plant had the smallest effect on yield.

Das *et al.* (1998) carried out an experiment with 8 genotypes of Indian mustard (*B. juncea*) and reported that the length of siliqua, seeds per siliqua had high positive genotypic correlated with seed yield per plant. The number of siliqua per plant, seed weight per plant and thousand seed weight were positively correlated with seed yield per plant were observed by Dileep *et al*. (1997).

Tyagi *et al.* (1996) carried out an experiment with six yield components in three cultivars of mustard and observed that plant height, siliqua per plant, siliqua length, seed weight, and seeds per siliqua had positive and significant effects on seed yield per plant.

Gill and Narang (1995) studied correlation in gobhi sarson (*B. campestris var.* sarson) and observed that seed yield was positively correlated with number of primary branches and secondary branches per plant, number of siliqua per plant and thousand seed weight.

Uddin *et al.* (1995) while studied correlation analysis in 13 Indian mustard (*B. juncea*) and reported that seed yield per plant had high positive arid significant correlations with plant height and thousand seed weight, but high negative and significant correlations with seeds per siliqua at both genotypic and phenotypic levels.

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

Malek *et al.* (2000) studied correlation analysis and reported that days to maturity showed insignificant correlation with seed yield at both genotypic and phenotypic levels. He also reported that number of branches per plant and number of siliqua per plant showed significant negative correlation with number of seeds per siliqua and 1000 seed weight.

Nanda *et al.* (1995) studied correlation analysis with 65 strains of *B. juncea*, *B. rapa* and *B. napus* and observed that positive association between yield and siliqua filling period. Similar results also found by Olsson (1990) in *B. napus*. He also observed positive correlation between siliqua density and yield.

Kumar *et al.* (1996) studied 12 genotypes of *B. juncea* for correlation analysis and found flowering time and plant height negatively correlated w.ith number of primary branches per plant.

Labana *et al.* (1980) also found that number of primary branches per plant was negatively correlated with plant height and siliqua length.

Shivahare *et al.* (1975) observed days to flowering were positively correlated with primary branches per plant and plant height.

Singh *et al.* (1987) observed number of primary branches per plant negatively correlated with siliqua length and 1000 seed weight, but positively correlated with number of siliqua per plant.

Gosh and Mukhopadhyay (1994) studied Tori-7 (*B. campestris var. toria*) for evaluation of seed yield and 5 seed yield contributing characters and found that plant height, siliqua per plant, seeds per siliqua and thousand seed weight was significant and positively correlated with seed yield.

Nasim *et al.* (1994) studied correlation analysis in *B. rapa* and found 1000 seed weight was significantly and positively correlated with seed yield per plant and number of siliqua per plant but significantly and negatively correlated with siliqua length and number of seeds per siliqua. In F_3 population of brown sarson.

Das *et al.* (1984) observed thousand seed weight had high significant genotypic and phenotypic correlation with seed yield.

Ahmed (1993) worked with 8 cv. of *B. campestris* and *B. juncea* for study of nature and degree of interrelationship among yield components and observed that siliqua length, number of siliqua per plant, number of seeds per siliqua and seed weight per siliqua was positively and linearly associated with seed yield per plant. He also observed that seed oil content was positively correlated with seed weight, but negatively correlated with number of seeds per siliqua.

Chaudhury *et al.* (1993) observed seed yield was positively correlated with siliqua length when evaluated seven of *B. juncea*, two of *B. carinata* cultivars and one cultivar each of *B. campestris* and *B. tournefortii.*

Zaman *et al.* (1992) studied several yield contributing traits of Swedish advanced rape lines and reported that number of seeds per siliqua negatively correlated with siliqua per plant.

Reddy (1991) studied correlation analysis in Indian mustard (*B. juncea*) and reported that positive and significant correlation between seed yield and number of primary branches per plant, number of secondary branches per plant, siliqua per plant and seeds per siliqua.

Swain (1990) studied correlations of yield components in 15 genotypes of brown sarson (*B. campestris var. dichotoma*) and found that number of siliqua per plant was the most important characters to yield.

Labana *et al.* (1980) observed plant height negatively correlated with siliqua length and seeds per siliqua.

Chowdhury *et al.* (1987) reported plant height positively correlated with seeds per siliqua, number of siliqua per plant and negative correlated with 1000 seed weight.

Singh *et al.* (1987) studied 179 genotype of Indian mustard and observed positive correlation of plant height with number of siliqua per plant, number of primary branches per plant and seeds per siliqua. Positive association of plant height with these three traits in eight strains of yellow sarson was also found by Banerzee *et al.* (1968).

Increasing the number of branches is a means of increasing yield, since the number of primary and secondary branches have a significant positive correlation with seed yield (Singh *et al.* 1969; Katiyar and Singh, 1974).

Srivastava *et al.* (1983) observed in *B. juncea* the number of primary branches per plant and secondary branches per plant, plant height and days to maturity showed significant positive association with the seed yield per plant. The number of primary branches showed positive and significant association with the number of secondary branches per plant, plant height and days to maturity. Plant height showed positive and significant correlation with the number of secondary branches and days to maturity.

Banerjee (1968) reported significant correlation between number of siliqua per plant and number of seeds per siliqua in yellow sarson. But negative genotypic correlation between number of siliqua per plant and number of seeds per siliqua in brown sarson and toria varieties was observed by Tak (1976) when studied with *B. rapa*.

Chay and Thurling (1989) studied the inheritance of siliqua length among several lines of *B. napus* and reported that the siliqua length when increased there was an increase in the number of seeds per siliqua and thousand seed weight. The siliqua length was positively correlated with both number of seeds per siliqua and thousand seed weight was observed by Singh *et al.* (1987) in *B. rapa*, Chowdhury *et al.* (1987), Lebowitz (1989) and Lodhi *et al.* (1979) in *B. juncea.*

In *B. juncea* Chowdhury *et al.* (1987) and Yadava *et al* (1978) observed thousand seed weight positively associated with days to 50% flowering and days to 80% maturity, but negative correlation was observed by Singh *et al.* (1987) and Shivhare *et al.* (1975).

Chowdhury *et al.* (1987) and Yadava *et al.* (1978) also reported that thousand seed weight negatively correlated with plant height, number of primary branches per plant and number of siliquae per plant.

Ramanujam and Rai (1963) observed significant positive correlations between yield and all the yield components in *B. rapa cv. yellow sarson.* Zuberi and Ahmed (1973) observed similar results in *B. rapa cv. toria.* Campbell and Kondra (197) observed positive correlation between yield and the yield components in rape seed (*B. napus*). However, Campbell and Kondra (1978) observed negative correlation between yield and the yield components.

2.3 Studies on path co-efficient analysis

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

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

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

Siddikee, (2006) conducted an experiment on oleiferous *Brassica campesiris L.* to study the path analysis and revealed that thousand seed weight had the highest positive direct effect on seed yield per plant.

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

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

Khulbe and Pant (1999) studied path co-efficient analysis in eight Indian mustard (*B. juncea*) parents and their 28 F_1 hybrids. The results revealed that harvest index, siliqua length, seeds per siliqua, siliqua per plant, thousand seed and days to initial flowering were the major traits influencing seed yield.

The number of seeds per siliqua exerted the highest effect on seed yield was observed by Masood *et al.* (1999) when they studied seven genotypes of *B. campestris* and standard cultivar of *B. napus*.

Sheikh *et al.* (1999) worked with 24 diverse genotypes of toria for assess the direct and indirect effects of seven quantitative and developmental traits on seed yield. Results revealed that thousand seed weight and siliqua per plant had highly positive direct effect on seed yield.

Yadava *et al.* (1996) when studied path co-efficient analysis of six yield components of 25 diverse varieties of Indian mustard and observed that number of siliqua per plant had the highest positive direct effect on seed yield.

Uddin *et al.* (1995) studied path analysis in 13 Indian mustard (*B. juncea*) and observed that seeds per siliqua and thousand seed weight had high positive direct effect on seed yield per plant.

Saini and Kumar (1995) studied 28 lines of yellow and brown sarson (*B. campestris*) for path coefficient analysis and revealed that seeds per siliqua and 1000 seed weight had direct positive effect on yield.

Chauhan and Singh (1995) observed that plant height, siliqua per plant and seeds per siliqua had high positive direct effect on seed yield.

Kachroo and Kumar (1991) studied path co-efficient analysis in *B. juncea* and found that thousand seed weight had positive direct effect but days to flowering and number of primary branches had negative indirect effect via seeds per siliqua on seed yield.

Han (1990) studied *B. napus* and observed negative direct effect of number of siliquae per plant, siliqua length and positive direct effect of seeds per siliqua and plant height on seed yield.

Dhillor *et al.* (1990) observed the highest positive direct effect on seed yield per plant.

Kudla (1993) reported that 1000 seed weight had positive direct effect on seed yield.

Chowdhury *et al.* (1987) worked with 42 strains of mustard and observed that siliqua length had highest positive direct effect and number of primary branches per plant had the highest negative direct effect on seed yield.

Gupta *et al.* (1987) observed that primary branching and thousand seed weight had the direct effect on seed yield.

Han *et al.* (1985) studied 38 cultivars of *B. juncea* and observed that siliqua number per plant and thousand seed weight had considerable direct effect on yield.

Kumar *et al.* (1984) also worked with *B. juncea* and found negative indirect effect of days to flowering via plant height and siliqua length, but negative direct effect of these traits was observed by Singh *et al.* (1978).

Varshney (1986) worked with several strains of *B. rapa* and observed that plant height, siliqua per plant and thousand seed weight had the negative direct effect on yield.

But many scientists like Das and Rahman (1989) in *B. rapa*, Gosh and Chatarzee (1988) in *B. juncea*, Mishra *et al.* (1987) in *B. rapa*, Alam *et al.* (1986) in *B. juncea*, Singh *et al.* (1985) in *B. juncea*, Chen *et al.* (1983) in *B. napus* and Srivastava *et al.* (1983) in *B. juncea* observed that plant height, days to maturity, siliqua per plant, seeds per siliqua and thousand seed weight had positive direct and indirect effect on seed yield.

Chaudhary *et al.* (1990) observed that days to 50% flowering and plant height indirectly contributed to plant yield.

Kakroo and Kumar (1991) studied several strains of *B. juncea* and found that thousand seed weight had positive direct effect, but days to 50% flowering and primary branches had negative indirect effect via seeds per siliqua on seed yield.

Kumar *et al.* (1988) found the indirect positive effect of days to 50% flowering on seed yield.

Kumar *et al.* (1984) worked with *B. juncea* and observed negative indirect effect on seed yield of days to flowering via plant height and siliqua length on seed yield.

Chauhan and Singh (1985) found high positive direct effect of days to 50% flowering, plant height, primary branches per plant, siliquae per plant and seeds per siliqua on seed yield while working with several strains of *B. juncea*.

Dhillon *et al.* (1990) reported that the plant height had the highest positive direct effect on seed yield per plant in *B. juncea*, but Singh *et al.* (1978) also found negative direct effect of the trait on seed yield.

Chapter III

Materials and Methods

CHAPTER III
MATERIALS AND METHODS

3.1 Experimental site:

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka -1207 during November 2010 to February 2011. The location of the experimental site was situated at 230 74' N latitude and 900 35' E longitude with an elevation of 8.6 meter from the sea level. Photograph showing experimental sites (Plate 1).

3.2 Soil and Climate

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

3.3 Experimental materials:

The healthy seeds of six parents (Nap-205, Nap -108, Nap -9901, Nap-9908 Nap-0130, Nap-9905) and their 34 BC_1F_1 of *Brassica napus* collected from the Dept. of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, which were used as experimental materials.

Table 1: Materials used for the experiment

Name of Crosses	Check varieties
Treatment	BARI Sarisa- 13
9905×9901 (9905)	
9905×0130 (0130)	
9905×0130 (9905)	
108×2066(108)	
9908×9906(9908)	
9901x205(205)	
9905x108(9905)	
205x0130(0130)	
108x0130(108)	
9905x108(108)	
9906x205(205)	
9905x9901(9901)	
9905x9908(9908)	
2066x205(2066)	
9905x9908(9905)	
108x205(108)	
2066x0130(0130)	
2066x205((205)	
2066x0130(2066)	
108x9901(108)	
9908x2066(9908)	
108x0130(0130))	
9906x2066(2066)	
9906x2066(9906)	
9906x205(9906)	
108x9908(9908)	
9906x0130(0130)	
108x9908(108)	
205x0130(205)	
9906x0130(9906)	
108x2066(2066)	
9908x0130(9908)	
9906x9901(9901)	
9901x205(9901)	

3.4 Methods

The following precise methods have been followed to carry out the experiment:

3.4.1 Land preparation

The experimental plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about good tilth. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

3.4.2 Application of manure and fertilizer

The crop was fertilized at the rate of 10 tons of Cowdung, 250 kg Urea, 175 kg Triple Super Phosphate (TSP), 85 kg Muriate of Potash (MoP), 250 kg Gypsum, 3 kg Zinc oxide and Boron 1 kg per hectare. The half amount of urea, total amount of Cowdung, TSP, MoP, Gypsum, Zinc Oxide and Boron was applied during final land preparation. The rest amount of urea was applied as top dressing after 25 days of sowing.

3.4.3 Experimental design and layout

Field lay out was done after final land preparation. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The total area of the experiment was 56m × 14m = 784 m^2. Each replication size was 56 m × 3.5 m, and the distance between replication to replication was 1 m. The spacing between lines to line was 30 cm. Seeds were sown in lines in the experimental plots on November, 2010. The seeds were placed at about 1.5 cm depth in the soil. After sowing the seeds were covered with soil carefully so that no clods were on the seeds.

3.4.4 Intercultural operations

Intercultural operations, such as weeding, thinning, irrigation, pest management, etc. were done uniformly in all the plots. One post sowing irrigation was given with cane

Plate 1. Photo graph showing a field view of experimental site at flowering stage at SAU farm

after sowing of seeds to bring proper moisture condition of the soil to ensure uniform germination of the seeds. A good drainage system was maintained for immediate release of rainwater from the experimental plot during the growing period. The first weeding was done after 15 days of sowing. At the same time, thinning was done for maintaining a distance of 10 cm from plant to plant in rows of 30 cm. apart. Second weeding was done after 35 days of sowing. Aphid infection was found in the crop during the siliqua development stage. To control aphids Malathion-57 EC @ 2ml/liter of water was applied. The insecticide was applied in the afternoon.

3.4.5 Crop harvesting

Harvesting was done from 4th to 20th February, 2011 depending upon the maturity. When 80% of the plants showed symptoms of maturity i.e. straw color of siliqua, leaves, stems desirable seed color in the mature siliqua, the crop was assessed to attain maturity. Ten plants were selected at random from the parental line and BC_1F_1 progenies in each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants.

3.4.6 Data collection

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

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

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

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

IV. **Number of primary branches/plant:** The total number of branches arisen from the main stem of a plant was counted as the number of primary branches per plant.

V. **Number of secondary branches/plant:** The total number of branches arisen from the primary branch of a plant was counted as the number of secondary branches per plant.

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

VII. **Siliqua length (cm):** This measurement was taken in centimeter (cm) from the base to the tip of a siliqua without beak of the ten representative siliquae.

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

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

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

3.4.7 Statistical analysis

The data were analyzed for different components. Phenotypic and genotypic variance was estimated by the formula used by Johnson *et al.* (1955). Heritability and genetic advance were measured using the formula given by Singh and Chaudhary (1985) and Allard (1960). Genotypic and phenotypic co-efficient of variation were calculated by the formula of Burton (1952). Simple correlation coefficient was obtained using the formula suggested by Clarke (1973); Singh and Chaudhary (1985) and path co-efficient analysis was done following the method outlined by Dewey and Lu (1995).

i) Estimation of genotypic and phenotypic variances:

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

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

Where, MSG = Mean sum of square for genotypes

MSE = Mean sum of square for error, and

r = Number of replication

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

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

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

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

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

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

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

Where, GCV = Genotypic co-efficient of variation

PCV = Phenotypic co-efficient of variation

δ_g = Genotypic standard deviation

δ_p = Phenotypic standard deviation

$\overline{x}$ = Population mean

iii) Estimation of heritability:

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

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

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

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

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

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

Where, GA = Genetic advance

δ^2_g = Genotypic variance

δ^2_p = Phenotypic variance

δ_p = Phenotypic standard deviation

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

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

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

vi) Estimation of simple correlation co-efficient:

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

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

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observations

vii) Path co-efficient analysis:

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1995) also quoted in Singh and Chaudhary (1985) and Dabholkar (1992), using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable.

In order to estimate direct & indirect effect of the correlated characters, say x1, x2 and x3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as shown below:

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

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

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

Where, r's denotes simple correlation co-efficient and P's denote path co-efficient (Unknown). P's in the above equations may be conveniently solved by arranging them in matrix from.

Total correlation, say between x_1 and y is thus partitioned as follows:

P_{yx1} = The direct effect of x_1 on y.

$P_{yx2}r_{x1x2}$ = The indirect effect of x_1 via x_2 on y

$P_{yx3}r_{x1x3}$ = The indirect effect of $x_1$via x_3 on y

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985):

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

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

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

riy = Correlation of the character with yield.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The present study was conducted with a view to determine the variability among thirty four BC_1F_1 materials and one check variety of *Brassica napus* genotypes and also to study the correlation and path co-efficient for seed yield and different yield contributing characters. The data were recorded on different characters such as plant height (cm), no. of primary branches per plant, no. of secondary branches per plant, days to 50% flowering, no. of siliqua per plant, days to maturity, no. of seds per siliqua, sliqua length (cm), thousand seed weight (g) and seed yield per plant (g). The data were statistically analyzed and thus obtained results are described below under the following heads:

4.1 Variability study in *Brassica napus*

4.1.1 Variability among the thirty four BC_1F_1 materials of *Brassica napus* and one check variety

Significant variations were observed for most of the characters among thirty four BC_1F_1 materials of *Brassica napus.* Table 2 & 3 showed the values of mean, range CV%, phenotypic variances, genotypic variances, phenotypic coefficient of variation, genotypic coefficient of variation for different yield related characters.

4.1.1.1 Plant height (cm)

In this study the highest plant height was observed in Nap-108 x Nap-9908(9908) (141.213 cm) where as the minimum plant height was observed in Nap-108x Nap-2066 (2066) (103.933 cm) (Table 2). Phenotypic variance and genotypic variance were observed as 63.08 and 28.5, respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this trait. The estimates of PCV (9.22%) and GCV (7.41 %) also indicated presence of considerable variability among the genotypes for this trait (Table 2).

Table 2. Estimation of genetic parameters in 34 genotypes in *Brassica napus* L. for ten characters

Parameters	Range	Mean	MS	σ^2 p	σ^2g	σ^2 e	PCV	GCV	ECV
PH	103.933-141.213	117.095	267.17**	116.59	75.29	41.30	9.22	7.41	5.49
NPB	2.983-13.143	5.095	10.85^{ns}	9.05	0.90	8.15	59.04	18.64	56.02
NSB	1.767-16.067	4.105	21.49**	10.12	5.67	4.45	77.39	57.94	51.31
D50%F	28.333-31.000	29.657	1.71**	1.02	0.35	0.66	3.40	2.00	2.75
NSP	109.267-392.000	225.326	13,954.51**	5361.46	4296.53	1064.93	32.50	29.09	14.48
DM	95.667-98.333	97.514	0.86^{ns}	0.76	0.05	0.70	0.89	0.24	0.86
NSS	21.517-29.203	26.849	10.36**	4.21	3.08	1.13	7.64	6.54	3.95
SL	6.319-8.969	8.191	1.24**	0.54	0.35	0.19	8.98	7.22	5.33
TSW	4.162-4.803	4.377	0.07**	0.03	0.02	0.01	4.12	3.50	2.17
SYP	17.208-40.270	25.499	114.48**	44.31	35.09	9.23	26.11	23.23	11.91

** Correlation is significant at the 0.01 level.

PH = Plant height (cm), NPB = No. of primary branches, NSB = No. of secondary branches, D50%F = Days to 50% flowering, NSP = No. of siliqua per plant, DM = Days to maturity, NSS = No. of seed per siliqua, SL = Siliqua length (cm), TSW = Thousand seed weight (g), SYP = Seed yield per plant (g), MS = mean sum of square, σ^2 p = Phenotypic variance, σ^2g = Genotypic variance and σ^2 e = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation and ECV = Environmental coefficient of variation.

The highest variation in plant height among parents and their hybrid was observed by Tyagi *et al.* (2001). High variability in plant height for *B. juncea, B. rapa* and *B. napus* was also observed by Varshney *et al.* (1986).

4.1.1.2 Number of primary branches per plant

Among the 34 BC_1F_1 populations the highest number of primary branches/plant was observed in 9905×0130 (9905) (3.033) where as the minimum number of primary branches/plant was observed in 9906x205(9906) (8.377) (Table 2). No. of primary branches per plant observed in check variety was 13.143in BS-13 (Table 2). Phenotypic variance and genotypic variance were observed 9.05and 0.90 respectively for number of primary branches per plant. Relatively large differences between them indicating large environmental influences on these character and relatively high difference between PCV (59.04 %) and GCV (18.64 %) value indicating the apparent variation not only due to genotypes but also due to the large influence of environment (Table 3). Chowdhury *et al.* (1987) also found significant differences for number of primary branches per plant. Genotypic and phenotypic variability in mustard are shown in Figure 1

4.1.1.3 Number of secondary branches per plant

Among the 34 BC_1F_1 populations the highest number of secondary branches/plant was observed in BS-13(16.067) where as the minimum number of secondary branches/plant was observed in Nap-9906x Nap-0130 (9906) (1.767) (Table 2). No. of secondary branches per plant observed in check varieties (BS-13) 16.067 was higher than other 34 BC_1F_1 populations (Table 2). The differences between phenotypic (10.12) and genotypic variance (5.67) were estimated higher for this trait indicating environmental influence on these character. Higher estimate of PCV (77.39%) and GCV (57.94%) values indicated presence of considerable variability among the genotypes for this trait (Table 3). Chowdhary *et al.* (1987) found significant differences for number of secondary branches per plant.

4.1.1.4 Days to 50% flowering

Considerable variations were observed among 34 BC_1F_1 populations for days to 50% flowering. The days to 50% flowering were observed lowest (28.333 days) in Nap-9905x Nap-9901(9905) and highest (31 days) was observed in Nap-9905x Nap-9908(9905) (Table2). The days to 50% flowering were observed in check variety was 29.00 (Table 2).

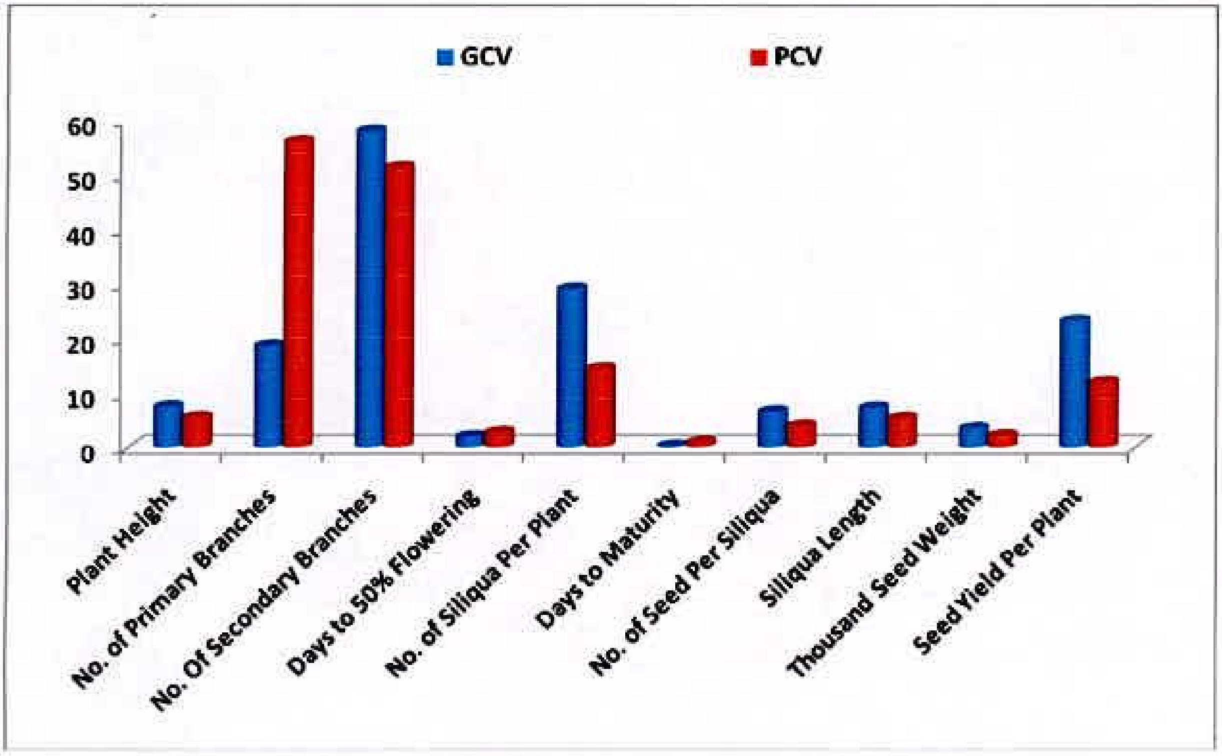

Fig 1.: Genotypic and Phenotypic Coefficient Variation of Mustard

Phenotypic and genotypic variance for days to 50% flowering was observed as 1.02 and 0.35, respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (3.40 %) was higher than the genotypic coefficient of variation (2.00 %) (Table 3), which suggested that environment has a significant role on the expression of this trait. High genotypic and phenotypic co-efficient of variation was recorded by Lekh *et al.* (1998). Significant genetic variability in days to 50% flowering in *B. napus* was also observed by Singh *et al.* (1991).

4.1.1.5 Days to maturity

The highest days to maturity was observed in Nap-205 x Nap-0130(0130) Nap-92066 x Nap-205(2066), Nap-9905 x Nap-9908(9908) (98.333 days) and the minimum days (85.33) to maturity was observed in Nap-9905 x Nap-9901(9905) (Table 2). The days to maturity was observed in check variety was 97.333 (Table 2). Phenotypic and genotypic variance for days to maturity was observed 0.76 and 0.05, respectively with moderate differences between them, suggested moderate influence of environment on the expression of the genes controlling this trait. The phenotypic coefficient of variation (2.46 %) was higher than the genotypic coefficient of variation (1.44 %) (Table 3), which suggested that environment has a significant role on the expression of this trait. Higher genotypic variances indicate the better transmissibility of a character from parent to the offspring . Similar results for this trait was also observed by Katiyar *et al.* (1974).

4.1.1.6 Number of siliqua per plant

The number of siliqua per plant was observed highest in Nap-2066 x Nap-0130(2066) (392.00). The minimum number of siliqua per plant was observed in BS13 (109.267) (Table 2). Number of siliqua per plant was observed in check variety was 109.267 which was lowest than other 34 BC_1F_1 materials (Table 2). Number of pods per plant showed highest phenotypic variance (5361.46) and genotypic variance (1064.93) with large environmental influence and the difference between the PCV (32.50 %) and GCV (29.09 %) indicated existence of adequate variation among the genotype (Table 3). High genetic variation was also found by Kudla (1993). (plate 2 to 9)

108x0130 (0130)

9905x9908 (9908)

2066x0130(0130)

9906x2066(2066)

Plate-2: Photograph showing performance of different plant materials in BC_1F_1 generation of 108x0130 (0130), 9905x9908 (9908), 2066x0130 (0130) and 9906x2066 (2066)

9906x2066 (9906)

9906x205 (9906)

9908x2066 (9908)

108x205 (108)

Plate-3: Photograph showing performance of plant materials in BC_1F_1 generation of 9906x2066 (9906), 9906x205 (9906), 9908x2066 (9908) and 108x205 (108)

108x9901 (108)

2066x205 (205)

2066x0130 (2066)

108x9908 (9908)

Plate-4: Photograph showing performance of plant materials in BC_1F_1 generation of 108x9901 (108), 2066x205 (205), 2066x0130 (2066) and 108x9908 (9908)

9906x0130 (0130)

108x2066 (2066)

9905x0130 (0130)

205x0130 (0130)

Plate-5: Photograph showing performance of plant materials in BC_1F_1 generation of 9906x0130(0130), 108x2066(2066), 9905x0130(0130) and 205x0130(0130)

108x2066 (108)

108x9908 (108)

9906x0130 (9906)

205x0130 (205)

Plate-6: Photograph showing performance of plant materials in BC_1F_1 generation of 108x2066 (108), 108x9908 (108), 9906x0130 (9906) and 205x0130 (205)

9906x205 (205)

9905x108 (108)

9905x0130 (9905)

9905x9908 (9905)

Plate-7: Photograph showing performance of plant materials in BC_1F_1 generation of 9906x205 (205), 9905x108 (108), 9905x0130 (9905) and 9905x9908 (9905)

9905x108 (9905)

108x0130 (108)

9908x9906 (9908)

9905x9901 (9905)

Plate-8: Photograph showing performance of plant materials in BC_1F_1 generation of 9905x108 (9905), 108x0130 (108), 9908x9906 (9908) and 9905x9901 (9905)

9908x0130 (9908)

9901x205 (205)

9905x9901 (9901)

Plate-9: Photograph showing performance of plant materials in BC_1F_1 generation of 9908x0130 (9908), 9901x205 (205) and 9905x9901 (9901)

4.1.1.7 Length of siliqua (cm)

Length of siliqua was observed highest in Nap-108 x Nap-0130 (0130) (8.969 cm) and the minimum length of pod was observed in Nap-2066 x Nap-0130 (2066) (6.319cm) (Table 2). Number of siliqua per plant was observed in check variety was 109.267 (Table 2). Length of siliqua showed phenotypic variance (0.54) and genotypic variance (0.35) with little difference between them indicating that they were less responsive to environmental factors for their phenotypic expression and relatively medium PCV (8.98 %) and GCV (7.22 %) indicating that the genotype has moderate variation for this trait (Table 3). High co-efficient of variation for this trait for both genotypic and phenotypic variability was recorded by Masood *et al.* (1999). High genetic variability for this trait was also found by Olson (1990).

4.1.1.8 Number of seeds per siliqua

The number of seeds per siliqua was observed highest in Nap-9908 x Nap-2066 (9908) (29.203). The minimum number of seeds per siliqua was observed in Nap-2066 x Nap-0130 (11.62) (Table 2). Number of seeds per siliqua observed in check variety was 23.810 (Table 2). The phenotypic and genotypic variances for this trait were 4.21 and 3.08 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this trait. The value of PCV and GCV were 7.64 % and 6.54 % respectively for number of seeds per siliqua which indicating that medium variation exists among different genotypes (Table 3). Similar variability was also recorded by Kumar and Singh (1994).

4.1.1.9 Thousand seed weight (g)

Thousand seed weight was found maximum in Nap-9905 x Nap-9901 (9905) (4.803 g) where as the minimum thousand seed weight was found in Nap-9906 x Nap-2066 (2066) (4.162 g) (Table 2). Thousand seed weight observed in check variety was 4.260g (Table 2). Thousand seed weight showed very low genotypic (0.03) and phenotypic (0.02) variance with high differences indicating that they were high responsive to environmental factors. The phenotypic coefficient of variation (4.12%) and genotypic coefficient of variation (3.50 %) were close to each other (Table 3). There was a very little difference between phenotypic and genotypic co-efficient of variation, indicating minor environmental influence on this character. Significant variability for this trait was also found by Kumar and Singh (1994).

4.1.1.10 Yield per plant (g):

Yield per plant was found maximum in Nap-108 x Nap-0130 (2066) (0130) (40.270g) when it was the minimum yield per plant was found in Nap-9905 x Nap-9901 (9901) (17.208 g) (Table 2). Yield per plant observed in check variety was 19.967 g (Table 2). The phenotypic variances and genotypic variances for this trait were 44.31 and 35.09 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this trait. The values of GCV and PCV were 26.11 % and 23.23 % indicating that the genotype has considerable variation for this trait (Table 3). Similar variability was also found by Khera and Singh (1988).

4.1.2 Heritability, genetic advance and selection

4.1.2.1 Plant height:

Plant height of BC_1F_1 showed high heritability 64.58% with moderately high genetic advance of 14.36 and genetic advance in percentage of mean of 12.26% (Table 3), revealed the possibility of predominance of additive gene action in the inheritance of this trait and indicating that this trait could be improved through selection process. Varshney *et al.* (1986) found high heritability for plant height. Heritability and genetic advance over mean in tomato are shown in Figure 2.

4.1.2.2 Number of primary branches per plant:

Number of primary branches per plant exhibited low heritability 9.97% with low genetic advance of 0.62 and genetic advance in percentage of mean of 12.17 %, which revealed that this trait was controlled by non-additive gene. As a whole, the low heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes for this trait. However, some of the individual plants showed quite a reasonable lower primary branches which were selected for further study in the next generation. Low heritability coupled with low genetic advance was also found by Singh *et al.* (1987).

Table 3. Estimation of genetic parameters in ten characters of 34 genotypes in *Brassica napus*

Parameters	Heritability	Genetic advance (5%)	Genetic advance (% mean)
PH	64.58	14.36	12.26
NPB	9.97	0.62	12.17
NSB	56.05	3.67	89.40
D50%F	34.49	0.72	2.43
NSP	80.14	120.88	53.65
DM	7.23	0.13	0.13
NSS	73.23	3.09	11.51
SL	64.74	0.98	11.96
TSW	72.24	0.27	6.17
SYP	79.18	10.86	42.59

PH = Plant height (cm), NPB = No. of primary branches, NSB = No. of secondary branches, D50%F = Days to 50% flowering, NSP = No. of siliqua per plant, DM = Days to maturity, NSS = No. of seed per siliqua, SL = Siliqua length (cm), TSW = Thousand seed weight (g), SYP = Seed yiled per plant (g)

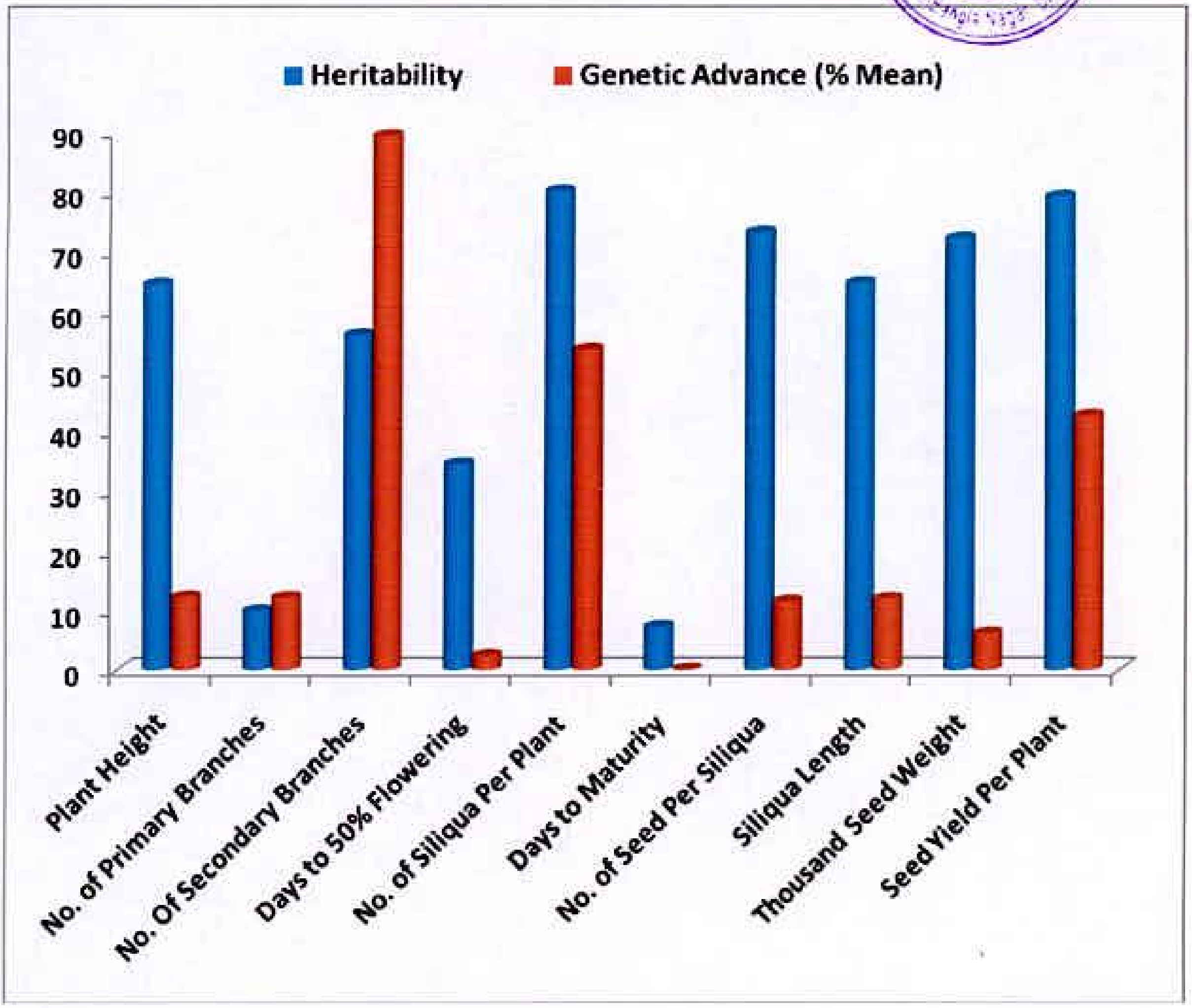

Fig. 2: Heritability and genetic advance (% mean) in *Brassica napus*

4.1.2.3 Number of secondary branches per plant:

Number of secondary branches per plant exhibited moderately high heritability (56.05%) with low genetic advance 3.67 and genetic advance in percentage of mean (89.40 %), such results revealed that this trait was controlled by non-additive gene. As a whole, the moderately high heritability and the consequent low genetic advance indicated the lower possibility of selecting genotypes. Moderately high heritability coupled with low genetic advance was also found by Singh *et al.* (1987).

4.1.2.4 Days to 50% flowering:

Days to 50% flowering exhibited low heritability (34.49%) with low genetic advance (0.72) and genetic advance in percentage of mean (2.43%) indicated that this trait was controlled by non-additive gene. This results support the reports of Malik *et al*. (1995).

4.1.2.5 Days to maturity:

Days to maturity shows low heritability (34.49%) with low genetic advance (0.72) and genetic advance in percentage of mean (2.43%) indicated that this trait was controlled by non-additive gene and medium possibility of selecting genotypes that would mature earlier. In some of the crosses the frequency of the segregating plants showing reduced maturity was comparatively higher than the other crosses. Low heritability coupled with low genetic advance for this trait was also observed by Sharma (1984).

4.1.2.6 Number of siliqua per plant:

Number of siliqua per plant exhibited very high heritability 80.14% with high genetic advance 120.88 and genetic advance in percentage of mean 53.65%. These results revealed the possibility of predominance of additive gene action in the inheritance of this trait. This trait possessed high variation; it is high potential for effective selection for further genetic improvement of this character. High heritability coupled with high genetic advance for this trait was also observed by Sheikh *et al.* (1999).

4.1.2.7 Siliqua length:

Siliqua length showed high heritability (64.74%) with low genetic advance (0.98) and low genetic advance in percentage of mean 11.96% indicated that this trait was controlled by non-additive gene. High heritability for this trait was observed by Chaudhury *et al.* (1989). Similar results was also found by Kwon *et al.* (1989) and Rao (1977).

4.1.2.8 Number of seeds per siliqua:

Number of seeds per siliqua showed high heritability 73.23% coupled with high genetic advance 3.09 and high genetic advance in percentage of mean 11.51%, indicated that this trait was controlled by additive gene and selection for this character would be effective. High heritability coupled with high genetic advance for this trait was also observed by Singh (1986).

4.1.2.9 Thousand seed weight:

Thousand seed weight exhibited high heritability 72.24% with low genetic advance 0.27 and genetic advance in percentage of mean 6.17%, revealed that this trait was controlled 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. High heritability for this trait was also observed by Yadava *et al.* (1993).

4.1.2.10 Seed yield per plant:

Seed yield per plant showed high heritability 79.18% with high genetic advance (10.86) and moderately high genetic advance in percentage of mean 42.59% indicated that this trait was controlled by additive gene and selection for this character would be effective. High heritability coupled with high genetic advance for this trait was also observed by Sheikh *et al.* (1999).

Significant variability was found in almost all the BC_1F_1 materials *Brassica napus* for most of the characters studied. The performance of the crosses also compared with the one check variety, BS-13 as per objectives, selection was carried out among the 34 BC_1F_1 materials of different cross combinations. 34 most promising plants with short duration and higher yield/plant were selected from the BC_1F_1 materials (Table 2). There were large variations in the twenty selected BC_1F_1 materials for siliqua/plant ranging from 121 to 209 siliqua. One plant from Nap-9905 x Nap-9901 (9905) produced 4.803g thousand seed weight. One plant from Nap-108 x Nap-0130 (2066) (0130) produced exceptionally high yield/plant 40.270g (Table 2).

4.1.3 CORRELATION CO-EFFICIENT

Seed yield is a complex product being influenced by several quantitative traits. Some of these traits are highly associated with seed yield. The analysis of the relationship among those traits and their association with seed yield is very much essential to establish selection criteria. Breeders always look for genetic variation among traits to select desirable type. Correlation co-efficient between pairs of trait for BC_1F_1materials of *B. napus* are shown in (Table 4).

4.1.3.1 Plant height (cm)

Plant height showed highly significant and positive interaction with number of primary branches (0.225), number of secondary branches (0.256) and number of siliqua per plant (0.568). Highly significant positive associations between plant height and other characters indicate that the traits were governed by same gene and simultaneous improvement would be effective. It had positive and insignificant interaction with siliqua length (0.004) and yield per plant (0.044). However, it had insignificant and negative interaction with number of days to 50% flowering (-0.120), days to maturity (-0.021), number of seeds per siliqua (-0.018) and thousand seed weight (-0.121) (Table 8). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. These findings are showed resemblance to the reports of Parveen (2007). Shalini *et al.* (2000) also observed that plant height was highly associated with seed yield.

4.1.3.2 Number of primary branches per plant

Number of primary branches per plant showed positive and insignificant interaction with number of secondary branch (0.059), number of siliqua per plant (0.107), number of seeds per siliqua (0.041) and siliqua length (0.004). However, it had insignificant and negative interaction was found in days to 50% flowering (-0.155), days to maturity (-0.097), thousand seed weight (-0.089) and yield per plant (-0.04) (Table 4). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Similar results were obtained by Rashid (2007).

Table 4. Correlation coefficient among different characters of BC_1F_1 of *Brassica napus*

Characters	NPB	NSB	D50%F	NSP	DM	NSS	SL	TSW	YPP
PH	0.225*	0.256**	-0.120	0.568**	-0.021	-0.018	0.004	-0.121	0.044
NPB		0.059	-0.155	0.107	-0.097	0.041	0.015	-0.089	-0.040
NSB			-0.170	0.195*	-0.032	-0.435**	-0.270**	-0.140	-0.095
D50%F				-0.075	0.149	0.130	0.151	-0.267**	0.081
NSP					0.014	-0.083	-0.165	-0.080	-0.100
DM						0.178	0.149	-0.024	0.151
NSS							0.613**	0.120	-0.100
SL								0.248**	-0.233**
TSW									-0.006

* Correlation is significant at the 0.05 level.

** Correlation is significant at the 0.01 level.

PH = Plant height (cm), NPB = No. of primary branches, NSB = No. of secondary branches, D50%F = Days to 50% flowering, NSP = No. of siliqua per plant, DM = Days to maturity, NSS = No. of seed per siliqua, SL = Siliqua length (cm), TSW = Thousand seed weight (g), SYP = Seed yiled per plant (g).

4.1.3.3 Number of secondary branches per plant

Number of secondary branch showed highly significant and positive interaction with number of siliqua per plant (0.195) indicated that the traits were governed by same gene and simultaneous improvement would be effective. It had highly significant and negative correlation with number of seed per siliqua (-0.435) and siliqua length (-0.270) indicated that if number of secondary branches increased then number of seed per siliqua and siliqua length decreased. However, it had insignificant and negative interaction with days to 50% flowering (-0.170), days to maturity (-0.435), thousand seed weight (-0.140) and yield per plant (-0.095). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. These findings are showing similar to the reports of Chowdhary *et al*. (1987).

4.1.3.4 Days to 50% flowering

Days to 50% flowering showed highly significant and negative correlation with thousand seed weight (-0.267) indicated that if days to 50% flowering increased then thousand seed weight decreased. It also exhibited insignificant and positive interaction with days to maturity (0.149), number of seeds per siliqua (0.130), siliqua length (0.151) and yield per plant (0.081). However, it had insignificant and negative interaction with number of siliqua per plant (-0.075) (Table 4). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Parveen (2007) also revealed that days to 50% flowering had insignificant and positive interaction with yield per plant.

4.1.3.5 Number of siliqua per plant

Siliqua per plant showed insignificant and positive correlation with days to maturity (0.014). Whereas the insignificant and negative interaction was found in number of seed per siliqua (-0.083) siliqua length (-0.165), thousand seed weight (-0.080) and yield per plant (-0.10) (Table 4). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Tyagi *et al*. (1996) reported that no. of seeds per siliqua had positive and significant effects on seed yield per plant.

4.1.3.6 Days to maturity

Days to maturity showed insignificant and positive correlation with number of seeds per siliqua (0.178), siliqua length (0.149) and yield per plant (0.151). However, it had insignificant and negative interaction with thousand seed weight (-0.024) (Table 4). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Parveen (2007) also revealed that days to maturity had insignificant and positive interaction with yield per plant.

4.1.3.7 Number of seeds per siliqua

Number of seeds per siliqua showed highly significant and positive interaction with thousand seed length (0.613). Highly significant positive associations between number of seeds per siliqua and thousand seed length indicated that the traits were governed by same gene and simultaneous improvement would be effective. It had insignificant and positive interaction with thousand seed weight (0.120). However, it had insignificant and negative interaction with yield per plant (-0.10) (Table 4). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Nasim *et al.* (1994) reported that no. of seeds per siliqua had negative and significant effects on seed yield per plant. Ahmed (1993) also found similar results for this trait.

4.1.3.8 Siliqua length (cm)

Siliqua length showed highly significant and positive correlation with thousand seed weight (0.248) indicated that the traits were governed by same gene and simultaneous improvement would be effective. It also showed highly significant and negative correlation with yield per plant (-0.233) (Table 4) indicated that if siliqua length increased then yield per plant decreased. Nasim *et al.* (1994) reported that seed yield per plant was significantly and negatively with siliqua length.

4.1.3.9 Thousand seed weight

Thousand seed weight showed insignificant and negative interaction with yield per plant (-0.006) (Table 4). Insignificant association of these traits indicated that the association between these traits is largely influenced by environmental factors. Saini and Kumar (1995), Kakroo and Kumar (1991) and Olsson (1990) found positive association which support the results.

4.1.4 PATH CO-EFFICIENT ANALYSIS OF BC_1F_1

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 hector. In order to find out a clear picture of the inter-relationship between seed yield per plant and other yield attributes, direct and indirect effects were worked out using path analysis at phenotypic level which also measured the relative importance of each component. Seed yield per plant was considered as a resultant (dependent) variable and days to 50% flowering, days to maturity, plant height, number of primary branches per plant, number of siliqua per plant, length of siliqua, number of seeds per siliqua and thousand seed weight were causal (independent) variables. Estimation of direct and indirect effect of path co-efficient analysis for *Brassica napus* is presented in Table 5. Figure 4 showing path diagram of yield and its contributing traits in thirty four BC_1F_1 genotypes in *Brassica napus*.

4.1.4.1 Plant height

Path analysis revealed that plant height had positive direct effect (0.285) on yield per plant. Negative indirect effect through number of primary branches per plant (-0.002), number of secondary branches (-0.048), days to 50% flowering (-0.015), number of siliqua per plant (-0.157), days to maturity (-0.004), siliqua length (-0.002) and thousand seed weight (-0.163) (Table 5). Han (1990) observed that plant hight had positive direct effect on yield per plant.

4.1.4.2 Number of primary branches per plant

Number of primary branches per plant had the negative direct effect on yield per plant (-0.008). This trait had positive indirect effect on plant height (0.064). On the other hand, negative indirect effect was found on number of secondary branches (-0.011), days to 50% flowering (-0.019), number of siliqua per plant (-0.030), days to maturity (-0.019), number of seed per siliqua (-0.001), siliqua length (-0.006) and thousand seed weight (-0.011) (Table 5). Chowdhury *et al.* (1987) observed that number of primary branches had the negative direct effect on yield per plant.

4.1.4.3 Number of secondary branches per plant:

Path co-efficient analysis revealed that number of secondary branches had negative direct effect (-0.186) on yield per plant. Plant height (0.073), number of seed per siliqua (0.010) and

Table 5. Path coefficient analysis showing direct and indirect effect of yield components on seed yield in BC_1F_1

	PH	NPB	NSB	D50%F	NSP	DM	NSS	SL	TSW	Correlation with yield
PH	**0.285**	-0.002	-0.048	-0.015	-0.157	-0.004	0.000	-0.002	-0.014	0.044
NPB	0.064	**-0.008**	-0.011	-0.019	-0.030	-0.019	-0.001	-0.006	-0.011	-0.040
NSB	0.073	0.000	**-0.186**	-0.021	-0.054	-0.006	0.010	0.106	-0.017	-0.095
D50%F	-0.034	0.001	0.032	**0.125**	0.021	0.030	-0.003	-0.059	-0.032	0.081
NSP	0.162	-0.001	-0.036	-0.009	**-0.276**	0.003	0.002	0.065	-0.009	-0.100
DM	-0.006	0.001	0.006	0.019	-0.004	**0.201**	-0.004	-0.059	-0.003	0.151
NSS	-0.005	0.000	0.081	0.016	0.023	0.036	**-0.024**	-0.241	0.014	-0.100
SL	0.001	0.000	0.050	0.019	0.046	0.030	-0.015	**-0.393**	0.029	-0.233**
TSW	-0.034	0.001	0.026	-0.033	0.022	-0.005	-0.003	-0.097	**0.118**	-0.006

** Correlation is significant at the 0.01 level.
Residual effect: 0.192

PH = Plant height (cm), NPB = No. of primary branches, NSB = No. of secondary branches, D50%F = Days to 50% flowering, NSP = No. of siliqua per plant, DM = Days to maturity, NSS = No. of seed per siliqua, SL = Siliqua length (cm), TSW = Thousand seed weight (g), SYP = Seed yiled per plant (g).

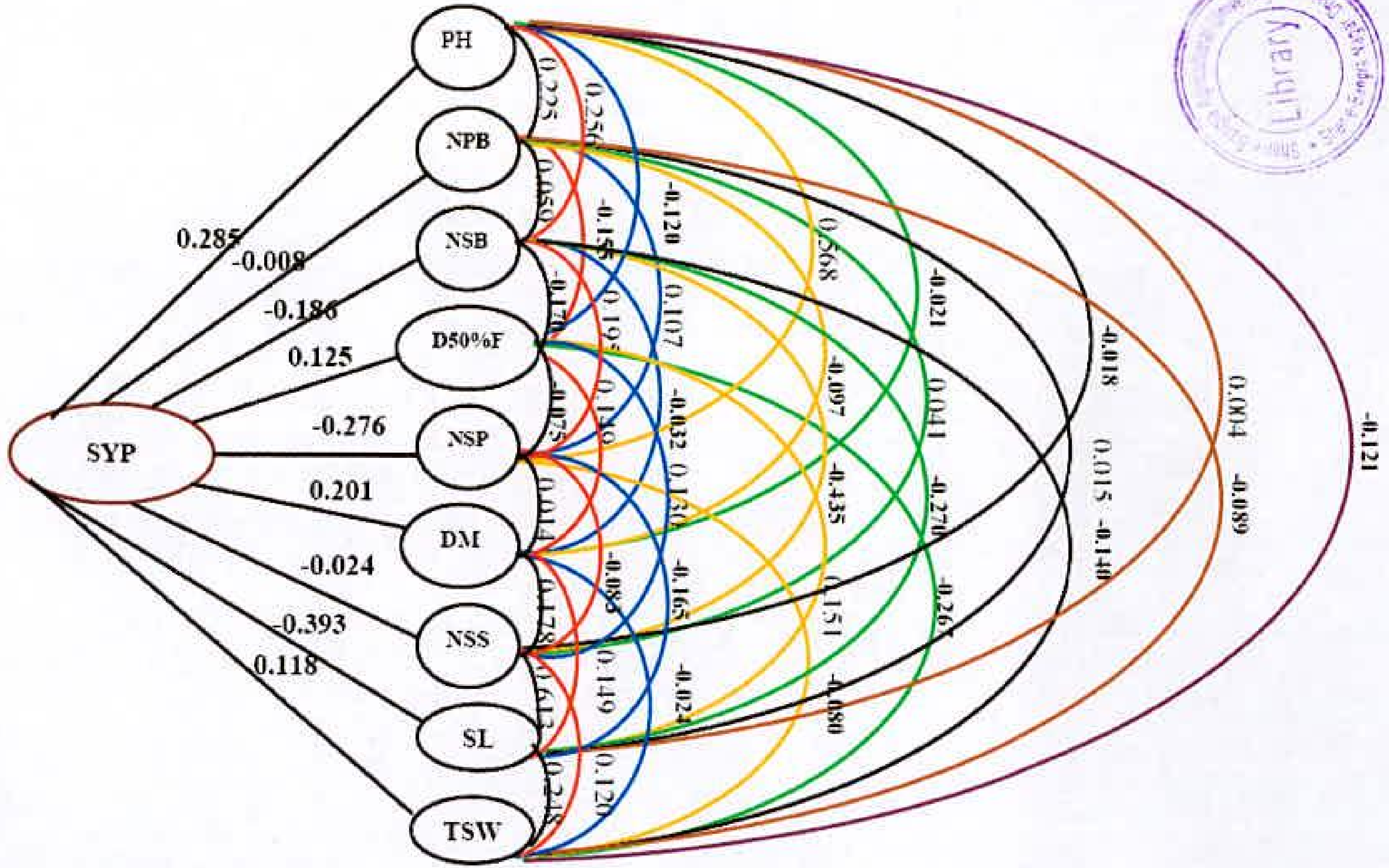

Fig. 3: Diagrammatic representation of direct effects and correlation coefficients of variables on dependent variable in BC_1F_1 of *Brassica napus*

siliqua length (0.106) had positive indirect effect on yield per plant. On the other hand, days to 50% flowering (-0.021), number of siliqua per plant (-0.054), days to maturity (-0.006) and thousand seed weight (-0.017) had negative indirect effect on yield per plant. (table 5). Yadava *et al.* (1996) found the number of secondary branch had the highest positive direct effect on seed yield.

4.1.4.4 Days to 50% flowering:

Path co-efficient analysis revealed that days to 50% flowering had positive direct effect (0.125) on yield per plant. Number of primary branches (0.001), number of secondary branch (0.032), number of siliqua per plant (0.021), days to maturity (0.030) had positive indirect effect on yield per plant. On the other hand, days to 50% flowering had negative indirect effect via plant height (-0.034), number of seed per siliqua(-0.003), siliqua length (-0.059) and thousand seed weight(-0.032) (Table 5). Chauhan and Singh (1995) revealed that days to 50% flowering had positive direct effect on yield per plant.

4.1.4.5 Number of siliqua per plant:

Path co-efficient analysis revealed that number of siliqua per plant had the negative direct effect (-0.276) on seed yield followed by positive indirect effect on plant height (0.162), days to 50% maturity (0.003), number seed per siliqua(0.002), siliqua length(0.065) and this trait had negative indirect effect on number of primary branches per plant (-0.001), number of secondary branch (-0.036), days to 50% flowering (-0.009) and thousand seed weight (-0.009) (Table 5). Yadava *et al.* (1996) found the number of siliqua per plant had the highest negative direct effect on seed yield.

4.1.4.6 Days to maturity:

Path co-efficient analysis revealed that days to maturity had positive direct effect (0.201) on yield per plant. Positive indirect effect through number of primary branches (0.001), number of secondary branches (0.006), days to 50% flowering (0.019). On the other hand days to maturity had negative indirect effect via plant height (-0.006), number of siliqua plant (-0.004), number of seed per siliqua (-0.004), siliqua length (-0.059) and thousand seed weight (-0.003) (Table 5). Rashid (2007) revealed that days to maturity had positive direct effect on yield.

4.1.4.7 Number of seeds per siliqua:

Path analysis revealed that number of seeds per siliqua had direct negative effect (0.024) on yield per plant. This trait had also indirect positive effect on number of secondary branches (0.081), days to 50% flowering (0.016), number of siliqua per plant (0.023), days to maturity (0.036) and thousand seed weight (0.014). On the other hand length of siliqua showed indirect negative effect on and plant height (-0.005), siliqua length (-0.241) (Table 5). Rashid (2007) reported that number of seeds per siliqua had direct positive effect on yield per plant. Parveen (2007) also found similar results for this trait. This discrepancy with present findings might be due to environmental variation.

4.1.4.8 Siliqua length:

Path analysis revealed that siliqua length had direct negative effect (-0.393) on yield per plant. This trait had also indirect positive effect on plant height (0.001), number of secondary branches (0.050), days to 50% flowering (0.019), number of siliqua per plant (0.046), days to maturity (0.030) and thousand seed weight (0.029). On the other hand length of siliqua showed indirect negative effect on number of seeds per siliqua (-0.015) (Table 5). Han (1990) reported that siliqua length had negative direct effect on yield per plant.

4.1.4.9 Thousand seed weight:

Thousand seed weight had positive direct effect on yield per plant (0.118) and positive indirect effect on number of primary branches per plant (0.001), number of secondary branch (0.026) and number of siliqua per plant (0.022). On the other hand this trait showed negative indirect effect on plant height (-0.034), days to 50% flowering (-0.033), days to maturity (-0.005), number of seeds per siliqua (-0.003) and siliqua length (-0.097) (Table 5). Siddikee (2006) reported that thousand seed weight had the highest positive direct effect on seed yield per plant.

Chapter V

Summary and Conclusion

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SUMMARY AND CONCLUSION

An experiment was conducted during the period of november, 2010 to March 2011, at the experimental farm of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University using thirty four BC_1F_1 progenies of *Brassica napus* and one check variety. The investigation was carried out to study variability, heritability, genetic advance and genetic advance in percentage of mean, character associations and direct and indirect effect of different traits on yield. All thirty four BC_1F_1 progenies varied significantly with each other for all the characters studied. The results of the present study are summarized as follows:

From variability analysis of BC_1F_1 progenies, it was observed that significant variation exist among all the genotypes used for most of the characters studied. Plant height exhibited highest in Nap-108 x Nap-9908(9908) and lowest in Nap-108x Nap-2066 (2066). The highest number of primary branches per plant was recorded in 9905x0130 (9905) and lowest number was recorded in 9906x205(9906). The highest number of secondary branches per plant was observed in BS-13 and lowest number of secondary branch was observed in Nap-9906x Nap-0130. The maximum days to 50% flowering was found in Nap-9905x Nap-9908(9905) and the lowest in Nap-9905x Nap-9901(9905). The highest days to 50% maturity was observed in Nap-205 x Nap-0130 (0130), Nap-92066 x Nap-205(2066) and Nap-9905 x Nap-9908(9908) and lowest days were observed in Nap-9905 x Nap-9901(9905). The number of siliqua per plant showed highest in Nap-2066 x Nap-0130(2066) and lowest in BS-13. The highest siliqua length was recorded in Nap-108 x Nap-0130 (0130) and lowest siliqua length was observed in Nap-2066 x Nap-0130 (2066). The number of seeds per siliqua was found highest in Nap-9908 x Nap-2066 (9908) and lowest in Nap-2066 x Nap-0130. The thousand seed weight exhibited highest in Nap-9905 x Nap-9901 (9905) and lowest in Nap-9906 x Nap-2066 (2066). The seed yield per plant was highest in Nap-108 x Nap-0130 (0130) and lowest observed in Nap-9905 x Nap-9901 (9901).

In the thirty four BC_1F_1 materials for most of the characters wide range of variation was observed. The phenotypic variance was higher than the corresponding genotypic variance for all the characters indicating greater influence on environment for the expression of these characters. In BC_1F_1 materials plant height, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and seed yield per plant showed moderate differences between genotypic and phenotypic variance. Days to 50% flowering, days to maturity, number of seeds per siliqua, siliqua length and thousand seed weight showed minimum differences between genotypic and phenotypic variance which indicated low environmental influence on these traits.

Plant height, days to 50% flowering, days to maturity, number of seeds per siliqua, siliqua length and thousand seed weight exhibited low genotypic and phenotypic co-efficient of variation. Number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant and seed yield per plant showed moderate genotypic and phenotypic co-efficient of variation.

High heritability with high genetic advance in percent of mean was observed for number of siliqua per plant and seed yield per plant indicating that these traits were under additive gene control and selection for genetic improvement for these traits would be effective. High heritability with moderate genetic advance was observed for plant high indicating medium possibility of selecting genotypes. High heritability with low genetic advance in percent of mean was observed for number of seeds per siliqua, siliqua length and thousand seed weight indicating that non-additive gene effects were involved for the expression of these characters and selection for such traits might not be rewarding.

Selection was carried out among the thirty four BC_1F_1 materials of *Brassica napus* for most promising plants with high yield and a short duration. The performance of the crosses also compared with one check variety (BS-13). Based on the variability and as per our objectives nineteen most promising plants with short duration and higher yield were selected from the thirty four BC_1F_1 materials.

Correlation revealed that yield per plant had positive association with plant height, days to 50% flowering and days to maturity and yield per plant had significant negative association with siliqua length.

Path co-efficient analysis revealed that plant height, days to 50% flowering, days to maturity and thousand seed weight had the positive direct effect on yield per plant. Whereas, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, number of seeds per siliqua and siliqua length had the negative direct effect on yield per plant.

As the traits like, number of siliqua per plant and seed yield per plant showed high heritability coupled with high genetic advance in percent of mean, selection would be effective for those traits.

Therefore, Nap-108 x Nap-9908(9908) for plant height, Nap-9905 x Nap-0130 (9905) for number of primary branches per plant, Nap-9905 x Nap-9908 (9905) for days to 50% flowering, Nap-2066 x Nap-0130(2066) for number of siliqua per plant, Nap-108 x Nap-0130 (0130) for siliqua length, Nap-9905 x Nap-9901 (9905) for thousand seed weight and Nap-108 x Nap-0130 (0130) for seed yield per plant were found highest.

So, Nap-108 x Nap-9908(9908), Nap-9905 x Nap-0130 (9905), Nap-9905 x Nap-9908(9905), Nap-2066 x Nap-0130(2066), Nap-108 x Nap-0130 (0130) and Nap-9905 x Nap-9901 (9905) can be further used for advance research or varietal improvement program.

The result of the present study revealed that a wide variability exists among the collected mustard genotypes. In addition, there was also genotypic variability of different yield contributing characters with yield of *Brassica napus*. From the findings of the present study, the following conclusions could be drawn:

i. Wide range of genetic variability existed among the *Brassica* genotypes. That variability could be used for future breeding programme of *Brassica napus* in Bangladesh.
ii. Selection carried out among the thirty four BC_1F_1 materials of *Brassica napus* would be most promising with high yield and short duration plants.
iii. Further collection of tomato germplasms would be continued for getting more variability and desired traits in mustard.

References

REFERENCES

Ahmad, M.R. (1993). Study of agronomic value of resynthesized rapeseed lines and early generations of crosses "rsyn-lines x improved varieties. *Iranian J. Agril. Sci.* **24**(3/4):1-13. [Plant Breeding Abstracts. **65(16):** 909]

Alam, M.S., Rahman, A.R.M.S. and Khair. A.B.M.A. (1986). Genetic variability and character association in groundnut (*Arachis hypogaea* L.). *Bangladesh J. Agron.* **10**(4): 9-16.

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

Andrahennadi, C.P., Weerasena, L.A. and Aberyrantne, M.D.R.S. (1991). Evaluation of brown mustard germplasm in Srilanka. *Cruciferae Newsletter*. **14**(15): pp. 62-63.

Arthamwar, D.N., Shelke, V.B. and Ekshinge. B.S. (1995). Correlation and regression studies in mustard. Marathwada Agricultural University.*Indian .J. Maharashtra. Agril. Univ.* **20**(2): pp. 237-239.

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

BBS. (2006). Statistical yearbook of Bangladesh. Bangladesh Bureau of Statistics. Statistic Division, Ministry of Planning. Govt. of the People's Republic of Bangladesh. pp. 151.

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

BBS. (2000). Statistical Year Book of Bangladesh (2000). Bangladesh Bureau of Statistics. Ministry of Planning, Government of the Peoples Republic of Bangladesh. Dhaka. pp.145.

Behl, R.K., B.D. Chowdhury. Shing, R.P. and Shing. D.P. (1992). Morphophysiological determinates of oil yield in *Brassica juncea* under dryland conditions. *Indian J. Genet. Pl. Breed.* **52**(3): 280-2 84.

Bhardwaj, R.P. and Singh, R.R. (1969). Morphological and genetic variability in brown sarson (*Brassica campestris* var. brown sarson). *Madras Agric.* J.**56**(1): 28-31.

Biswas, K.P. (1989). Performance evaluation of 14^{th} genotype of oleiferous *Brassica*. Proceeding of the 14^{th} Annual Bangladesh Sci. Conf. pp. 70.

Burton, G.W. (1952). Quantitative inheritance in grass pea. Proc. 6^{th} Grassl. Cong.**1**: 277-283.

Campbell, D.C. and Kondra. Z.P.(1978). Relationship among growth patterns, yield components and yield of rapeseed. (*Can. .J. P1. 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.

Chatterjee, S.D. and Bhattacharya, 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. Plant Physiology.* **31**(1): 38-44.

Chaudhury, P.K., P. and Kumar, A. (1990). Association and Interdependence of morphophysiological characters under moisture stress in *Brassica. Beitrage Zar Tropichen Landuitshaft.* **18**(l): 43-47.

Chaudhury, 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.

Chauhan, J. and Singh, P. (1995). Association of some morpho-physiological determinants with seed yield in toria *(B. campestris* L var. toria). Thesis Abst. XI-1: pp. 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*. **103**(1): 54-62.

Clarke, G.M. (1973). Statistics and Experimental Design. Edward Arnold. 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 genentic advance. *Indian J. Hill.* **6**(2): 171-174

Dabholkar, A.R. (1992). Elements of Biometrical Genetics. Concept Publishing, New Delhi, India.

Das, K., Barua, P.K. and Hazarika, G.N. (1998). Genetic variability and correlation in Indian mustard. *J Agril. Sci. Society of North East India.* **11**(2): 262-264.

Das, M.L., and Rahman, A., Khan, M.H.R. and Miah, A.J. (1984). Correlation and path co-efficient studies in soybean. *Bangladesh J. Bot.* **13**(1): 1-5.

Dewey, D.R. and Lu, K.H. (1995). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* **51:** 515-518.

Dhillor, S.S., Labana, D.S. and Ahuja, K.L (1990). Association analysis in Indian mustard. *J. Agric. Res.* **27**(3): 385-388.

Dileep, K., Arvind, S.V.K., Bali, D. and Kumar, K. (1997). Correlation and regression studies between different yields attribute and seed yield in mustard (*Brassica juncea* L.) *Part Univ. Agric. Tech.* **14**(2): pp. 202-206.

Downy, R. K. (1990). *Brassica* oilseed breeding- achievements and opportunities. *Plant Breeding Abstracts.* **60**: 1165-1170

FAO. (2005). Production Year Book. Food and Agricultural Organization of the United Nations, Rome 00100 Italy. **57**:115-133.

FAO. (2004). FAOSTAT Database of Agriculture (Crops). http://www.fao.org.

FAO. (2001). Production Year Book for 1999. Food and Agricultural Organization of United Nations, Rome 00108. Italy. pp: 118.

FAO. (Food and Agricultural Organization), (2000). Production Yearbook . Food and Agricultural Organization of the united Nations, Rome 00108, Italy. pp. **48**: 115.

Gebre-Mariam, M. (1982). Index selection for genetic improvement of yield, kernel, weight and protein content in wheat. Dissertation Abstracts International. B **42**(121)4679 B.

Ghosh, D.C. and Mukhopadhyay, D. (1994). Path analysis of yield and yield attributes of toria (*Brassica rapa* var. napus) as affected by date of sowing and plant density. *Indian J Agril. Sci.* **64**(1): 56-58.

Gill, M.S. and Narang, R.S. (1995). Correlation and path coefficient analysis studies in gobhi sarson (*Brassica napus* L.). Subsp Oleifera DC. var. annua. *Res. And Dev. Reporter.* **12**(1-2): pp. 30-34.

Gupta, M..L. Lahana, K.S. and Badwal, S.S. (1987). Correlation and path co-efficient of metric traits contributing towards oil yield in Indian mustard. International rapeseed congress, Poznan. Poland, pp. 107.

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

Gurdial. S. and Hardip. S. (1998). Correlation studies among different growth parameters and seed yield of gobhi sarson (*Brassica napus* L.) *Environ. and Ecol.* **16**(2): pp. 337-343.

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

Hari, S.A.K. Adav,Y.,Yadava,T.P.and Lather, V.S. (1985). Morphophysiological attributes in relation to seed yield in Indian mustard. *J Haryana Agril. univ.* **15**(3): 295-299.

Jain, A.K., Tiwaari. A.S. and Kushwah. V.S. (1988). Genetics of quantitative traits in Indian mustard. *Indian J. Genet. Pl. Breed.* **48**(2): 117-119.

Johnson, H.W., Robinson, H.F. and Comstock. R.E. (1955). Estimation of genetic and environmental variability in soybean. *Agron. .J.* **47**:314-318.

Kachroo, P. and Kumar, S. (1991). Genetic determination of seed yield through its components in mustard (*Brassica juncea* L.). Thesis abs. 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). Interrelationship 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. P1. Breed.* **21**(1): 22-27.

Kaul, A. K. and M.L Das,M.L. (1978). Oil seeds in Bangladesh Canada Agric. Sector team. Ministry of Agric. Govt. of the peoples Republic of Bangladesh. pp: 1.

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

Khulbe, R.K. and Pant, D.P. (1999). Correlation and path co-efficient analysis of yield and its components in Indian mustard. *Crop Res. Hisar.* **17**(3): pp. 371- 375.

Kibite, S. (1981). Genetic studies on the simultaneous improvement of grain yield and grain protein content in wheat (*Triticurn aestivurn* L. em. Thell). Dissertation Abstracts International B. **41**(9): 3263 B.

Knott, D.R. (1972). Effects of selection for F_2 plant yield on subsequent generations in wheat. *Can. .J. P1. Sci.* **52**: 72 1-726.

Kudla, M. (1993). Comparative analysis of winter swede rape genotypes. *Biuletyn instytutu Hodowli Roslin*. **90**: pp. 99-107.

Kumar, C.H.M.V., Arunachalam, V. and Rao, P.S.K. (1996). Ideotype and relationship between morpho-physiological characters and yield in Indian mustard (*B. juncea*). *Indian .J. Agric. Sci.* **66**(11): l4-1 7.

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.

Kumar, N., Bisht, J.K. and Joshi, M.C. (1988). Correlation and discriminant function of analysis in Indian mustard. *Indian J. Agric. Sci.* **58**(l): 5 1-52.

Kumar, P., Yadava, T.P. and Yadav, A.K. (1984). Association of seed yield and its component traits in the F_2 generation of Indian mustard. *Indian J. Agric. Sci.* **54**(7): 604-607.

Kwon, B.S., Lee, J.I and Chae, Y.A. (1989). Genetic studies on some agronomic characters in rapeseed, *Korean J. Pl. Breed.* **21**(l): 22-27.

Labana, 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 of repeatability estimates of siliqua morphological traits in *Brassica campestris* L. *Euphytica.* **43** (1-2): pp. 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**(l): pp. 87-88.

Lodhi, G.P., Singh. R.K. and Sharma, S.C. (1979). Correlated 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**(1): 25-59.

Malik. V., Singh, H. and Singh, D. (1995). Gene action of seed yield and other desirable characters in rapeseed. Analysis Biol (Ludhiana). **11**(1/2): 94-97.

Masood, T., Gilani, M.M. and Khan, F.A. (1999). Path analysis of the major yield and quality characters in *Brassica campestris. .J. Ani. P1. Sci.* **9**(4): 69-72.

Meneal, 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.

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 *Brassica species. Indian J. Agric. Sci.* **64**(4): 227-232.

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

Olsson, G. (1990). Rape yield-production components. Sversk Fortidning. **59**(9): 194-197. Cited from *P1. Br. Abs.* **61**(5): 588, 1991.

Pankaj, S., Gyanendra, T., Gontia, A.S., Patil, V.D. and Shah, P (2002) correlation studies in Indian Mustard. *Agric. Sci. Digest*. Dept. of Genetics and Plant Breeding. Marathwada Agricultural University, India. **22**(2): 79-82.

Parveen, S. (2007). Variability study in F_2 progenies of the inter-varietal crosses of *Brassica rapa.* MS thesis, Department of Genetics and Plant Breeding, Shere-e-Bangla Agricultural University. Dhaka.

Paul, N.K.,Joarder, 0.I. and Eunus, A.M. (1976). Genotypic and phenotypic variability and correlation studies in *B. juncea* L. Zeitschrifl fur pflazenzuchtung. **77**(2): 145-154.

Ramanujam, S. and Rai, B. (1963). Analysis of yield components in *Brassica campestris* var. yellow sarson. *Indian .J.* (Genet. **23**: 3 12 1-319.

Rao, T.S. (1977). Genetics of yield components in brown sarson. *Genetica Iberica*. **29**(3/4): 2 19-227.

Rashid, M.H. (2007). Characterization and diversity analysis of the oleiferous *Brassica* species. MS thesis, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka.

Reddy, N.N. (1991). Correlation studies in lndan mustard (*Brassica juncea* L. Czern and Coss.). J. *Oilseeds Res.* **8**(2): 248-250.

Saini, H.C. and Kumar, R.P. (1995). Model plant architecturer through association and path co-efficient analysis in Indian Colza. *Indian .J. Agric. Res.* **29**(3): 109-115.

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

Shalini, T.S., Sheriff, R.A., Kulkarmi, R.S. and Venkataramana, p. (2000). Correlation and path analysis in Indian mustard germplasm. Research on. crops Dept. of Genetics and Plant Breeding. University of Agricultural Science. India. **1**(2): 226-229.

Sharma, S.K., Rao, D., Singh, D.P., Harbir, S. And Singh, H. (1994). Correlative analysis of yield, biomass and its partitioning components in Indian mustard (*Brassica juncea* L. Czern. Coss.). *Hariana Agril. Univ. .J. Res.* **27**(2-4): 149- 152.

Sharma, S.K., (1988). Variation and correlation studies in Indian mustard (*B. juncea*). Thesis Abst. **10**(2): 146-147.

Shebeski, L.H. (1967). Wheat breeding. **In** : Canadian Centennial wheat symposium. (ed. F. Nielsen). Modern Press. pp. 249-277.

Sheikh, F.A., Rathen, A.G. and Wani, S.A. (1999). Path analysis in toria (*Brassica campestris* L.) var. toria. *Adv. P1. Sci.* **12**(2): pp. 385-388.

Shivahare, M.D., Singh, A.B., Chauhan, Y.S. and Singh, P. (1975). Path co-efficient analysis of yield components in Indian mustard. *Indian J. Agric. Sci.* **45**(9): 422-425.

Siddikee, M.A. (2006). Heterosis, intergenotypic variability, correlation and path analysis of quantitative characters of oleiferous *Brassica campesiris* L. MS thesis. Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University. Dhaka.

Singh, R.P., Khera, M.K. and Gupta, V.P. (1991). Variability and correlation studies for oil and seed yield in gobhi sarson. *Crop lmprov.* **18**(2): 99-102.

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

Singh, R.S., Singh, P. and Dixit, R.K. (1987). Combining ability analysis of yield and developmental traits in Indian canola (*Brassica campesiris* L. var. yellow sarson prain). *Farm Sci.* **12**(2): I 70-I 74.

Singh, H. (1986). Genetic variability, heritability and drought indices analysis in *Brassica* species. *.J. 0ilseeds Res.* **3** (2): 170-177.

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

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

Srivastava, M.K. and Singh, R.P (2002). Correlation and path analysis in Indian Mustard. *Crop Res. Hisar*, Dept. of Genetics and Plant Breeding. CSA University of Agriculture and Technology. India. **23**(3): 517-521.

Srivastava P.P. Salara. B.S. and Gowda, M.V.C. (1983). Variability and correlation studies in groundnut (*Arachis hypogaea*). *Crop lrnprov.* **25** (I): 122-123.

Swain, S.K. (1990). Correlation and path analysis in brown sarson (*Brassica campestris* var. dichotoma watt.). *Orissa .J. Agril. Res.* **3**(3-4): 197-200.

Tak. G.M. (1976). Correlation and path analysis of the yield components in the three forms of *Brassica campestris* L. *Crop Iniprov.* **3** (2): 43-52.

Teresa, W. (1987). Selection criteria of winter rape single plant and its seed yield. **In**: 7th International Rapeseed Congress, Poland. 11-14, May. pp. 284-289.

Thakral, N.K., Yadava, T.P., Kumar.P., Singh, A. and Chandra, N. (1999). Association analysis for some quantitative traits in Indian mustard. Cruciferae Newsletter. **21**: 105-106.

Thakral, N.K. (1982). To study the association of some morphophysiological attributes with yield in toria. Thesis Abst. **8**(11): pp. 66-67.

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

Tyagi, M.K., Chauhan. J.S., Kumar, P.R. and Singh, K.H. (2001). Estimation of heterosis in Indian mustard [*Brassica juncea* (L.) Czern and Coss.]. *Annals Agric. Bio. Res.* **69**(2): pp. 193-200: 4 refs.

Tyagi, P.K., Singh, K., Rao, V. and Kumar, A. (1996). Correlation and path coefficient analysis in Indian mustard (*Brassica juncea* L.). *Crop Res. Hisar*.**11**(3): 3 19-322.

Uddin, M.J., Chowdhury, M.A.Z. and Miah, M.F.U. (1995). Genetic variability, character association and path analysis in Indian mustard (*Brassica juncea* L.).*Ann. Bangiadesh Agric.* **5**(1): PP. 5 1-52.

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

Wan, Y.L. and Hu, G.C. (1983). Studies on heritability, genetic correlations and genetic advances of the major characters in rape. *Chinese Oil Crops.* **1**: 1-7.

Whan, B.R., Knight, R. and Rathijen, A. (1982). Response to selection for grain yield and harvest index in F_2, F_3 and F_4 derived lines of wheat crosses. *Euphytica.* **31**: 139-150.

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

Yadava. A.K., Verma, A.K., Singh, D.N. and Singh, S.K. (1996). Path co-efficient analysis in Indian mustard (*Brassica juncea* L. Czern and Coss.) . *J. Res. Birsa. Agril. Univ.* **8**(2): 135-137.

Yadava, Y. P., Singh. H. and Singh. D.(1993). Gene action for seed yield and its attributes under research. Jndian.J. Genet. P1. Breed. 6(1): 168-172.

Yadava, C.K. (1983). Studies on genetics of yield and its components in Indian mustard *(Brassica juncea* L. Czern and Coss). Thesis Abst. **9**(2): 186-1 87.

Yadava, T.P., Yadav, A.K. and Singh, H. (1978). A concept of plant Ideotype in Indian mustard (*B. juncea* L. Czern and Coss). 5^{th} International Rapeseed Conf June. 1978: 7.

Yadava, T.P. (1973). Variability and correlation studies in *Brassica juncea L.* Czern and Coss. *.Madras . Agric. J.* 60: 1508-1511

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

Yin, J.C. (1989). Analysis on ecological, Physiological and production characteristics of high quality rapeseed cultivars. *Acta Agriculture, Shanghae.* **5**(4): pp. 25-32.

Zajac, T., Bieniek, J., Witkowiez, R. and Gierdziewicz, M. (1998). Individual share of field components in winter oilseed rape yield formation. *Akademia Rolniezaw Kraikowie, Poland.* **19**(2) : 4 13-422.

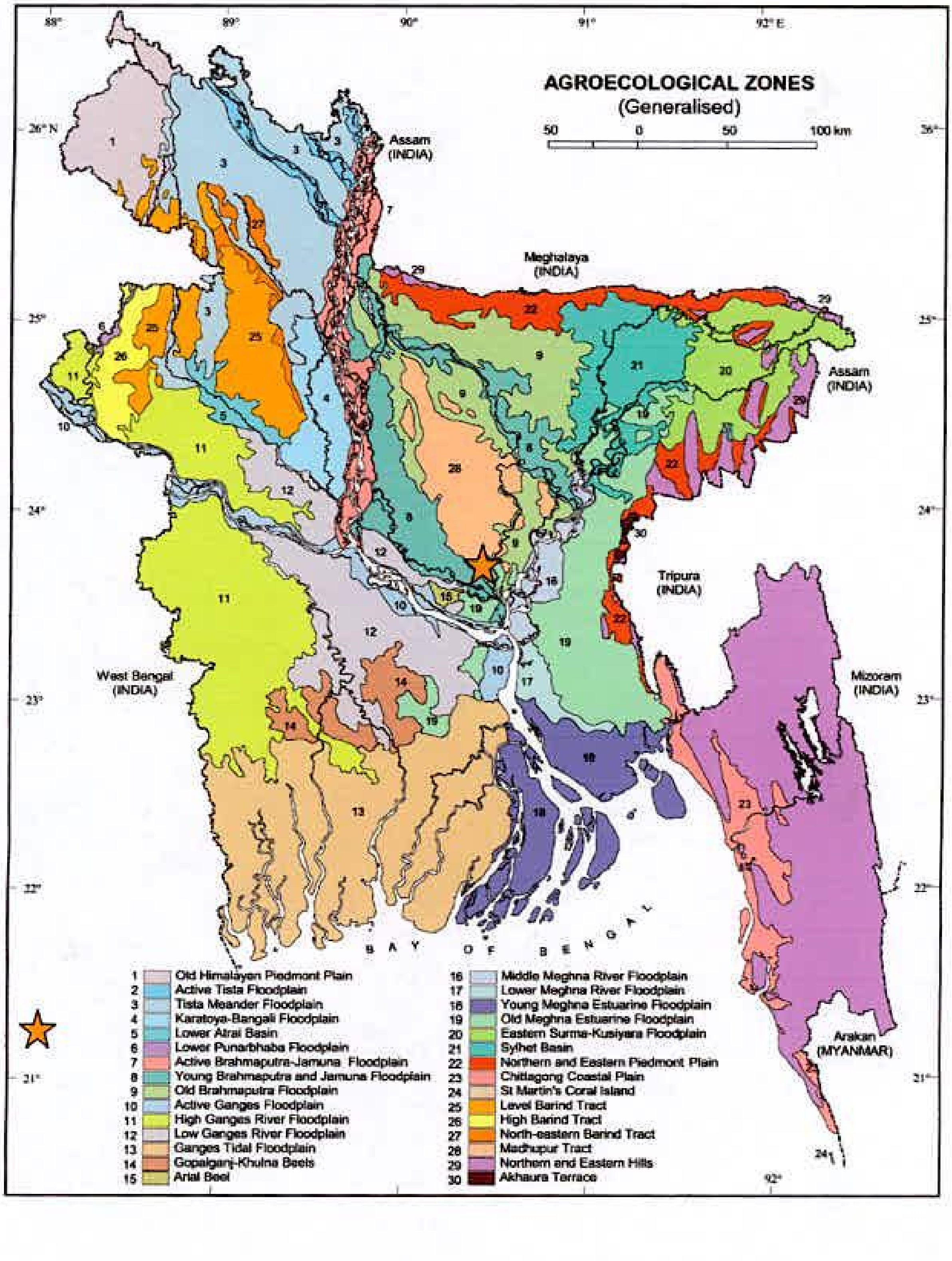
Zaman, M.W., Talukder, M.Z.I., Biswas, K.P. and Au, M.M. (1992). Development allometry and its implication to seed yield in *Brassica napus* L. Sveriges Utsades foreign Tidskrift. **102**(2): 68-71.

Zuberi, M.I. and Ahmed, S.V. (1973). Genetic study on yield and some of its components in *Brassica campestris* var. toria. *Crop. Sci.* **13**: 13-15.

Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

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

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall of the experimental site during the period from October, 2010 to March, 2011

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2010	34.8	18.0	77	227	5.8
November, 2010	32.3	16.3	69	0	7.9
December, 2010	29.0	13.0	79	0	3.9
January, 2011	28.1	11.1	72	1	5.7
February, 2011	33.9	12.2	55	1	8.7
March, 2011	34.6	16.5	67	45	7.3
April, 2011	35.8	20.3	65	88	8.3

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