GENETIC ANALYSIS IN F_3 POPULATIONS OF INDIAN MUSTARD [*Brassica juncea* (L.) Czern & Coss.]

THESIS

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Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior

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AGRICULTURE
(PLANT BREEDING & GENETICS)

By

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CERTIFICATE – I

This is to certify that the thesis entitled **"Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss.]"** submitted in partial fulfilment of the requirement of the degree of **Master of Science in Agriculture (Plant Breeding & Genetics)** of the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** is a record of the bonafide research work carried out by **Shri Samrath Maida** under my guidance and supervision. The subject of the thesis has been approved by Students Advisory Committee and the Director of Instruction.

No part of the thesis has been submitted for any degree or diploma (Certificate/award etc.) or has been published. All the assistance and help received during the course of investigations have been duly acknowledged by him.

Place : Gwalior
Date :

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Thesis approved by the students advisory committee

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Member	**Dr. A.K. Singh**
Member	**Shri Y.M. Indapurkar**
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Member	**Dr. V.B. Singh**

CERTIFICATE – II

This is to certify that the thesis entitled **"Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss.]"** submitted by **Shri Samrath Maida** to the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** in partial fulfilment of the requirements for the degree of **M.Sc. (Ag.)** in the **Department of Plant Breeding & Genetics, College of Agriculture, Gwalior,** has after evaluation, been approved by the external examiner and by the Students Advisory Committee after an oral examination of same.

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Dean of the collage (Dr. Asha Arora): ………………………………

Director Instruction (Dr. B.S. Baghel):…………………………………..

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Place: Gwalior

Date: (**Samarath Maida)**

List of Contents

List of Tables

CHAPTER- I
INTRODUCTION

Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is one of the most important oilseed crops belonging to the Cruciferae (Brassicaceae) family, commonly known as the mustard family. It is self pollinated crop up to 30% out-crossing does occur under natural field conditions, depending upon wind and bee activities (Rakow and Wood 1987).

Its seed contain nutritional value *viz*., Carbohydrates 4.51 g, Sugar 1.41 g, Dietary fiber 2 g, Fat 0.47 g and Protein 2.56 g per 100 g. The oil content varies from 37 to 49% (Bhowmik *et el*., 2014). It is mainly grown for oil usage in India and presently gaining importance in Canada and USA as an alternative to rapeseed i.e. *B. napus*. It is also grown as a spice crop in North America. In India it is grown in 63.40 Lakh ha area with an annual production of about 78.20 Lakh tones. The average productivity of mustard is approximately 1233.40 kg/ha. In Madhya Pradesh the area under mustard is about 8.00 Lakh ha which produces seed yield approximately 11.40 Lakh tones annually and productivity is approximately 1425 kg/ha (FAO STAT 2013-14).

Genetic variability is a key of any crop improvement programme and it is utmost important to the effectiveness of selection for desired trait. Selection of high yielding genotype with broad genetic base is essential to increase the production both locally and globally. Good combinations of various plant characters are essential for enhancing the yield. Therefore, keeping in view of above facts, the present investigation was undertaken to select the ideal plants from the segregating generation of mustard with the following objectives:

1. To estimate genetic variability, heritability and expected genetic advance for yield and its component characters.
2. To find out genotypic and phenotypic co-variance, co-heritability for yield and its component traits.
3. To work out correlation coefficient and its partition into cause and effects through path coefficient analysis.

CHAPTER- II
REVIEW OF LITERATURE

The relevant literatures related to various aspects of present study are reviewed under the following heads.

1. Variability analysis
2. Heritability and genetic advance
3. Correlation coefficients
4. Path coefficient analysis

Variability:

Singh *et al.* (1979) observed significant differences among the varieties for days to 50% flowering, plant height, primary branches per plant, secondary branches per plant, siliquae per plant, seed number per siliquae, length of siliqua, yield per plant, 1000 seed weight and days to maturity.

Labana *et al.* (1980) reported significant variation among mutants for seed yield, number of secondary branches, seed yield per plant and number of seeds per siliqua.

Singh (1986) reported that number of secondary branches had the greatest genetic variability followed by seed yield per plant, number of siliquae per plant and 1000 seed weight in *Brassica* juncea.

Uddin *et al.* (1995) reported considerable genotypic and phenotypic coefficients of variation for 1000 seed weight, seed yield per plant, primary branches per plant and siliqua per plant.

Singh *et al.* (1997) reported high genotypic and phenotypic coefficients of variation for siliquae per plant and seed yield.

Das *et al.* (1998) observed high estimates of genotypic and phenotypic coefficients of variation for siliquae per plant and number of secondary branches per plant.

Hussain *et al.* (1998) reported that number of secondary branches, number of seeds per siliqua showed the highest phenotypic and genotypic coefficient of variation values.

Lekh *et al.* (1998) reported highest genotypic coefficient of variation for secondary branches and high genotypic and phenotypic coefficient of variation for days to 50% flowering.

Mondal and Khajuria (2000) reported that days to maturity and 1000-grain weight showed moderate to high genotypic coefficient of variation.

Ghosh and Gulati (2001) reported that the genotypic and phenotypic coefficient of variability were high in magnitude for primary branches, secondary branches, number of siliquae per plant, seed per siliqua, days to 50% flowering and days to maturity. The difference between the phenotypic and genotypic coefficients were narrow for all the character studied.

Mahla *et al.* (2003) reported significant coefficient of variation for plant height, number of branches per plant, number of seed on main branch, number of seeds per siliqua, yield per plant, test weight, days to flowering and number of days to maturity among the genotypes. The phenotypic coefficient of variation was slightly high than genetic coefficient of variation.

Singh *et al.* (2003) reported highly significant varietal differences for plant height, days to 50% flowering, siliquae per plant, seeds per siliqua, days to maturity, 100 seed weight and seed yield per plot. The coefficient of gentotypic and phenotypic variations were highest for 1000 seed weight and was medium for days to maturity.

Gupta (2005) in *Brassica napus* observed highly significant differences among the genotypes for seed yield per plant, primary branches and secondary branches per plant and number of seed per pod. All these traits were highly influenced by environment as revealed by phenotypic and genotypic coefficient of variation.

Kumar (2013) observed significant differences for all the quality characters. The environmental effects were significant for erucic and oleic acid content and the influence of environmental factors appeared to be less on other characters. The coefficients of variation at phenotypic level varied from 4.6% for oil content to 50.9% for oleic acid. The genotypic coefficients of variability were high for oleic, palmitic +

stearic, erucic and linolenic acid, erucic acid and palmitic acid + stearic acid had the least genotypic variation (GCV: 16.3 to 16.9%).

Heritability and genetic advance:

Singh *et al.* (1975) reported that estimates of heritability were higher for days to flowering, plant height and number of secondary branches.

Labana *et al.* (1980) reported high heritability estimated for plant height, number of seeds per siliqua and seed yield per plant.

Bang *et al.* (1986) observed high heritability (broad sense) estimates for flowering time and seed yield. Heritability estimates for plant height, and total number of branches were moderately high.

Kumar and Sangwan (1994) noted high levels of genetic advance and broad sense heritability and recommended that yield improvement was possible through selection for yield per plant, siliquae per plant, number of secondary branches and 1000-seed weight.

Uddin *et al.* (1995) reported high heritability values for 1000 seed weight and moderate for the other characters except branches per plant. Thousand seed weight and siliqua per plant had high values for genetic advance.

Singh *et al.* (1997) reported high heritability estimates for siliquae per plant and seed yield. Genetic advance was high for plant height, siliquae per plant and seed yield.

Das *et al.* (1998) reported high heritability coupled with genetic advance for siliquae per plant, number of secondary branches per plant, 100 seed weight and plant height indicating predominance of additive gene action in inheritance of these traits.

Hussain *et al.* (1998) reported that number of secondary branches, plant height, 1000 seed weight and number of seeds per siliqua showed high estimates of heritability and gentic advance.

Lekh *et al.* (1998) reported high heritability estimates for 50% flowering, days to maturity, plant height, seed yield per plant, number of branches per plant under all environment. Highest genetic advance was recorded for days to 50% flowering.

Mondal and Khajuria (2000) reported that days to maturity and 1000-grain weight showed high heritability and genetic advance.

Ghosh and Gulati (2001) reported high heritability coupled with genetic advance for number of primary branches and number of seeds per siliqua. This suggested presence of additive gene action and improvement could be brought about by phenotypic selection.

Prasad *et al.* (2001) reported high heritability in narrow sense for days to flowering, days to maturity, length of main raceme and test weight. The genetic advance was also high for days to flowering, length of main raceme, number of secondary branches and yield. Low to medium estimates of expected genetic advance were noted for days to maturity, test weight and oil content.

Swarnkar *et al.* (2002) reported moderate heritability with low genetic advance in majority of characters indicating the effect of non-additive gene action.

Ghosh and Gulati (2001) recorded high heritability coupled with high genetic advance for yield per plant, test weight, number of siliquae on main branch and number of branches per plant, indicating that the heritability of these traits is attributed to additive gene effects. High heritability among with medium to low genetic advance was recorded for plant height, length of main branch and number of days to flowering, indicating the presence of non-additive gene action.

Singh *et al.* (2003a) observed high heritability for oil content, 1000 seed weight, plant height and seed yield per plant, whereas low heritability was recorded for the number of branches per plant. High genetic advance was observed for seed yield per plant and 1000 seed weight

Singh *et al.* (2003b) obtained highest genetic advance with 1000 seed weight, followed by seed yield per plot, days to 50% flowering and siliquae per plant.

Kumar (2013) reported that the heritability in broad-sense was relatively high for oleic (61.5%) and erucic acid (56.3%). The high heritability was associated with high genetic advance only for oleic acid suggesting the role of additive gene action in the inheritance of this character.

Singh *et al*. (2013) observed higher magnitude of heritability coupled with higher genetic advance expressed as percentage of mean for number of secondary branches/plant and seed yield/plant.

Correlation:

Singh *et al.* (1979) found that yield was closely associated with number of primary branches, number of secondary branches, days to flowering and plant height in Indian mustard.

Reddy (1991) reported that seed yield was positively and significantly correlated with primary and secondary branches per plant, siliquae per plant and seeds per siliqua.

Arthamwar *et al.* (1995) reported that weight of siliquae per plant showed the highest correlation with seed yield followed by number of siliquae per plant, number of seeds per siliqua and 1000 seed weight.

Uddin *et al.* (1995) reported that seed yield per plant had high positive and significant correlations with plant height, primary branches per plant and 1000 seed weight, but high negative and significant correlations with seeds per siliqua at both the genotypic and phenotypic levels.

Singh *et al.* (1997) reported that seed yield was significantly and positively associated with branches per plant, siliquae per plant, seeds per siliqua and 1000-seed weight.

Das *et al.* (1998) reported that high positive genotypic correlations were exhibited by siliqua length and seeds per siliqua with seed yield per plant.

Khulbe and Pant (1999) reported that siliquae per plant, siliqua length, seeds per siliqua, 1000 seed weight and harvest index were positively associated with grain yield.

Karkoo *et al.* (2000) reported that seed yield had highly significant positive correlations with seed weight and secondary branch number.

Larik and Rajput (2000) reported that seed yield per plant had strong positive association with plant height, branches per plant, siliqua per plant, seeds per siliqua and dry matter per plant.

Shalini *et al.* (2000a) observed that the number of siliqua, number of secondary branches, number of primary branches, seeds per siliqua and plant height were highly associated with seed yield.

Ghosh and Gulati (2001) reported that seed yield exhibited significant positive association with days to 50% flowering, days to maturity, plant height and number of secondary branches. These components in turn, exhibited significant positive correlation with each other. The results indicated that selection for one of these characters might automatically combine the other variables those appeared to be the most important selection criteria for increasing seed yield in Indian mustard.

Shah *et al.* (2002) reported from study of F_4 progenies of Indian mustard that number of siliquae per plant, days to 50% flowering, number of primary and secondary branches, plant height and number of seed per siliquae had strong positive and significant correlation with yield at genotypic as well as phenotypic levels.

Mahla *et al.* (2003) reported that yield per plant was positively correlated with number of branches per plant, number of siliquae on main branch, plant height and number of seeds per siliqua. The genotypic correlation was greater than the phenotypic correlation.

Singh *et al.* (2003a) found that seed yield had significant positive association with number of days to flowering, number of primary and secondary branches per plant, number of siliqua on the main fruiting branch, plant height, number of days to maturity and number of seed per siliqua. They observed no association between seed yield and 1000-seed weight.

Sudan *et al.* (2004) reported that seed yield had significant and positive correlation with number of primary branches per plant, number of secondary branches per plant and 1000 seed weight.

Dastidar and Patra (2004) reported that due to the presence of a strong positive correlation between plant height, number of primary branches per plant, number of secondary branches per plant and number of siliquae per plant, selection for any of these 4 characters is likely to generate a correlated response over the remaining 3 characters. They further reported that due to the presence of a strong positive correlation between the number of siliquae per plant and seed yield, indirect selection for any of these characters might lead to a correlated response on seed yield.

Gupta (2005) reported that seed yield of gobhi sarson was significantly and positively correlated with primary branches, secondary branches and plant height.

Gangapur *et al.* (2009) reported on the basis of correlation study that seed yield per metre was highly and significantly correlated with seed yield per plant, number of siliquae per plant, number of primary and secondary branches per plant, biological yield per plant, 1000-seed weight, number of seeds per siliqua at both genotypic and phenotypic levels in protected and unprotected conditions.

Belete (2011) reported on the basis of correlation study that seed yield per plot was positively correlated with number of seeds per pod, number of seeds per plant and oil yield per plot.

Mekonnen *et al.* (2013) observed positive and significant correlation of seed yield per plot with oil yield per plot, biomass per plot, plant height, days to maturity, grain-filling period, and secondary branches per plant and 1000-seed weight at both genotypic and phenotypic levels. However, it was negatively correlated with days to flowering, number of pod per plant, number of seeds per pod and pod length at phenotypic level and, with primary branches per plant and harvest index at genotypic level, and oil content negatively correlated with at both levels.

Path analysis:

Arthamwar *et al.* (1995) found that the order of contribution of plant characters to yield was in the order weight of siliquae per plant, 1000 seed weight, number of siliquae per plant and number of seeds per siliqua.

Ramani *et al.* (1995) reported that number of primary branches per plant had the most direct positive effect on yield followed by the number of secondary branches per plant.

Uddin *et al.* (1995) reported that seeds per siliqua, 1000 seed weight and primary branches per plant had high positive direct effects on seed yield per plant. Days to maturity and plant height had considerable negative direct effects on seed yield per plant.

Tyagi *et al.* (1996) found that plant height, siliqua per plant, siliquae length, seed weight per siliqua and seed yield per plant had positive effects on yield.

Yadav *et al.* (1996) reported that number of siliquae per plant had the highest positive direct effect on seed yield per plot.

Singh *et al.* (1997) observed that siliquae per plant, seeds per siliqua and 1000-seed weight had the highest positive direct effect on seed yield.

Khulbe and Pant (1999) reported that harvest index, siliquae per plant, siliqua length, 1000 seed weight, seeds per siliqua and days to initial flowering were the major characters influencing the grain yield directly and indirectly. They recommended harvest index and siliquae per plant as selection criterion for yield improvement.

Patel *et al.* (1999) reported that siliquae per plant, primary branches per plant and plant height were greatest contributors to seed yield.

Karkoo *et al.* (2000) reported that seed weight, secondary branch number, primary branch number and siliquae on the main shoot had direct positive contributions towards seed yield.

Mondal and Khajuria (2000) reported that days to maturity and 1000-grain weight had positive direct effect on yield but indirect effects via siliquae per plant and seeds per siliqua varied over the period of study.

Shalini *et al.* (2000a) reported 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. They suggested that the characters number of siliqua and number of secondary branches, should be given emphasis for the improvement of Indian mustard yield by selection.

Pant *et al.* (2002) reported that seed yield was positively correlated with days to flower, plant height, number of primary and secondary branches and number of siliqaue on main raceme at the genotypic level, but was negatively correlated with siliqua length and 1000 seed weight. Days to flowering was positively associated with plant height and number of secondary branches at genotypic and phenotypic levels. Number of primary branches showed significant and positive association with number of secondary branches. The major yield contributing characters which consisted of days to flowering, plant height, number of primary and secondary branches, number of siliquae on main raceme, 100 seed weight and oil content may be used for developing cultivars with high yield potential.

Jankowski and Budzynski (2003) reported that yield of white mustard was mainly determined by number of siliquae per plant.

Mahla *et al.* (2003) reported that number of branches per plant had the greatest direct and indirect effects on grain yield.

Singh *et al.* (2003b) found that number of secondary branches per plant, number of siliquae on main fruiting branch and number of days to maturity had direct positive effects on seed yield.

Sudan *et al.* (2004) reported that number of primary branches was the most important character with the highest direct effect on seed yield. Other characters i.e. days to flowering, 1000 seed weight and number of seed per siliqua had high positive effect via other characters.

Dastidar and Patra (2004) reported that with the slight delay in flowering and maturity, the biological yield increased with the increase in the number of pods, resulting in high seed yield.

Gupta (2005) reported that primary branches, secondary branches and pod length were the most reliable indices of yield.

Verma and Mahto (2005) reported that days to 50% flowering had the highest positive direct effect on seed yield per plant followed by for number of siliquae per plant, plant height and number of primary branches per plant at the genotypic level. The residual effects were 0.4730 and 0.4185 for phenotypic and genotypic levels, respectively.

Khulbe and Pant (2007) reported that harvest index, siliquae per plant, siliqua length, 1000-seed weight, seeds per siliqua and days to initial flowering were the major characters influencing grain yield directly and indirectly. The role of oil content was negligible. On the basis of the results, harvest index and siliquae per plant are recommended as selection criteria for yield improvement.

Gangapur *et al.* (2009) found on the basis of path coefficient analysis of eleven yield contributing characters that number of siliquae per plant had highest positive direct effect on seed yield in both protected and unprotected conditions even though number of primary branches per plant and number of secondary branches per plant, biological yield per plant, harvest index indicated positive direct effects in descending order and other characters contributed indirectly towards seed yield. The present study has clearly indicated the need for giving due weightage for number of siliquae per plant, number of secondary branches per plant, harvest index and biological yield per plant for improving seed yield in mustard.

Belete (2011) reported that number of seeds per plant was the most important component for improvement of the seed and oil yield of Ethiopian mustard genotypes.

Mekonnen *et al.* (2013) reported on the basis of phenotypic and genotypic path coefficient analysis that harvest index had exerted positive direct effect on seed yield. Grain filling period and harvest index had exerted positive direct effect on oil content at genotypic level. Day to maturity, grain filling period, secondary branches per plant, harvest index and seed yield seed yield per plot had exerted negative effect on oil content at phenotypic level.

Singh *et al.* (2013) reported that number of secondary branches/plant, number of siliquae on main shoot and total siliquae/plant had positive and direct effect on seed yield/plant, indicating that indirect selection for these traits in early generations would be effective in improving seed yield. The result suggested that high yielding progenies could be selected in further generations, if selection is practiced for more number of secondary branches/plant, higher number of siliqua on main shoot and total siliquae/plant.

Hasan *et al*. (2014) carried out research to determine the best selection criteria for yield improvement in rapeseed. Nine genotypes of *Brassica napus* were sown at Oilseeds Research Institute, Faisalabad, to evaluate path analysis for yield and various yield components. Path coefficient revealed that the seeds/siliqua, 1000 seed weight, days to flowering, days to maturity and seeds/plant had direct positive contribution towards seed yield per plant. For rapeseed breeding seed per plant was the variable with maximum potential of selection for seed yield improvement because this trait possessed maximum positive direct effects with yield.

Shweta and Prakash (2014) reported that siliquae per plant exhibited the highest positive direct effect on seed yield followed by 1000 seed weight, seeds per siliqua, number of primary branches per plant, days to 50 per cent flowering, days to maturity and plant height. Considering both, the correlation coefficients and path coefficients together, siliquae per plant, 1000 seed weight, seeds per siliqua, number of primary branches per plant and plant height emerged as important components of seed yield which should be given due importance during indirect selection criteria.

CHAPTER-III

MATERIALS AND METHODS

The present investigation entitled "Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss.]", was carried out during Rabi of 2014-15 at Research Farm, ZARS, Morena (M.P.), which is situated between latitude 25º 15' to 26º 45' N and longitude 70º 30' to 76º 22' E and at an altitude of 150 to 240 metres above the mean sea level. This chapter comprises the details about the materials used and the methods adopted during the course of investigation.

Experimental material:

The experimental material consisted of 18 F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss.]". The pedigree/sources are cited in Table 1.

Table 1: F_3 populations of Indian mustard (*Brassica juncea*)

S. No.	Entries	S. No.	Entries
1	RVM1 × Kranti	10	JM 2 × Divya 33
2	RVM1 × B 85	11	JM 2 × JD 6
3	RVM1 × NDRE 4	12	JM 2 × SeJ 2
4	RVM1 × Divya 33	13	JM 3 × Kranti
5	RVM1 × JD 6	14	JM 3 × B 85
6	RVM1 × SeJ 2	15	JM 3 × NDRE 4
7	JM 2 × Kranti	16	JM 3 × Divya 33
8	JM 2 × B 85	17	JM 3 × JD 6
9	JM 2 × NDRE 4	18	JM 3 × SeJ 2

Experimental Details:

Experiments were conducted in randomized complete block design with 3 replications. Every entry had a five rows plot each of five metres length with row to row spacing of 30 cm. The sowing of experiment was done on 7th November, 2014 in rows with spacing of 30 cm apart and 4-6 cm within row. The Recommended packages of practices were adopted for optimum crop growth. The fertilizer was applied at the dose of 60:30:30 kg NPK /ha

Observations recorded:

Observations were recorded on, plot as well as single plant basis. Five competitive plants were selected randomly and tagged from each genotype in all replications for the purpose of recording observations. Observations on plot basis were recorded for days to 50% flowering and oil content.. Average of five plants in respect of plant height, number of primary branches per plant, number of secondary branches per plant, number of siliqua per plant, number of seeds per siliqua, 1000-seed weight, length of siliqua and seed yield per plant were used for statistical analysis. The observations were recorded on the following characters.

1) Days to 50% flowering:

Number of days from the date of sowing to the date when 50% plants flowered in a plot was recorded as days to 50% flowering.

2) Number of primary branches per plant:

The branches arising from the main stem were counted from each of the selected plants of each genotype in each replication at maturity.

3) Number of secondary branches:

Number of secondary branches emerged from primary branches were counted from each of the selected plants of each genotype in each replication at maturity.

4) Number of siliquae per plant:

All the siliquae present on the primary and secondary branches, which were full of seeds, were counted from each of the selected plants of each genotype in each replication at maturity.

5) Siliqua length (cm)

Length of siliqua was measured from base to the top of randomly selected ten siliquae of each selected plant of each genotype.

6) Plant height (cm):

At maturity plant height of all the tagged plants was measured in centimeters from the ground level to the top of the main axis including inflorescence with the help of the meter rod.

7) Days to maturity:

The total numbers of days to physiological maturity were counted from the date of sowing up to full maturity of the plants of each genotype in each replication.

8) Seeds per siliqua:

Seeds per siliqua were counted from the same randomly selected ten siliquae of each selected plant of each genotype, used for measuring siliqua length.

9) 1000-seed weight (g):

1000-seed weight was taken in grams from each tagged plant of each genotype in each replication.

10) Seed yield per plant (g):

At maturity, all the selected plants of each genotype in each replication were harvested collectively and the seed yield per plant was calculated by averaging the total seed yield obtained by all the five selected plants.

Statistical procedures:

1. Analysis of variance and covariance:

The data on various crop characters were subjected to statistical analysis by using appropriate method of analysis of variance and covariance as described by Panse and Sukhatme (1954). The range and estimates of mean, phenotypic, genotypic and environmental variance and covariance, standard error, coefficient of variation and critical difference were obtained for all the 10 traits. The significance of difference between entries for various characters was tested.

2. Estimation of phenotypic and genotypic coefficients of variation:

The phenotypic and genotypic coefficients of variation in per cent were computed by the following formulae given by Burton (1952).

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\text{Phenotypic standard deviation}}{\text{Mean}} \times 100$$

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\text{Genotypic standard deviation}}{\text{Mean}} \times 100$$

3. Estimation of heritability and genetic advance:

Heritability:

Heritability in per cent in broad sense was estimated by the following formula given by Singh and Choudhary (1977):

$$\text{Heritability } (h^2) = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

Genetic advance:

The estimates of expected genetic advance from selection, G(s), was obtained by the formula suggested by Robinson, Comstock, and Harvey (1949).

$G(s) = k \times h^2 \times \sigma p$

where,

k = Selection differential in standard deviation units which is 2.06 for 5% selection intensity,

h^2 = Heritability in broad sense, and

σ_p = Phenotypic standard deviation

4. Estimation of co-heritability:

Estimates of co-heritability in per cent were obtained by the following formula given by Bedrad et al. (1971).

$ch_{ij} = h_i \times h_j \times rg_{ij}$

where,

ch_{ij} = Co-heritability between the i^{th} and j^{th} characters,

h_i = Square root of the heritability of the i^{th} character,

h_j = Square root of the heritability of the j^{th} character, and

rg_{ij} = Genotypic correlation coefficient between i^{th} and j^{th} characters

5. Estimation of correlations:

Phenotypic, genotypic and environmental correlation coefficients between characters were computed utilizing respective components of variance and co-variance, by following formula suggested by Miller *et al.* (1958).

$$r_{xy} = \frac{\text{Cov}(x, y)}{\sqrt{V(x) \times V(y)}}$$

where,

r_{xy} = Correlation coefficient between character x and y,

Cov (x, y) = Co-variance of character x and y, V (x) = Variance of character x, and

V (y) = Variance of character y.

To test the significance of correlation coefficients, the estimated values were compared with the tabulated values of Fisher and Yates (1938) at n-2 d.f. at two levels of probability, viz., 5% and 1%.

6. Path coefficient analysis:

The proportion of direct and indirect contributions of various characteristics to the total correlation coefficients with grain yield was estimated through path coefficient analysis as suggested by Wright (1921, 1934) and elaborated by Dewey and Lu (1959).

Path coefficient is a standardized partial regression, which measures the direct influence of one variable upon another and allows partition of correlation coefficient into components of direct and indirect effects.

To estimate various direct and indirect effects, the following set of simultaneous equations were formed and solved.

$r_{1y} = P_{1y} + r_{12}P_{2y} + r_{13}P_{3y} + \ldots + r_{1l}P_{ly}$

$r_{2y} = r_{2y}P_{1y} + P_{2y} + r_{23}P_{3y} + \ldots + r_{2l}P_{ly}$

.

.

.

$r_{ly} = r_{l1}P_{1y} + r_{l2}P_{2y} + r_{l3}P_{3y} + \ldots + P_{ly}$

where,

r_{1y} to r_{ly} = Coefficient of correlation between causal factor 1 to l and dependent character y,

r_{12} to $r_{l-1,l}$ = Coefficient of correlation among causal factors themselves, and

P_{1y} to P_{ly} = Direct effects of characters 1 to l on character y.

Residual effect, which measures the contribution of the characters not considered in the causal scheme, was obtained as:

Residual effect (P_{RY}) = $\sqrt{1 - R^2}$

where, $$R^2 = \sum_{iy} P_i^2 Y + 2 \sum_{\substack{i \neq j \\ i > j}} P_{iy}\, P_{jy}\, R_{ij}$$

CHAPTER-IV

RESULTS

In this chapter experimental results of the present study are presented under the following headings:

(A) Univariate analysis:

1. Analysis of variance
2. Population mean and range
3. Phenotypic and genotypic coefficients of variation
4. Heritability
5. Genetic advance
6. Co-heritability

(B) Association analysis:

1. Correlation coefficients estimates
2. Path analysis

(A) Univariate analysis:

1. Analysis of variance:

The data for all the 10 traits were analysed for different sources of variation for RBD and reported in Table 4.1. The analysis of variance revealed that component of variance for treatment was significant at 1% level of probability in respect of all the characters except number of seeds per siliqua. Highly significant differences between genotypes indicated existence of large variability among F_3 populations for these characters under study.

2. Mean and range:

The values of range and estimates of means for different characters are presented in Table 4.2. The values of range revealed wide variability for each character among lines. The distribution of variation was almost uniform on both sides of the means obtained for each character indicating normal distribution of the lines (Appendix-I).

Table 4.1: Mean squares and their significance from analysis of variance of different plant traits in Indian mustard

S. No	Characters	Mean squares		
		Replication df=2	Genotype df=17	Error df=34
1	Days to 50% flowering	12.5703	30.2439**	4.8684
2	No. of primary branches /plant	0.0096	0.6067**	0.1555
3	No. of secondary branches / plant	0.1926	21.9640**	0.2053
4	No. of siliquae/ Plant	370.3750	7635.2940**	90.6618
5	Length of siliqua	0.0052	0.1589**	0.0326
6	Plant height	67.4375	971.5270**	52.5967
7	Days to maturity	7.1562	80.5588**	3.4026
8	No. of seeds/ siliqua	19.4761	3.7400	2.5218
9	**1000 seed weight**	0.2407	0.7886**	0.2183
10	Seed yield per plant	2.0313	467.4868**	8.5787

**** - significant at p=0.01**

The range for days to 50% flowering was from 58.00 to 69.33 days, for number of primary branches per plant from 4.70 to 6.47, for number of secondary branches per plant from 7.40 to 19.13, for number of siliquae per plant from 131.80 to 317.00, for length of siliqua from 3.07 to 3.87 cm, for plant height from 171.43 to 233.93 cm, for days to maturity from 114 to 130 days, for number of seeds per siliqua from 11.27 to 16.00, for 1000 seed weight from 2.42 to 4.35 g and for seed yield per plant from 36.78 to 75.71 g.

3. Coefficient of variation:

The characters showing wide range and high coefficient of variation (CV) would provide more opportunities for selection of better genotypes. Estimates of phenotypic coefficient of variation (PCV) and genotypic coefficients of variation (GCV) were worked out and are presented in Table 4.2.

The highest PCV was recorded for number of secondary branches per plant, 26.38%, followed by seed yield per plant and number of siliquae per plant while moderate PCV was noticed for 1000 seed weight and number of seeds per siliqua. However, low PCV was observed for days to maturity, 4.41%, followed by days to 50% flowering, length of siliqua, plant height and number of primary branches per plant; the values being 5.81, 7.84, 9.75 and 9.90 per cent, respectively.

The highest GCV was observed for number of secondary branches per plant, 26.01%, which was followed by seed yield per plant and number of siliquae per plant and moderate GCV was recorded for 1000 seed weight, 12.95%. rest of the characters recorded low GCV estimates.

4. Heritability:

The degree of success in selection programmes depends primarily on the magnitude of heritable variation. High heritability estimates (Table 4.2) were recorded for number of secondary branches per plant (97.2%), number of siliquae per plant (96.5%), seed yield per plant (94.7%), days to maturity (88.3%), plant height (85.3%) and days to 50% flowering (63.5%). Moderate heritability estimates were recorded for length of siliqua (56.3%), number of primary branches per plant (49.2%) and 1000 seed weight (46.6%). Relatively low (13.9%) heritability was recorded for number of seeds per siliqua.

5. Genetic advance:

The estimates of expected genetic advance expressed as percentage of mean (Table-4.2) was highest for number of secondary branches per plant (52.85%) followed by seed yield per plant and number of siliquae per plant. It is moderate for 1000 seed weight (18.10%), plant height and number of primary branches per plant. Number of seeds per siliqua (3.39%), days to 50% flowering (7.59%), days to maturity (8.02%) and length of siliqua (9.17%) showed relatively lower estimates.

6. Co-heritability:

The estimates of co-heritability are presented in Table 4.3.

(a) Co-heritability with grain yield:

High co-heritability with seed yield per plant was exhibited by number of siliquae per plant (73.47%), followed by number of secondary branches per plant (67.55%), number of primary branches per plant (33.55%), plant height (28.27%), days to maturity (24.33%) and 1000 seed weight (17.70%). However, low co-heritability (5.05%) was observed for days to 50% flowering.

Co-heritability among yield components:

Days to 50% flowering showed highest (46.65%) co-heritability with days to maturity followed by 1000 seed weight, number of secondary branches per plant and plant height.

Number of primary branches per plant showed highest co-heritability (29.55%) with number of secondary branches per plant, followed by number of siliquae per plant, length of siliqua and 1000 seed weight.

Number of secondary branches per plant showed highest co-heritability (54.47%) with plant height followed by number of siliquae per plant, days to maturity, number of primary branches per plant, length of siliqua and 1000 seed weight..

Number of siliquae per plant showed highest co-heritability (51.96%) with number of secondary branches per plant followed by number of primary branches per plant, plant height and days to maturity.

Length of siliqua showed highest co-heritability (31.74%) with plant height followed by number of secondary branches per plant.

Plant height showed highest co-heritability (54.47%) with number of secondary branches per plant followed by length of siliqua, days to maturity, number of siliquae per plant, number of primary branches per plant and days to 50% flowering.

Days to maturity showed highest co-heritability (46.65%) with days to 50% flowering followed by number of secondary branches per plant, plant height, 1000 seed weight and number of siliquae per plant.

1000 seed weight exhibited highest co-heritability (12.28%) with days to 50% flowering followed by days to maturity, number of secondary branches per plant and number of primary branches per plant.

Table 4.2: Estimates of various parameters of genetic variability for different traits in Indian mustard

S. No.	Characters	Mean	Range	PCV (%)	GCV (%)	Heritability (Broad sense) (%)	Genetic advance	Genetic advance as % of mean
1	Days to 50% flowering	62.85	58.00-69.33	5.81	4.63	63.50	4.77	7.59
2	No. of primary branches /plant	5.58	4.70-6.47	9.90	6.94	49.20	0.56	10.04
3	No. of secondary branches / plant	10.35	7.40-19.13	26.38	26.01	97.20	5.47	52.85
4	No. of siliquae/ Plant	251.63	131.80-317.00	20.29	19.93	96.50	101.49	40.33
5	Length of siliqua	3.49	3.07-3.87	7.84	5.88	56.30	0.32	9.17
6	Plant height	194.22	171.43-733.93	9.75	9.01	85.30	33.31	17.15
7	Days to maturity	122.50	114.00-130.00	4.41	4.14	88.30	9.82	8.02
8	No. of seeds/ siliqua	14.45	11.27-16.00	11.84	4.41	13.90	0.49	3.39
9	**1000 seed weight**	3.37	2.42-4.35	18.98	12.95	46.60	0.61	18.10
10	Seed yield per plant	52.47	36.78-75.71	24.23	23.57	94.70	24.79	47.25

Table 4.3: Estimates of co-heritability values (%) for different pairs of characters in Indian mustard.

Characters	No. of primary branches /plant	No. of secondary branches / plant	No. of siliquae/ Plant	Length of siliqua	Plant height	Days to Maturity	No. of seeds/ siliqua	1000 seed weight	Seed yield per plant
Days to 50% flowering	-13.28	9.07	0.86	-10.26	4.82	46.65	-4.93	12.28	5.05
No. of primary branches/plant		29.55	26.64	-2.94	6.63	-8.47	-0.90	5.25	33.55
No. of secondary branches/ plant			51.96	8.65	54.47	32.61	-7.67	5.44	67.56
No. of siliquae/ Plant				-23.25	10.45	7.92	-3.61	-4.00	73.47
Length of siliqua					31.74	-4.52	-5.21	-6.03	-6.61
Plant height						30.20	-9.44	-7.31	28.27
Days to maturity							-2.69	10.95	24.33
No. of seeds/ siliqua								-3.06	-6.32
1000 seed weight									17.70

(B) Association analysis:

1. Estimates of correlation coefficients:

Phenotypic, genotypic and environmental correlation coefficients between seed yield per plant and contributing characters and among contributing traits themselves were calculated and presented in Table 4.4, 4.4 and 4.5, respectively.

(i) **Correlation with seed yield per plant**:

(a) Phenotypic:

Table 4.4 reveled that seed yield per plant showed positive correlation with number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, plant height, days to maturity and 1000 seed weight. No correlation was observed with days to 50% flowering, length of siliqua and number of seeds per siliqua.

(b) Genotypic:

Table 4.5 showed that number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, plant height, days to maturity and 1000 seed weight had positive correlation while number of seeds per siliqua had negative correlation.

(c) Environmental:

Table 4.6 showed that days to 50% flowering, number of secondary branches per plant and plant height had positive correlation.

(ii) Correlation among yield attributes:

(a) Phenotypic:

Days to 50% flowering had positive correlation with days to maturity and 1000 seed weight while days to 50% flowering did not show correlation with any of the attributes.

Number of primary branches per plant showed positive correlation with number of secondary branches per plant and number of siliquae per plant.

Number of secondary branches per plant had positive correlation with number of primary branches per plant, number of siliquae per plant, plant height and days to maturity.

Number of siliquae per plant had positive correlation with number of primary branches per plant and number of secondary branches per plant.

Length of siliqua exhibited positive correlation with plant height.

Plant height showed positive correlation with number of secondary branches per plant, length of siliqua and days to maturity while negative with number of seeds per siliqua.

Days to maturity showed positive correlation with days to 50% flowering, number of secondary branches per plant and plant height.

Number of seeds per siliqua exhibited negative correlation with plant height.

1000 seed weight exhibited positive correlation with days to 50% flowering.

(b) Genotypic:

Days to 50% flowering showed positive correlation with days to maturity and 1000 seed weight and negative with number of primary branches per plant, length of siliqua and number of seeds per siliqua.

Number of primary branches per plant had positive correlation with number of secondary branches per plant and number of siliquae per plant while negative with days to 50% flowering.

Number of secondary branches per plant showed positive correlation with number of primary branches per plant, number of siliquae per plant, plant height and days to maturity and negative with number of seeds per siliqua.

Number of siliquae per plant showed positive correlation with number of primary branches per plant and number of secondary branches per plant and negative correlation with length of siliqua and number of seeds per siliqua.

Length of siliqua showed positive correlation with plant height and negative with days to 50% flowering, number of siliquae per plant and number of seeds per siliqua.

Plant height showed positive correlation with number of secondary branches per plant, length of siliqua and days to maturity and negative with number of seeds per siliqua.

Days to maturity showed positive correlation with days to 50% flowering, number of secondary branches per plant and plant height.

.Number of seeds per siliqua showed negative correlation with days to 50% flowering, number of secondary branches per plant, number of siliquae per plant, length of siliqua, plant height and 1000 seed weight.

1000 seed weight showed positive correlation with days to 50% flowering and negative with number of seeds per siliqua.

(c) Environmental:

Days to 50% flowering had positive correlation with number of secondary branches per plant, number of seeds per siliqua and 1000 seed weight.

Number of primary branches per plant showed positive correlation with days to maturity.

Number of secondary branches per plant had positive correlation with days to 50% flowering.

Number of siliquae per plant showed positive correlation with length of siliqua and 1000 seed weight while negative with days to maturity.

Length of siliqua had positive correlation with number of siliquae per plant, number of seeds per siliqua and 1000 seed weight.

Plant height did not have any correlation with other characters.

Days to maturity showed positive correlation with number of primary branches per plant and negative with number of siliquae per plant.

Number of seeds per siliqua had positive correlation with days to 50% flowering and length of siliqua.

1000 seed weight had positive correlation with days to 50% flowering, number of siliquae per plant and length of siliqua.

Table 4.4: Estimates of phenotypic correlation coefficients for 10 characters in Indian mustard

Characters	No. of primary branches /plant	No. of secondary branches / plant	No. of siliquae/ Plant	Length of siliqua	Plant height	Days to Maturity	No. of seeds/ siliqua	1000 seed weight	Seed yield per plant
Days to 50% flowering	-0.174	0.146	0.021	-0.084	0.117	0.677**	-0.015	0.353*	0.127
No. of primary branches/plant		0.431**	0.409*	0.043	0.153	-0.052	-0.098	0.116	0.494**
No. of secondary branches/ plant			0.536**	0.116	0.594**	0.366*	-0.237	0.099	0.724**
No. of siliquae/ Plant				-0.261	0.128	0.069	-0.074	-0.018	0.762**
Length of siliqua					0.524**	-0.097	0.096	0.024	-0.080
Plant height						0.320	-0.278	-0.059	0.339*
Days to maturity							-0.146	0.133	0.272
No. of seeds/ siliqua								-0.027	-0.174
1000 seed weight									0.311

* - Significant at p= 0.05 ** - Significant at p= 0.01

Table 4.5: Estimates of genotypic correlation coefficients for 10 characters in Indian mustard

Characters	No. of primary branches /plant	No. of secondary branches / plant	No. of siliquae/ Plant	Length of siliqua	Plant height	Days to Maturity	No. of seeds/ siliqua	1000 seed weight	Seed yield per plant
Days to 50% flowering	-0.425**	0.147	0.014	-0.287*	0.089	0.832**	-0.559**	0.415*	0.084
No. of primary branches/plant		0.618**	0.561**	-0.106	0.158	-0.195	-0.132	0.229	0.720**
No. of secondary branches/ plant			0.554**	0.158	0.657**	0.380*	-0.568**	0.120	0.734**
No. of siliquae/ Plant				-0.428**	0.127	0.093	-0.269*	-0.089	0.804**
Length of siliqua					0.661**	-0.091	-0.666**	-0.230	-0.124
Plant height						0.401*	-0.796**	-0.184	0.350*
Days to maturity							-0.219	0.266	0.291*
No. of seeds/ siliqua								-0.472**	-0.480**
1000 seed weight									0.401*

Table 4.6: Estimates of environmental correlation coefficients for 10 characters in Indian mustard

Characters	**No. of primary branches** /plant	**No. of secondary branches** / plant	**No. of siliquae/** Plant	Length of siliqua	Plant height	Days to Maturity	No. of seeds/ siliqua	1000 seed weight	Seed yield per plant
Days to 50% flowering	0.148	0.306*	0.086	0.219	0.219	0.261	0.269*	0.289*	0.446**
No. of primary branches/plant		0.036	0.174	0.211	0.185	0.316*	-0.097	0.013	0.017
No. of secondary branches/ plant			-0.024	-0.008	-0.067	0.241	-0.184	0.149	0.517**
No. of siliquae/ Plant				0.444**	0.176	-0.270*	0.141	0.305*	-0.172
Length of siliqua					0.260	-0.143	0.460**	0.293*	0.066
Plant height						-0.216	-0.012	0.204	0.275*
Days to maturity							-0.220	-0.151	0.080
No. of seeds/ siliqua								0.137	0.002
1000 seed weight									0.268*

*** - Significant at p= 0.05** **** - Significant at p= 0.01**

(2.) Path Analysis:

(a) Phenotypic:

Days to 50% flowering, length of siliqua and number of seeds per siliqua had negative but negligible direct contribution. Number of secondary branches per plant, number of siliquae per plant and 1000 seed weight showed considerable positive direct contribution (Table 4.7).

Number of primary branches per plant, plant height and days to maturity had negligible positive direct contribution.

(b) Genotypic:

Days to 50% flowering had substantial negative direct contribution and indirect positive contribution through days to maturity, 1000 seed weight and number of primary branches per plant (Table 4.8).

Number of primary branches per plant had substantial negative direct contribution. It had negative indirect contribution through days to maturity and positive through number of siliquae per plant, days to 50% flowering, 1000 seed weight and number of secondary branches per plant.

Number of secondary branches per plant had positive indirect contribution through number of siliquae per plant and days to maturity and negative *via* number of primary branches per plant and days to 50% flowering. However, its direct contribution was positive but not considerable.

Number of siliquae per plant showed substantial positive direct contribution. It had positive indirect contribution through number of secondary branches per plant and negative through number of primary branches per plant.

Length of siliqua showed positive but negligible direct contribution. However, it had positive indirect contribution *via* days to 50% flowering and negative through number of siliquae per plant and 1000 seed weight.

Plant height did not show direct contribution on seed yield per plant. However, Ii had indirect positive contribution through days to maturity, length of siliqua, number of siliquae per plant and number of secondary branches per plant and negative through 1000 seed weight.

Days to maturity showed considerable direct positive contribution. It had positive indirect contribution through 1000 seed weight, number of primary branches per plant and number of siliquae per plant while negative *via* days to 50% flowering.

Number of seeds per siliqua did not have direct contribution on seed yield per plant. However, Ii had indirect positive contribution through days to 50% flowering and negative through 1000 seed weight, number of siliquae per plant, days to maturity, length of siliqua and number of secondary branches per plant.

One thousand seed weight exhibited substantial direct positive contribution. It had indirect positive contribution through days to maturity and negative through days to 50% flowering, number of primary branches per plant and number of siliquae per plant.

Table 4.7: Phenotypic path coefficient of 9 yield components of yield in Indian mustard

Characters	Days to 50% flowering	No. of primary branches /plant	No. of secondary branches / plant	No. of siliqua/ plant	Length of siliqua	Plant height	Days to maturity	No. of seeds/ siliqua	1000 seed weight	Correlation with seed yield /plant
Days to 50% flowering	**-0.149**	-0.014	0.038	0.012	0.001	0.010	0.115	0.000	0.114	0.127
No. of primary branches/plant	0.026	**0.081**	0.111	0.234	-0.001	0.013	-0.009	0.000	0.037	0.494**
No. of secondary branches/ plant	-0.022	0.035	**0.258**	0.307	-0.002	0.052	0.062	0.001	0.032	0.724**
No. of siliquae/ Plant	-0.003	0.033	0.138	**0.572**	0.004	0.011	0.012	0.000	-0.006	0.762**
Length of siliqua	0.012	0.004	0.030	-0.149	**-0.014**	0.046	-0.016	0.000	0.008	-0.080
Plant height	-0.017	0.012	0.153	0.073	-0.007	**0.088**	0.054	0.001	-0.019	0.339*
Days to maturity	-0.101	-0.004	0.094	0.039	0.001	0.028	**0.170**	0.001	0.043	0.272
No. of seeds/ siliqua	0.002	-0.008	-0.061	-0.042	-0.001	-0.025	-0.025	**-0.005**	-0.009	-0.174
1000 seed weight	-0.053	0.009	0.026	-0.010	0.000	-0.005	0.023	0.000	**0.322**	0.311

Residual =0.1780 **Note:** Underlined values denote direct effect

Table 4.8: Genotypic path coefficient of 9 yield components of yield in Indian Mustard.

Characters	Days to 50% flowering	No. of primary branches /plant	No. of secondary branches / plant	No. of siliqua/ plant	Length of siliqua	Plant height	Days to maturity	No. of seeds/ siliqua	1000 seed weight	Correlation with seed yield /plant
Days to 50% flowering	**-1.090**	0.235	0.029	0.016	-0.063	0.000	0.568	0.009	0.380	0.084
No. of primary branches/plant	0.463	**-0.553**	0.121	0.634	-0.024	0.000	-0.133	0.002	0.210	0.720**
No. of secondary branches/ plant	-0.161	-0.342	**0.195**	0.627	0.035	-0.001	0.260	0.009	0.110	0.734**
No. of siliquae/ Plant	-0.016	-0.310	0.108	**1.131**	-0.095	0.000	0.064	0.004	-0.082	0.804**
Length of siliqua	0.313	0.059	0.031	-0.484	**0.221**	-0.001	-0.062	0.011	-0.211	-0.124
Plant height	-0.098	-0.087	0.128	0.144	0.146	**-0.001**	0.274	0.013	-0.169	0.350*
Days to maturity	-0.907	0.108	0.074	0.106	-0.020	0.000	**0.683**	0.004	0.244	0.291
No. of seeds/ siliqua	0.609	0.073	-0.111	-0.305	-0.147	0.001	-0.150	**-0.017**	-0.434	-0.480**
1000 seed weight	-0.452	-0.127	0.023	-0.101	-0.051	0.000	0.182	0.008	**0.918**	0.401*

Residual =-0.1096 **Note:** Underlined values denote direct effe

CHAPTER-V
DISCUSSION

The investigation entitled "Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss.]" was carried out during rabi 2014-15 at research farm, Zonal Agricultural Research Station, Morena.

The salient finding of this work are interpreted and discussed in this chapter in conjunction with the findings of other workers. The discussion is confined to the relevant topics, viz., variability, heritability, genetic advance, co-heritability, correlation and path analysis.

Variability:

A broad spectrum of variability is fundamental for success of a plant breeding programme since it provides an opportunity to the plant breeder to use his skill and art in making useful selections.

Variability was measured by estimation of mean, coefficient of variation (genotypic and phenotypic), heritability, genetic advance and genetic gain. Environment plays an important role in the expression of phenotype and genotype facts, which are inferred, form phenotypic observations. Hence, variability can be observed through biometric parameters like genotypic coefficient of variation, heritability (broad sense) and genetic advance. This would be of great help to breeder in evolving a selection programme for gene.

Considerable amount of variability for most of the traits was observed in the experimental material. It was revealed by univariate analysis. Mean sum of squares due to genotypes for all the traits except length of siliqua and number of seeds per siliqua were highly significant. Wide variability was also evident from wide range and high values of PCV and GCV.

In general estimates of PCV were higher than their corresponding GCV however good correspondence was observed between GCV and PCV for all characters. A wide range of phenotypic coefficient of variation (PCV) was observed for traits ranging from 4.41% for days to maturity to 26.38% for number of secondary branches per plant. Higher magnitude of phenotypic coefficient of variation was recorded for number of secondary branches per plant (26.38 %), seed yield per plant (24.23%) and number of siliquae per plant (20.29 %). While moderate estimates observed for 1000 seed weight (18.96 %) and number of seeds per siliqua (11.84%) and low estimates of phenotypic coefficient of variation values was observed in days to maturity (4.41 %), days to 50% flowering (5.81%), length of siliqua (7.84%), plant height (9.75%) and number of primary branches per plant (9.90%).

Genotypic coefficient of variation (GCV) ranged from 4.14% for days to maturity to 26.01% for number of secondary branches per plant. Higher magnitude of genotypic coefficient of variation was recorded for number of secondary branches per plant (26.01 %), seed yield per plant (23.57%) and number of siliquae per plant (19.93%) while moderate for 1000 seed weight (12.95%).

On an average, the higher magnitude of genotypic coefficient of variation and phenotypic coefficient of variation were recorded for number of secondary branches per plant, seed yield per plant and number of siliquae per plant suggesting that sufficient variability was present in the gene pool thus ample scope for genetic improvement through selection for these traits. Similar results were also reported by Das *et al.* (1998), Singh *et al.* (1997), Ghosh and Gulati (2001), Mahla *et al.* (2003), Singh *et al.* (2003) and Gupta (2005).

Relatively low magnitudinal differences were observed between genotypic coefficient of variation and phenotypic coefficient of variation for number of secondary branches per plant, number of siliquae per plant, seed yield per plant, plant height and days to maturity indicates less environmental influence in the expression of these attributes. Relatively high differences between genotypic coefficient of variation and phenotypic coefficient of variation were observed for number of seeds per siliqua, 1000 seed weight, number of primary branches per plant and days to 50% flowering. These findings suggested that greater influence of the environment in the expression of these traits.

Heritability:

Heritability is a measure of the extent of phenotypic variation caused by the action of genes. For making effective improvement in the character for which selection is practiced, heritability has been adopted by large number of workers as a reliable indicator. The proportion of genetic variability which is transmitted from parents to offspring is reflected by heritability. According to Lush (1949) heritability in broad sense is the ratio of total genotypic variance to phenotypic variance, expressed in percentage. The estimates of heritability are more advantageous when expressed in terms of genetic advance. Johnson *et al.* (1955) suggested that heritability and genetic advance when calculated together would prove more useful in predicting the resultant effect of selection on phenotypic expression, without genetic advance the estimates of heritability will not be of practical value and emphasized the concurrent use of genetic advance along with heritability. High heritability alone is not enough to make sufficient improvement though selection in genetic advance generation.

In present investigation, high estimates of heritability in broad sense were observed for number of secondary branches per plant, number of siliquae per plant, seed yield per plant, plant height, days to maturity and days to 50% flowering. Correlation of seed yield per plant with number of secondary branches per plant, number of siliquae per plant, plant height and days to maturity was also significant. These four traits, thus, may be used for selecting high yielding genotypes. Singh *et al.* (1975), Singh *et al*. (1997), Lekh *et al.* (1998) and Singh *et al.* (2013) also reported similar findings.

Estimates of heritability values were relatively moderate for length of siliqua, number of primary branches per plant and number of seeds per siliqua. These characters may be used to construct selection indices but progress made through them would be relatively slow.

Genetic advance:

In the present investigation the estimates of the expected genetic advance expressed as percentage of mean were high for number of secondary branches per plant (52.85%), seed yield per plant (47.25%) and number of siliquae per plant (40.33%).

High heritability coupled with high genetic advance observed for number of secondary branches per plant, seed yield per plant and number of siliquae per plant indicated that these traits are governed by additive gene action. Hence there are good chances of improvement of these traits through selection in the material. Kumar and Sangwan (1994), Das *et al.* (1998), Hussain *et al.* (1998), Ghosh and Gulati (2001) and Singh *et al.* (2013) also reported similar findings.

Co-heritability:

Co-heritability is the joint heritability of two traits which is defined as the product of square root of heritabilities of the two characters and genotypic correlation coefficient between them. Information about co-heritability of characters helps plant breeder in viewing the inheritance of both the traits simultaneously. It also helps in the selection process due to correlated response. Estimates of co-heritability values of the characters with seed yield per plant were in general high except of days to 50% flowering, length of siliqua and number of seeds per siliqua. In addition to this, many of the yield components also indicated high co-heritability estimates among themselves. Days to 50% flowering, length of siliqua and number of seeds per siliqua indicated low magnitude of co-heritability with seed yield per plant. Hence selection on the basis of these traits will not be effective enough for improvement of seed yield.

Co-heritability estimates of seed yield with yield components suggest that more correlated responses through selection for any of these trait would be expected resulting ultimately in the increase in seed yield.

Correlation coefficients:

Information about correlations is of great significance to a plant breeder because all the phenotypic traits are the result of interplay of several genetic factors among themselves and their individual and combined interaction with the environmental factors.

Knowledge of correlation helps a plant breeder to determine the methodology to improve a particular trait which is not readily amenable to direct selection and so indirect selection becomes inevitable. It also provides information about the correlated response to directional selection to predict genetic advance and thus can be used as selection indices for operating more efficient selection programme.

Seed yield per plant was highly and significantly correlated with number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, plant height, days to maturity and 1000 seed weight at both genotypic and phenotypic levels while its association with number of seeds per siliqua was negative only at genotypic level.

In the present study, days to 50% flowering was positively correlated with days to maturity and 1000 seed weight at both phenotypic and genotypic level. Number of primary branches per plant, number of seeds per siliqua and length of siliqua was positively correlated with days to 50% flowering at only genotypic level. Number of primary branches per plant showed strong positive phenotypic and genotypic correlation with number of secondary branches per plant and number of siliquae per plant but its genotypic correlation with days to 50% flowering was positive and considerable. At both genotypic and phenotypic levels, number of secondary branches per plant was found to be positively and strongly associated with number of primary branches per plant, number of siliquae per plant, plant height and days to maturity but it was negatively associated with number of seeds per siliqua at genotypic level only. In the present study, the number of siliquae per plant exhibited strong and positive correlation with number of primary branches per plant and number of secondary branches per plant at phenotypic and genotypic levels. It also had negative correlation with length of siliqua and number of seeds per siliqua only at genotypic level. A positive association of length of siliqua was observed with plant height at both genotypic and phenotypic levels but its association with days to 50% flowering, number of seeds per siliqua and number of siliquae per plant was negative only at genotypic level. Plant height had positive association with number of secondary branches per plant, length of siliqua and days to maturity and negative with number of seeds per siliqua at both phenotypic and genotypic levels. Similarly, days to maturity exhibited positive association with days to 50% flowering, number of secondary branches per plant and plant height at both genotypic and phenotypic level. Number of seeds per siliqua had negative association with days to 50% flowering, number of secondary branches per plant, number of siliquae per plant, length of siliqua, plant height and 1000 seed weight at d genotypic level but its association with all these traits except plant height was missing at phenotypic level. Similarly, 1000 seed weight exhibited positive association with days to 50% flowering at both genotypic and phenotypic level but it showed negative correlation with number of seeds per siliqua at genotypic level only.

The present study revealed maximum positive association of seed yield per plant with number of siliquae per plant at phenotypic level followed by number of number of secondary branches per plant, number of primary branches per plant,

plant height, 1000 seed weight and days to maturity. This was in confirmation with the findings of Singh *et al.* (1979), Khulbe and Pant (1999), Karkoo *et al.* (2000), Larik and Rajput (2000), Ghosh and Gulati (2001), Shah et al. (2002), Mahla et al. (2003), Sudan *et al.* (2004), Dastidar and Patra (2004), Gupta (2005), Gangapur *et al.* (2009), Belete (2011) and Mekonnen *et al.* (2013).

In general, genotypic correlation coefficients were slightly higher than the phenotypic correlation coefficients. This emphasized that in spite of strong inherent association between various characters pair studied, the environment may modify the full expression of genotypes. While reviewing the studies on correlation made on several crop plants, it has been observed that strength and direction of correlation in different character combinations depends on the nature of the experimental material and environmental conditions in which they have been studied. As such from existing agroclimatic situation of Morena, it could be stressed that more emphasis should be given for number of siliquae per plant, number of secondary branches per plant, number of primary branches per plant, plant height, 1000 seed weight and days to maturity as they showed fair to very high degree of positive association with seed yield.

Path analysis:

The yield is a complex polygenic trait. It is greatly influenced by its component characters. The inter-relationship among the component traits therefore, often limit the magnitude of yield. Correlation coefficient measures the strength of relationship among different traits but it does not reveal contribution of each trait to the resultant correlation. Thus the information of correlation coefficient does not help in precise ranking of characters to be used in selection indices. Analysis of ultimate correlation coefficient, therefore, becomes essential to quantify the magnitude and direction of each trait.

Path analysis, a technique suggested by Wright (1921), quantifies the direct and indirect contributions of different traits to the total correlation coefficients and helps to understand there inter-relationship.

In order to obtain the development relations, the cause and effect of relationship between yield per se, nine yield components was studied in mustard through path coefficient analysis. Among the characters studied, at phenotypic and genotypic level, number of siliquae per plant followed by 1000 seed weight exerted maximum direct effect which was supported by very high positive correlation with seed yield. Similar observations were also made by Arthamwar *et al*. (1995), Tyagi *et al.* (1996), Yadav *et al.* (1996), Singh *et al.* (1997), Khulbe and Pant (1999), Shalini *et al.* (2000a), Jankowski and Budzynski (2003), Singh *et al.* (2003b), Khulbe and Pant (2007), Singh *et al.* (2013) and Shweta and Prakash (2014).

The result of path analysis of genotypic correlation coefficients further indicated that the days to maturity, which had positive correlation with seed yield had substantial direct contribution to the seed yield per plant. Similar observations were also made by Mondal and Khajuria (2000), Singh *et al.* (2003b), Dastidar and Patra (2004), Hasan *et al.* (2014) and Shweta and Prakash (2014).

The direct effect of number of secondary branches per plant as well as plant height on seed yield was negligible but both had positive correlation with seed yield at phenotypic and genotypic levels. This was mainly due to its indirect effects through number of siliquae per plant, 1000 seed weight and days to maturity.

Though number of primary branches per plant showed negative direct effect but its correlation with seed yield per plant was converted into positive and significant correlation due to substantial positive indirect effect via number of siliquae per plant, days to 50% flowering, 1000 seed weight and number of secondary branches per plant.

Among other traits, days to 50% flowering exhibited high negative direct effect on seed yield per plant but it had non-significant association with seed yield per plant at genotypic level. Substantial negative direct effect of days to 50% flowering converted into negligible (non-significant) correlation was mainly due to its positive indirect effects through days to maturity, 1000 seed weight and number of primary branches per plant.

The direct effect of number of seeds per siliqua was negative and low but it has strong negative genotypic correlation with seed yield which implied that number of seeds per siliqua might probably contributed for yield through negative indirect effects through 1000 seed weight, number of siliquae per plant, days to maturity, length of siliqua and number of secondary branches per plant.

Length of siliqua showed negligible direct effect on seed yield along with non-significant correlation with seed yield per plant.

On the basis of above results it can be concluded that number of siliquae per plant, 1000 seed weight and days to maturity directly contributed significantly to the correlation coefficient. However, some traits not directly contributed significantly to the correlation coefficient and their significant correlation coefficient estimates were the results of small indirect contributions via other traits. Though direct contribution of days to 50% flowering was negative, however positive contribution through other traits resulted in its non-significant correlation with yield.

Therefore, this study has clearly indicated the need for giving due weightage for number of siliquae per plant, 1000 seed weight and days to maturity for improving seed yield in mustard.

CHAPTER-VI

SUMMARY

"Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss]**"** was conducted on 18 F_3 populations lines. The experiment was grown during rabi 2014-15 in RBD with 3 replications at Research Farm, Zonal Agricultural Research Station, Morena (M.P.).

The observations were recorded on days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, length of siliqua, plant height, days to maturity, number of seeds per siliqua, 1000 seed weight and seed yield per plant for collecting the information on existing variability, heritability and co-heritability of traits, expected genetic advance in selection, inter relationship among traits and direct and indirect contribution of traits. The data on all characters were subjected to statistical analysis the following conclusions were drawn:

Analysis of variance revealed highly significant differences among lines for most of the characters except length of siliqua and number of seeds per siliqua. Estimates of population mean were high and range was wide for most of the traits. Trend of variability at genotypic level was similar to that of at phenotypic level for most of the characters. The genotypic co-efficient of variation was highest for number of secondary branches per plant followed by seed yield per plant and number of siliquae per plant.

The estimates of heritability in broad sense for most of the traits were high to moderate. High estimates were observed for number of secondary branches per plant, number of siliquae per plant, seed yield per plant, days to maturity, plant height and days to 50% flowering and relatively moderate for length of siliqua, number of primary branches per plant and 1000 seed weight.

The estimates of expected genetic advance on selection for number of secondary branches per plant, seed yield per plant and number of siliquae per plant were high while moderate for 1000 seed weight, plant height and number of primary branches per plant.

The estimates of co-heritability of seed yield per plant with number of siliquae per plant, number of secondary branches per plant, number of primary branches per plant, plant height, days to maturity and 1000 seed weight were high.

Among yield components, days to 50% flowering with days to maturity; number of primary branches per plant with number of secondary branches per plant and number of siliquae per plant; number of secondary branches per plant with number of siliquae per plant, plant height and days to maturity; length of siliqua with plant height; and plant height with days to maturity exhibited high estimates of co-heritablity.

The estimates of genotypic and phenotypic correlations were mostly in agreement in both sign and magnitude and genotypic correlation coefficients were higher than the phenotypic and environmental correlation coefficients for most of the pairs of characters. This indicated that there is strong inherent association between the various character studied.

Number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, plant height, days to maturity and 1000 seed weight showed positive correlation with seed yield per plant. These traits may be used for construction of index for selection of yield.

The inter-correlations among number of primary branches per plant, number of secondary branches per plant and number of siliquae per plant were also found positive.

Based on correlation studies, it could be suggested that maximum weightage should be given to higher number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, taller plant, late maturity and more 1000 seed weight while making selection for increased yield.

Path analysis revealed that, number of siliquae per plant, 1000 seed weight and days to maturity were the major characters which had highest direct contribution towards seed yield per plant.

Thus on the basis of above findings pertaining to correlation and path analysis, the three traits viz. number of siliquae per plant, 1000 seed weight and days to maturity were undisputedly most important components for further yield improvement in mustard. Moreover, the importance of number of primary branches per plant and number of secondary branches per plant on the basis of correlation studies should not be under estimated.

Suggestions for further work:

On the basis of significant variation present for different traits the promising parents may be selected as: RVM1 × SeJ 2, JM 2 × Kranti, RVM1 × Divya 33, RVM1 × B 85, JM 2 × B 85 and JM 2 × NDRE 4 for days to 50% flowering, JM 2 × NDRE 4 and JM 2 × Divya 33 for number of primary branches per plant, JM 2 × Divya 33 for number of secondary branches per plant, JM 2 × NDRE 4, JM 2 × Divya 33, JM 3 × Kranti and JM 3 × B 85 for number of siliquae per plant, JM 2 × Divya 33 for plant height, JM 2 × Divya 33, JM 2 × JD 6 and JM 3 × B 85 for days to maturity, JM 3 × SeJ 2, RVM1 × NDRE 4 and JM 2 × NDRE 4 for 1000 seed weight and JM 2 × NDRE 4 and JM 2 × Divya 33 for seed yield per plant for use in future breeding programmes.

The three traits viz., number of secondary branches per plant, seed yield per plant and number of siliquae per plant possessing high genetic advance coupled with high heritability may be further improved through simple selection.

While making selection, maximum weightage should be given to higher number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, taller plant, late maturity and more 1000 seed weight for getting higher yields in future breeding programmes.

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Appendix I: Means, minimum, maximum and least significant difference for the 10 quantitative characters in Indian mustard

Genotypes	Days to 50% flowering	No. of primary branches /plant	No. of secondary branches / plant	No. of siliquae / Plant	Length of siliqua (cm)	Plant Height (cm)	Days to maturity	No. of seeds/ siliqua	1000 seed weight (g)	Seed yield/ plant (g)
RVM1 × Kranti	66.00	5.33	9.73	222.73	3.27	172.20	123.00	15.47	3.24	39.31
RVM1 × B 85	59.00	5.87	9.27	294.60	3.13	171.53	121.00	15.00	2.94	59.74
RVM1 × NDRE 4	62.33	5.93	9.13	255.87	3.27	171.80	123.00	16.00	4.29	58.69
RVM1 × Divya 33	59.00	5.53	8.73	291.33	3.40	181.00	118.00	15.27	3.09	53.98
RVM1 × JD 6	61.33	5.87	7.53	230.60	3.23	174.47	116.00	14.60	3.22	36.78
RVM1 × SeJ 2	58.67	5.60	8.67	212.33	3.87	200.13	115.00	15.07	3.24	53.12
JM 2 × Kranti	58.00	5.80	10.00	201.87	3.77	199.77	114.00	15.87	3.44	43.44
JM 2 × B 85	60.00	5.20	9.80	267.53	3.57	192.20	116.00	14.60	2.42	40.35
JM 2 × NDRE 4	61.00	6.47	13.90	317.00	3.57	203.47	118.00	11.27	3.80	70.60
JM 2 × Divya 33	63.33	6.20	19.13	297.00	3.70	233.93	129.00	13.87	3.52	75.71
JM 2 × JD 6	64.33	5.60	10.77	195.57	3.53	206.33	130.00	14.73	2.99	40.55
JM 2 × SeJ 2	66.00	4.87	9.60	260.33	3.53	219.87	126.00	13.40	3.38	49.97
JM 3 × Kranti	65.33	5.47	12.00	311.60	3.07	196.27	125.00	14.20	3.18	63.33
JM 3 × B 85	64.67	5.60	11.80	312.07	3.43	200.67	129.00	14.93	3.45	66.93
JM 3 × NDRE 4	63.00	5.00	7.40	131.80	3.60	198.07	125.00	12.93	3.76	37.47
JM 3 × Divya 33	63.67	5.67	9.60	250.13	3.83	211.87	126.00	14.40	2.52	47.40
JM 3 × JD 6	66.33	4.70	8.63	201.27	3.57	171.43	124.00	14.47	3.78	41.07
JM 3 × SeJ 2	69.33	5.87	10.67	275.67	3.43	191.07	127.00	14.13	4.35	65.95
C.D. (5%)	**3.53**	**0.63**	**0.73**	**15.24**	**0.29**	**11.61**	**2.95**	**2.54**	**0.75**	**4.69**

ABSTRACT

1.	Title of the thesis	:	**Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss]**
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3.	Advisor	:	**Dr. V.K. Tiwari** Scientist, ZARS, Morena
4.	Degree awarded	:	Master of Science in Agriculture (Plant Breeding and Genetics)
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Signature	**Signature**	**Signature**
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Genetic analysis in F_3 populations of Indian Mustard [*Brassica juncea* (L.) Czern & Coss]”

Samrath Maida*

Chairman and Research Guide **Dr. V.K. Tiwari**
Department of Plant Breeding & Genetics

ABSTRACT

The experiment was grown during rabi 2014-15 in RBD with 3 replications at Research Farm, ZARS, Morena (M.P.). The observations were recorded on days to 50% flowering, number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, length of siliqua, plant height, days to maturity, number of seeds per siliqua, 1000 seed weight and seed yield per plant for collecting the information on existing variability, heritability and co-heritability of traits, expected genetic advance in selection, inter relationship among traits and direct and indirect contribution of traits. Analysis of variance revealed highly significant differences among lines for most of the characters except number of seeds per siliqua. The genotypic co-efficient of variation was highest for number of secondary branches per plant followed by seed yield per plant and number of siliquae per plant. High estimates of heritability were observed for number of secondary branches per plant, number of siliquae per plant, seed yield per plant, days to maturity, plant height and days to 50% flowering. The estimates of expected genetic advance on selection for number of secondary branches per plant, seed yield per plant and number of siliquae per plant were high. The estimates of co-heritability of seed yield per plant with number of siliquae per plant, number of secondary branches per plant, number of primary branches per plant, plant height, days to maturity and 1000 seed weight were high. Number of primary branches per plant, number of secondary branches per plant, number of siliquae per plant, plant height, days to maturity and 1000 seed weight showed positive correlation with seed yield per plant. These traits may be used for construction of index for selection of yield. The inter-correlations among number of primary branches per plant, number of secondary branches per plant and number of siliquae per plant were also found positive. Path analysis revealed that, number of siliquae per plant, 1000 seed weight and days to maturity were the major characters which had highest direct contribution towards seed yield per plant. Thus on the basis of above findings pertaining to correlation and path analysis, the three traits viz. number of siliquae per plant, 1000 seed weight and days to maturity were undisputedly most important components for further yield improvement in mustard. Moreover, the importance of number of primary branches per plant and number of secondary branches per plant on the basis of correlation studies should not be under estimated.

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