

**DIALLEL ANALYSIS FOR YIELD AND YIELD
CONTRIBUTING CHARACTERS IN INDIAN
MUSTARD (*Brassica juncea*)**

THESIS

Submitted to
Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola
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IN

**AGRICULTURE
(AGRICULTURAL BOTANY)
(Genetics and Plant Breeding)**

By

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DECLARATION OF STUDENT

I hereby, declare that the experimental work and its interpretation of the Thesis entitled "**DIALLEL ANALYSIS FOR YIELD AND YIELD CONTRIBUTING CHARACTERS IN INDIAN MUSTARD (*Brassica juncea*)**" or the part there of has neither been submitted for any other degree or diploma of any University , nor the data have been derived from any thesis / publication of any University of scientific organization. The source of materials used and all assistance received during the course of investigation have been duly acknowledged.

Place : Nagpur

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CERTIFICATE

This is to certify that the thesis entitled “**DIALLEL ANALYSIS FOR YIELD AND YIELD CONTRIBUTING CHARACTERS IN INDIAN MUSTARD (*Brassica juncea*)**” submitted in partial fulfillment of the requirements for the degree of “**Master of Science in Agriculture (Agricultural Botany)**” of the Dr. Punjabrao Deshmukh Krishi Vidyapeeth, Akola is a record of bonafide research work carried out by **Aghao Rahul Rameshrao**, under my guidance and supervision.

The subject of the thesis has been approved by the Student's Advisory Committee.

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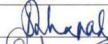


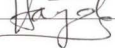

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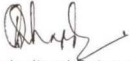
Abbreviations

cm.	:	Centimeter
C.D.	:	Critical difference
%	:	Per cent
g	:	Gram
<i>et al.</i>	:	et alia (and associate)
GCA/gca	:	General combining ability
i.e.	:	that is
NS	:	Non significant
SCA/sca	:	Specific combining ability
S.E. (d)	:	Standard error difference
S.E. (m) \pm	:	Standard error of mean
Viz.	:	Namely
Vs	:	Versus

(C)

THESIS ABSTRACT

- a) Title of the Thesis : DIALLEL ANALYSIS FOR YIELD AND YIELD CONTRIBUTING CHARACTERS IN INDIAN MUSTARD
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ABSTRACT

Diallel analysis in mustard involving ten parents were used to estimate the general and specific combining ability of parents and crosses respectively to isolate superior crosses in further generations. Forty five crosses along with ten parents were raised during *rabi* 2008-09. and data were recorded on days to 50% flowering, days to maturity, plant height (cm), number of primary branches plant⁻¹, number of siliqua plant⁻¹, seed yield plant⁻¹ (g), 1000 seed weight (g), oil content (%). The gca and sca effects showed wide variation in the level of significance for various yield contributing characters. The parents Seeta, Varuna and Laxmi were identified as best parents for yield and yield contributing characters on the basis of high mean performance and significant gca effects. Among the crosses Varuna x Seeta was identified as best F₁ cross which can be forwarded to the next generation by single seed descent method with an aim to get useful transgrates in the succeeding generation.

Chapter – I

INTRODUCTION

1.1 Background information

Mustard is second important oilseed in India, after groundnut in area and production. In India, the area under mustard is 5.9 million ha, producing 6.43 million tonnes of seed with an average productivity 1089kg/ha. (Anonymous, 2008) During the year 2006-07, 13900 ha, area was under cultivation in Maharashtra having a production of 4800 tonnes and productivity of 350 kg/ha. At present mustard is a minor oil seed crop of Vidarbha region covering an area of 5900 hectares with a production of 2628 tonnes and productivity of 441kg/ha (Anonymous, 2007).

Indian mustard (*Brassica juncea*) is called as "rai", "raya" or "laha" is an important oilseed crop belonging to *Brassicaceae* group. Indian mustard belongs to the family *cruciferae*, genus *Brassica* with chromosome number $2n=36$. The oil content in Indian mustard seeds varies from 30 to 48 per cent. Over 159 species have been reported in genus *Brassica*.

The important species of *Brassica* that are extensively cultivated commercially are *Brassica campestris*, *B. juncea* and *B. napus*. Of these, *B. campestris* and *B. juncea* are largely cultivated in Asia (India, China, Pakistan, Bangladesh and Nepal), while *B. napus* and *B. campestris* are largely cultivated in Sweden, Germany, France, Canada and Australia.

Indian mustard seed is largely crushed for oil which is the cheapest source of oil in our diet and rich source of energy predominantly in vegetarian diet. Apart from culinary purposes, oil is also utilized for medicinal uses, preparation of hair oil and soap making. The oil cake remaining after oil extraction is used as animal feed and as manures. Mustard meal is considered as an excellent source of dietary protein.

Though, Indian mustard oil has a long tradition of edible use, as a cooking oil. the high erucic acid content (38-57%) besides being health hazard, also result in an unpleasant odour when used for frying. Keeping these things in mind, low erucic acid varieties (less than 3%) have been developed and presently such varieties are under cultivation. Indian mustard seed meal contain 3 to 8% glucosinolate, an antinutritional factor which decreases the palatability of the cake. The varieties with less than 3mg glucosinolate per gram have been developed. The varieties with low levels of both erucic acid and glucosinolate are called double low or double zero (00) varieties and such varieties are in vogue in countries like Canada, sold there in the name of canola oil. Higher fibre content in the meal is another factor which hinders its wider quality for which attempts are under way to produce varieties with lower crude fibre and such varieties with low levels of all three constituents (erucic acid, glucosinolate and crude fibre) are called triple zero (000). The work in these directions has been initiated in our country.

1.2 Importance of study

Considering the low productivity in Vidarbha region there is need of producing high yielding varieties with early maturity and high oil content. The aim of any plant breeder to achieve the above

target will be to evolve strains superior to those of existing strains. Improving the genetic potential of crop for increasing yield with quality characters should be over emphasized.

The plant breeder uses many biometrical approaches like diallel, line x tester, top cross and poly cross to choose appropriate parents. Of these, diallel analysis is one of the efficient, convenient and often used biometrical tool that provides information on the parents from the study of F_1 itself. This is widely employed in estimating the extent of general combining ability of the parents and specific combining ability of their hybrids and is also useful to assess the nature of inheritance of a character.

1.3 Objectives of the study

With the above views in mind, research work was undertaken with the following objectives

1. To study the general and specific combining ability of the parents and crosses respectively.
2. To identify the better parents on the basis of their combining ability for their use in breeding programme.
3. To isolate the superior crosses for studying them in further generations.

1.4 Scope and limitations

The *per se* performance of parents themselves does not always give a correct indication of their breeding potentiality. It is therefore, important to study the combining ability of parents which when crossed gives high proportion of desirable segregates. This information concerning to breeding behaviour of parents is of prime importance in planning the breeding programme.

Selection of parents for crossing is the first and the most important task to evolve superior hybrid or strains. The selection of parents for hybridization is difficult task, as yield is a complex character involving number of components each of which are polygenically controlled, and hence sensitive to environmental fluctuations. The initial selection of suitable parents is stated to be of immense importance by many workers for utilization of heterosis to its maximum extent (Singh and Joshi, 1966) Seed set after hybridization becomes a limitation as mustard is a predominantly self pollinated crop.

1.5 Hypothesis

This research work will help to identify superior parents for hybridization and selection of superior crosses to carry forward to further generations.

Chapter II

REVIEW OF LITERATURE

A brief account of research work carried out and published by earlier workers on combining ability effect is reviewed in this chapter.

Combining ability is the capacity of a parent to transmit desirable traits to its progeny. The analysis of combining ability is used to assess the ability of genotypes to combine and thus, helps in identifying parents which are likely to be successful to get desirable segregants in a hybridization programme.

Combining ability analysis is one of the most powerful analytical tools to decipher the genetic architecture of quantitative traits. Thus, it provides a guideline for an assessment of the relative breeding potential of parent material and for understanding the type of gene action involved in the inheritance of different traits. Genetic evaluation is made to know the nature of genetic variation present in the base populations through various genetic parameters. An understanding of the susceptibility of these genetic parameters to changes in environment is of great importance to a breeder to initiate a successful breeding programme. Also knowledge of the relative magnitude of additive and non-additive gene effects, would be very useful in designing breeding methodology.

The concepts of general and specific combining ability and their significance in breeding have been evolved primarily through fundamental investigation on corn. Sprague and Tatum (1942) were the first workers who defined the performance of parents and crosses in terms of combining ability and they coined the term "General combining ability" (gca) for the overall performance of the parents in a number of crosses. Similarly, for the deviation from the performance of a cross as expected on the basis of

general combining ability of the two parents, they used the term "Specific combining ability" (sca). They also suggested that general combining ability is expected to be the result of additive gene effects and epistatic interaction involving additive effects and specific combining ability depends on the dominance and epistatic interactions which are not included in general combining ability. Thus, the estimates indicate the type of gene action involved in the inheritance of the characters.

The following methods are generally used to study the combining ability.

1. Top cross
2. Line x Tester analysis
3. Polycross technique
4. Diallel analysis

Out of these diallel is one of the most common method used for combining ability testing.

Combining ability studies in *B. juncea* by Tiwari and Singh (1975) reported highly significant gca and sca mean squares for yield and plant height. Yadava *et al.* (1976) in *B. juncea* revealed significant general and specific combining ability for days to maturity. Kashi Ram *et al.* (1976) in *B. juncea* reported that estimates of general and specific combining ability effects for yield plant⁻¹, number of branches, length of siliqua, 1000 seed weight and plant height were significant.

Anand *et al.* (1978) studied combining ability in a set of 12 x 12 diallel cross in F₁ and F₂ generations and reported that the parental lines BIC 1692, BIC 1434 and BIC 1632 showed good general combining ability for majority of characters and recommended for use in breeding. This was further supported by specific combining ability

ability effects in the F_1 and F_2 where the best crosses were found to have one parent with high general combining ability.

Dixit *et al.* (1983) in *B. juncea* observed that both additive and non-additive types of gene action influenced inheritance of 1000 seed weight. Varuna was the best general combiner and B85 x Varuna, the best specific combiner for this trait.

Badwal and Labana (1983) recorded combining ability in diallel cross involving ten parents and revealed that the best three crosses for the characters under study were identified on the basis of specific combining ability effects and mean performance.

In the combining ability analysis in 5 x 5 non-reciprocal diallel set of crosses in yellow sarson, Yadav and Yadav (1985) reported that both general (gca) and specific combining ability (sca) squares were significant for all the traits except number of seeds siliqua⁻¹, indicating the importance of both additive and non-additive gene effects. However, the gca/sca ratio indicated a prepondance of additive gene effect in controlling all the traits. The highest ratio was observed for seed weight followed by plant height.

Singh *et al.* (1985) studied diallel analysis of nine *B. juncea* (rai) varieties and observed that variances due to general combining ability (GCA) and specific combining ability (SCA) were highly significant for the plant height, number of primary and secondary branches and other characters. They also observed that Prakash and L-101 were the best general combiners for seed yield and the best crosses for seed yield were Varuna x Pusa bold and Varuna x L-101.

Fatfeh *et al.* (1986) performed a diallel analysis of seven parents of *B. juncea* (excluding reciprocals) to examine the combining ability

in respect of yield and its components. It revealed that additive gene effects were larger than non-additive gene effects for days to maturity and plant height while the latter was predominant for yield, number of branches and siliquae plant⁻¹.

In eight parent diallel (including reciprocals) in Indian Mustard, Ram Kumar and Yadav (1986) observed significant GCA and SCA variances for the traits viz., days to 50% flowering, days to maturity, plant height and primary branches.

Combining ability studies carried out by Singh *et al.* (1986) in Indian Mustard (7 x 7 diallel excluding reciprocals), indicated the predominance of additive and additive x additive gene actions for flowering, maturity, primary branches plant⁻¹, whereas predominance of non-additive gene action was observed only for 1000 seed weight. However, secondary branches plant⁻¹, seeds siliqua⁻¹ and yield plant⁻¹ were solely governed by additive genes. Pusa bold and B85 were identified as donors for developing early maturing and dwarf varieties.

In an 8 x 8 diallel cross without reciprocals of *B. juncea* genotypes, Gupta *et al.* (1987) reported significant gca and sca mean squares for all characters. Non-additive gene effects appeared to be predominant for number of branches. Number of siliqua, length of siliqua, number of seeds siliqua⁻¹ and seed yield, while additive gene effects were apparently predominant for plant height.

When combining ability analysis for seed yield and its component traits and oil content were studied in a 10 x 10 diallel cross (excluding reciprocals) in *B. juncea* Yadav *et al.* (1992) reported that all the characters studied were governed by both additive and non-additive genetic variances. Parents Varuna, Kranti, RLC 1359 and RLC 1357 were good

combiners for seed yield, earliness, siliqua length, seeds siliqua⁻¹ and 1000 seed weight, whereas parent EC 126743, EC 126745 and EC 126746-1 were considered as good combiners for plant height, primary branches and oil content.

In 8 x 8 diallel crosses excluding reciprocals (28 F₁ s + 8 parents) in *B. juncea*, Diwaker and Singh (1993) reported the significant general and specific combining ability variances for days to 50% flowering, plant height, number of primary branches, siliqua length, number of seeds siliqua⁻¹ and seed yield plant⁻¹ while for oil content, only general combining ability variance was significant. σ^2_g was prepondant for days to 50% flowering and plant height, whereas for the remaining traits, σ^2_s s was prepodant.

Yadava *et al.* (1993) studied the combining ability in *B. juncea* and revealed that genotype RH-7513 possessed the highest significant and positive GCA effects for all traits in both F₁ and F₂ generation except number of secondary branches in the F₁ generation. Over dominance was shown for all traits in both generation.

Studies on a set of crosses involving seven parent from Indian mustard by Malkhandale (1993) revealed significant variation in gca and sca for all the metric traits studied.

In 8 x 8 diallel analysis in Indian mustard, Singh and Mittal (1993) observed significant GCA variances for seed yield plant⁻¹, plant height, number of siliquae on main raceme and significant SCA variances for these characters, except number of seeds siliqua⁻¹. The hybrids Vaibhav x Kranti, Pusabold x Kranti and Vaibhav x RLM 198 had shown the better performance and sca effects.

In 8 x 8 diallel cross (excluding reciprocals) of *Brassica juncea* studied by Singh and Mittal (1994) revealed that significant differences were observed in F₁ population due to gca and sca for oil content. Parents, Pusa bold, RLM 198 and Kranti showed good general combining ability for high oil percentage. Hybrid Vaibhav x Pusa bold was desirable in obtaining selections with improved oil content.

The combining ability analysis of eight *Brassica juncea* parents and their 28 F₁s generated through diallel system of mating showed significant differences for general and specific combining ability for all the characters as reported by Khulbe *et al.* (1998). They reviewed that the crosses with high sca effects did not always have parents with good GCA effects such a relationship between GCA and SCA indicates the importance of epistasis and the crosses were expected to produce desirable transgressive segregants.

Shiekh and Singh (1998) studied combining ability analysis of Indian mustard and revealed that Pusa barani was best general combiners for seed yield, oil content, 1000 seed weight, days to flowering and length of siliqua, Varuna and RH-30 also good general combiners for seed yield, and several other characters. Pusa barani x glossymutant showed superior sca for seed yield, oil content, plant height and primary branches the majority of crosses showing high sca effect for seed yield involved high x low gca parents.

Kumbhalkar *et al.* (1999) studied combining ability in 21 crosses obtained from diallel analysis of seven parents. The crosses RW 351 x Pusa bold and Pusa bold x ACN-9 were identified as best combination with high sca effects, high mean performance and heterosis. These crosses can be used as a source of population for improving through selection.

A diallel analysis was carried out with nine inbred lines of Indian mustard by Thakral *et al* (2000). and reported that parents, Varuna, RH-30, RC-781, and RH-8912 possessed significant GCA effects for two or more than two traits at a time and were considered as the best general combiners. Likewise, crosses RH-30 x PM and RH 8912 x RC 199 attained significant SCA effects for most of the component traits and were identified as superior crosses.

The combining ability analysis of 21 F₁ hybrids derived from the diallel cross of 7 Indian mustard cultivars by Lalta Prasad *et al.* (2002) revealed that Varuna recorded high *per se* performance of high general combining ability for most of the characters. Specific combining ability for early maturity, length of main raceme, number of secondary branches, yield plant⁻¹, test weight and oil content were observed in the cross Krishna x Seeta, Krishna x Pusa bold, RLM – 198 x Krishna, Varuna x Pusa bold, Rohini X Varuna, and RLM – 198 x Seeta, and Rohini x Varuna respectively.

Combining ability analysis was performed using 36 F₁ hybrid and their parents by diallel mating for eleven characters in Indian mustard (*B. juncea*) by Swarnkar *et al.* (2002). They observed that parents RC-781, Varuna and PR-15 for primary branches, RC-781 for secondary branches, number of siliqua on main raceme and grain yield per plant, RK – 1467 and KR – 5610 for length of main raceme, KRV – Tall and RLM –198 for seed yield per plant and Varuna, KRV-Tall and PR-15 for seed weight appeared to be good general combiners in both generations whereas, parents KRV-tall, T-6342, PR-15 and Varuna for oil content and parents Varuna, KR-5610 and RLM – 198 for protein content appeared to be good general combiners and out of 36 crosses only eight crosses had desirable specific combining ability effects for grain yield in both generations.

Yogeshwarsingh *et al.* (2003) studied combining ability in 8x8 diallel crosses of *Brassica juncea* and reported the estimates of gca effects on the basis of pooled analysis revealed that the national control cultivar, Kranti displayed greater potential as good combiner for all the traits.

Combining ability for yield and yield components of ten Indian mustard cultivars was studied by Singh *et al.* (2003). Based on sca and *per se* performance the superior crosses were identified and the results suggested the suitability of biparental mating in selected progeny and further selection of segregating generations recurrent selection or diallel selected matings for the improvement of yield and yield components.

Singh *et al.* (2005) studied 6 indigenous and 4 exotic genotypes of Indian mustard in a diallel fashion excluding reciprocals. They revealed that the widely adopted mustard cultivar Kranti and promising line PHR-2 were identified as the best general combiners for most of the characters followed by Pusa bold, Pusa barani and RLM -198. The early maturing dwarf strain Divya was identified as the best general combiner for early flowering and maturing as well as dwarf height. The crosses with the highest mean did not possess the highest specific combining ability (SCA) effects. Divya x Zem-1, Kranti x EC - 322090, RLM-198 x EC 322090, EC 322090 x EC 322092, Divya x EC - 322090 and Pusa barani x Divya showed high sca effects for yield and its component characters. Desirable transgressive segregants for various characters are expected from these crosses.

Parmar *et al.* (2005) studied combining ability in a set of 10 x 10 diallel crosses excluding reciprocals in Indian mustard (*Brassica juncea*) They observed that the parents SKM 9928 for seed yield plant⁻¹, primary and secondary branches plant⁻¹, PCR 7 for length of main branch, TM 18 for number of siliquae per plant, days to 50% flowering and maturity. SAL 1 for plant height, RH 30 for seed weight and oil content were the best general

combiners. The cross GM 1 x SAL 1 for number of siliquae per plant and 1000 seed weight and RH 819 x SKM 9928 for length of main branch and 50% flowering were the best cross combinations.

From the review of work done by various scientist on diallel analysis for estimation of combining ability, it could be concluded that, diallel analysis can be effectively used for estimation of combining ability and this would help in identifying superior parents and crosses for their use in mustard breeding programme.

Chapter – III

MATERIAL AND METHODS

3.1 Material required

The experimental material consisted of ten genotypes of mustard of (*Brassica juncea*) and their forty five crosses. The crosses were made in a diallel fashion excluding reciprocals. The details of parents and their pedigree, with important characters, used in the investigation are given below.

Table 1. Pedigree and sailent feature of mustard genotypes

Sr. No.	Genotypes	Parentage	Important characters
1	Pusa bold	Derivative of the cross Varuna x BIC 1780	Bold seeded genotypes having high yielding potential
2	Varuna	Pureline selection from varanasi local	Suitable for early and late sown condition and highly stable
3	Vardhan	Derived through biparental mating involving, Varuna Keshri, CSU 10, IB 1775, IB 1786, and 1886	High yielding, suitable for late sown irrigated condition
4	Seeta	Developed by single plant selection from the local material	Early duration genotype
5	Bio-902	Somaclonal variant	Extra bold size and high yielding potential
6	Laxmi	Derived from the cross PR 15 x RH 30	Bold and Black seeded

7	PCR-7	Selection from JMG 32-6	Late duration genotype having high yielding potential and non shattering
8	Ashirvad	Derivative of the cross Krishna x Vardhan	Suitable for the late sown condition
9	Kranti	Pureline selection from Varuna x PR-15	More tolerant to alternaria blight and frost
10	ACN-9	Derivative of the cross Varuna x BIC 1780	Dwarf and early duration genotype.

3.2 Methods adopted

The details of layout are as follows.

1	Design of experiment	R.B.D.
2	No. of treatments	55(45 crosses + 10 parents)
3	Plot size	0.45 x 2.25m ² (single row with 15 hills)
4	Spacing	45 cm x 15 cm
5	No. of replications	3
6	Plants under observation	5
7	Date of sowing	25-10-2008
8	Date of harvesting	As per maturity

All the package of practices and plant protection measures were taken as per the recommended schedule.

3.2.1 Recording of experimental data

45 hybrids and their ten parents were studied in detail for their economic characters. The data were recorded on five randomly selected plants in each replication for the following characters.

1. Days to 50% flowering

The date on which 50% of the plants flowered in each treatment was recorded and the number of days required for 50% flowering were calculated.

2. Days to maturity

Days to maturity was calculated by recording the date on which the plants reached physiological maturity.

3. Plant height at maturity (cm)

The plant height was recorded in centimeter from the ground level to tip of the main shoot of five randomly selected plants and mean plant height per plant was calculated.

4. Number of primary branches plant⁻¹

The number of primary branches were recorded on the main stem of the five randomly selected plants and mean primary branches were calculated.

5. Number of siliqua plant⁻¹

The number of siliqua of five randomly selected plants were counted prior to harvest and mean number of siliqua plant⁻¹ was calculated.

6. 1000 seed weight (g)

1000 seed were counted from five randomly selected plants and weighed in gram separately on precision electronic balance and mean 1000 seed weight plant⁻¹ was recorded.

7. Yield plant⁻¹(g)

The seed yield obtained from five randomly selected plant were weighed in gram separately on precision electronic balance and mean seed yield plant⁻¹ were calculated.

8. Oil content (%)

The oil content was determined from bulk sample of each cross and parent for each replication by the use of Soxhlet apparatus.

3.3 Statistical analysis

The data were subjected to the following statistical and biometrical analysis.

- a. Analysis of variance for the experimental design (Fisher, 1938)
- b. Analysis of combining ability (Griffings, 1956, Method 2 Model I)
- c. Estimates of gca and sca effects

a. Analysis of variance

The data were analysed statistically for testing the significance of the results by Analysis of Variance as suggested by Fisher (1938).

The analysis of variance based on this model is given below

Source of variance	Degree of freedom (df)	Mean sum of squares	
		Observed	Expected
Replications	(r-1)	MSr	
Genotypes	(g-1)	MSg	$\sigma^2e + r\sigma^2g$
Parents	(p-1)	MSp	
Crosses	(c-1)	MSc	
Parents vs crosses	1	MSp/c	
Error	(g-1) (r-1)	MSe	σ^2e

Where,

r = Number of replications

c = Number of crosses

g = Number of genotypes

e = error

p = No. of parents

b. Analysis of combining ability

Diallel tables were prepared from the values of F_1 's arranged over three replications only for those characters that showed significant differences between the treatment. The prepared diallel table was analysed for 'gca' and 'sca' effects by Model I (Fixed effect model) and Method 2 (Parents and one set of crosses excluding reciprocals) as described by Griffing, 1956.

In model I (Eisenhart, 1947) which is a fixed effect model, the objectives are to compare the combining abilities of the parents and to

identify the higher yielding combinations. Hence, in this experiment, only the combining ability effects and appropriate standard errors were estimated.

Anova for Combining Ability Analysis in Model I Method 2

Source	d.f.	M.S.S.	E.M.S.
gca	(n-1)	Mg	$\sigma_e^2 + \frac{n+2}{n-1} \sum_i g_i^2$
sca	n (n-1)/2	Ms	$\sigma_e^2 + \frac{2}{n(n-1)} \sum_{i < j} s_{ij}^2$
error	M	M'e	σ_e^2

m = d.f. for error as obtained from R.B.D.

c. Computation of gca and sca effects

The effects were estimated as follows .

gca estimates of parent i

$$g_i = \frac{1}{n+2} [(X_{i.} + X_{.i}) - \frac{2}{n} X \dots]$$

where g_i = general combining ability effect of the i^{th} male parent

sca estimates of cross i x j

$$s_{ij} = X_{ij} - \frac{1}{n+2} (X_{i.} + X_{.i} + X_{.j} + X_{j.}) + \frac{2}{(n+1)(n+2)} X \dots$$

where s_{ij} = specific combining ability effect of ij^{th} cross combination.

Standard error to test the significance of gca and sca estimates were computed from the following formula.

$$\text{S.E. for gca effects } (g_i) = \sqrt{\frac{n-1}{n(n+2)}} V'e$$

$$\text{S.E. for sca effects } (s_{ij}) = \sqrt{\frac{n(n-1)}{(n+1)(n+2)} V'e (i \neq j)}$$

Where, $V'e$ = error mean square.

The (S.E.) values of gca and sca effects were used to test its significance by calculating the 't' value and compared with the table 't' value at error degrees of freedom.

3.4 Place/Duration/seasons of experiment

The crosses were made at Agricultural Botany Section Farm, College of Agril. Nagpur. The resulting hybrids and their parents were sown during *rabi* 2008-09 in Randomized Complete Block Design, replicated thrice.

Chapter – IV

RESULTS AND DISCUSSION

The experimental results obtained from various statistical and biometrical analysis have been presented and discussed under the following sub headings.

- 4.1 Analysis of variance for experimental design
- 4.2 Mean performance
- 4.3 Analysis of variance for combining ability
- 4.4 General and specific combining ability effects

4.1 Analysis of variance for experimental design

The analysis of variance for experimental design has been presented in Table 1.

The variation among the genotypes was highly significant for all characters, except days to maturity, number of primary branches plant⁻¹ and 1000 seed weight thereby, indicating a substantial amount of genetic variability. The parents exhibited significant variation for plant height, number of siliqua plant⁻¹, and seed yield plant⁻¹ while the crosses exhibited significant variation for days to 50% flowering, number of siliqua plant⁻¹, and seed yield plant⁻¹. However, parents vs crosses exhibited significant differences for only one trait namely days to 50% flowering while non significant variation was recorded for days to maturity, plant height, number of primary branches plant⁻¹, number of siliqua plant⁻¹, 1000 seed weight, seed yield plant⁻¹.

Khumbalkar (1998), Verma and Kushwaha (1999) and Katiyar *et al.* (2000) recorded significant mean sum of square for genotype and crosses for seed yield plant⁻¹ and yield contributing characters like number of siliqua plant⁻¹, plant height, thus exhibiting wide variability for these

Table 1 : The Analysis of variance for experimental design

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height at maturity (cm).	No. of primary branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	Yield plant ⁻¹ (g)
Replications	2	48.92**	236.19**	214.56	1.28	411.17	0.06	0.21
Genotypes	54	10.1**	8.16	286.76*	0.77	2167.95**	0.13	7.06**
Parents	9	6.90	6.58	470.03*	1.05	3468.09**	0.20	7.24**
Crosses	44	10.21**	8.65	254.92	0.73	1949.86**	0.12	7.18**
Parents Vs. crosses	1	29.10*	0.65	38.33	0.00	62.55	0.04	0.15
Error	108	4.48	5.97	188.24	0.75	383.23	0.19	1.30

Note : * Significant at 5% level

** Significant at 1% level

characters. The analysis of variance showed significant variation among experimental material, and hence can be exploited in better way in breeding programme.

4.2 Mean performance

The mean value of the parent and crosses for various characters are presented in Table 2.

A. Days to 50% flowering

Among the ten parents in the study Laxmi and ACN-9 were the earliest (46 days) to attain 50% flowering followed by Varuna (47 days), Bio-902 (48 days). Among the crosses, Ashirvad x ACN – 9 (45 days) was the earliest followed by Varuna x ACN –9 (46 days) and Laxmi x Kranti (47 days). The parental mean value, ranged from 46 to 50 days, while the range of crosses was 45 to 53 days. The parent which attained 50% flowering late was Vardhan (50 days), while the cross Varuna x Kranti (53 days), Vardhan x PCR-7 (53 days) attained 50% flowering late.

B. Days to maturity

Out of ten parents under study, Vardhan and Seeta was the earliest (99 days) in attaining maturity followed by Varuna (100 days) Among the crosses Laxmi x Kranti (98 days) was earliest followed by Laxmi x PCR-7, and Vardhan x Laxmi (99 days). The range for days to maturity among parents was from 99 to 103 days while that of crosses was from 98 to 194 days. The late maturing parent was Pusa bold (103 days) while the cross was Pusa bold x Ashirvad (105 days) followed by Varuna x PCR –7 (104 days).

C. Plant height (cm)

The dwarfest parent was Laxmi (123.6 cm) followed by ACN-9 (126.6 cm). Among the crosses Varuna x Kranti (122.4 cm) was dwarfest

Table 2 : Mean performance of parents and their crosses for various characters

Sr.No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height at maturity (cm)	No. of primary Branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	Yield plant ⁻¹ (g)	Oil content (%)
	Parents								
1	Pusa Bold	49	103	144.5	3	100	2.69	4.22	34.40
2	Varuna	47	100	150.0	5	125	2.76	5.49	34.80
3	Vardhan	50	99	143.4	4	135	2.94	4.58	38.40
4	Seeta	50	99	159.4	5	150	2.70	6.40	35.20
5	Bio-902	48	100	142.7	4	96	6.78	4.68	40.80
6	Laxmi	46	101	123.6	4	89	2.78	2.75	38.00
7	PCR-7	49	103	146.8	4	118	2.86	5.31	32.00
8	Ashirvad	50	103	132.4	3	114	2.90	4.92	32.80
9	Kranti	50	102	135.1	3	90	3.10	3.14	36.00
10	ACN-9	46	101	126.6	4	106	2.80	4.00	31.60
	Crosses								
1	Pusa Bold x Varuna	49	101	153.3	5	118	3.14	5.87	28.00
2	Pusa Bold x Vardhan	51	103	145.8	4	134	2.96	6.50	31.20
3	Pusa Bold x Seeta	50	101	144.6	4	136	3.10	5.10	34.80
4	Pusa Bold x Bio 902	50	103	142.4	4	143	2.41	5.79	42.00
5	Pusa Bold x Laxmi	49	100	137.0	4	104	2.88	4.34	35.60

Table 2. Continued....

Sr.No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height at maturity (cm)	No. of primary Branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	Yield plant ⁻¹ (g)	Oil content (%)
6	Pusa Bold x PCR-7	51	103	151.0	5	141	3.80	6.82	28.00
7	Pusa BoldxAshirwad	52	105	141.7	4	152	3.26	8.85	33.60
8	Pusa Bold x Kranti	49	102	139.8	4	117	3.16	4.15	26.00
9	Pusa Bold x ACN-9	50	101	150.8	4	182	3.13	7.50	36.00
10	Varuna x Vardhan	49	101	131.6	4	103	2.65	3.42	28.00
11	Varuna x Seeta	48	103	138.6	5	159	2.68	8.12	24.40
12	Varuna x Bio-902	51	103	146.0	4	122	2.86	6.44	28.00
13	Varuna x Laxmi	48	101	131.5	4	103	3.00	4.77	24.80
14	Varuna x PCR-7	52	104	141.2	4	121	2.82	5.86	24.00
15	Varuna x Ashirvad	50	104	132.9	4	136	2.93	6.16	27.20
16	Varuna x Kranti	53	104	122.4	3	75	2.97	4.61	31.20
17	Varuna x ACN-9	46	103	140.2	5	145	2.90	5.26	24.80
18	Vardhan x Seeta	51	100	144.6	4	140	2.62	6.36	32.00
19	Vardhan x Bio-902	52	101	152.4	5	188	2.80	9.31	26.40
20	Vardhan x Laxmi	49	99	123.0	4	129	2.85	4.82	30.40
21	Vardhan x PCR-7	53	101	156.6	4	155	2.84	6.83	24.00
22	Vardhan x Ashirvad	51	102	125.8	4	109	9.68	3.86	25.60

Table 2 : Continued....

Sr.No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height at maturity (cm)	No. of primary Branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	Yield plant ⁻¹ (g)	Oil content (%)
23	Vardhan x Kranti	52	104	145.0	4	135	3.10	5.31	33.60
24	Vardhan x ACN-9	51	103	150.8	5	140	2.82	6.91	32.00
25	Seeta x Bio -902	51	103	153.6	4	141	3.20	5.36	26.40
26	Seeta x Laxmi	49	103	136.7	5	140	2.90	6.92	25.20
27	Seeta x PCR-7	52	102	145.2	4	131	2.85	6.00	46.80
28	Seeta x Ashirvad	50	103	141.7	4	168	3.60	7.59	30.40
29	Seeta x Kranti	53	104	128.1	4	122	2.80	5.66	24.80
30	Seeta x ACN-9	51	102	133.1	4	153	6.74	5.86	30.40
31	Bio-902 x Laxmi	48	100	143.8	4	152	3.60	8.86	28.00
32	Bio-902 x PCR-7	49	103	154.8	4	125	2.90	7.34	29.60
33	Bio-902 x Ashirvad	50	100	146.6	4	130	2.90	6.47	28.00
34	Bio-902 x Kranti	51	102	154.2	5	163	2.80	8.60	30.40
35	Bio-902 x ACN-9	50	102	159.6	5	154	3.25	7.61	34.40
36	Laxmi x PCR-7	52	99	153.9	5	176	3.80	9.16	27.20
37	Laxmi x Ashrivad	50	101	149.8	4	145	2.52	5.54	28.00
38	Laxmi x Kranti	47	98	152.4	5	161	3.20	6.84	25.60
39	Laxmi x ACN-9	49	98	137.7	4	120	3.90	3.86	33.20
40	PCR-7 x Ashrivad	50	103	143.1	3	90	2.92	4.34	30.00
41	PCR-7 x Kranti	51	102	158.4	5	195	2.80	6.87	26.00

Table 2 : Continued....

Sr.No.	Genotypes	Days to 50% flowering	Days to maturity	Plant height at maturity (cm)	No. of primary Branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	Yield plant ⁻¹ (g)	Oil content (%)
42	PCR-7 x ACN-9	51	104	149.0	4	148	3.34	6.58	38.00
43	Ashirvad x Kranti	48	103	151.4	4	155	2.81	4.90	41.60
44	Ashirvad x ACN-9	45	102	127.7	3	84	2.85	3.62	46.80
45	Kranti x ACN-9	48	101	149.9	4	149	2.65	4.79	40.80
	S.E ±	1.22	1.40	7.92	0.50	11.30	0.25	0.65	-
	C.D. at 1%	4.52	5.22	29.36	1.85	41.90	0.93	2.43	-

123.6 to 159.4 cm among the parents and 122.4 to 159.6 cm among the crosses. Seeta (159.4 cm) was the tallest parent followed by Varuna (150.0 cm) while the cross Bio-902 x ACN -9 (159.6 cm) was the tallest followed by PCR-7 x Kranti (158.4 cm).

D. Number of primary branches⁻¹

The parent Varuna and Seeta and the crosses Pusa bold x Varuna and Varuna x Seeta recorded maximum five primary branches. The range for number of primary branches was 3 to 5 among parents as well as the crosses.

The minimum number of three primary branches were exhibited by three parents namely Pusa bold, Ashirvad and Kranti and three crosses viz. Varuna x Kranti, PCR-7 x Ashirvad and Ashirvad x ACN-9.

E. Number of siliqua plant⁻¹

The parent Seeta (150) produced maximum number of siliqua plant⁻¹ followed by Vardhan (135), while the cross PCR-7 x Kranti (195) exhibited maximum number of siliqua followed by Laxmi x PCR-7 (176). The number of siliqua plant⁻¹ ranged from 89 to 150 among the parents and 75 to 195 among the crosses. The minimum number of siliqua plant⁻¹ was produced by the parent Laxmi (89) followed by Kranti (90) and the cross Varuna x Kranti (75) followed by Ashirvad x ACN -9 (84).

F. 1000 seed weight

Parent Bio-902 (6.78 g) recorded the highest 1000 seed weight followed by Kranti (3.10 g) and Vardhan (2.94 g). Parental range for 1000 seed weight was from 2.8 to 6.78 g. Cross Vardhan X Ashirvad (9.68 g) recorded highest 1000 seed weight followed by Seeta x ACN-9 (6.74 g) and PCR - 7 x ACN-9 (3.34 g). The range for 1000 seed weight in crosses was from 2.8 to 9.68 g. Minimum 1000 seed weight were exhibited by the parent

from 2.8 to 9.68 g. Minimum 1000 seed weight were exhibited by the parent Seeta (2.70 g), followed by Laxmi (2.78 g) and ACN-9 (2.80 g). The crosses Pusa bold x Bio 902(2.41g) followed by Vardhan x Seeta (2.62 g) and Vardhan x Bio902 (2.80 g) recorded minimum 1000 seed weight.

G. Seed yield plant⁻¹

Among the parents Seeta (6.4 g) was the best for seed yield plant⁻¹ followed by Varuna (5.49 g) and PCR-7 (5.31 g). The crosses Vardhan x Bio – 902 (9.31 g) followed by Laxmi x PCR-7 (9.16 g) and Bio 902 x Laxmi (8.86 g) were found to be the high yielders.

The parental range was from 2.75 g to 6.4 g while the range for crosses was from 3.42 g to 9.31 g. Parents exhibiting minimum yield was Laxmi (2.75 g) followed by Kranti (3.14 g). The cross Varuna x Vardhan (3.42 g) followed by Ashirvad x ACN-9 (3.62 g) exhibited minimum yield.

H. Oil content (%)

Estimation of oil content was done on bulk basis from each treatment and hence it was not subjected to any statistical analysis. The parent exhibiting the greater amount of oil content was Bio-902 (40.8%) followed by Vardhan (38.4%) and Laxmi (38%). The range of oil content among the parent was from 31.8 to 40.8% Per cent. The cross Ashirvad x ACN-9 (46.8%) had highest amount of oil content followed by Ashirvad x Kranti (41.6%) and Kranti x ACN-9 (40.8%). The range of oil content among the crosses was from 24 to 46.8% per cent.

Parent exhibiting the minimum oil content was ACN-9 (31.6%) followed by PCR-7 (32%) and Ashirvad (32.8%) while crosses exhibiting minimum oil content was Vardhan x PCR – 7 (24%) followed by Varuna x Seeta (24.4%) and Vardhan x Ashirvad (25.6%).

Considering the *per se* performance for seed yield plant⁻¹ and yield contributing character i.e. number of siliqua plant⁻¹, the cross Vardhan x Bio – 902 was identified as the best cross as it yielded highest i.e 9.31 g and had significantly high number of siliqua i.e 188. The crosses Pusa bold x Ashrivad and Varuna x Seeta were also identified as better crosses next to Vardhan x Bio – 902 as they also produced significantly high yield 8.85 g and 8.12 g respectively with 152 and 159 siliqua plant⁻¹ respectively.

The *per se* performance of crosses gives only some indication of their usefulness in selecting potential cross but their long term potentialities are not known. Hence, selection of superior parents which has the potential to produce superior cross combinations and identifying the best cross combinations on the basis of combining ability will give the required information in the absence of knowledge of genetic basis of continuously varying character. The breeders are often at a loss to know which particular combination of parents would nick well to produce large number of superior offspring's (Joshi *et al.* 1961). Therefore, the information of combining ability for assessment of breeding, potential of the parental material along with the type of genetic components involved in yield and yield contributing traits in Indian mustard can be of immense help to the mustard breeders and has been widely used by many workers Katiyar *et al.* (2000), Joshi (2001), Parmar *et al.* (2005).

4.3 Analysis of variance for combining ability

Analysis of variance for combining ability are presented in table 3. The variation between crosses was partitioned into different components representing mean sum of squares due to general combining ability and specific combining ability. The mean squares due to gca was of higher magnitude than those due to sca indicating larger diversity among the parents than the crosses for most of the characters. The mean sum of squares due to gca were significant for days to 50% flowering, number of

Table 3 : The analysis of variance for combining ability

Source	d.f.	Days to 50% flowering	Days to maturity	Plant height at maturity (cm)	No. of primary branches plant ⁻¹	No. of siliqua plant ⁻¹	1000 seed weight (g)	Yield plant ⁻¹ (g)
GCA	9	5.73**	1.70	85.33	0.17	853.72**	0.04	3.23**
SCA	45	2.86**	2.92	97.64*	0.27	696.43**	0.04	2.18**
Error	108	1.49	1.99	62.75	0.25	127.74	0.06	0.43
Predictability Ratio		0.80	0.54	0.64	0.56	0.71	0.67	0.75

*significant at 5% level

**significant at 1% level

siliqua plant⁻¹ and seed yield plant⁻¹ and non significant for all the other characters under study. The mean sum of squares due to specific combining ability were significant for days to 50% flowering, plant height, number of siliqua plant⁻¹ and seed yield plant⁻¹.

Tiwari and Singh (1975), Labana *et al.* (1975), Kashi Ram *et al.* (1976), Singh *et al.* (1985), Malkhandale (1993), Singh *et al.* (2003) also reported highly significant differences among the progenies for seed yield.

The predictability ratio ranged from 0.54 for days to maturity to 0.80 for days to 50% flowering. The ratio of predictability for number of siliqua plant⁻¹, and seed yield plant⁻¹ and were 0.75 and 0.71 respectively. Yadav and Yadav (1985) also observed highest predictability ratio for seed weight followed by plant height. The value of predictability ratio worked out for these two characters reveal that the gca effects of parents involved in the crosses as well as the sca effects of crosses should be considered while selecting the parents or crosses for their exploitation to recover transgressive segregates as the value of predictability ratio is greater than 0.50 but not closer to unity.

4.4 General and specific combining ability effects

The gca effects of ten parents for days to 50% flowering, number of siliqua plant⁻¹ and seed yield plant⁻¹ are presented in Table 4. The sca effects of 45 crosses for days to 50% flowering, plant height, number of siliqua plant⁻¹ and seed yield plant⁻¹ are presented in Table 5. The gca effects of parents and the sca effects of crosses for rest of characters were not calculated as their respective mean sum of squares were non significant.

Table 4 : General combining ability effects of parents

Sr.No.	Parents	Days to 50% flowering	Number of siliqua plant ⁻¹	Yield plant ⁻¹ (g)
1	Pusa bold	0.139	-1.233	0.031
2	Varuna	0.222	2.239	0.610**
3	Vardhan	0.889**	0.017	-0.121
4	Seeta	0.500	9.906**	0.909**
5	Bio-902	0.528	-0.344	0.008
6	Laxmi	0.250	17.600**	0.202
7	PCR-7	-0.083	-3.622	0.170
8	Ashirvad	-1.556**	-8.122**	-0.591**
9	Kranti	-0.556	-10.622**	-0.762**
10	ACN-9	-0.333	-5.817	-0.455*
	S.E (gi) ±	0.334	3.0952	0.180

Note : * Significant at 5% level

** significant at 1% level

Note : GCA effect of parents for days to maturity, plant height, no. of primary branches plant⁻¹, 1000 seed weight were not calculated as their respective mean squares were non-significant .

Table 5 : Specific combining ability effects of crosses for different characters

Sr.No.	Crosses	Days to 50% flowering	Plant height at maturity (cm)	No. of siliqua plant ⁻¹	Yield plant ⁻¹ (g)
1	Pusa Bold x Varuna	1.215	4.052	0.134	0.050
2	Pusa Bold x Vardhan	-0.785	2.102	4.023	-0.585
3	Pusa Bold x Seeta	-0.063	-2.176	1.467	-0.955
4	Pusa Bold x Bio 902	-1.758	-8.642	-27.950*	-1.502*
5	Pusa Bold x Laxmi	0.520	2.858	-8.227	0.778
6	Pusa Bold x PCR-7	1.854	-4.904	23.662*	2.843**
7	Pusa Bold x Ashirwad	0.326	-6.665	-7.172	-1.096
8	Pusa Bold x Kranti	0.992	11.574	60.995**	2.422**
9	Pusa Bold x ACN-9	-0.230	-12.981	-22.811*	-1.959**
10	Varuna x Vardhan	-0.202	7.630	-13.116	0.150
11	Varuna x Seeta	-2.813*	-8.848	-42.338**	-2.554**
12	Varuna x Bio-902	1.492	-0.315	-5.755	-0.567
13	Varuna x Laxmi	0.104	-4.348	-16.366	-0.454
14	Varuna x PCR-7	2.770*	-20.042**	-57.144**	-1.975**
15	Varuna x Ashirvad	-2.091	-2.137	17.356	-0.561
16	Varuna x Kranti	1.576	9.569	15.189	0.377
17	Varuna x ACN-9	2.354*	12.346	58.717**	3.350**
18	Vardhan x Seeta	1.520	15.402	12.217	0.237
19	Vardhan x Bio-902	0.159	-16.465*	-26.866*	-1.835**

Table 5 : Continued....

Sr.No.	Crosses	Days to 50% flowering	Plant height at maturity (cm)	No. of siliqua plant ⁻¹	Yield plant ⁻¹ (g)
20	Vardhan x Laxmi	1.437	0.302	-15.811	-0.576
21	Vardhan x PCR-7	0.437	7.541	10.078	1.056
22	Vardhan x Ashirvad	1.242	10.513	16.245	0.270
23	Vardhan x Kranti	-1.091	0.819	17.745	2.001**
24	Vardhan x ACN-9	1.687	4.396	3.273	0.774
25	Seeta x Bio -902	2.215	-16.209*	-21.088*	-1.125
26	Seeta x Laxmi	0.492	-13.642	-7.033	-1.053
27	Seeta x PCR-7	-1.841	-1.404	12.523	1.980**
28	Seeta x Ashirvad	0.298	9.702	-9.311	1.220
29	Seeta x Kranti	0.298	8.741	-2.811	0.518
30	Seeta x ACN-9	1.409	11.385	25.717*	1.797*
31	Bio-902 x Laxmi	1.465	6.024	26.551*	2.481**
32	Bio-902 x PCR-7	-0.535	3.463	14.439	-0.440
33	Bio-902 x Ashirvad	-1.396	6.102	36.273**	1.621*
34	Bio-902 x Kranti	-0.396	-1.326	-2.561	-1.195
35	Bio-902 x ACN-9	0.381	-0.881	-37.366**	-1.015
36	Laxmi x PCR-7	1.076	0.230	0.828	0.400
37	Laxmi x Ashirvad	-0.452	2.735	12.328	-0.513

Table 5 : Continued....

Sr.No.	Crosses	Days to 50% flowering	Plant height at maturity (cm)	No. of siliqua plant ⁻¹	Yield plant ⁻¹ (g)
38	Laxmi x Kranti	-4.119**	-13.759	-55.838**	-1.622*
39	Laxmi x ACN-9	-2.008	3.485	3.689	-0.763
40	PCR-7 x Ashrivad	-1.452	2.774	3.551	0.106
41	PCR-7 x Kranti	0.881	3.413	16.384	-0.630
42	PCR-7 x ACN-9	0.659	14.524	26.912*	0.516
43	Ashirvad x Kranti	-1.313	-16.215*	-25.449*	-1.703**
44	Ashirvad x ACN-9	1.465	1.963	-1.255	0.550
45	Kranti x ACN-9	1.131	-2.465	-27.088*	-1.452*
	S.E. (sij) ±	1.126	7.296	10.410	0.607

Note : * significant at 5% level

** significant at 1% level

Note : SCA effect for days to maturity, no. of primary branches plant⁻¹, 1000 seed weight, were not calculated because mean square due to crosses were non-significant.

1. Days to 50% flowering (days)

Significant gca effects were exhibited by two parents, Vardhan (0.889) recorded highest positive gca effect while Ashirvad (-1.556) recorded highest negative gca effect followed by Kranti (-0.556).

Four crosses out of 45, exhibited significant sca effects. Two crosses showed significant positive sca effects. Varuna x PCR-7 (2.770) recorded highest positive sca effects followed by Varuna x ACN-9 (2.354). Two crosses showed significant negative sca effect. Cross Laxmi x Kranti (-4.119) recorded highest negative sca effect followed by Varuna x Seeta (-2.813).

2. Plant height at maturity (cm)

Four crosses out of 45 showed significant sca effect of which all the four crosses showed negative significant sca effects. Varuna x PCR – 7 (-20.042) recorded highest sca effect followed by Vardhan x Bio-902 (-16.465) and Ashirvad x Kranti (-16.215) and Seeta x Bio-902 (-16.209).

3. Number of siliqua plant⁻¹,

Out of ten, only four parents showed significant gca effects, two parents showed significant positive gca effects. While other two parents showed highly significant negative gca effects. Parent Laxmi (17.600) showed highest gca effects, followed by Seeta (9.906). Parent Kranti (-10.622) showed highest negative gca effects followed by Ashirvad (-8.122).

Out of 45 crosses, seventeen crosses showed significant sca effects, of which seven crosses showed significant positive sca effects and ten crosses showed significant negative sca effects. Cross Pusa bold x Kranti (60.995) showed highest positive sca effect followed by Varuna x ACN-9 (58.717) and Bio-902 x Ashirvad (36.273). Cross Varuna x PCR-7

(-57.144) showed highest negative sca effect followed by Laxmi x Kranti (-55.838) and Bio-902 x ACN-9 (-37.366).

4. Seed yield plant⁻¹

Five parents out of ten, recorded significant gca effects for yield plant⁻¹. Out of these, only two parents exhibited positive significant gca effects and other three parents exhibited negative significant gca effects. Seeta (0.909) recorded highest significant positive gca effects followed by Varuna (0.610). Kranti (-0.762) exhibited highest significant negative gca effect followed by Ashirvad (-0.591) and ACN-9 (-0.455).

Out of forty five crosses, sixteen exhibited significant sca effects of which eight crosses showed positive significant sca effects and remaining eight showed negative significant sca effects. Varuna x ACN-9 (3.350) recorded highest significant positive sca effects followed by Pusa Bold x PCR - 7 (2.843) and Bio-902 x Laxmi (2.481). Varuna x Seeta (-2.554) exhibited highest significant negative sca effects followed by Varuna x PCR-7 (-1.975) and Vardhan x Bio-902 (-1.835).

The estimates of gca effect among the parent showed that the parent Seeta had highest significant gca effect for seed yield plant⁻¹ and higher significant gca effect for number of siliqua plant⁻¹. The parent Laxmi exhibited highest significant gca effect for number of siliqua plant⁻¹ and positive non-significant gca effect for seed yield plant⁻¹. The parent Varuna exhibited higher significant gca effect for seed yield plant⁻¹ and non-significant gca effect for number of siliqua plants⁻¹. Hence, the genotype Seeta, Varuna and Laxmi would be useful as desirable parents for enhancing the yield potential through assembling the favourable genes for desirable yield components. Dixit *et al.* 1983, Thakral *et al.* 2000, Yadav *et al.* 1992 and Sheikh and Singh 1988 also identified Varuna as a good general combiners. The comparison of gca effect with the *per se*

performance of the parents revealed that the ranking of parents on the basis of mean values was nearly the same as that on the basis of gca effect for most of the characters. In some characters there was slight variation in the rankings i.e. the parents ranking first for *per se* performance may be ranked second or third for gca effect and vice-versa. This suggest that the potentiality of a variety as a parent may be judged by comparing its *per se* performance with the F_1 value and the combining ability effects.

In self pollinated crop like mustard, the aim of a breeder is to produce homozygous lines, unless commercial exploitation of heterosis becomes feasible. Production of true breeding varieties thus requires to identify crosses with low sca effects and involving parents with high gca effects.

The cross Varuna x Seeta exhibited highest significant negative sca effect for seed yield plant⁻¹ and high significant sca effect for number of siliqua plant⁻¹. The parents involved in this cross also exhibited highest significant gca effect for seed yield plant⁻¹ and number of siliqua plant⁻¹. Negative significant sca effect for seed yield plant⁻¹ and number of siliqua plant⁻¹ and days to 50% flowering were exhibited by the cross Laxmi x Kranti. The same cross also had one parent with positive significant gca effect for number of siliqua plant⁻¹ and positive non-significant gca effect for seed yield plant⁻¹, whereas the other parent exhibited negative significant gca effect for both number of siliqua plant⁻¹ and seed yield plant⁻¹, Negative significant sca effects indicated the involvement of additive gene action for yield components which is a general situation observed in self pollinated crops (Badwal *et al.* 1974), Due to the presence of additive gene action in these crosses, the genotypes of inherent superiority can be produced from this population by blending and fixing maximum favourable genes as stated by Rai and Das, 1974. Alternatively improvement for seed yield can also be

sought by using simple selection method or any other method which can capitalize additive gene action.

Among the 45 crosses studied, eight crosses exhibited significant negative sca effects for number of siliqua plant⁻¹ and seed yield plant⁻¹. The cross Varuna x PCR-7 exhibited high negative sca effects for seed yield plant⁻¹, number of siliqua plant⁻¹ and plant height at maturity. This cross also had one parent exhibiting significantly high gca effect for seed yield plant⁻¹ and number of siliqua plant⁻¹ while the other parent exhibited positive non significant gca effect for seed yield plant⁻¹ and negative non significant gca effect for number of siliqua plant⁻¹.

Selection of parents and crosses

Specific combining ability effects generally do not contribute a lot in the improvement of self pollinated crop, except where commercial exploitation of heterosis is feasible. However, in the production of homozygous line, the attention of breeder normally rests on transgressive segregates shown by the crosses, hence in such crops the breeder is restricted to produce true breeding varieties only, as the non-additive portion of phenotypic variation is not fixable in later generations. Therefore, a breeder would prefer to isolate the crosses which have low sca effect but have high mean performance and better gca for parent.

Considering the above points, the potentiality of variety may be judged by comparing *per se* performance and the combining ability of the parents and the F₁ value (Singh *et al.* 1985), while the potentiality of the cross to be forwarded to next generation is decided on the basis of high mean performance, high heterosis, high gca of one or both the parents involved in the cross and with negative sca effect. The selection of crosses in this manner was also done by Arunachalam and Katiyar (1982) and

Khumbalkar (1998). Based on these criteria, promising crosses and their selected *per se* performance are given in table 6.

Considering the overall performance and the gca effects of the parents, Seeta and Varuna were identified as good combiners for seed yield and number of siliqua plant⁻¹ and hence may be exploited for intensive breeding programme. This was not in line with Parmar *et al.* (2005) who identified different parents for different yield contributing characters. Dixit *et al.* (1983), Yadav *et al.* (1992), Sheikh and Singh (1998), Thakral *et al.* (2000), Lalta Prasad (2002), also identified Varuna as a parent either on the basis of high mean performance or on the basis of high general combining ability.

Out of eight crosses which recorded desirable sca effects, only one cross Varuna x Seeta was found to be the best population which can be forwarded to the next generation. This cross possessed both the parents exhibiting highly significant gca effect for yield, and involved one parent with high non-significant gca effect for number of siliqua plant⁻¹. This cross also recorded high mean performance for seed yield plant⁻¹ and number of siliqua plant⁻¹. The presence of negative sca effect for several yield components in Varuna x Seeta indicates the predominant role of additive gene action for yield components, which is a general situation observed in self pollinated crop. Singh *et al.* (2003), and Badwal and Labana (1983) identified superior crosses based on sca and *per se* performance and suggested the suitability of biparental matings in selected progeny and further selection of segregating generations, recurrent selection or diallel selected matings may be used for improvement of yield and yield components

Table 6 : Selected cross and its performance for important characters

Cross	Mean	GCA effects		SCA effects
		P ₁	P ₂	
Number of siliqua plant ⁻¹				
Varuna x Seeta	159	2.239	9.906**	-42.338**
Seed yield plant ⁻¹ (g)				
Varuna x Seeta	8.12	0.610**	0.909**	-2.554**

Note : * significant at 5% level

 ** significant at 1% level

Chapter – V

SUMMARY AND CONCLUSIONS

The present study entitled "Diallel analysis for yield and yield contributing characters in Indian mustard. (*Brassica juncea*)" was undertaken using ten parents to assess the general and specific combining ability of parents and crosses to isolate superior crosses for studying them in further generations. The experimental material consisted of ten diverse genotypes crossed in diallel fashion to secure forty five F_1 's. These forty five crosses along with their respective parents were sown in Randomized complete Block Design replicated thrice at Shankar Nagar, Farm of Botany Section, College of Agriculture, Nagpur during *rabi* 2008-09. Data was recorded for days to 50% flowering, days to maturity, number of primary branches, plant height at maturity (cm), number of siliqua plant⁻¹, 1000 seed weight (g) seed yield plant⁻¹ (g) and oil content in percentage.

Considerable variability existed among the genotypes for all the characters studied as observed from the significant mean squares due to genotypes. The cross Vardhan x Bio-902 was identified as a best cross on the basis of mean values for yield plant⁻¹, and number of siliqua plant⁻¹. The other crosses exhibiting high mean performance for seed yield plant⁻¹ and number of siliqua plant⁻¹ were Laxmi x PCR-7, Bio-902 x Laxmi, Pusa bold x Ashirvad and Varuna x Seeta.

The mean squares due to gca were greater in magnitude than those due to sca for seed yield plant⁻¹, number of siliqua plant⁻¹ and days to 50% flowering. indicating larger diversity among the parents than the crosses for these characters.

The gca estimates of parents emphasized the importance of the parents Varuna, Seeta, and Laxmi for their use as good general combiners for yield contributing characters which may be exploited for intensive breeding programme by producing intermating populations involving all possible crosses among the parents.

Out of the eight crosses which exhibited desirable sca effects, the crosses Varuna x ACN-9, Pusa bold x PCR-7, Bio-902 x Laxmi and Varuna x Seeta, were identified as the best crosses for economically important characters. However, out of these crosses the cross Varuna x Seeta was found to be best cross based on high mean performance, high significant gca effect of parents involved in the cross and negative sca effects and hence can be forwarded to next generation for producing genotype of inherent superiority by blending and mixing maximum favourable genes, by following a simple selection method.

Chapter - VI

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