STUDIES ON HETEROSIS, INBREEDING DEPRESSION, COMBINING ABILITY AND GENE ACTION IN INDIAN MUSTARD (*Brassica juncea* (L.) Czern & Coss.)

Thesis

SUBMITTED TO THE

G. B. Pant University of Agriculture & Technology
Pantnagar-263 145
(U. S. Nagar) Uttaranchal, INDIA

By

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IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Doctor of Philosophy

(Genetics and Plant Breeding)

DECEMBER,2000

Dedicated
to my
Beloved Parents

ACKNOWLEDGEMEMT

I feel extremely to take this opportunity to express my profound regard and deep sense of gratitude to Dr. Basudeo Singh, Chief Scientist & Head, Department of Genetics & Plant Breeding and chairman of my advisory committee for suggesting the research problem and for his excellent guidance and persistent encouragement during the course of my investigation and preparation of the manuscript.

My grateful thanks are due to the members of my advisory committee, Dr. I. S. Singh, Professor, Genetics & Plant Breeding; Dr. S. J. Kolte, Professor, Department of Plant Pathology and Dr. J.N. Sachan, Senior Research Officer (Oil seed Breeding) for their valuable guidance, keen interest and constructive criticisms during the preparation of the manuscript.

I am also thankful to Head, Department of Genetics & Plant Breeding; Dean Post Graduate Studies; Dean, College of Agriculture; Director, Experiment station, Associate Director Crop Research Centre and Librarian for providing suitable facilities during the course of this study.

I express my deep gratitude to all the staff of the Department of Genetics and Plant Breeding particularly Dr. Rameshwar Singh, Dr. M.P. Pandey and Dr. G.C. Bajpai for extending their guidance and cooperation to me.

It is nicest time to express my sincere thanks to Dr. S.P.singh, Dr. D.P. Pant, R.A. Khan, O.P. Ojha, Rajveer Singh, Rakesh Kumar, Ram Prakash, Iswar Prasad and labourers for their valuable help and affection during the investigation.

Indeed words fail to express my profound sense of gratitude and heartfelt indebtedness to my brother's, Jija ji (Dr. L. R. Singh), Didi (Indra Singh), my life partner Sadhna and My Children Khushboo and Rahul for their constant encouragement and moral support to materialize this dream.

I express my deep sense of gratitude to my all companions Santosh, Pawan, Ajju, Brijesh, Sailendra, Akhilesh, Dhirendra, Promode, Naveen, Bhupendra, Shivji, Prabhat, Raju Ratan, R. L. Shah, K. S. Bora, Maheshwari, S. S. Singh, S. K. Srivastava, T.P. Singh, U. P. Shahi, Sanjay Shahi, A. S. Jeena, K. A. Khan, K. P. S. Tomer, Yogeshwar, and Sudarson Joshi, for their everlasting encouragement and help to me.

I am also highly thankful to V.K. Prabhakaran and Ranjeet Singh for his excellent typing of this manuscript.

Pantnagar
December, 2000

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CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON HETEROSIS, INBREEDING DEPRESSION, COMBINING ABILITY AND GENE ACTION IN INDIAN MUSTARD (*Brassica juncea* (L.) Czern & Coss)".** *submitted in partial fulfilment of the requirements for the degree of* ***Doctor of Philosophy*** *with major in* ***Genetics & Plant Breeding*** *of the college of Post-Graduate Studies, G. B. Pant University of Agriculture and Technology, Pantnagar, is a record of bona fide research carried out by* ***Mr. Anil Kumar Singh Id. No. 20563*** *under my supervision, and no part of the thesis has been submitted for any other degree or diploma.*

The assistance and help received during the course of this investigation have been duly acknowledged.

12/12

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CERTIFICATE

We, the undersigned, members of the Advisory Committee of ***Mr. Anil Kumar Singh Id. No. 20563****, a candidate for the degree of* ***Doctor of Philosophy*** *with major in* ***Genetics and Plant Breeding*** *agree that the thesis entitled* **"STUDIES ON HETEROSIS, INBREEDING DEPRESSION, COMBINING ABILITY AND GENE ACTION IN INDIAN MUSTARD (*Brassica juncea* (L.) Czern & Coss)".** *may be submitted in partial fulfilment of the requirements for the degree.*

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INTRODUCTION

Introduction

Brassica oil crops are widely grown throughout the world as oilseed crops for edible oil, as vegetable crop, as condiments and spices for improving flavour of human food and as fooder crops for livestock feeding. However, these crops are largely cultivated for edible oil production. The Brassica group of oilseed crops are commonly known as Rapeseed-mustard. In India, Rapeseed-mustard comprise of traditionaly grown indigenous species, namely Indian mustard (*Brassica juncea* L., Czern & Coss), brown & yellow sarson and toria (*Brassica campestris* L.) and non-traditional species like gobhi sarson (*Brassica napus*) and Ethiopian mustard (*Brassica carinata*) are the second most important oilseed crops after groundnut in terms of area and production.

India with 6.71 million ha area under rapeseed-mustard during 1997-98 is the largest rapeseed mustard growing country in the world. Its total production is 4.94 million tones, the second highest in the world after China. India account for 26.4 percent and 13.80 per cent of the global hectarage and production, respectively. In Asia, India contributes 35.88 per cent to the total rapeseed-mustard production from 48.38 per cent of the area (Yadava *et al.* 2000)

In India, the production rapeseed-mustard has undergone phenomenal change. The area, production and productivity have increased from 1.94 million ha., 0.81million tonnes and 417 kg/ha in 1949-50 to 6.60 million ha, 5.77 milion tonnes and 875 kg/ha, respectively in 1998-99. This increase in area, production and productivity is largely accounted by the *Brassica juncea* (L.) Czern & Coss which accounts about 90 per cent of the total area under rapeseed-mustard

The major rapeseed-mustard producing states in the country are Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujrat, Haryana and Punjab. In Uttar Pradesh, mustard occupied about 0.759 million ha area with an annual production of 0.554 million tonnes with an average productivity of 730 kg/ha in year 1992-93 , which increased to 1.11 million ha and annual production of 0.92 million tonnes with an average productivity of 831 kg/ha in 1998-99.

The quantum jump in production of rapeseed-mustard crop is attributed to the development of improved breeding system. The hybridization and selection programmes have come to stay as the potent breeding tool in the genetic improvement of yield in crop plants. In breeding better varieties of field crops, the hybridiztion approach is usually followed either to recombine or to infuse the favourable gene(s) in the various commercial cultivars. It is equally used to make an assembly of hybrids for picking the best and the balanced productive hybrid population for the commercial cultivation in all those crops, where it is biologically or economically feasible to produce the hybrid seed on large scale. The selection after the hybridization were generally followed for funneling out and concentrating the desirable gene(s) governing the characters of economic importance in otherwise unselected or segregating populations. The success in the first approach generally depends upon choosing the most appropriate genetic material from a vast collection of germplasm and handling it properly and effectively through the segregating generations. The success in the latter i.e. the selection programme, usually needs the basic information on the type of gene action involved in the expression of various quantitative or economic characters , the extent of their heritability and the magnitude of advance that could be obtained by utilizing a particular scheme of selection.

As Indian mustard is highly self-pollinated crop, scope for the exploitation of hybrid vigour depend on the direction and magnitude of heterosis and biological feasibility. The study of heterosis will have a bearing on the breeding methodology to be employed for varietal improvement. The information of inbreeding depression gives a picture of the hybrids that could be possibly utilized in a meaningful hybrid programme. In practical plant breeding programme, these information are, therefore, helpful in the breeding better varieties for commercial cultivation.

The available basic biometrical information on yield and yield component including oil content for selecting a suitable breeding methodology and synthesizing a suitable genotype for commercial cultivation from the available Indian mustard germplasm material is rather inadequate in this crop. The present investigation was, therefore, planned and conducted using 10 varieties /lines combed out of the germplasm maintained at this university in two sets of experimental material with a view to obtaining the information on :

i) the general combining ability effects of parents and specific combining ability effects of their all possible crosses,

ii) the nature of gene effects and extent of heritability for quantitative traits,

iii) the extent of heterosis and inbreeding depression for yield and its important components including oil content in F_1 & F_2 generations and.

iv) identify the good parents and promising crosses.

REVIEW

OF

LITERATURE

Review of Literature

Rapeseed–mustard occupy second position both in terms of acerage and production in India. This increase is largely accounted by *Brassica juncea* (L.) Czern & Coss. which account for about 90 percent. The available literature on relevant aspect of the present investigation is presented under the following heads.

2.1 Combining ability studies.

2.2 Nature of gene action.

2.3 Estimation of the extent of heritability.

2.4 Extent of heterosis and inbreeding depression.

2.1 Combining ability studies

The concept of combining ability is becoming increasingly important in plant and animal breeding programmes. This analysis is usually restricted to spot out suitable lines/hybrids for utilising them in the breeding programmes and for understanding the nature of gene action in the useful economic characters. For the first time, **Sprague and Tatum (1942)** gave the concept of combining ability and classified it into two i.e., general and specific combining ability. They defined general combining ability (gca) as average performance of a line in a set of hybrid combinations. The term specific combining ability (sca) was defined as the case in which certain cross combination do relatively better or worse than would be expected on the basis of the average performance of the lines involved. It was also expressed that gca was mainly due to additive gene effects and additive × additive interaction, while specific combining ability was a consequence of dominance and epistatic deviation and genotype × environment interactions. They also investigated that in single cross involving selected lines, *sca* had greater effect while in unselected lines *gca* effect were predominant in determining the yield.

Henderson (1952) considered *gca* as the average merit with respect to some traits or weighted combination of traits in large number of progenies of an individual lines when mated with a random sample from the same specific population under a set of enivronmental conditions. He defined *sca* as deviation of value of a cross from the average of an indefinitely large number of progenies of an individual or lines which would be expected on the basis of *gca* of these two lines.

According to **Griffing (1956)** *gca* includes both additive effects as well as additive × additive interactions.

Diallel analysis has been extensively used in determining *gca* and *sca* effects in crop plants following the theoretical development of diallel cross concept by **Hayman (1954) and Griffing (1956).**

Allard (1960) suggested that high yielding lines may not necessarily be able to transmit their superior ability to their crosses. Hence, the estimate of *gca* and *sca* may be more relaible rather than their per se performance.

Singh and Singh (1972) reported partial dominance for days to flowering and plant height and full dominance for siliqua length while studying diallel cross in *B. juncea* for two consecutive years. The degree of dominance varied over seasons for most of the characters.

Singh (1973) conducted a diallel analysis of 6 parents in Indian mustard and observed that both *gca* and *sca* were equally important for height, number of primary and secondary branches per plant, main shoot length, number of siliqua on main shoot, yield per plant, number of seed per siliqua and 1000-seed weight. However, the additive genetic variance was reported to be longer than non-additive genetic variance for all characters except for seeds per siliqua.

Yadav *et al.* (1974) observed highly significant *gca* and *sca* variances indicating the presence of both additive and non-additive gene action per yield and other characters. Labana *et al.* (1975) made a similar observation for yield, number of siliqua bearing primary branches, siliqua length and plant height.

From a study of 10 × 10 diallel in Indian mustard, **Tiwari and Singh (1975)** reported significant *gca* and *sca* estimates for yield, height and days to flowering. The same suggestions were also made by **Yadav and Gupta (1975).**

A line × tester (8 × 3) analysis in mustard by **Badwal *et al.* (1976)** revealed that lines were more variable than tester parents. The variety T-59 was the best general combiner for seed size, seed yield and siliqua length. **Kashi Ram *et al.* (1976)** found that the estimate *of gca* and *sca* were significant for all the traits, T-59, T-53 and IB-760 were observed to be good general combiners for most of the characters.

Labana *et al.* (1978) in a study of complete 6 × 6 diallel of yellow *sarson*, observed significant and higher *gca* variance than *sca* variance for height, seeds per pod and pods on main shoot and reverse for yield and pods per plant.

Chauhan and Singh (1979) studied 20 × 20 diallel in *B. juncea* and reported that variance due to *gca* and *sca* were highly significant for all characters in both F_1 and F_2 generation. The estimates of component of variance indicated that magnitude of σ^2_g was higher for flowering and days to maturity and lower for secondary branches, siliqua length, seeds per siliqua and yield. They further reported higher magnitude of σ^2_g in F_1 and σ^2_s in F_2 indicating that both additive and non-additive gene action are important for height whereas, higher value of σ^2_s in F_1 and nearly equal values of σ^2_g and σ^2_s in F_2 were important for primary branches. **Rishipal**

and Singh (1981) studied the combining ability in 9 × 9 diallel set of *Brassica* spp. and reported highly significant *gca* and *sca* variance for all the characters.

The study conducted by **Yadav *et al.* (1981)** revealed the preponderance of non-additive genetic variance for all characters. According to them Varuna (T-59) emerged as the best general combiner having high *gca* effects for yield, earliness, main shoot length, seeds per siliqua and seed weight.

The combining ability study were made by **Dixit *et al.* (1983)** in a non-reciprocal diallel cross of seven parents. They have reported that Varuna was the best general combiner and B-85 × Varuna the best specific combination for 1000-seed weight, oil content and protein content. From a line × tester (18 × 3) analysis in Indian mustard, **Singh and Singh (1983)** were identified that the good general combiner and specific cross combination for days to 50% flowering days to maturity, seed yield and oil content.

Chander *et al.* (1985) conducted a line × tester (14 × 3) analysis in Indian mustard and reported that mean square due treatment and their component (parent, crosses, lines, testers and line × tester) were significant for most of the characters except days to flowering and maturity. Genotype 11/7-1 was the best tester for *gca* having high *gca* value for seed yield, number of secondary branches, height and 1000-seed weight. Whereas, RL-48 × 11/7-1 was the best specific combination for seed yield, number of secondary branches and number of siliqua on main shoot. From a 9 × 9 diallel study of *B. juncea*, **Singh *et al.* (1985)** reported that Prakash and Laha are the best general combiner for seed yield. **Most of the crosses** showing significant *sca* effect involved both low × low and low × high general combiners. The promising crosses for seed yield were Varuna × Pusa bold, Varuna × Laha-101 and Varuna × Kanpur-1. They were also good for other trait. Higher *sca* effect were recorded in crosses between morphologically different parents. **Gupta *et al.* (1985)** estimated *gca* and *sca* effect in 36 crosses involving 9 parents. They revealed that RH-785 had the best *gca* effect and 15 crosses showed positive *sca* effect.

Jindal and Labana (1986) while working on 14 × 14 diallel analysis of *B. juncea* they identified T-59 and RLM-196 as good general combiner for seed yield per plant and some related trait. The promising crosses RL-18 × T-6342 and RLM-188 × T-6342 were showed high *sca* effect for seed yield per plant and most yield contributing characters.

Wang and wang (1986) conducted a study on combining ability in *B. juncea* and found significant difference in *gca* of 6 exotic cultivars. They also reported that preponderance of *gca* variance for number of primary branches and siliqua length, whereas, preponderance of *sca* variance was noticed for siliquae per plant and number of secondary branches.

Badwal and Labana (1987) studied 9 × 9 half diallel in *B. juncea* under two environment, found significant variance due to *gca* and *sca* for seed size and *sca* variance for oil content. They also observed that M-160 was the best general combiner and P-16-13 was best for seed size, the best crosses for *sca* are identified. **Gupta *et al.* (1987)** in a study of diallel cross of *B. juncea gca* and *sca* mean square were significant for all characters studied. The best general combiner for seed yield was RLM-198. The best crosses for further selection were RLM-198 × Varuna and RLM-198 × RH-30. **Prakash *et al.* (1987)** in 8×8 diallel cross study of Indian mustard and reported that *gca* and *sca* variance were significnat for oil content and yield components. The *sca* variance was higher than *gca* variance for number of seeds per siliqua, 1000-seed weight, seed yield and oil content. DIR-146 and RLC-1017 were good general combiner for most of the characters. The best crosses for seed yield and oil content are listed.

Chaudhary *et al.* (1988) evaluated 13 *B. juncea* varieties and their 78 hybrids for their combining ability analysis. RH-30, RH-785 and Varuna emerged as good combiners and showed significant *gca* effect for seed yield per plant and yield components. The hybrids RC-781 × RH-30 and

RH-513 × Varuna were observed as the best specific combinations with the best mean performance for yield and its components.

Chauhan *et al.* (1989) identified four best general combiners NDR-8602, Krishna, Pusa bold and TM-9 and nine best specific cross combinations for seed yield while working line × tester analysis in *B. guncea*. **Thakur *et al.* (1989)** studied combining ability for nine economic traits in Indian mustard. Among the lines Gonda-3 and RH-2 had the highest *gca* for seed yield.

Singh *et al.* (1989) evaluated F_1 and F_2 hybrids of Indian mustard together with 6 parents for combining ability with respect to plant height, length of main shoot, seed yield, 1000-sed weight and oil content. RLM-198 and RNS-12 are identified good general combiners whereas, RLM-198 × R-75-7 show significant *sca* effect for seed yield in both F_1 and F_2 generations. **Singh and Kumar (1990)** identified T-6342 and RLM-198 as good general combiner for aphid resistance. The crosses RH-30 × RLM-198 and RH-30 × T-6342 were promising for developing aphid tolerant genotypes.

Yashpal and Singh (1991) studied the combining ability of Indian mustard genotypes for oil content. They reported that RH-7859 was the best general combiner followed by Kranti, RH-30 and Prakash. Hybrid

Prakash × EC-126743-2 and Kranti × RC-781 emerged as the two best of nine promising crosses showing high *sca* effects.

Yadava *et al.* (1992) evaluated 45 F_1 hybrids of Indian mustard together with 10 parents in two environment for combining ability with respect to seed yield, its component and oil content. Varuna, Kranti, RLC-1359 and RLC-1357 revealed as good general combiners for seed yield, earliness, siliqua length, seeds per siliqua and 1000-seed weight whereas, EC-126743, EC-126745 and EC-126746-1 emerged as good combiners for plant height, primary branches, secondary branches and oil content. Three crosses were identified as promising for isolation of transgressive segregants in later generations.

Malkhandale (1993) studied a set of crosses involving seven parents from Indian mustard. The study revealed that significant variation in *gca* and *sca* for all the metric traits studied, indicating that both additive and non-additive gene action are important. However, number of seeds per siliqua and 1000-seed weight were influenced by additive gene action. Among all the traits, number of primary branches played the most important role in the improvement of seed yield. Pusa barani was the best general combiner. Among the crosses Seeta × RW-151 was the best specific combination followed by Pusa barani × Seeta. **Diwakar *et al.* (1993)** observed that the genotypes K-2 and K-4 were superior per *gca* and most measured traits. Cross K-7 × K-8, K-2 × K-4 and K-4 × K-5 had the highest *sca* for seed yield per plant. **Singh and Mital (1993)** conducted a study on yield and 7 component traits in 8 cultivars and their 28 F_1 hybrids. They reported positive and significant correlation between performance of parents and their *gca*. Vaibhav, Kranti, Pusa bold and Vardan were recommended for use in breeding programme aimed at developing high yielding cultivars.

Yadav and Prakash (1993) derived information on combining ability from data on plant height, numebr of primary and secondary branches in F_1 and F_2 generation of 8 × 8 diallel cross of *B. juncea*. Genotype 7513 possessed the highest significant and positive *gca* effect for all traits in both the generation except for number of secondary branches in the F_1 generation.

From a study for five yield component in 10 Indian mustard (*B. juncea*) and their F_1 hybrids, **Baisakh and Panda (1994)** observed that the appraised mutant type was the best general combiner. **Yadava *et al.* (1994)** genetic variance and combining ability derived from data on siliqua length number of seed per siliqua and 1000-seed weight in 8 *B. juncea* parents and their 28 F_1 and 28 F_2 hybrids.

Bhateria *et al.* (1995) conducted a line × tester analysis in India mustard and reported that crosses RLM-198 × Varuna, RLM-135 × RLM-

619, TM-4 × Vardan and Rj-8 × RLM-619 had high *sca* effect for several characters whereas, Varuna identified as best general combiner.

Yadava and Yadava (1996) in a study of 8 × 8 diallel analysis observed that the parent Sangam was the best general combiner for seed yield, primary branches, secondary branches and seed per siliqua. From a study of diallel analysis in *B. juncea* under 4 environment. **Ravi *et al.* (1997)** reported that both *gca* and *sca* variance were important. Seeta exhibited good general combiner for number of siliquae on main shoot in two environment. Top ranking of crosses are selected on the basis of desirable *sca* effects.

Sheikh and Singh (1998) concluded from a diallel study of *Brassica juncea* and found that the Pusa barani was the best general combiner for seed yield, oil content, 1000-seed weight, plant height, length of main shoot and length of siliqua. Varuna and RH-30 was also good general combiner for seed yield and several other characters. Cross Pusa barani × Glossy showed superior *sca* effect for seed yield, oil content, plant height and primary branches. The majority of crosses showed high *sca* effect for seed yield involving high × low gca parents.

In a line tester study in *Brassica juncea,* **Verma and Kushwaha (1999)** found significant differences among the lines for all characters. Variance due to *sca* was greater than that due to *gca*. **Yadava and Kumar**

(1999) conducted a study on combining ability for oil content in 10 *Brassica juncea* genotypes and their 45 F_1. They reported that RH-781 was the best general combiner whereas RH-781 × Varuna was the best specific cross combination for this trait. From a 10 × 10 diallel study in Indian mustard (*Brassica juncea*) for earliness, **Yadava and Kumar (1999)** reported that RH-30 was the best general combiner for earliness followed by RH-838 and RH-8602. The best specific cross combination was RH-838 × RH-30 for earliness.

Combining ability study conducted in Indian mustard by **Sood *et al.* (2000)** revealed that TM4, RCC15 and DIRA337 were good general combiners for plant height, sliquae per plant and secondary branches per plant. They found RCC15 × RLM 619 best specific combination for seed yield and plant height

2.2 Nature of gene action

The analysis for partitioning the measurable phenotypic and genotypic variance was first suggest by **Fisher (1918).** Later on Fisher *et al.* (1932) developed method for determining the contribution of each gene to fixable (D) and non-fixable (H) components. **Wright (1935)** analysed the variance into additive gene effects, dominance deviations, epistatic deviations, environmental effect and non-additive effects of heridity and environment. **Mather (1949)** devised a procedure to estimate the fixable and non-fixable components with their standard errors using the Least Squares Technique. **Anderson and Kempthorne (1954)** gave a model for the study of quantitative inheritance and concluded that epistatic interaction may contribute considerably to genotypic values. **Comstock and Robinson (1952)** presented a theoretical model together with experimental procedure for estimating the components to genetic variance in population of biparental progenies and their use in estimating the average degree of dominance.

Singh *et al.* (1970) in a study of complete diallel set of 5 *B. campestris* var. sarson, varieties observed partial dominance for days to flowering, primary branches and height, and over-dominance for secondary branches and yield, in graphical analysis; on the basis of component analysis they observed partial-dominance for days to flowering and over-dominance for primary and secondary branches, height and yield of the plant.

Singh *et al.* (1971) while working on 8 × 8 diallel analysis in yellow sarson reported that partial dominance for days to flowering, over-dominance for primary branches, pods per plant, pod length, seeds per pod and yield and partial dominance to over dominance for height. They also indicated that for days to flowering, primary branches and height of the parent used in the study had excess of dominant gene while for other characters they had excess of recessive gene.

Singh and Singh (1972) studied diallel cross of *B. juncea* for two consecutive years and reported partial dominance for days to flowering and height and full dominance for main shoot length and siliqua length. The degree of dominance varied over season for majority of the characters.

Tiwari and Singh (1973) also reported partial dominance for days to flowering and height and over dominance for yield. **Chauhan and Singh (1973)** in Indian mustard observed partial dominance for height, primary branches and number of pods on main shoot, nearly complete dominance for flowering and over dominance for number of leaves.

Rawat (1975) reported over-dominance for flowering, primary branches and seeds per siliqua, nearly complete dominance for siliquae on main shoot and partial dominance for secondary branches and height. All the component of variance were found to be significant for primary branches and height.

From a 6 × 6 diallel analysis of Indian mustard, **Paul *et al.* (1976)** reported D and H component were significant for all characters except yield. "F" was significant only for grain weight. Component analysis revealed partial dominance for all characters except grain weight. This discrepancy could be due to particular combination of positive and negative effects of genes or a complementary type of gene action or simply correlated gene distribution. Further they observed that parents used in the study had unequal distribution of positive and negative alleles. They further indicated the absence of non-allelic gene interactions for seeds per pod, primary and secondary branches.

Chauhan and Singh (1979) reported partial dominance in F_1 generation for flowering and maturity, height, primary and secondary branches, length of siliqua, seeds per siliqua and yield and over-dominance in F_2 generation for height. This may not be an index of real over-dominance at gene level.

Trivedi (1980) in a study of 10 × 10 diallel of *Brassica juncea* observed the non-significant t^2 values for all the characters indicating the probable fulfilment of all assumption of diallel analysis. Serious distortion in the position of observed regression line in the graphic analysis was observed for most of the characters.

From 9 × 9 diallel of Indian mustard, **Rishipal *et al.* (1981)** observed the non-significant t^2 value for all characters indicating the probable fulfilment of all assumption of diallel analysis. They observed that highly significant D and H_1 component indicating both additive and non-additive type of gene action were involved in the inheritance of height, primary and secondary branches, siliqua length; seeds per siliqua, yield and grain weight. The ratio of frequency of positive and negative alleles in the parents indicated the presence of more dominant alleles than recessive alleles.

Yadava ***et al.*** **(1981)** worked on genetic architecture of yield and its component in a 8 × 8 diallel, excluding reciprocal of *Brassica juncea* and the test of homogeneity of arrays gave non-significant value for yield, days to flowering and maturity, grain weight, length of main shoot and seed per siliqua and significant value for height. They reported that D and H_1 component were significant for all traits. The magnitude of H_1 was higher than D. They concluded that both additive and non-additive genetic variance could be exploited by making selections in further generations.

Govil ***et al.*** **(1983)** studied gene action for oil content in Indian mustard using ten parent diallel and observed that both additive and dominance component of variances were highly significant in F_1 and F_2 with higher dominance variance. Non-additive gene action predominated for all the major yield traits were reported by **Anand and Rawat (1984).**

Gupta ***et al.*** **(1985)** in a 9 × 9 half diallel cross in *Brassica juncea*, revealed that oil content was conditioned by both additive and dominance component being of the greater importance. A minimum 2 dominant genes for every one recessive gene affected oil content. **Singh and Singh (1985)** concluded from a diallel study that additive as well as non-additive genes were important for number of siliquae per plant, but non-additive gene effects were predominate. **Singh** ***et al.*** **(1985)** conducted a study of 9 × 9 diallel cross in *Brassica juncea* and found that both additive and non-additive gene effects were important for siliqua length, seeds per siliqua, seed weight and seed yield per plant, although non-additive gene effects were predominant.

Jindal *et al.* (1986) reported that additive and non-additive effects were equally important for all trait in Indian mustard. From a diallel cross of *Brassica juncea* cultivar, **Singh *et al.* (1986)** observed that additive and additive × additive effects were predominant for days to flowering, primary branches per plant and length of main shoot, whilenon-additive effects were observed only for test weight. Number of secondary branches per plant, number of seed per siliqua and yield per plant were controlled by additive genes alone.

Gupta *et al.* (1987) in a study of diallel cross of *Brassica juncea* was grown in 8 environment. Additive gene effects were relatively more important than non-additive for seed yield per plant and yield component.

Badwal and Labana (1987) from a study of 10 × 10 half diallel cross in *Brassica juncea* revealed that both additive and non-additive component of variance were controlled the inheritance of seed yield, seeds per siliqua, plant height, primary branches, length of main shoot, siliquae on main shoot and siliqua length, only non-additive variance were significant for secondary branches. There was a prepondernace of dominance effect per plant height, primary branches, main shoot length and siliquae on main shoot. Over-dominace occurred for all characters except for plant height, for which partial dominance was evident.

Sachan and Singh (1980) reported that additive effect were important for primary branches per plant, plant height, oil content, siliquae on main shoot, harvest index and length of main shoot. However, predominance of dominant effect was noticed for plant height, oil content and number of siliquae on main shoot. Additive × additive interaction contributed more in the inheritance of harvest index and oil content. The significant contribution of additive × dominance and dominance × dominance interaction were observed for inheritance of plant height and oil content, respectively.

Yadav *et al.* (1990) observed that genetic control of three characters viz. harvest index, biological yield and seed yield was mainly through dominance and epistatic effect of the additive × additive and dominance × dominance interaction. Yashpal and Singh (1991) reported that non-additive gene effects determined the inheritance of oil content.

Malkhandale (1993) studied a set of cross involving seven parents from Indian mustard. The study revealed that both additive and non-additive gene action are important in their control. However, number of seeds per siliqua, and 1000-seed weight seemed to be more influenced by additive gene action. Among all the traits number of branches play an important role in the improvement of seed yield.

Kumar and Singh (1994) conducted genetic analysis of 9 characters including seed yield in 9 × 9 diallel cross of Indian mustard. Both additive and dominance component were significant for all characters except seed yield which was found to be mainly controlled by dominant components. Partial dominance was observed for days to flowering and maturity and 1000-seed weight. Complete dominance for siliqua length; over dominance for plant height, number of primary and secondary branches, siliquae on main shoot, seeds per siliqua and seed yield.

Bhateria *et al.* (1995) from a line × tester analysis in *Brassica juncea*, they observed preponderance of non-additive gene action. **Thakral *et al.* (1995)** reported the additive (D) and dominance component (H_1, H_2) of genetic variance were significant for seed yield, the F and h^2 were also significant and estimates of mean degree of dominance indicated that over dominance for this traits. For oil content D was not significant but H_1 and H_2 are significant. The mean degree of dominance showed over-dominance and F values were positive.

Luczkiewicz (1996) reported that additive gene action was significant for plant height, number of branches per plant, siliquae per plant, seeds per siliqua and seed weight per plant. Whereas, dominance effect were not significant. In a study of 8 × 8 diallel (excluding reciprocal) in *Brassica campestris* var. toria, **Yadav and Yadava (1996)** found that both additive and dominance genetic component were important for seed yield and yield components, however, the magnitude of dominance component was higher than the additive component for seed yield, primary and secondary branches, seeds per siliqua and test weight.

Ravi ***et al.*** **(1997)** reported that non-additive variance were more important than additive variance in controlling the number of siliquae on main shoot and seed yield per plant. Additive × environmental variance indicating that non-additive variance was more prone to environmental variation.

Sheikh and Singh (1998) revealed that preponderance of non-additive gene action for oil content, 1000-seed weight, days to flowering and maturity, plant height and length of siliqua, whereas additive genetic variance was important for length of siliqua and plant height.

2.3 Estimation of the extent of heritability

Heritability is an index of transmission of characters from the parents to their offspring and a measure of relationship between parents to progenies. The most important function of the heritability in the genetics of metric characters is its predictive role, expressing the reliability of phenotypic value as a guide to the breeding value.

From a study of complete diallel set of 5 *Brassica campestris* var. sarson, **Singh** ***et al.*** **(1970)** reported that high heritability values for days to flowering and primary branches and low for height, yield secondary branches. The high heritability values for flowering was perhaps due to significant additive component (D) and low heritability value for the character like yield due to non-significant additive component.

Investigating diallel analysis of yellow sarson, **Singh** ***et al.*** **(1971)** observed that the heritability estimates ranged from 10 - 56 per cent, the minimum being for yield and maximum being for flowering suggested that selection will be less effective for primary branches, siliqua length, siliquae per plant seeds per siliqua and yield. The low heritability values for yield were perhaps due to internal cancellation of gene effects.

Bagrecha ***et al.*** **(1972)** reported that high broad sense heritability for seed yield per plant (96.35%), primary branches per plant (80.03%), secondary branches per plant (84.5%) and plant height (96.24%) and moderate were reported for siliquae per plant (62.79%) in a study of yellow sarson.

Tiwari and Singh (1973) observed seed yield per plant had the maximum heritability of 45.77 per cent followed by plant height 42.47 and days to flowering 34.20 per cent in a collection of *Brassica juncea* comprising of 10 varieties and their F_2s.

High estimates of heritability for all the characters i.e. 1000-seed weight (8.4%), number of siliquae per plant (86.4%), total seed yield per plant (82.1%), number of seeds per siliqua (75.8%) and siliqua length (67.7%) was reported by **Zuberi and Ahmad (1973)** in a population of *Brassica juncea* comprising of 4 parents F_1s and F_2s.

Paul *et al.* (1976) evaluated 6 × 6 diallel analysis of Indian mustard for eleven characters they observed high heritability (66.0 - 89.0 per cent) for seeds per pods, number of primary and secondary branches per plant and for all other characters under study.

Rao (1977) observed high heritability for days to flowering, plant height, siliqua length and seed size while working on half diallel analysis from 9 varieties of brown sarson.

Paul (1978) observed high broad sense heritability values for number of primary and secondary branches, number of siliquae per plant, seeds per siliqua and 1000-seed weight in F_2 population of rapeseed, *Brassica campestris.*

Rishipal and Singh (1981) in a study of 9 × 9 diallel of Indian mustard reported low heritability values for height, secondary branches, siliqua length, seeds per siliqua, yield and grain weight. Whereas, heritability estimates were found low for all the characters by **Singh and Murthy (1982).**

Gupta *et al.* (1985) from a 9 × 9 half diallel cross in *Brassica juncea* reported that narrow sense heritability was 34.72% indicating the possibility of utilization conventional breeding method for the exploitation of additive genetic variance, whereas narrow sense heritability was highest for oil content (58.15%) reported by **Jindal and Labana (1985)** from a complete diallel involving 14 *Brassica juncea* lines.

Wang and Wang (1986) from an incomplete diallel cross between 6 foreign and 5 local cultivars, the pattern of heritability in *B. juncea* was similar to that seen in *B. napus* while high values were observed for siliqua length and branch position.

Badwal and Labana (1987) observed heritability in the narrow sense was 20 per cent for seed yield in a population of half diallel cross from 10 varieties of *Brassica juncea.* Whereas, narrow sense heritability 83 per cent for seed weight, reported by **Pawan and Sinha (1987)** in a half diallel cross of 6 *Brassica juncea* varieties.

Li *et al.* (1989) reported broad sense heritability estimates in the 9 segregating generation excluding reciprocal of *Brassica napus* were in order of 1000-seed weight (85.0%) > plant height (82.4%) > seeds per 10 pods (81.8%) > pods on main shoot (78.8%) > seed weight per plant (62.7%) > length of main shoot (60.7%) > primary branches per plant (55.4%), the order being relatively stable.

Han (1990) reported the narrow (30.90%) and broad sense heritability for oil content (31.16%) in *Brassica napus.* Narrow sense heritability also reported by **Diwakar and Singh (1993)** for days to flowering and plant height in 8 cultivars and their 28 F_3 in *Brassica juncea.*

Malik *et al.* (1995) in a study of 7 × 7 diallel (one way) mating design in *Brassica napus* they observed that heritability estimates were high for number of primary and secondary branches and oil content, while h^2 was evident for plant height and siliquae on main shoot.

Luczkiewicz (1996) reported the highest h^2 (narrow sense) for number of branches per plant (50.6%) and lowest for seed yield per plant (14.1%) in a 6 winter rape dihaploid lines.

In a study of 8 × 8 diallel analysis of *Brassica campestris* var. toria by **Yadav and Yadava (1996)** observed heritability estimates were higher for days to maturity and 1000-seed weight. **Hussain *et al.* (1998)** found high estimates of heritability of number of siliquae per plant, and length of main shoot in toria whereas in mustard for 1000-seed weight and plant height were showed high estimates. High broad sense heritability was reported by Kim *et al.* (1999) from a study of 7 parental diallel set of *Brassica campestris.*

2.4 Extent of heterosis and inbreeding depression

In case of *Brassica* species, **Howing (1940)** first reported desirable heterosis of 20 per cent. **Anderson (1950)** reported 10 per cent higher seed yield in F_1 as compared to the better parent. Working with mustard, **Zdanov (1951)** found the hybrid of a cross superior to standard variety.

Singh and Mehta (1954) from a diallel cross among six strains of brown sarson found that extent of increase in yield in F_1 varied with different combinations, One of the hybrid gave an about 250 per cent heterosis over their parents. Some of them also showed negative heterosis.

Singh and Singh (1967) reported high heterosis for oil content and yield in yellow sarson. **Singh and Singh (1972)** while studying a set of 10 × 10 diallel cross of *Brassica juncea* over a two year period reported that in first year, 6 hybrid and second year 10 hybrid out yielded the best cultivars.

Singh (1973) the performance of F_1 hybrids and found significant heterosis for yield in six hybrid and a moderately high heterosis for the number of primary and secondary branches in some of the hybrids at an average of 49 per cent. Singh *et al.* (1973) reported heterosis for siliquae per plant in most of the crosses and observed up to 290.97 per cent heterosis over best parent for yield.

Yadav *et al.* (1974) observed a range of -13.9 to 239.0 per cent heterosis over best parent for yield in *Brassica juncea*. Gupta (1976) studied 4 F_1 crosses of *brassica juncea* and reported heterosis up to 34 per cent over mid-parent and 20.3 per cent over better parent for height and upto 98.7 per cent over mid-parent and 62.8 per cent over better parent for grain yield.

Schuster and Michael (1976) reported inbreeding depression for seed yield, rate of increase in height and crude oil content was observed as a result of artificial self pollination over eight generations. The F_1 showed 21.0 per cent heterosis for yield and 18.0 per cent heterosis for height.

Asthana and Pandey (1977) found as high as 111 per cent relative heterosis in the cross KB-1 × T-59 for seed yield in *Brassica juncea*. The mean heterosis of 48 per cent for number of siliquae on main shoot and 19.00 per cent for oil content was recorded in T-59 × Dwarf mutant. **Patnaik and Murthy (1978)** worked out heterosis in *brown sarson* And observed low heterosis for all characters.

Schuster *et al.* (1978) obsrved mean inbreeding depression was 22 per cent for number of seeds per siliqua, 29 per cent for seed yield per plant and also high for number of branches per plant. For 1000-seed weight and plant height it was 4 - 7 per cent, respectively and for oil content it was very lower. The F_1 showed heterosis 20.3 per cent for seed yield, (211 per cent) number of seeds per siliqua and 123 per cent for branching. There was little or no heterosis for 1000-seed weight and oil content.

Chaurasia (1979) found heterobeltiosis upto 50 per cent for seed yield, 15 per cent for plant height, 44 per cent for number of primary branches, 40 per cent for main shoot length and siliquae on main shoot, 53 per cent for 1000-seed weight and 25 per cent for oil content in *Brassica juncea*. Jindal (1980) reported heterobeltiosis in raya the extent of 165 per cent for seed yield and 152 per cent for secondary branches.

Doloi and Rai (1981) studied inbreeding depression in 9 elite rapeseed cultivars of *B. campestris* for yield, yield component and oil content under different form of selfing. They reported both type positive and as well as negative inbreeding depression for all the character under study. The characters showing high inbreeding depression were plant height, number of primary branches, number of secondary branches, number of siliquae and yield. The depressing effect of inbreeding expression of the characters, number of seeds per siliqua and 1000-seed weight comparatively less.

Chaudhary and Sharma (1982) noticed highest heterosis for plant height (24.46 per cent) in Indian mustard. **Lefort-Busom *et al.* (1982)** observed heterosis for seed yield in *Brassica napus* (L.). **Singh (1982)** reported considerable amount of heterosis in inter-varietal crosses of Indian mustard.

Singh and Singh (1983) recorded heterosis for seed yield in 27 crosses of Indian mustard. These crosses also showed heterosis for number of primary and secondary branches per plant and siliqua length out of which 6 crosses showed high heterosis over the better parent. **Singh and Singh (1983)** observed substantial heterosis in different combination of Indian mustard for days to 50 per cent flowering, days to maturity and seed yield over two environments. **Varshney and Rao (1983)** observed the hybrid which has exhibited highest heterosis also showed higher inbreeding depression. Heterosis over better parent was highest for siliquae per plant followed by economic yield per plant (129.4%), biological yield per plant (118.7) and primary branches per plant (88.1) per cent, respectively.

Banga and Labana (1984) studied 139 F_1 hybrids from crosses between Indian and European lines. They found that greatest heterobeltiosis for seed yield per plant, number of siliquae on main shoot and number of secondary branches. The crosses RLM-514 × E-12 showed greatest superiority in the seed yield to RLM-514, the check variety. In general, heterosis was not observed for those characters in which parental lines possessed high values.

A study of Indian × Exotic crosses by **Singh *et al.* (1985)** revealed that the progenies of 8 crosses were superior to Indian × Indian cross progenies in number of siliquae on main shoot, number of secondary branches and number of seeds per siliqua. Highest heterosis for plant height, seed yield and number of secondary branches was recorded in RLK-78-6-1 × Pahari rai (82.76 per cent) and Pahari rai × Blaze (89.66 per cent). Indian × Exotic crosses, Varuna × Demo (84.4 per cent) showed highest heterosis for seed yield..

Paul ***et al.*** **(1987)** observed considerable heterosis over both mean parental value and better parent followed by inbreeding depression.**Lefort-Buson** ***et al.*** **(1987)** reported that heterosis differed among classes for traits. Heterosis was greatest when parental lines were unrelated and came from different geographical pools. About 50 per cent of the seed yield variation due to mean parental heterosis was explained by variation in Kinship coefficient.

Thakur ***et al.*** **(1988)** studied divergence in relation to heterosis in Indian mustard and found relationship between genetic divergence and heterosis in all the hybrids studied for seed yield and 9 other yield contributing characters. **Verma** ***et al.*** **(1989)** observed that progeny of cross PY-53 × PY-56 showed the highest heterobeltiosis (82.13 per cent) for seed yield in *Brassica campestris.*

Kumar ***et al.*** **(1990)** studied heterosis in Indian mustard and reported that positive heterosis for seed yield was exhibited only in those crosses which showed heterosis for primary and secondary branches, siliqua length and seeds per siliqua. The cross RLM-154 × RH-30 × Varuna, RL-18 × Varuna and RLM-564 × Varuna. Highest heterosis for secondary branches was recorded in the cross RLM-198 × RH-30.

Hirve and Tiwari (1991) evaluated 28 F_1 and F_2 generations obtained from a diallel cross of 8 elite *B. juncea* lines. The highest heterosis for seed yield was obtained in the cross, RAVRP-4 × PR-18 (161 per cent). RLM-198 × Varuna, RAVRP-4 × Varuna, and TM-7 × Varuna also gave good seed yield heterosis and also show high heterosis for other yield contributing characters. In most of the crosses there is no inbreeding depression and only above crosses showing positive heterosis in F_1 generation showed high inbreeding depression in F_2 generation.

Pradhan *et al.* (1991) selected 10 out of 25 accessions of diverse origin and crossed them in a diallel fashion without reciprocals to study combining ability and heterosis none of the accession was a good general combiner for all the quantitative characters studied. Analysis of component characters showed that mean performance of the majority of hybrid was intermediate for 5 out of 6 yield components. It was observed that estimate of heterosis over better yielding parent was more accurate method to determine the contribution of component character toward the yield heterosis based on mid-parent or better parent. From the component character analysis it was concluded that character such as primary and secondary branches and number of siliquae per plant contributed significantly to heterosis for yield.

From a study of line × tester, **Thakur and Bhateria (1993)** reported high heterosis in F_1 was accompanied by significant inbreeding depression in F_2 generation. **Baisakh and Panda (1994)** studied 10 *Brassica juncea* cultivars and their F_1 hybrids for yield. Relative heterosis for yield was positive and highest in the cross Varuna × Pusa bold followed by Kranti × V-85 and Kranti × Appressed mutant.

Damgard and Leoschcke (1994) reported effect of dominance suppression competition were include with the effect of inbreeding. The biological yield per plant decreased by 17 per cent were highly correlated with seed yield. There were also 15 per cent fewer for flowering.

Singh and Rai (1995) evaluated 28 inter-varietal crosses for extent of inbreeding depression, the average inbreeding depression for seed yield from the F_1 to F_2 generation was 14.74 per cent and from F_2 to F_3 19.93 per cent indicated the yield losses. In general, the advance generation could be high for yield component, number of branches, number of siliquae and yield per plant, the inbreeding from F_1 to F_3 generation was very high but for 1000-seed weight, the inbreeding depression was lower.

Rai (1997) observed higher value of inbreeding depression for seed yield to S_1 and S_0 to S_2 generation. The average inbreeding depression from

F_1 to F_2 generation of 7 parent diallel in *Brassica campestris* var. brown sarson was 8.8 for seed yield and 3.1 for oil content while in 8 parent diallel it was 14.7 and 2.8 per cent, respectively.

Singh and Rai (1997) revealed mean value of inbreeding depression of 14.3 per cent for seeds per siliqua, 10.2 per cent for 1000-seed weight and 1.7 per cent for oil content. Varshney and Rao (1997) heterosis and inbreeding depression were estimated in yellow sarson (*Brassica campestris*) for 11 characters. The hybrid which exhibited highest heterosis also show higher inbreeding depression. Heterosis over better parent was highest for siliquae per plant (162%) followed by economic yield per plant (129%), biological yield per plant (118.7%) and primary branches per plant (88.1%).

Agrawal and Badwal (1998) the extent of heterosis for yield and other character was studied in 19 F_1 hybrid of *Brassica juncea*. They observed that overall heterosis for seed yield was very high 59.69 per cent while other shows less heterosis. **Varma *et al.* (1998)** 45 crosses of Indian mustard were evaluated for seed yield and oil content. Five crosses showed positive significant heterosis for seed yield and 4 crosses for oil content. The crosses RK-8801 × Kranti and JCM-88-1 × Kranti had best vigour and lowest inbreeding depression.

Wang ***et al.*** **(1999)** observed that positive mean heterosis varied among the crosses. The positive mean heterosis of number of siliquae per plant was 17.6 per cent was highest followed by number of seed per siliqua and 1000-seed weight.

From a line× tester study **Sood** ***et al.*** **(2000)** reported that none of the hybrid was consistently showed high heterosis and *SCA* effect for the character under study in Indian mustard. They also noticed that cross NDR8602 × RLM619 (141%) showed the highest heterosis for seed yield per plant.

MATERIALS AND METHODS

Materials and methods

The present investigation was conducted at the Crop Research Centre of the G.B. Pant University of Agriculture and Technology, Pantnagar during winter season (rabi) 1996-97, 1997-98 and 1998-99. Pantnagar is geographically situated at 29°N latitude, 79.3°E longitude and an altitude of 243.83 meters above the mean sea level, in humid sub-tropical climatic zone in the foot hills, commonly known as "Tarai". The weather data during crop season starting from Oct to May for the above mention year are given in Appendix-I&II.

3.1 Experimental material

The experimental material comprised of ten genetically and geographically diverse lines/varieties. The origin and salient features of experimental material are given in Table 3.1.

Table 3.1 : Origin and salient features of different lines /varieties

Lines/ Varieties	Origins	Height	Branching habit	Maturity	Seed colour	Seed size
Kranti	Pantnagar (India)	Medium	Lax	Medium	Brown	Medium
Pusa bold	IARI, New Delhi	Medium	Lax	Medium	Brown	Bold
Pusabarani	IARI, New Delhi	Medium	Lax	Medium	Brown	Bold
RLM 198	Ludhiana,(India)	Tall	Lax	Medium	Brown	Medium
PHR-2	Pantnagar,(India)	Tall	Lax	Late	Brown	Small
Divya	Pantnagar,(India)	Dwarf	Lax	Early	Brown	Small
Zem-1	Australia	Tall	Lax	Late	Yellow	Small
EC 322090	China	Tall	Lax	Late	Yellow	Small
EC 322092	China	Tall	Lax	Late	Yellow	Small
Domo	Canadian	Tall	Lax	Late	Yellow	Small

3.2 Development of the experimental material

The parental lines/varieties were selected on the basis of their important diverse characters and parental lines were grown at Crop Research Centre, Pantnagar during rabi 1996-97 and crossed in diallel fashion (excluding reciprocals). All the F_1s were grown and selfed to produce F_2 and the parents were crossed in diallel fashion (excluding reciprocals) during the rabi 1997-98 evaluate them for economic traits.

3.3 Experimental layout and design

The Experiment I of 55 treatments (45 F_1s + 10 Parents) whereas, the Experiment II includes 100 treatments (45 F_1s + 45 F_2s + 10 parents). The experiment I and II were conducted in Randomized complete Block design with three replication during the rabi season 1997-98 and 1998-99. The plot size consisted of one row of each of the parents and F_1s and 4 rows of each F_2s of 5 meter long. Row to row distance was kept 30 cm and plant to plant distance (10-15cm) by thinning. One border row of mustard line Krishna was sown on either side of the experimental plot to minimize border effects and to provide sufficient competitiveness to experimental material. All recommended package of practices were followed for growing the crop.

3.4 Sampling

The observations on 14 characters were recorded on 10 randomly selected competitive plants in experiment I. In the experiment II observations were recorded on 10 randomly selected competitive plants in parent and F_1 and 20 plants in F_2. These plants were tagged for recording the observation. At maturity tagged plants were uprooted from each plot for recording observation.

3.5 Characters studied

Observations on the following characters were recorded:

1. Days to 50 per cent flowering
2. Days to maturity
3. Plant height
4. Length of the main shoot
5. Primary branches/plant
6. Secondary branches/plant
7. Siliquae on main shoot
8. Siliqua length
9. Seeds per siliqua
10. Biological yield per plant
11. Seed yield per plant
12. 1000-seed weight
13. Oil content
14. Harvest index

3.6 Observational procedure

Observations on various characters were recorded as per the procedure described below :

3.6.1 Days to 50 per cent flowering

It is the number of days from the date of sowing to the date when 50 per cent plants of the plot flowered.

3.6.2 Days to maturity

Number of days from the date of sowing to the date on which pods of the selected plants started turning yellow was recorded as the number of days to maturity.

3.6.3 Plant height

Plant height was measured in centimeters from ground level to the tip of the plant at maturity.

3.6.4 Length of the main shoot

It was measured in centimeters from the base of the terminal primary branch to the tip of the main shoot at maturity.

3.6.5 Primary branches per plant

The number of branches arising from the main stem of the plant were recorded as the number of primary branches at the time of maturity.

3.6.6 Secondary branches per plant

It is the number of branches arising from the primary branches at maturity.

3.6.7 Siliquae on main shoot

Number of seed bearing siliquae on the main shoot was counted.

3.6.8 Siliqua length

Five siliquae were randomly selected from each plant and were measured in centimeters from the base to the tip of the siliqua. Their average gave the siliqua length.

3.6.9 Seeds per siliqua

Five siliquae were randomly selected from each plant and the total seeds from these siliquae were counted. Their average was recorded as the number of seed per siliqua.

3.6.10 Biological yield per plant

At maturity, plants were harvested from the base, dried and weighted the chaff and seed yield of selected plants.

3.6.11 Seed yield per plant

The harvested seed from the selected plant was sun dried and weighed in grams. Their average gave the seed yield per plant.

3.6.12 1000-seed weight

One thousand dried seeds from the bulk selected plants for each plot were counted using seed counter and weighed in grams.

3.6.13 Oil content

Seed sample was taken from the bulk produce of the selected plants of each plot and oil content was determined by Nuclear Magnetic Resonance (NMR) spectroscopy.

3.6.14 Harvest index

After threshing, the chaff of each of the selected plant was collected in muslin cloth bag and dried. The chaff of each bag was weighed which gave the dry weight of per plant excluding seed yield.

$$\text{Harvest index} = \frac{\text{Seed yield (g)}}{\text{Biological yield (g)}} \times 100$$

Where,

* Biological yield = Seed yield & chaff yield.

The data for harvest index was transformed using 'angular transformation'.

3.7 Statistical and Genetical Analysis

Before making the detailed statistical analysis the replication wise mean values of different entries were subjected to the randomized block design analysis. The following linear model was used to represent the mean performance of a genotype in any plot. The analysis of variance for randomized block design was done as described by **Steel and Torrie (1960).** The model utilized in this design is as follows.

$$Y_{ij} = \mu + t_i + b_j + e_{ij}$$

where,

i = 1, ------ 55 for experiment I and 1 ----100 for experiment II

j = 1, ------3

yij = Performance of the ith variety in jth block,

μ = General mean effect,

bj = True effect of the jth block/replication,

ti = True effect of ith variety, and

eij = Random error

A general format for the analysis of variance used in the present study is given in Table 3.2.

Table 3.2 : **General format for analysis of variance**

Experiment	Source of variation	d.f	MSS
I	Block	r-1	MSB
	Genotypes	t-1	MSG
	Parents	p-1	MSP
	Hybrids	F_1-1	MSH
	Parents Vs F_1	1	MSPH
	Error	(r-1) (t-1)	MSE
II	Block	r-1	MSB
	Genotypes	t-1	MSG
	Parents	p-1	MSP
	$F_1 + F_2$	h-1	$MSF_1 + F_2$
	F_1	F_1-1	MSF_1
	Parents Vs F_1	1	$MSPVF_1$
	F_2	F_2-1	MSF_2
	Parents Vs F_2	1	$MSPVF_2$
	F_1 Vs F_2	1	MSF_1VF_2
	Error	(r-1) (t-1)	MSE

Where,

r = replication, t= treatment, p= parent, h= crosses, F_1 = F_1 crosses and F_2 = F_2 crosses

$$GM = \frac{Y--}{r^t}$$

$$SEm = \sqrt{E/r}$$

The significance of difference was tested by F-test. Wherever the F-test was found to be significant, critical difference (C.D.) and coefficient of variation (C.V.) was calculated by the following formula :

C.D. = SE x table value of 't' at error degree of freedom.

Where,

$$SE = \sqrt{\frac{2MSE}{r}}$$

Coefficient of variation (CV) was calculated as :

$$C.V.\% = \frac{SD}{Mean} \times 100$$

SD = standard deviation as square root of variance

3.7.1 Combining ability analysis

The data obtained for all possible F_1s, F_2s and parents of the Experiment I and II were utilized for the analysis of combining ability following **Griffing's (1956)** Model 1 and Method 2.

The mathematical model underlying this analysis is as follows :

Xij = μ + gi + gj + Sij + eij

where,

μ	=	General mean effect,
gi	=	General combining ability (gca) effect of the ith parent,
gj	=	General combining ability (gca) effect of the jth parent
Sij	=	Specific combining ability (sca) effect of the (i × j) th cross,
eij	=	Error component

The table for the analysis of variance was set up as follows :

Table 3.3 : Analysis of variance

Source of variation	df	SS	MS	Expectations of MS
Gca	P-1	S_g	M_g	$\sigma_e^2 + \frac{P+2}{P-1}\sum_i g_i^2$
Sca	$\frac{P(P-1)}{2}$	S_s	M_s	$\sigma_e^2 + \frac{2}{P(P-1)}\sum_{i=1}^{P}\sum_{i=1}^{P} S_{ij}^2$
Error	m	S_e	M'_e	σ_e^2

Where,

$$S_g = \frac{1}{P+2}\left[\sum_{i=1}^{P}(X_i + X_{ii}) - \frac{4}{P}X^2..\right]$$

$$S_g = \sum_{i=1}^{P}\sum_{i=1}^{P} X_{ij}^2 - \frac{1}{P+2}\sum_i (X_i + X_{ii})^2 + \frac{2}{(P+1)(P+2)}X^2..$$

$$M'_e = \frac{\text{Error mean square in RBD analysis}}{\text{Number of replication}}$$

X_i = total of array of i^{th} parent

X_{ii} = mean value of i^{th} parent ($i \times i$ cross)

X_{ij} = mean value of $(i \times j)^{th}$ cross

$X..$ = Grand total of $\frac{P(P-1)}{2}$ progenies and 'P' parental lines

m = Error degree of freedom.

The following F-ratios were used to test gca and sca effects in the above given ANOVA table.

(a) To test the differences between *gca* effects of a character:

$$F_{[(P-1), M]} = \frac{M_g}{M'_e}$$

(b) To test the differences between sca effects of a character:

$$F_{[\{P(P-1)/2\}, m]} = \frac{M_s}{M'_e}$$

The various effect of the model were estimated as follows :

(i) General mean effect $\mu = \frac{2}{P(P+1)}(X........)$

(ii) General and specific combining ability effects

$$\hat{g}i = \frac{1}{P+2}(Xi + Xii) - \frac{2}{P}X...........$$

$$Sij = Xij - \frac{1}{P+2}(Xi + Xii + Xj + Xjj) + \frac{2}{(P+1)(P+2)}X -$$

Standard error for combining ability effects were calculated as follows:

(i) SE (gi) = [(n-1) σ^2_e /n(n+2)1/2]

(ii) SE(Sii)=[(n^2+n+2) σ^2_e/(n+1)(n+2)]1/2

(iii) SE (gi-gj)=[2σ^2_e/(n+2)]1/2

(iv) SE (Sij)=[n(n-1) σ^2_e/(n+1)(n+2)]1/2 (I#j)

(v) SE (Sii-Sjj)=[2(n-2) σ^2_e/(n+2)]1/2

(vi) SE (Sij-Sik)=[2(n+1) σ^2_e/(n+2)] ½

(vii) SE (Sij-Skl)=[2nσ^2_e/n+2]1/2

Where,

σ^2_e = Me' = error variance, n = no of parents

The variance of any parent of F_1 or F_2 mean value was :

$$\text{Var. Xij} = \sigma^2_e = \text{Me'}$$

The variance of the difference between any two mean values was :

$$\text{Var. Xij - X Kl} = \hat{\sigma}^2_e = \text{Me'}$$

Variance of the effects and difference between effects were estimated as follows :

i. $$\text{Var } (\hat{\mu}) = \frac{2}{P(P+1)}\hat{\sigma}^2$$

ii. $$\text{Var } \hat{g}i = \frac{P-1}{P(P+2)}\hat{\sigma}^2$$

iii. $$\text{Var } \hat{S}ij = \frac{P^2+P+2}{(P+1)(P+2)}\hat{\sigma}^2 \quad (i \neq j)$$

iv. $$\text{Var } \hat{g}i - \hat{g}j = \frac{2}{P+2}\hat{\sigma}^2 \quad (i \neq j)$$

v. $$\text{Var } (\hat{S}ij - \hat{S}i\,L) = \frac{2P}{P+2}\hat{\sigma}^2$$

vi. $$\text{Var } (\hat{S}ij - \hat{S}i\,k) = \frac{2P}{P+2}\hat{\sigma}^2$$

$(i \neq j, k, L; \quad j \neq k, L; \quad k \neq L)$

Following restrictions are imposed on the mathematical model :

i. $\sum_{i=1}^{P} gi = 0$ ii. $\sum_{j=1}^{P} Sij + eii = 0$ (for each i)

CD = S.E. (difference) x t at 5% and 1 % probability level at error degree of freedom.

The allied genetic parameters like degree of dominance $(\hat{\sigma}^2 s/\hat{\sigma}^2 g)^{1/2}$, and the ratio of additive to total genotypic variance $\left[Rg = \frac{2\hat{\sigma}g^2}{2\hat{\sigma}g^2 + 2\hat{\sigma}s^2}\right]$ were estimated as suggested by **Kempthorne and Curnow (1961).**

$$\text{Heritability in narrow sense} = \left[\frac{2\hat{\sigma}g^2}{2\hat{\sigma}g^2 + 2\hat{\sigma}s^2 + 2\hat{\sigma}e^2}\right] \text{and}$$

$$\text{Heritability in broad sense} = \left[\frac{2\hat{\sigma}g^2 + \hat{\sigma}s^2}{2\hat{\sigma}g^2 + 2\hat{\sigma}s^2 + 2\hat{\sigma}e^2}\right]$$ were,

Estimated by the method given by **Gardner (1963).**

3.7.2 Numerical diallel analysis

The F_1 and F_2 diallel analysis were carried out as suggested by **Hayman (1954a, 1958b), Jinks (1954, 1956), Jinks and Hayman (1953) and Mather and Jinks (1971).** The components of genetic variance were estimated as suggested by Lee and **Kaltsikes (1972).** The detailed methodology involved in the estimation of components of genetic variance is given in (Table 3.4). The expected values of these components were estimated by solving the following equations separately for F_1 and F_2 generations.

Equations for F_1 :

i.	$\hat{D}$	=	$VOLO - E$
ii.	$\hat{F}$	=	$2\ VOLO - 4\ WOLO - 2\ (P-2)\ E/P$
iii.	$\hat{H}_1$	=	$VOLO - 4\ WOLO + 4\ V_1L_1 - (5P-4)\ E/P$
iv.	$\hat{H}_2$	=	$4\ V_1L_1 - 4\ VOL_1 - 4\ (P^2 - P+1)\ E/P^2$
v.	$\hat{h}^2$	=	$4(ML_1 - MLO)^2 - 4\ (p-1)E/P^2$
vi.	$\hat{E}$	=	Me

Equation for F_2 :

i.	$\hat{D}$	=	$VOLO - E$
ii.	$\hat{F}$	=	$8\ WOLO_1 + 4\ VOLO - (4 - 8/p)\ E$
iii.	$\hat{H}_1$	=	$4\ VOLO - 16\ WOLO_1 + 16\ V_1L_1 - 4(5P-4)\ E/P$
iv.	$\hat{H}_2$	=	$16\ V_1L_1 - 16\ VOL_1 - 16\ (P^2 - P+1)\ E/P^2$
v.	$\hat{h}^2$	=	$16(ML_1 - MLO)^2 - 16\ (p-C)\ E/P^2$

Where,

D = Component of genetic variance due to additive effect of gene

F = Relative frequency of dominant to recessive alleles in the parental population and variation in the dominance level over loci.

H_1 = Component of genetic variance due to dominance gene effect

H_2 = $H_1\ [1-(u-v)\ ]^2$ (where u = proportion of positive gene in the parents and v = proportion of negative genes in the parents.

h^2 = dominance effect (as the algebric sum over all loci in heterozygous phase in all crosses.

VOLO = Variance of the parents

Vr = Variance of one array

V_1L_1 = Mean variance of the mean of the arrays

Wr = Covariance between parents and their offspring in one array

$WOLO_1$ = Mean covariance between parents and the arrays

VOL_1 = The variance of the mean of the arrays

ML_1-MLO = The difference between the mean of the parents and the mean of their P (P-1) progenies, and

E = The expected component of variation due to environment

The accuracy of the components of genetic variance was tested using the following formulae :

i. Standard error (S.E.) (D) = $(S^2 \times CD)$ ½

ii. Standard error (S.E.) (F) = $(S^2 \times CF)$ ½

iii. Standard error (S.E.) (H_1) = $(S^2 \times CH_1)$ ½

iv. Standard error (S.E.) (H_2) = $(S^2 \times CH_2)$ ½

v. Standard error (S.E.) (E) = $(S^2 \times CE)$ ½

vi. Standard error (S.E.) h^2 = $(S^2 \times Ch^2)$ ½

where,

S^2 = ½ Var (Wr - Vr) amd CD, CF, CH_1, CH_2, Ch^2 and CE are the multipliers, the terms of the main diagonal of the covariance matrix given by **Hayman (1954, Table 1, p. 798).**

The allied genetic parameter like Degree of dominance $(H_1/D)^{1/2}$, Proportion of the genes with positive and negative effects in the parents $(H_2/4H_1)$ and The proportion of dominant and recessive genes in the parents $\left(\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}-F}\right)$ were also estimated.

In case of unequal gene frequencies the sign and amount of 'F' was determined by the relative frequency of dominant and recessive alleles. F_1 was positive where dominant alleles were more frequent than recessive, irrespective of whether or not the dominant alleles had increasing or decreasing effect **(Mather and Jinks, 1971).**

Table 3.4 : Expectations for the statistics calculated for F_1 and F_2 generation (excluding reciprocals).

Statistics	Components					
	D	**F**	**H_1**	**H_2**	**h^2**	**E**
VoLo	1					1
Wr	½					1/P
$WoLo_1$	½	$F_1 = -1/4$ $F_2 = -1/8$				1/P
Vr	¼	-1/4	$F_1 = 1/4$ $F_2 = 1/16$			1
V_1L_1	¼	$F_1 = -1/4$ $F_2 = -1/8$	$F_1 = 1/4$ $F_2 = 1/16$			1
VoL_1	¼	$F_1 = -1/4$ $F_2 = -1/8$	$F_1 = 1/4$ $F_2 = 1/16$	$F_1 = -1/4$ $F_2 = -1/16$		$(P-1)/p^2$
$(ML_1-ML_0)^2$				$F_1 = 1/4$ $F_2 = 1/16$		$(P-1)/p^2$

The validity of graphical (Uniformity of Wr - Vr values) is tested using t^2 test. Which is an F with 4 and n-2 degree of freedom

$$t^2 = \frac{(P-2)\,[\mathrm{var.(Vr)} - \mathrm{Var.(Wr)}]^2}{4[(\mathrm{var.(Vr)} \times \mathrm{Var.(Wr)} - \mathrm{Cov}^2\,(\mathrm{Vr, Wr})]}$$

3.7.4 Estimation of heterosis and inbreeding depression

Heterosis expressed as the percentage increase or decrease in the mean value of F_1 hybrid over the mid-parent (relative heterosis), better parent (heterobeltiosis) and standard (check) plant (standard heterosis) was calculated as follows:

$$\text{Relative heterosis (\%)} = \frac{\overline{F_1} - \overline{MP}}{MP} \times 100$$

$$\text{Heterobeltiosis (\%)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

$$\text{Economic heterosis (\%)} = \frac{\overline{F_1} - \overline{CP}}{\overline{CP}} \times 100$$

Where,

$\overline{F_1}$ = Mean of F_1 hybrid.

$\overline{MP}$ = Mean of two parents of a particular cross.

$\overline{BP}$ = Mean of better parent of a particular cross.

$\overline{CP}$ = Mean of check parent.

The difference in magnitude of heterosis were tested using the formulae mentioned below :

CD for mid parent heterosis $= \sqrt{\frac{3Me}{2r}} \times$ 't' value

CD for better parent heterosis and standard heterosis $= \sqrt{\frac{2Me}{r}} \times$ 't' valu

Where,

Me = Error mean square of RBD analysis

r = Number of replications and

t = Table value of 't' at error degrees of freedom corresponding to 5 per cent and 1 per cent level of significance.

Inbreeding depression in F_2 generation for the characters studied was calculated as follows :

$$\text{Inbreeding depression} = \frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}} \times 100$$

where,

$\overline{F_1}$ = Mean of the F_1 hybrids (generation)

$\overline{F_2}$ = Mean of the F_2 generation of the same cross

EXPERIMENTAL RESULTS

Experimental Results

The experimental results obtained through the present investigation have been presented under the following sections.

4.1 General analysis of variance.

4.2 Analysis of combining ability.

4.3 Estimation of the extent of heritability for various characters.

4.4 Numerical diallel analysis.

4.5 Estimation of extent of heterosis and inbreeding depression.

4.1 General analysis of variance

The analysis of variance for the characters under study in Experiment I and II are presented in Tables 4.1 and 4.2 respectively. The analysis indicated that the parents used in the present study differed significantly among themselves for all the characters in the Experiment I and II except for oil content in Experiment-II. It was also observed that the F_1 and F_2 generationsin Experiment I and II also differed among themselves significantly for all the characters except for number of seed per siliqua of Experiment I in F_1 generation and number primary branches, number of siliquae in main shoot, biological yield and oil content in the F_2 generation of Experiment II. This indicate that the parental material utilized in the present investigation had inherent genetic differences for the attributes studied. The result of general statistical analysis, therefore, warranted

Table 4.1 : General analysis of variance for yield and other characters (Experiment-I)

Sources of variation	d.f.	MEAN SQUARES — Characters studied													
		Days to 50% flowering (No)	Days to maturity (No)	Plant height (cm)	Length of main shoot (cm)	Primary branches / plant (No)	Secondary branches / plant (No)	Siliquae on main shoot (No)	siliqua length (cm)	Seeds/ siliqua (No)	Biological yield/ plant (g)	Seed yield/ Plant (g)	1000 -seed weight (g)	Oil content (%)	Harvest index (%)
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
Replication	2	81.46	81.84	172.22	11.38	1.72	1.75	21.74	0.62	13.37	1.68	0.24	0.05	4.53	0.11
Genotypes	54	296.86**	278.28**	2663.46**	135.38**	1.94**	3.87**	67.76**	0.49**	2.24*	80.59**	2.82**	0.41**	1.48**	0.57**
Parents (Ps)	9	457.72**	639.05**	4700.49**	114.08**	3.60**	5.56**	78.66	0.91**	4.79**	161.34**	3.45**	0.72**	1.73**	1.11**
F_1S	44	269.23**	210.75**	2282.20**	129.81**	1.61**	3.38**	51.93**	0.36**	1.77	65.42**	2.64**	0.35**	1.32**	0.44**
P V F_1S	1	64.89**	2.88	1107.75**	572.19**	1.46**	10.68**	666.37**	2.36**	0.07	21.89	4.87**	0.05	6.42**	1.62**
Error	108	5.39	7.26	59.65	9.99	0.30	0.81	10.97	0.06	0.94	12.03	0.42	0.03	0.32**	0.11

*,** Significant at 5% and 1% probability levels, respectively

Table 4.2 : General analysis of variance for yield and other characters (Experiment-II)

Sources of variation	d.f.	MEAN SQUARES Characters studied													
		Days to 50% flowering (No)	Days to maturity (No)	Plant height (cm)	Length of main shoot (cm)	Primary branches / plant (No)	Secondary branches / plant (No)	Siliquae on main shoot (No)	Siliqua length (cm)	Seeds/ Siliqua (No)	Biological yield/ plant (g)	Seed yield/ plant (g)	1000- seed weight (g)	Oil content (%)	Harvest index (%)
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Replication	2	6.25	25.12	628.02	133.17	3.07	5.04	2.10	0.04	0.46	108.80	4.77	0.03	19.53	0.07
Genotypes	99	476.72**	142.43**	1318.38**	339.07**	1.68**	4.03**	52.97**	0.34**	1.93**	58.67**	8.53**	0.20**	1.91*	0.49**
Parents (Ps)	9	1405.43**	501.79**	2865.19**	761.94**	3.41**	6.16**	123.51**	1.10**	6.23**	39.26**	4.53**	0.40**	1.15	0.60**
Crosses	89	376.97**	106.60**	1162.03**	271.15**	1.52*	3.86**	40.93*	0.25**	1.51*	60.50**	8.84**	0.18**	1.99*	0.47**
P Vs crosses	1	996.15**	97.50**	1306.94**	2579.53**	1.33*	0.01	489.66**	1.22**	0.28	70.41**	17.11**	0.09**	1.68	1.24**
F_1s	44	328.16**	103.78**	1109.08**	267.27**	1.59**	3.83**	51.87**	0.26**	1.42*	58.71**	9.81**	0.19**	2.39*	0.55**
P V F_1S	1	841.60**	56.08**	1529.73**	2941.69**	0.01	4.26**	549.66**	1.38	0.34	468.03**	73.32**	0.13**	1.31	0.73**
F_2s	44	434.06**	110.90**	1235.99**	272.74**	1.11	2.81*	29.54	0.25**	1.64*	17.19	2.74**	0.17**	1.63	0.31**
P V F_2S	1	971.92**	128.62**	889.32**	1816.01**	5.31**	4.99**	351.62**	0.88**	0.18	31.73*	0.46	0.05	1.74	0.23*
F_1 Vs F_2S	1	12.89	40.84**	237.31	371.48**	15.93**	50.79**	60.59**	0.16*	0.09	2044.62**	235.33**	0.18**	0.26	3.81**
Error	198	15.14	7.31	139.03	49.48	0.59	1.36	18.97	0.07	0.73	12.68	1.00	0.04	0.97	0.09

*,** Significant at 5% and 1% probability levels, respectively

further detailed genetic analysis to investigate the nature of gene action and quantitative genetic informations to draw useful conclusions for initiating a suitable breeding strategy for genetic improvement of the yield in this crop. Further details of the result so obtained have been presented below.

4.2 Analysis of Combining ability

The result of the analysis of variance for combining ability of Experiment I and II have been presented in Table 4.3. The estimates of general combining ability (gca) effect of parent, general mean of the parent, standard error of gi and (gi-gj) have been presented in Table 4.4.1 and 4.4.2 The estimates of specific combining ability (sca) effect of crosses in F_1 and F_2 generation and different related standard errors have been given in Table 4.5 and 4.6 The details of the results obtained for different character have been given below.

4.2.1 Days to 50 per cent flowering

Highly significant differences for gca were observed in both the Experiment I and II. For sca the variance were also highly significant in both the Experiment I & II. In general, the magnitude of variance due to gca was higher in comparison to sca indicating major contribution of the additive gene action in the expression of this character. The parent differed in their order of merit for gca effect between Experiment I & II. But the order of merit did not change in F_1 and F_2 generation of Experiment II. The highest negative and positive gca effect were expressed by the varieties

Table No. 4.3 Analysis of variance for combining ability (Experiments - I and II).

Sources of variation		MEAN SQUARE		
		General combining ability (GCA)	specific combining ability (SCA)	Error F_1 F_1F_2
D.F		9	45	108 198
Character				
Days to 50% flowering	F_1^{+}	465.63**	25.62**	1.80
	F_1^{++}	914.54**	23.98**	5.05
	F_2^{++}	1041.02**	34.16**	5.05
Days to maturity	F_1^{+}	423.17**	25.68**	2.42
	F_1^{++}	285.67**	10.56**	2.44
	F_2^{++}	311.19**	8.31**	2.44
Plant height (cm)	F_1^{+}	4218.93**	221.63**	19.89
	F_1^{++}	2399.83**	83.85	46.33
	F_2^{++}	2665.61**	67.37	46.33
Length of main shoot (cm)	F_1^{+}	180.78**	17.99**	3.33
	F_1^{++}	389.77**	81.74**	16.49
	F_2^{++}	505.37**	52.07**	16.49
Primory branches/plant	F_1^{+}	2.69**	0.24*	0.10
	F_1^{++}	1.69**	0.41*	0.197
	F_2^{++}	1.67**	0.29	0.197
Secondary branches/ plant	F_1^{+}	1.92**	1.17**	0.27
	F_1^{++}	3.95**	0.90*	0.45
	F_2^{++}	3.55**	0.65	0.45
Siliquae on main shoot	F_1^{+}	37.53**	19.60**	3.66
	F_1^{++}	45.33**	20.15**	6.33
	F_2^{++}	47.07**	11.05	6.33
Silqua length (cm)	F_1^{+}	0.69**	0.06**	0.018
	F_1^{++}	0.48**	0.07**	0.02
	F_2^{++}	0.58**	0.05**	0.02
Seeds /siliqua	F_1^{+}	1.97**	0.50	0.31
	F_1^{++}	2.76**	0.33	0.24
	F_2^{++}	3.86**	0.28	0.24
Biological yield/Plant (gm)	F_1^{+}	104.12**	11.42**	4.01
	F_1^{++}	49.42**	15.33**	4.22
	F_2^{++}	18.59**	4.73	4.22
Seed yield/plant (g)	F_1^{+}	1.42**	0.84**	0.14
	F_1^{++}	6.64**	2.72**	0.33
	F_2^{++}	2.06**	0.78*	0.33
1000 - Seed weight (g)	F_1^{+}	0.65**	0.04**	0.009
	F_1^{++}	0.30**	0.03*	0.014
	F_2^{++}	0.33**	0.02	0.014
Oil content (%)	F_1^{+}	1.59**	0.27*	0.11
	F_1^{++}	1.28**	0.61	0.33
	F_2^{++}	0.99**	0.42	0.33
Harvest Index (%)	F_1^{+}	0.41**	0.15**	0.035
	F_1^{++}	0.38**	0.16**	0.029
	F_2^{++}	0.28**	0.09**	0.029

F_1^{+} Diallel conducted during 1997-98 (Experiment-I)

F_1^{++} and F_2^{++} Diallel conducted during 1998-99 (Experiment-II)

*,** Significant at 5% and 1% probability levels, respectively

Table 4.4.1 : Estimates of general combining ability and general mean (±) of the parents (Experiment-I&II)

Characters		Parents										General mean ±	SE (gi)±	SE (gi-gj)±
		Kranti	Pusa bold	Pusa barani	RLM198	PHR2	Divya	Zem1	EC322090	EC322092	Domo			
Days to 50% flowering	F_1^{+}	-3.91	-4.68	-5.60	-1.57	8.40	-10.57	3.09	2.90	4.15	7.79	62.17±0.78	0.37	0.55
	F_1^{++}	-8.82	-8.18	-7.15	-3.76	7.10	-12.18	7.13	7.60	8.10	10.16	69.71±1.30	0.62	0.92
	F_2^{++}	-7.91	-7.96	-7.24	-4.27	8.87	-14.96	8.29	8.26	7.51	9.40	69.35±1.30	0.62	0.92
Days to maturity	F_1^{+}	-2.87	-4.18	-4.32	-3.57	5.38	-11.09	6.10	4.29	7.93	5.32	145.26±0.90	0.43	0.64
	F_1^{++}	-4.29	-4.15	-2.62	-2.51	3.07	-8.23	5.18	4.74	4.16	4.66	148.77±0.90	0.43	0.64
	F_2^{++}	-4.04	-3.48	-3.07	-2.34	4.63	-9.37	3.43	5.21	3.79	5.24	149.41±0.90	0.43	0.64
Plant height	F_1^{+}	-11.83	-13.91	-17.39	-0.87	20.11	-34.62	8.08	18.72	17.68	14.04	193.25±2.58	0.39	0.58
	F_1^{++}	-7.70	-13.15	-9.97	3.03	4.63	-27.35	9.93	15.24	17.03	8.31	190.02±3.93	1.89	2.78
	F_2^{++}	-11.05	-10.63	-10.78	-1.44	10.40	-28.09	9.35	20.49	12.31	9.44	188.49±3.93	1.86	2.78
Length of main shoot	F_1^{+}	4.97	4.77	4.27	1.73	-3.54	1.15	-1.82	-5.62	-3.51	-2.42	44.75±1.05	0.50	0.75
	F_1^{++}	6.92	6.76	4.94	4.78	-1.43	1.93	-5.79	-7.16	-4.78	-6.17	48.52± 2.35	1.11	1.66
	F_2^{++}	8.33	5.17	7.76	3.71	-5.43	3.48	-2.2	-9.86	-3.86	-7.13	46.61 ±2.25	1.11	1.66
Primary branches/ plant	F_1^{+}	-0.50	-0.70	-0.39	-0.06	0.60	-0.40	0.29	0.59	0.19	0.38	4.86±0.18	0.09	0.13
	F_1^{++}	-0.38	-0.24	-0.25	0.00	0.22	-0.65	0.08	0.55	0.39	0.27	6.28 ±0.26	0.12	0.18
	F_2^{++}	-0.54	-0.17	-0.18	-0.14	0.24	-0.50	0.10	0.62	0.20	0.37	5.88± 0.26	0.12	0.18
Secondary branches/ plant	F_1^{+}	-0.61	-0.49	-0.27	-0.34	0.56	-0.27	-0.10	0.23	0.23	0.84	6.01 ±0.30	0.24	0.37
	F_1^{++}	-0.58	-0.68	-0.02	0.02	0.29	-1.00	0.26	0.58	0.72	0.40	7.53± 0.39	0.18	0.27
	F_2^{++}	-0.74	-0.40	0.03	-0.33	0.30	-0.81	0.11	0.65	0.58	0.59	6.82 ±0.39	0.18	0.27
Siliquae on main shoot	F_1^{+}	0.83	-0.54	1.16	0.87	2.73	-0.67	0.52	-3.70	-1.71	0.50	32.82 ±1.11	0.52	0.78
	F_1^{++}	1.85	1.92	0.93	1.78	2.12	-1.08	-1.81	-3.17	-1.85	-0.07	32.13± 1.45	0.69	1.03
	F_2^{++}	2.39	1.43	1.47	1.38	1.64	0.78	-0.90	-3.92	0.95	-1.76	31.35± 1.45	0.69	1.03

F_1^{+} Diallel conducted during 1997-98 (Experiment I)

F_1^{++} and $F2^{++}$ Diallel conducted during 1998-99 (Experiment II)

(Divya – 10.57, Pusa barani – 5.60 and Pusa bold -4.68) and (PHR2 8.40, Domo 7.79 and EC322092 4.15) in the Experiment I. In the Experiment II the varieties Divya (-12.18 and –14.96) Kranti (-8.82 and –7.91) and Pusa bold (-8.18 and –7.96) were expressed highest negative sca effects, whereas highest positive effects were exhibited by Domo (10.16 and 9.40), EC322092 (8.10 and 7.51) Zem1 (7.13 and 8.29) in both generations. The variety Divya which expressed highest negative gca effect in both the experiments. The sca effects for days to 50 per cent flowering ranged from –10.03 for cross Pusa barani × Domo to 10.45 for cross EC 322090 × EC 322092, -8.13 for cross Divya × EC322090 to 6.67 for cross Divya × Zem1 and –12.18 for cross Pusa barani × Domo to 13.85 for cross Pusa barani × Divya in the Experiment I, and F_1 and F_2 generation of Experiment II, respectively. Both type of effects, positive and negative, were observed in each variety with one or the other possible single cross.

4.2.2 Days to maturity

The mean square for gca and sca both were highly significant for this characters but the magnitude of gca were about 15 to 35 times more than that of sca. This denoted that though there was marked distinction between the role of additive and non-additive gene action in the expression of this character. The gca effect of different varieties varied from –11.09 for Divya to 6.10 for Zem1 in the Experiment I. In the Experiment II this range varied from –8.28 for Divya to 5.18 for Zem1 and –9.37 for Divya to

Table 4.5 : Estimates of specific combining ability of 45 crosses (Experiment I and II)

Hybrids	Days to 50 % flowering			Days to maturity			Plant height			Length of main shoot			Primary branches/plant			Secondary branches/plant			Siliquae on main shoot		
	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}
Kranti×P.bold	2.42	2.29	-1.15	-0.20	0.00	-0.22	3.82	6.00	0.90	2.64	-7.44	-2.87	-0.33	-0.56	0.26	-0.67	-0.44	0.68	-1.12	-5.67	0.99
Kranti×P.barani	3.67	2.26	2.13	2.93	0.81	0.70	-5.33	5.21	-8.89	-0.96	-3.45	-8.52	0.03	0.95	0.00	-0.03	0.88	-0.18	-1.51	-2.28	-3.55
Kranti×RLM198	0.97	0.54	1.82	2.85	0.03	1.31	-0.35	0.45	-0.26	0.01	-0.42	-2.08	-0.20	0.09	0.46	-1.16	0.60	0.41	-0.32	3.38	0.58
Kranti×PHR2	-2.33	2.01	1.35	-7.76	1.45	3.34	-8.27	0.95	5.40	3.81	-3.35	4.57	0.31	0.34	-0.62	-0.11	-0.43	-0.56	-3.32	0.37	0.41
Kranti×Divay	-1.03	-3.71	0.18	4.71	0.75	1.01	-5.81	21.95	5.26	-5.04	-4.88	-3.65	-0.26	1.14	0.42	-0.12	1.39	0.46	-1.48	-1.44	-3.60
Kranti×Zeml	-4.64	-2.02	0.93	10.52	1.67	1.20	-14.06	-7.09	0.91	-0.34	6.11	10.47	-0.95	-0.22	0.03	-0.09	-0.37	-0.16	-0.38	-0.97	5.09
Kranti×EC322090	-4.83	-5.16	-0.04	-5.34	-1.22	1.09	10.60	-8.70	11.64	4.69	11.68	9.86	0.55	-0.49	-0.10	0.69	0.71	0.71	4.71	5.58	3.71
Kranti×EC322092	-6.08	-2.33	-4.62	3.02	-0.97	0.17	2.74	1.35	-7.22	3.42	7.80	0.09	0.55	-0.33	-0.78	0.31	-0.50	-1.12	5.72	3.67	-0.26
Kranti × Domo	-3.39	0.95	-2.85	-5.70	2.53	-1.27	4.51	-0.34	-4.45	4.83	6.69	6.66	0.30	-0.31	-0.54	-0.66	0.58	-0.94	5.81	2.62	1.75
P.bold × Pusa barani	2.45	5.29	-2.15	3.57	-0.66	-4.19	-3.51	-2.37	1.96	-2.36	-3.99	-1.40	0.03	0.25	0.06	0.28	0.74	-0.12	-3.28	-2.55	-3.35
P.bold × RLM 198	1.09	1.56	3.54	0.49	2.22	1.42	-5.41	9.34	-0.34	2.41	-2.36	-3.89	-0.46	0.66	-0.48	-0.81	1.20	1.24	-0.09	-2.83	-2.49
P.bold × PHR2	-1.55	-4.96	4.07	6.21	0.64	1.78	4.39	-1.60	6.64	1.28	5.74	4.86	-0.52	0.20	-0.96	-0.51	0.16	-1.32	3.94	2.53	1.64
P.bold × Divya	-2.25	1.31	4.57	-5.65	0.61	0.45	-0.46	6.08	-2.30	0.36	-9.22	-6.79	-0.16	-0.20	0.72	-0.21	0.95	-0.85	-3.98	-1.41	0.69
P.bold × Zeml	-0.91	0.67	-3.35	4.49	-1.47	-1.02	12.52	5.87	-5.70	0.03	9.20	10.13	0.48	-0.69	0.19	-0.24	-1.14	0.07	0.66	4.75	1.88
P.bold×EC323290	0.28	-4.13	-6.65	-2.04	-1.69	-0.47	4.88	-4.47	13.05	2.93	8.84	-3.65	1.05	0.31	-0.40	0.91	1.04	0.53	3.61	5.78	-2.13
P.bold×EC322092	-5.64	-2.30	0.10	-4.01	-2.11	0.95	-11.98	-10.93	5.05	2.02	10.13	6.55	0.36	-0.30	0.62	0.19	-0.94	0.17	4.79	2.23	-0.90
P.bold× Domo	6.28	-1.69	-0.79	-5.73	-1.94	0.84	10.66	4.32	-0.47	3.27	2.92	0.69	0.40	-0.18	-0.85	0.57	0.55	-0.51	4.84	3.25	6.21
P.barani×RLM198	-2.66	-1.13	1.15	-0.70	2.03	-1.99	2.45	-8.18	-0.20	2.54	0.66	-0.47	-0.30	0.06	0.03	0.40	0.81	0.05	-0.82	1.23	0.90
P.barani × PHR2	2.03	-1.19	-1.32	-4.32	-0.22	-0.30	4.97	-4.17	-2.31	2.95	-2.53	0.67	-0.39	-0.32	-0.52	-0.73	-0.09	0.15	3.85	-1.18	-1.13
P.barani × Divya	4.34	7.29	13.85	16.49	3.09	8.03	57.73	13.33	19.12	-1.27	-3.66	-3.11	0.73	-0.55	-0.08	0.44	-0.91	-0.27	1.46	0.02	-0.01
P.barani ×Zeml	-2.66	-8.02	-2.73	-9.04	-4.00	-0.77	13.77	-10.48	-0.99	6.53	-0.47	3.25	0.27	-0.61	0.76	-0.16	-1.77	-0.12	4.43	-1.08	2.14
P.barani×EC322090	2.20	-1.49	-3.37	-3.57	3.11	-1.88	1.89	6.61	-8.93	1.03	-7.01	5.33	0.17	-0.61	-0.23	0.16	-1.02	-01.26	2.42	-2.63	1.80
P.barani×EC322092	-7.39	-3.33	-0.29	-4.54	0.03	1.20	-20.33	3.42	4.41	3.82	9.02	-0.30	-0.42	0.44	0.16	-0.99	1.27	0.48	3.23	6.30	-0.38

Contd..

Table 4.5 contd....

Hybrids	Days to 50 % flowering			Days to maturity			Plant height			Length of main shoot			Primary branches/plant			Secondary branches/plant			Siliquae on main shoot		
	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2
P.barani × Domo	-10.03	-2.71	-12.18	-3.59	-1.14	1.76	-47.16	3.93	-3.72	0.90	13.98	14.54	-0.31	0.33	-0.18	-0.11	0.06	0.03	-6.62	3.07	5.11
RLM198 × PHR2	-3.33	-1.71	8.04	10.27	0.34	0.98	10.85	2.32	6.99	-3.01	6.23	-1.92	0.48	-0.48	0.01	1.19	-0.43	-0.19	-1.06	-2.92	-0.67
RLM198 × Divya	9.97	1.56	0.88	-1.26	2.31	-1.36	-3.99	-12.10	1.58	0.33	-7.20	-1.17	-0.06	-0.44	0.22	0.15	-0.81	0.62	1.42	-7.26	-2.22
RLM198 × Zeml	-0.03	-5.74	-5.04	0.88	-6.44	-2.16	-3.82	-13.42	-20.23	2.77	13.69	2.12	-0.15	0.50	-0.54	-0.79	0.30	-0.33	2.42	3.60	-0.53
RLM198×EC322092	-2.83	3.79	-2.68	-2.65	-3.66	2.73	1.94	7.58	-3.04	0.20	6.69	-6.26	0.21	0.03	0.10	-0.27	0.41	0.26	1.84	0.59	-1.98
RLM198×EC322090	0.25	0.29	-5.26	-3.95	3.59	0.48	13.25	15.52	-6.79	-0.81	-12.82	2.94	0.32	0.38	-0.58	-2.16	1.26	-1.77	4.46	-0.89	1.75
RLM198 × Domo	-2.72	3.23	-2.82	-1.66	0.42	1.37	15.82	-1.03	1.81	0.87	-2.99	4.11	0.50	-0.76	0.02	1.05	-0.08	0.15	1.34	2.99	0.20
PHR2 × Divya	4.34	0.70	-0.60	-4.20	0.72	1.01	7.63	-12.70	4.71	4.87	0.11	7.58	0.14	-0.19	-0.19	-0.63	-0.48	-0.38	-1.95	-4.64	4.85
PHR2 × Zeml	4.00	-1.60	-8.85	0.60	-1.03	-3.80	-11.63	4.58	-1.71	-0.13	0.23	4.67	-0.21	-0.16	-0.32	-0.17	0.16	-0.93	0.39	1.16	-0.84
HR2 × EC322090	-7.47	-1.74	-6.15	-0.93	-2.58	-1.24	2.56	-0.79	-1.45	-0.79	8.06	-0.91	-0.74	-0.52	-0.35	-1.14	-0.46	-1.16	2.61	2.72	0.86
HR2 × EC322092	5.28	-4.91	7.40	-0.57	-5.33	-1.49	5.23	-0.41	-0.57	-1.61	10.49	-5.88	-0.24	-0.23	0.17	-0.43	-0.64	0.27	1.76	4.24	-3.25
HR2 × Domo	-0.36	-1.96	1.04	0.71	-0.83	0.39	11.81	13.50	3.93	2.14	4.01	-4.50	0.61	-0.78	-0.09	1.45	-0.25	0.36	5.44	3.92	-1.53
vya × Zeml	0.97	6.67	-3.68	-1.26	6.28	4.20	4.53	2.46	7.09	6.62	9.80	6.55	0.05	0.25	0.45	-0.15	0.81	1.48	6.13	9.82	1.39
vya × EC322090	-2.16	-8.13	-11.32	-0.79	3.72	2.42	-15.98	3.08	-10.59	4.71	12.74	14.77	-0.05	-0.42	-0.27	-0.56	0.23	-0.16	6.82	4.68	5.44
vya × EC322092	-8.41	1.70	-7.23	2.1	3.64	4.17	-6.81	5.63	5.22	4.54	6.46	1.27	0.49	-0.23	-0.45	-0.18	0.31	-0.52	4.60	2.27	0.97
vya × Domo	-5.72	-6.02	-7.12	0.52	4.14	2.06	-14.60	6.74	-1.24	3.79	15.88	6.95	0.53	1.09	-0.39	1.19	1.14	-0.30	3.01	6.78	0.95
ml × EC322090	0.84	-5.22	0.57	0.02	0.97	-1.38	4.46	9.87	10.64	1.82	-6.54	-2.11	-0.38	1.49	-0.07	0.25	1.24	-0.01	0.35	-0.39	1.03
ml × EC322092	-4.08	-4.94	2.18	0.71	2.89	-2.30	-5.70	11.38	-4.79	-3.16	-6.22	0.43	-0.04	0.58	-0.25	0.27	0.79	-0.24	-3.47	-2.67	1.86
ml × Domo	5.28	-1.3	2.96	-0.68	-0.61	-1.41	-5.66	-2.00	10.55	-5.11	-4.10	-3.60	0.04	0.09	0.25	-0.04	1.18	-0.29	-3.05	-1.99	0.61
322090×EC322092	10.45	4.59	7.21	-1.82	2.00	0.26	6.96	7.51	11.41	-2.59	-10.89	0.69	0.00	1.28	1.09	0.04	0.74	1.63	-2.44	-7.34	2.52
322090×Domo	9.47	-5.46	1.99	5.46	-1.50	0.81	5.17	-13.17	2.68	-8.71	1.74	-4.95	0.41	-0.71	0.09	-0.92	-0.57	0.94	-8.39	3.60	-3.24
322092×Domo	5.89	-0.30	0.74	-1.51	-0.25	-0.11	4.24	0.07	4.39	-6.76	-0.50	10.05	-0.45	-0.72	-0.66	-0.75	-2.02	-0.62	-6.11	-2.38	5.99
(Sij)	1.24	2.07	2.07	1.43	1.44	1.44	1.30	6.27	6.27	1.68	3.74	3.74	0.29	0.41	0.41	0.83	0.62	0.62	1.76	2.32	2.32
(Sij-Sik)	1.82	3.04	3.04	2.11	2.12	2.12	1.91	9.22	9.22	2.47	5.50	5.50	0.43	0.61	0.61	1.21	0.91	0.91	2.59	3.40	3.40
(Sij-Skl)	1.73	2.90	2.90	2.01	2.02	2.02	1.82	8.79	8.79	2.36	5.24	5.24	0.41	0.58	0.58	1.73	0.87	0.87	2.47	3.25	3.25

\+ Diallel conducted during 1997-98 (Experiment I)

++ and F2++ Diallel conducted during 1998-99 (Experiment II)

5.24 for Domo respectively in both generation F_1 and F_2. The variety Divya which expressed highest negative gca effect in both the experiment while Zem1 show highest positive gca effect in both the experiments of F_1 generation. The highest value of negative sca effect for days to maturity were exhibited by the crosses –9.04 Pusa barani × Zem1, -6.44, RLM198 × Zem1 and –4.19 Pusa bold × Pusa barani in the experiment I, F_1 and F_2 generation of the Experiment II, whereas, the highest positive sca effect expressed by the cross 16.49 Pusa barani × Divya, 6.28 Divya × Zem1 and 8.03 Pusa barani × Divya, respectively in both the experiments.

4.2.3 Plant height

The variance for gca and sca were highly significant in the Experiment I. The mean square of gca was highly significant in both generation of Experiment II but the variance of sca was not observed significant in both generation of Experiment II. The comparison of the magnitude of the gca and sca variance pointed out the genetic variability for this attribute was associated with gca variance. High negative gca were observed in Divya, Pusa bold and Pusa barani and significantly high positive gca effect detected in PHR2, EC322092 and EC322090 in both the experiment (Table 4.4). The crosses Pusa barani × Domo (-47.16), RLM 198 × Zem 1) (-13.42) and RLM 198 × Zem 1 (-20.23) show high negative sca in both the experiments, respectively. While the crosses Pusa barani × Divya (57.33), Kranti × Divya (21.95) and Pusa barani × Divya (19.12) were exhibited very high sca effect in Experiment I and F_1 and F_2 generation of the Experiment II, respectively.

4.2.4 Length of main shoot

In comparing the relative magnitude of general Vs specific combining ability, a large part of total genetic variability was associated with general combining ability. However the mean square value of sca were also highly significant in both Experiment I and F_1 and F_2 generation of Experiment II. This indicated that significant role of both additive and non-additive gene action in the expression of this character. Comparative study of the gca effects showed that Kranti, Pusa bold and Pusa barani were good parent among high general combiner. The parent EC 322090, Domo and PHR 2 were spotted out as poor general combiner for the length of main shoot. The greatest effect for sca were detected in crosses Divya × Zem1 (6.62) of Experiment I and Divya × Domo (15.88) and Divya × EC 322090 (14.72) in the F_1 and F_2 generation of the Experiment II, respectively.

4.2.5 Primary branches per plant

The analysis of variance for combining ability has been presented in Table 4.3. The data given in this table indicated that highly significant differences for gca were observed in both the Experiment I and II. For sca, the variance were significant in F_1 generation of Experiment I and II but the variance of sca did not differ significantly in the F_2 generation of the Experiment II. The comparison of the magnitude of gca and sca variance pointed out that genetic variability for this character was associated with gca variance. Higher positive gca effect were observed in PHR 2 and EC 322090, while significantly greater negative gca effect were detected in Pusa bold , Divya and Kranti in both the Experiment I and F_1 and F_2 generation of Experiment II. Among the various cross combinations, the crosses Pusa bold × EC 322090 (1.05) in the Experiment I, and Zem1 × EC 322090 (1.49) in F_1 generation of Experiment II and EC 322090 × EC 322092 (1.09) in F_2 generation of Experiment II showed the high sca effect. The high negative sca effects were detected in the cross Kranti × Zem1 (-0.95) of the Experiment I, and PHR 2 × Domo (-0.78) and Pusa bold × PHR 2 (-0.96) of the F_1 and F_2 generation of Experiment II, respectively.

4.2.6 Secondary branches per plant

The mean square for gca and sca both were highly significant in the Experiment I . In the Experiment II the gca were highly significant in both the generations and sca were significant only in F_1 generation but not significant in F_2 generation. This indicated that the significant role of both additive and non-additive gene action in the expression of this attribute. Comparative analysis of gca effects showed that Domo, PHR 2, EC 322092 and EC 322090 were good parents among high general combiner. The parent Divya, Kranti and Pusa bold were poor general combiner for this character. The greatest effect for sca were observed in Divya×Domo (1.45) of

Experiment I and Kranti × Divya (1.39) and EC322090×EC322092 (1.63) in the F_1 and F_2 generation respectively of the Experiment II.

4.2.7 Siliquae on main shoot

The analysis of variance for combining ability has been presented in Table 4.3. The data given in the table show that the magnitude of gca were highly significant in both Experiment I and II, while the mean square of sca were highly significant in the F_1 generation of both experiments but the variance of sca was not significant in F_2 generation of Experiment II. The estimate of positive gca effects were detected in PHR 2, Kranti and Pusa bold and highly negative gca effect showed by EC 322090 in both the experiments for this character. The estimates of sca effect for number of siliquae on main shoot were highest in crosses Divya × EC 322090 (6.83), Divya× Zem1 (9.82) and Pusa bold × Domo (6.21) in the Experiment I and F_1 and F_2 generation of Experiment II respectively. The high negative sca effects were observed in the crosses Pusa barani × Domo (-6.62) in the Experiment I and RLM 198 × Divya (-7.26) and Kranti × Divya (-3.60) respectively in F_1 and F_2 generation of Experiment II.

4.2.8 Siliqua length

The combining variance for gca and sca due to length of siliqua were significant at 1 per cent probability level in the Experiment-I and F_1 generation of the Experiment II and 5 per cent probability level in the F_2

Table 4.4.2 : Estimates of general combining ability and general mean (±) of the parents (Experiment-I&II)

Characters		Parents										General mean ±	SE (gi)±	SE (gi-gj)
		Kranti	Pusa bold	Pusa barani	RLM198	PHR2	Divya	Zem1	EC322090	EC322092	Domo			
Siliqua length	F_1^{+}	0.19	0.24	0.29	0.01	-0.17	-0.26	0.00	-0.36	-0.27	-0.19	3.45± 0.08	0.04	0.58
	F_1^{++}	0.24	0.23	0.24	0.13	-0.10	0.05	-0.16	-0.17	-0.28	-0.18	3.10 ±0.09	0.04	0.62
	F_2^{++}	0.26	0.25	0.27	0.06	-0.18	0.12	-0.07	-0.3	-0.23	-0.17	3.06 ±0.09	0.04	0.62
Seeds /siliqua	F_1^{+}	0.64	0.41	0.15	0.43	-0.15	0.09	-0.25	-0.45	-0.41	-0.48	11.23 ±0.33	0.15	0.23
	F_1^{++}	0.39	0.43	0.65	0.50	-0.33	0.13	-0.37	-0.24	-0.42	-0.74	11.66±0.29	0.13	0.20
	F_2^{++}	0.57	0.47	0.77	0.66	-0.48	0.02	-0.36	-0.42	-0.59	-0.65	11.69± 0.29	0.13	0.20
Biological yield/plant	F_1^{+}	-1.76	-2.78	-3.28	-1.31	3.80	-3.73	2.36	2.55	0.38	3.77	27.46 ±1.56	0.55	0.82
	F_1^{++}	-0.91	-0.32	-1.35	-1.29	0.71	-4.38	0.43	1.21	2.15	2.59	31.81± 1.19	0.56	0.84
	F_2^{++}	-1.28	-0.47	-0.64	-0.86	0.78	-2.00	1.75	1.42	0.92	0.44	27.30± 1.17	0.56	0.84
Seed yield/plant	F_1^{+}	0.20	-0.02	-0.42	0.53	0.25	-0.68	0.10	0.07	-0.12	0.09	3.95 ±0.22	0.10	0.15
	F_1^{++}	0.30	-0.05	-0.23	0.72	-0.28	-1.88	0.17	0.09	-0.65	0.51	6.95 ±0.33	0.16	0.24
	F_2^{++}	0.17	-0.20	-0.06	0.28	0.18	-1.08	0.38	0.21	-0.01	0.13	5.43 ±0.33	0.16	0.24
1000 -seed weight	F_1^{+}	0.11	0.39	0.42	-0.06	-0.22	-0.08	-0.10	-0.11	-0.16	-0.20	2.91±0.06	0.03	0.04
	F_1^{++}	0.15	0.22	0.27	-0.02	-0.18	-0.17	-0.09	-0.03	-0.06	-0.09	3.10±0.07	0.03	0.05
	F_2^{++}	0.10	0.26	0.25	0.05	-0.19	-0.16	-0.04	-0.01	-0.06	-0.18	3.12±0.07	0.03	0.05
Oil content(%)	F_1^{+}	0.16	-0.24	0.25	0.07	0.88	-0.19	0.11	-0.33	-0.22	-0.25	40.09±0.19	0.09	0.14
	F_1^{++}	0.23	0.00	-0.05	0.31	0.37	-0.74	-0.20	-0.13	-0.02	0.25	39.15±0.33	0.16	0.23
	F_2^{++}	0.02	-0.25	0.08	0.31	0.28	-0.64	0.24	0.05	-0.02	-0.03	39.12±0.23	0.16	0.23
Harvest index (%)	F_1^{+}	0.22	0.20	0.00	0.34	-0.11	-0.15	-0.12	-0.12	-0.08	-0.18	3.79± 0.11	0.06	0.08
	F_1^{++}	0.25	-0.01	0.04	0.21	-0.03	-0.40	0.02	-0.08	0.06	-0.07	4.64 ±0.10	0.05	0.07
	F_2^{++}	0.16	-0.03	0.03	0.23	0.05	-0.35	0.01	-0.06	-0.05	0.00	4.45±0 .10	0.05	0.07

F_1^{+} Diallel conducted during 1997-98 (Experiment I)

F_1^{++} and $F2^{++}$ Diallel conducted during 1998-99 (Experiment II)

Table 4.6 : **Estimates of specific combining ability of 45 crosses (Experiment I and II)**

Hybrids	Siliqua length			Seeds/siliqua			Biological yield/plant			Seed yield/plant			1000-seed weight			Oil content			Harvest index		
	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}
Kranti×P.bold	0.11	-0.13	-0.27	0.35	0.62	0.58	1.08	-0.24	1.45	0.33	0.86	1.12	0.26	0.03	0.15	0.07	-0.30	0.36	0.03	0.27	0.36
Kranti×P.barani	0.13	-0.04	-0.29	0.60	0.46	0.23	2.24	2.12	-2.05	-1.10	0.24	-0.79	-0.17	-0.02	0.06	-0.02	0.09	-0.46	-0.73	0.17	-0.13
Kranti×RLM198	-0.05	-0.30	0.02	-0.17	0.28	0.28	-2.06	4.48	1.84	0.30	1.54	0.24	0.26	0.16	-0.09	-0.78	-0.93	0.13	0.38	0.42	-0.09
Kranti×PHR2	-0.04	0.06	0.03	-0.53	-0.62	-0.91	5.83	-4.19	-2.14	0.45	-1.80	-0.21	0.16	-0.15	0.07	-0.19	-0.35	0.21	0.13	-0.39	0.09
Kranti×Divay	-0.01	-0.29	-0.17	0.86	-0.46	-0.08	-3.98	1.48	-0.97	-0.84	0.96	0.37	-0.04	-0.09	-0.19	-0.94	0.38	-0.17	-0.22	0.24	0.51
Kranti×Zeml	0.06	-0.11	-0.22	-0.10	-0.38	-0.50	-6.73	-2.66	-2.11	-1.55	-1.53	0.65	-0.14	-0.20	-0.09	-0.52	-0.92	0.16	-0.27	-0.38	-0.08
Kranti×EC322090	-0.09	0.13	0.02	-0.53	-0.98	-0.24	1.41	0.23	-0.11	0.96	-1.10	0.51	-0.20	0.01	0.00	-0.11	0.31	-0.42	0.31	-0.41	-0.06
Kranti×EC322092	0.13	0.18	0.01	-0.30	-0.53	-0.47	-1.76	0.95	1.39	0.75	0.76	-0.73	0.00	-0.10	-0.03	0.65	1.31	-0.23	0.35	0.18	-0.42
Kranti × Domo	0.42	-0.02	0.35	0.84	-0.67	-0.41	1.19	3.17	-2.47	0.14	2.18	-0.31	-0.11	0.23	-0.18	-0.10	0.38	-0.49	-0.27	0.46	-0.36
P.bold × P.barani	-0.09	-0.17	0.05	-1.29	0.09	0.17	-1.39	-0.13	-0.19	-0.98	0.20	0.75	0.11	0.19	-0.82	-0.07	-0.64	-0.82	-0.43	0.11	0.38
P.bold × RLM 198	0.16	-0.09	0.13	0.10	0.37	0.32	-3.03	5.56	0.03	-0.21	1.01	0.23	0.34	0.08	0.12	0.07	0.48	-0.57	0.30	-0.10	0.06
P.bold × PHR2	-0.23	0.13	0.14	1.44	-0.53	-0.30	2.19	2.56	-2.94	-0.89	2.12	-1.69	0.01	-0.08	-0.10	0.30	0.09	0.49	-0.62	0.52	-0.55
P.bold × Divya	-0.23	-0.29	0.17	-0.13	-0.49	-0.18	1.05	-0.77	-0.11	-0.41	0.16	0.93	-0.18	-0.26	-0.05	0.21	0.41	0.98	-0.26	0.20	0.46
P.boldx Zeml	-0.10	-0.01	0.16	-1.13	-0.08	-0.19	3.63	-3.24	0.09	0.55	-2.85	-0.87	0.02	-0.20	-0.24	-0.44	0.32	-0.64	-0.01	-0.83	-0.38
P.bold×EC322090	0.03	0.40	-0.10	-0.93	-0.39	-0.27	0.44	0.69	-0.58	1.35	0.07	-0.24	0.39	-0.06	0.01	0.39	0.33	0.34	0.52	0.07	-0.02
P.bold×EC322092	0.48	0.29	0.08	-0.53	-0.27	-0.23	-0.39	2.03	0.59	-0.58	0.27	-0.35	-0.58	-0.25	-0.11	0.23	-0.42	0.51	-0.26	-0.01	-0.11
P.bold × Domo	0.16	0.25	0.02	-0.79	-0.08	-0.46	2.22	1.92	0.39	1.41	1.95	0.29	-0.16	0.06	-0.03	0.57	0.83	-0.63	0.39	0.53	0.08
P.barani × RLM198	0.05	0.13	-0.13	0.65	-0.05	0.24	-2.87	1.59	-0.14	-1.29	0.06	-0.60	-0.10	-0.11	0.08	0.47	-0.21	0.02	-0.42	-0.14	-0.25
P.barani × PHR2	-0.01	-0.04	0.08	0.53	-0.05	-0.48	0.02	-3.08	0.56	0.90	-0.59	0.35	-0.08	-0.18	-0.15	-0.18	-0.81	0.13	0.48	0.03	0.07
P.barani × Divya	-0.27	-0.39	-0.12	0.12	-0.37	-0.05	9.55	-4.41	-1.28	2.10	-0.01	-1.01	0.07	0.00	0.13	0.63	1.00	0.41	0.42	0.33	-0.38
P.barani ×Zeml	0.03	0.45	0.10	-0.24	-0.64	-0.37	2.80	-2.72	-0.75	1.57	-1.89	-1.04	0.08	-0.01	0.01	-0.16	-1.49	0.12	0.53	-0.52	-0.36
P.barani×EC322090	0.11	-0.24	0.21	-0.20	-0.34	-0.78	-1.73	-5.66	1.56	0.38	-2.58	-0.75	-0.23	0.16	-0.09	0.45	0.04	0.88	0.28	-0.52	-0.20
P.barani×EC322092	-0.07	0.08	-0.04	-0.64	-0.52	0.09	-3.89	5.73	-4.25	-0.36	0.96	-0.08	0.04	0.24	0.12	-0.21	0.01	0.06	0.13	-0.08	0.30
P.barani × Domo	0.32	0.11	0.07	-0.17	-0.07	-0.14	-2.95	4.95	-0.78	-0.29	2.47	-0.34	-0.14	-0.05	0.02	-0.12	0.64	-0.62	0.05	0.46	-0.05
RLM198 × PHR2	-0.03	0.17	-0.24	-0.81	-0.50	-0.40	4.72	0.62	-0.55	0.53	-0.13	0.27	-0.11	-0.12	-0.12	0.70	0.55	1.22	-0.12	-0.13	0.33
RLM198 × Divya	0.07	-0.02	0.00	-0.12	0.18	-0.03	1.91	-0.72	3.28	-0.68	-1.01	0.98	0.14	-0.18	-0.10	0.10	-1.00	-1.93	-0.38	-0.24	0.17
RLM198 × Zeml	0.24	0.36	0.15	-0.55	-0.36	-0.26	-1.51	2.48	-0.86	-0.90	1.92	-0.97	-0.11	-0.05	-0.16	0.03	-0.57	0.19	-0.35	0.38	-0.36

Contd…

Table 4.6 contd…

Hybrids	Siliqua length			Seeds/siliqua			Biological yield/plant			Seed yield/plant			1000-seed weight			Oil content			Harvest index		
	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}
LM198×EC322090	0.13	0.27	-0.21	0.19	-0.42	-0.24	0.97	7.70	0.81	0.11	1.99	0.93	-0.14	-0.19	0.06	0.23	1.13	-0.45	-0.05	0.10	0.24
LM198×EC322090	-0.22	-0.05	0.01	-0.05	0.89	-0.23	-2.87	-2.24	-1.03	-0.76	0.69	-0.69	-0.17	-0.18	-0.07	0.20	-0.74	0.22	-0.19	0.28	-0.19
LM198 × Domo	-0.07	-0.35	0.05	-0.11	-1.32	0.04	-0.92	2.64	1.11	1.30	-0.68	0.29	-0.09	-0.11	-0.07	0.12	0.51	0.31	0.60	-0.34	0.00
HR2 × Divya	0.18	0.01	-0.10	-0.81	0.61	0.24	-3.53	-1.38	1.64	0.30	0.10	0.59	0.23	-0.32	0.08	0.51	0.12	0.49	0.12	0.22	0.15
HR2 × Zeml	0.38	0.06	0.19	1.10	0.18	0.22	-1.28	1.14	0.84	1.00	-0.56	0.39	0.07	-0.18	-0.02	0.19	0.44	-0.03	0.49	-0.25	0.45
HR2 × EC322090	-0.03	0.30	0.16	0.50	-1.04	1.08	-0.48	3.03	-2.16	-0.43	2.77	0.74	-0.16	-0.02	0.10	-0.28	0.24	-0.73	-0.14	0.66	0.05
HR2 × EC322092	0.12	0.28	0.15	0.19	0.39	0.72	1.02	0.09	-2.00	1.29	0.98	-0.46	0.10	0.13	0.11	0.32	-0.45	-0.96	0.43	0.32	-0.07
HR2 × Domo	-0.12	-0.02	0.12	0.60	0.41	0.22	1.63	-4.69	-2.19	-0.62	-1.49	0.21	-0.01	0.20	-0.30	0.23	0.57	-0.22	-0.34	-0.11	0.27
ivya × Zeml	-0.02	0.14	0.19	0.52	0.15	0.25	-1.09	4.48	6.00	0.07	2.91	2.12	0.07	0.06	-0.04	-0.65	-0.10	0.12	0.18	0.75	0.45
ivya × EC322090	0.14	0.54	0.13	-1.01	0.62	-0.36	-3.95	-0.63	-0.66	1.02	-0.51	-0.79	-0.03	0.04	0.02	-0.38	0.45	0.13	0.75	-0.09	-0.27
ivya × EC322092	0.19	0.23	0.02	0.68	0.17	0.28	1.88	3.42	-2.50	0.76	-0.30	-0.95	-0.11	-0.12	-0.12	-1.06	-0.75	-0.73	0.46	-0.25	-0.32
ivya × Domo	0.24	0.29	0.26	-0.21	0.39	0.28	0.83	1.98	-1.69	0.05	-1.10	-0.88	-0.01	-0.12	-0.05	-0.84	-1.11	-0.67	-0.06	-0.45	-0.23
:ml × EC322090	0.34	-0.21	0.32	0.13	0.39	0.42	-6.03	5.23	-1.14	-0.88	2.41	-0.37	0.07	0.04	0.00	0.23	-0.42	0.84	-0.08	0.47	-0.02
:ml × EC322092	0.06	-0.16	0.27	0.56	0.30	0.29	0.80	-0.72	-0.30	0.52	0.63	0.76	0.32	0.00	0.14	0.72	1.15	-0.89	0.17	0.24	0.29
:ml × Domo	-0.06	0.11	-0.26	0.66	0.59	0.39	1.80	0.84	-0.16	0.76	1.32	0.79	0.02	0.15	0.26	0.59	0.99	0.24	0.27	0.43	0.34
:322090×EC32209:	-0.16	-0.35	0.04	0.79	0.17	-0.15	-0.73	-0.83	3.70	-0.54	1.46	1.59	0.02	0.24	0.06	-0.02	-0.18	0.11	-0.23	0.56	0.31
:322090×Domo	-0.17	0.08	-0.30	0.13	0.56	0.52	-1.45	0.73	0.84	-0.44	0.21	0.53	0.09	-0.06	0.12	0.32	-1.10	0.78	-0.13	0.09	0.25
:322092×Domo	0.01	0.16	0.27	0.13	0.44	0.12	-1.62	1.78	0.67	-0.82	0.94	-0.23	0.31	0.16	0.09	0.78	-1.29	0.03	-0.28	-0.56	0.11
: (Sij.)	0.13	0.14	0.14	0.51	0.45	0.45	1.84	1.90	1.90	0.35	0.53	0.53	0.09	0.11	0.11	0.31	0.52	0.52	0.18	0.16	0.16
: (Sij-Sik)	0.19	0.21	0.21	0.75	0.66	0.66	2.71	2.79	2.79	0.51	0.78	0.78	0.14	0.16	0.16	0.45	0.77	0.77	0.27	0.24	0.24
: (Sij-Skl)	0.18	0.20	0.20	0.72	0.63	0.63	2.59	2.66	2.66	0.48	0.74	0.74	0.13	0.15	0.15	0.43	0.73	0.73	0.26	0.22	0.02

F_1^+ Diallel conducted during 1997-98 (Experiment I)

F_1^{++} and F2[++] Diallel conducted during 1998-99 (Experiment II) generation of the Experiment II. This indicated that a greater part of the total genetic variability was controlled by the additive type of gene action for this characters. The variety Pusa barani exhibited highest gca effect of the almost similar magnitude in both the experiments (0.29, 0.24 and 0.27 of F_1 of Experiment I and F_1 and F_2 of Experiment II, respectively followed by Kranti and Pusa bold). The other varieties included in this investigation showed negative gca effects. The gca effects ranged from -0.36 for EC 322090 to 0.29 for Pusa barani. The highest positive sca effect was detected in the cross Pusa bold ×EC 322092 (0.48) in the Experiment I and Divya ×EC 322090 (0.54) and Kranti × Domo (0.35) in the F_1 and F_2 generation of Experiment II, respectively. The highest negative sca effects were observed in the crosses. Pusa barani × Divya (-0.27) in the Experiment I and Pusa barani × Divya (-0.39) and EC 322090 × Domo (-0.30) in the both generations of Experiment II respectively.

4.2.9 Seeds per siliqua

The mean squares for gca were highly significant for this character but the variance of sca was not significant for both the experiments. The positive gca effects were observed in Kranti, Pusa bold, RLM 198, Pusa barani and Divya, while Domo, PHR 2, Zem 1, EC 322090 and EC 322092 exhibited negative gca effects for this character. The estimates of sca effects in the various cross combinations, the crosses Pusa bold × PHR 2 (1.44) in the Experiment I, RLM 198 × EC 322090 (0.89) and PHR 2 × EC

322090 (1.08) in the F_1 and F_2 generation respectively in the Experiment II. The low value of sca effects were detected in the crosses Divya × EC 322090 (-1.01) of the Experiment I and RLM 198 × Domo (-1.32) and Kranti × PHR 2 (-0.91) of the F_1 and F_2 generation of Experiment II, respectively.

4.2.10 Biological yield per plant

The variance for gca and sca were highly significant in the Experiment I and F_1 generation of Experiment II. The mean square of gca was highly significant in F_2 generation of Experiment II but the variance of sca was not significant. The comparison of the magnitude of the gca and sca variance pointed out that genetic variability for this character was associated with gca variance. Higher positive gca effects were observed in PHR 2, Domo, Zem 1, EC 322090 and EC 322092 whereas negative gca effects were detected in Divya, Kranti, Pusa bold, Pusa barani and RLM 198 (Table 4.4). The crosses Pusa barani × Divya (9.55), RLM 198×EC 322090 (7.70) and Divya × Zem 1 (6.00) exhibited very high positive sca effect in the Experiment I and F_1 and F_2 generation of Experiment II respectively. The crosses Kranti × Zem 1 (-6.73), PHR 2 × Domo (4.69) and Pusa barani × EC 322092 (-4.25) of the Experiment I and F_1 and F_2 generation of Experiment II respectively.

4.2.11 Seed yield per plant

Relatively greater role of additive gene action was observed in the manifestation of this character. The analysis of variance for combining ability indicated that the mean square of gca were highly significant in the Experiment I and F_1 generation of Experiment II. The mean square of gca was highly significant in the F_2 generation of Experiment II but the variance of sca was significant. The variety RLM 198 exhibited highest gca effect in the both experiments (0.53, 0.72 and 0.28 of the Experiment I and F_1 and F_2 generation of Experiment II respectively) whereas, the variety Divya exhibited highest negative gca effect in the both experiments (-0.68, -1.88 and –1.08 in the Expt. I and F_1 and F_2 generation of Experiment II respectively). The sca effect for yield per plant ranged from –1.55 for cross Kranti × Zem 1 to 2.10 for cross Pusa barani × Divya, -2.85 for cross Pusa bold × Zem1 to 2.91 for cross Divya × Zem 1, -1.69 for cross Pusa bold × PHR 2 to 2.12 for cross Divya × Zem 1 in the Experiment I, and F_1 and F_2 generation of Experiment II. Both type of effects, positive and negative, were observed in each variety with one or other possible single crosses. The crosses Pusa barani × Divya (2.10), Pusa barani × Zem 1 (1.57) and Pusa bold × Domo (1.41) exhibited highest sca effect in the Experiment I, whereas in Experiment II the cross Divya × Zem 1 (2.91 and 2.12) revealed maximum sca effect in F_1 and F_2 generation, respectively.

4.2.12 1000-seed weight

The variance for gca and sca was significant in the Experiment I and F_1 generation of Experiment I. The mean square of gca was highly significant in F_2 generation of Experiment II but the variance of sca was not significant. The comparison of the magnitude of the gca and sca variance pointed out that genetic variability for this attribute was associated with gca variance. Higher positive gca effects were observed in Pusa bold, Pusa barani and Kranti in both experiments. The other varieties included in this investigation showed negative gca effect in both experiments. The highest positive sca effects for 1000-seed weight were exhibited by crosses Pusa bold × EC 322090 (0.39), Pusa barani × EC322092 (0.24) and Zem 1 × Domo (0.26) in the Experiment I and F_1 and F_2 generation of Experiment II respectively while the highest negative sca effects were exhibited by crosses, Pusa bold × EC 322092 (-0.58), PHR 2 × Divya (-0.32) and PHR 2 × Domo (-0.30) in the Experiment I and F_1 and F_2 generation of the Experiment II, respectively.

4.2.13 Oil content

Highly significant value of mean square for gca were observed in both the Experiment I and II for sca, the variance were significant only in the Experiment I. In general the magnitude of the variance due to gca was higher in comparison to sca indicating additive gene action in the expression of this character. Comparative analysis of gca effect showed that PHR 2, RLM 198 and Kranti were good parent among general combiners, all the three parents showed positive gca effect while other parent showed negative gca effect in both the experiments. The highest positive sca effect showed by the crosses Kranti × Divya (0.94), Kranti × EC 322092 (1.31) and RLM 198 × PHR2 (1.22) in the Experiment I and F_1 and F_2 generation of the Experiment II respectively, whereas, the highest negative sca effects exhibited by the crosses Divya × EC 322092 (-1.06), Pusa barani × Zem 1 (-1.49) and RLM 198 × Divya (-1.93) in the Experiment I and F_1 and F_2 generation of the Experiment II.

4.2.14 Harvest index

The mean square value for gca and sca both were highly significant for this character. But the magnitude of gca were about 2 to 3 times more than that of sca. This denoted that though there was marked distinction between the role of additive and non-additive gene action in the expression of this attribute. Considering both the experiments, the varieties RLM 198 (0.34), Kranti (0.25) and Pusa bold (0.20) showed significant positive gca effects for this character. Higher negative gca effect over the experiments were observed due to varieties Divya (-0.40), Domo (-0.18), Zem 1 (-0.12) and PHR 2 (-0.11). With regard to sca effect of the crosses, Divya × EC 322090 (0.75), Divya × Zem 1 (0.75) and Kranti × Divya (0.51), While the crosses Kranti × Pusa barani (-0.73), Pusa bold × Zem 1 (-0.83) and

Pusa bold × PHR 2 (-0.55) exhibited maximum negative sca effects in Experiment I , and F_1 and F_2 generation of Experiment II respectively.

4.3 Estimation of the extent of heritability for various characters

The extent of heritability of the various characters studied was calculated in broad and narrow sense, the value obtained have been presented in Table 4.7. Narrow sense heritability ranged from 15.53 for harvest index to 76.02 for plant height (Experiment I) and from 20.38 for oil content to 86.34 for days to 50 per cent flowering in F_1 generation (Experiment II) and from 20.88 for oil content to 86.63 for plant height in F_2 generation (Experiment II). In general, the broad sense heritability estimates were higher than those in the narrow sense. The range of broad sense heritability was observed from 60.16 for seeds per siliqua to 99.78 for plant height (Experiment I) and 57.96 for oil content to 97.12 for days to 50 per cent flowering in F_1 generation, and 39.35 for oil content to 97.56 for days to 50 per cent flowering in F_2 generation (Experiment II).

The ratio of additive genetic variance to total genetic variance (Rg) ranged from 0.18 for harvest index to 0.81 for 1000-seed weight in the Experiment I. The range of Rg values varied from 0.31 for seed yield per plant and harvest index and 0.91 for plant height in the F_1 generation of Experiment II. The range of Rg values varied from 0.39 for seed yield per plant to 0.97 for 1000-seed weight in the F_2 generation of Experiment II.

Table 4.7 : Estimates of heritibility and R_g values

Character	F_1 Experiment I			F_1 Experiment II			F_2 Experiment II		
	h^2n	H^2b	Rg	h^2n	h^2b	Rg	h^2n	h^2b	Rg
Days to 50% flowering	75.11	98.25	0.76	86.34	97.12	0.89	83.48	97.56	0.86
Days to maturity	72.45	97.50	0.74	81.74	95.78	0.85	86.11	95.92	0.90
Pant height (cm)	76.02	99.78	0.76	82.42	90.23	0.91	86.63	90.80	0.95
Length of main shoot (cm)	63.27	93.41	0.68	43.21	88.55	0.49	61.77	87.81	0.70
Primary branches /plant	64.51	85.04	0.76	37.97	69.55	0.55	45.41	62.93	0.72
Secondary branches/plant	20.17	81.80	0.25	39.25	69.73	0.56	44.57	61.58	0.72
Siliquae on main shoot	22.37	85.50	0.26	24.39	76.28	0.32	38.14	64.65	0.59
Length of siliqua(cm)	65.51	88.31	0.74	51.58	84.49	0.61	67.42	83.22	0.81
Seed per siliqua	35.58	60.16	0.59	56.30	67.95	0.83	68.18	72.72	0.94
Biological yield/plant(gm)	45.19	89.67	0.50	32.82	81.55	0.40	33.36	40.69	0.83
Seed yield/plant(gm)	20.26	86.66	0.23	27.80	91.21	0.31	26.89	69.32	0.39
1000-seed weight (gm)	75.48	92.93	0.81	61.68	82.82	0.75	78.35	80.22	0.97
Oil content (%)	47.5	78.85	0.60	20.38	57.96	0.35	20.88	39.35	0.53
Harvest index(%)	15.53	84.59	0.18	26.60	86.37	0.31	31.78	76.77	0.41

ı²n : heritability in narrow sense
ı²b : heritibility in broad sense

4.4 Numerical diallel analysis

The diallel analysis developed and described by **Jinks (1954)** and **Hayman (1954 a, 1954 b)** was used to estimate the genetic parameters involved in the expression of the characters studied. The numerical method, based on **Hayman (1954 b)** assumes that the experimental material used for study and analysis of quantitative characters must have (i) diploids segregation, (ii) homozygous parents, (iii) no reciprocal differences, (iv) no multiple alleles, (v) no linkage and (vi) no epistasis. The validity of the hypothesis was tested by t^2 for all the characters studied. The significant t^2 indicated failure of at least one of the hypothesis postulated and suggested the presence of some nonallelic interaction. The value of t^2 were significant for days to 50 per cent flowering, days to maturity, length of main shoot, siliquae on main shoot and harvest index in Experiment I while oil content in F_1 and seeds per siliqua in F_2 of Experiment II. For other character, the values of t^2 were not significant which suggested that the additive-dominance model was adequate to explain the variation present. The estimates of genetic and environmental components of variation and their t^2 value have been presented in Table 4.8. The detail of this result obtained for the characters where t^2 was not significant are given below.

4.4.1 Days to 50 per cent flowering

The value of t^2 was significant for days to 50% flowering in Experiment I. Therefore, the results obtained from Experiment II only

Table 4. 8 : Estimates of genetic components of variation from F_1 and F_2 diallel analysis (Experiment I & II)

Component Of variation	Days to 50 percent flowering(No)			Days of maturity(Nc)			Plant height(cm)			Length of main shoot (cm)			Primary branches/plant(No)			Secondary branches/plant(No)			Siliquae on main shoot(No)		
	F_1^{+}	F_1^{++}	F_2^{++}	F_1^{+}	F_1^{++}	F_2^{++}	F_1^{+}	F_1^{++}	F_2^{++}	F_1^{+}	F_1^{++}	F_2^{++}	F_1^{+}	F_1^{++}	F_2^{++}	F_1^{+}	F_1^{++}	F_2^{++}	F_1^{+}	F_1^{++}	F_2^{++}
D	150.78** ±10.93	463.41** ±7.13	453.37** ±15.31	210.60** ±12.82	164.70** ±4.58	159.93** ±4.08	1546.95** ±192.54	912.05** ±28.92	816.00** ±24.04	34.70** ±8.01	239.18** ±18.35	204.44** ±14.32	1.10** ±0.06	0.91** ±0.15	0.55** ±0.10	1.58** ±0.47	1.64** ±0.31	0.69** ±0.23	22.56** ±6.47	35.46** ±7.29	22.18** ±3.07
H_1	107.10** ±23.26	91.94** ±15.17	274.82** ±32.60	115.24** ±27.28	52.83** ±9.74	45.27** ±8.69	905.44** ±409.83	232.85** ±61.57	-1307.15** ±51.18	67.61** ±17.06	277.22** ±39.07	-65.03* ±30.48	0.88** ±0.13	1.31** ±0.33	-5.26** ±0.22	5.32** ±1.00	3.01** ±0.66	-12.92** ±0.49	66.53** ±13.77	67.74** ±15.52	-154.35** ±6.53
H_2	92.76** ±19.77	63.86** ±12.89	245.18** ±27.71	94.17** ±23.19	27.02** ±8.28	-7.17 ±7.39	787.32** ±348.31	209.81** ±52.33	-1104.47** ±43.50	51.40** ±14.50	242.68** ±33.20	-52.13* ±25.90	0.61** ±0.11	1.01** ±0.28	-4.74** ±0.19	3.20** ±0.85	2.40** ±0.56	-10.66** ±0.42	58.55** ±11.71	56.58** ±13.19	-136.18** ±5.55
h^2	7.92 ±13.23	109.27** ±8.63	71.89** ±18.55	-0.50** ±15.52	6.48** ±5.54	83.17 ±4.95	139.10 ±233.15	186.40** ±35.03	-106.51** ±29.12	74.33** ±9.70	382.97** ±22.22	22.45 ±17.34	0.16** ±0.07	-0.08 ±0.19	92.84** ±0.13	1.31* ±0.57	0.41 ±0.38	91.74** ±0.28	86.64** ±7.84	70.50** ±8.83	66.38** ±3.72
F	7.12 ±25.21	215.04** ±16.44	279.76** ±32.60	101.65** ±29.57	105.22** ±10.56	162.57 ±8.69	272.53 ±444.24	165.18** ±67.74	-147.16** ±51.18	-16.20 ±18.49	163.84** ±42.35	110.70** ±30.47	0.49** ±0.14	0.73* ±0.36	0.23 ±0.22	2.97* ±1.08	1.01 ±0.71	-1.06* ±0.49	19.68 ±14.93	35.24* ±16.28	23.07** ±6.53
E	1.80 ±3.29	5.06 ±2.15	15.14 ±4.61	2.42 ±3.86	2.56 ±1.38	7.31 ±1.23	19.89 ±58.05	43.02 ±8.72	139.03 ±7.25	3.33 ±2.42	14.80 ±5.53	49.48 ±4.32	0.10 ±0.02	0.23 ±0.05	0.59 ±0.03	0.27 ±0.14	0.42 ±0.09	1.36 ±0.07	3.66 ±1.95	5.79** ±2.20	18.97** ±0.93
$(H_1/D)^{1/2}$	0.84	0.45	0.78	0.74	0.57	0.53	0.77	0.51	1.26	1.40	1.08	0.56	0.89	1.20	3.11	1.83	1.36	4.33	1.72	1.38	2.64
$H_2/4H_1$	0.22	0.17	0.22	0.20	0.13	-0.04	0.22	0.23	0.21	0.19	0.22	0.20	0.17	0.19	0.23	0.15	0.20	0.21	0.22	0.21	0.22
$\frac{(4DH_1)^{1/2}+F}{(4DH_1)^{1/2}+F}$	1.06	3.18	2.31	1.79	3.60	43.73	1.28	1.44	0.87	0.71	1.93	2.85	1.73	2.01	1.15	3.10	1.59	0.69	1.68	2.12	1.49
t^2	Sig.	Ns.	Ns.	Sig.	Ns.	NS	NS	Ns.	Ns.	Sig	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Sig	Ns	Ns

F_1^{+} Diallel conducted during 1997-98 (Experiment I)
F_1^{++} and $F2^{++}$ Diallel conducted during 1998-99 (Experiment II)

Table 4. 8 Table continued

Component of variation	Siliqua length(cm)			Seeds/siliqua (No)			Biological yield/plant (g)			Seed yield/plant (g)			1000-seed weight (g)			Oil content (%)			Harvest index (%)		
	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}	F_1^+	F_1^{++}	F_2^{++}
D	0.29** ±0.01	0.35** ±0.03	0.30** ±0.01	1.28** ±0.21	0.72** ±0.12	1.35** ±0.12	49.77**± 4.61	8.98** 4.27	0.41 ±1.67	1.01** ±0.32	1.17 ±0.91	0.52** ±0.24	0.23** ±0.02	0.12** ±0.01	0.09** ±0.01	0.47** ±0.09	0.05 ±0.24	-0.59** ±0.17	0.34** ±0.05	0.17** ±0.05	0.11** ±0.02
H_1	0.18** ±0.03	0.26** ±0.05	-0.42** ±0.02	1.55** ±0.45	0.78** ±0.26	-9.84** ±0.25	45.38** 9.81	56.66 9.09	-137.74** ±3.56	3.21** ±0.68	10.43** ±1.94	-3.40** ±0.51	0.12** ±0.04	0.11** ±0.02	-0.46** ±0.01	0.86** ±0.19	7.18** ±0.52	-10.20** ±0.37	0.53** ±0.11	0.55** ±0.10	-0.07 ±0.04
H_2	0.15** ±0.02	0.20** 750.05	-0.45** ±0.01	1.17** ±0.39	0.54** ±0.22	-7.74** ±0.22	31.73** 8.34	38.65** 7.73	-121.21** ±3.03	2.88** ±0.58	9.17** ±1.65	-3.22** ±0.44	0.12** ±0.03	0.07** ±0.02	-0.38** ±0.01	0.73** ±0.16	1.60** ±0.44	-7.97** ±0.31	0.46** ±0.09	0.45** ±0.08	-0.01 ±0.04
h^2	0.31** ±0.02	0.17** ±0.03	93.60** ±0.01	-0.10 ±0.26	0.62** ±0.15	92.65** ±0.14	1.45 5.58	5.17	75.44** ±2.03	0.59 ±0.39	9.89** ±1.0	92.26** ±0.29	0.00 ±0.02	0.01 ±0.01	93.64** ±0.01	0.81** ±0.11	0.05 ±0.30	92.29** ±0.21	0.20** ±0.06	0.35** ±0.05	93.57** ±0.02
F	0.09** ±0.03	0.28** ±0.06	0.31** ±0.02	1.15* ±0.49	0.81** ±0.28	-0.13 ±0.25	30.52** 10.64	6.65 9.85	-10.62** ±3.56	0.95 ±0.74	-024 ±2.11	0.32 ±0.51	0.03 ±0.04	0.06** ±0.02	-0.05** ±0.01	0.07 ±0.20	-0.21 ±0.56	-2.36** ±0.37	0.31** ±0.12	0.07** ±0.01	0.08* ±0.03
E	0.02 ±0.00	0.02 ±0.01	0.07 ±0.01	0.31 ±0.06	0.23 ±0.04	0.73 ±0.04	4.01 1.39	4.60 1.29	12.68 0.51	0.14 ±0.10	0.34 ±0.28	1.00 ±0.07	0.01 ±0.01	0.01 ±0.00	0.04 ±0.01	0.11 ±0.03	0.34 ±0.07	0.97 ±0.05	0.04 ±0.02	0.03 ±0.01	0.09 ±0.01
$(H_1/D)1/2$	0.79	0.87	1.20	1.10	1.05	2.70	0.95	2.58	18.26	1.78	2.98	2.56	0.71	0.9	2.29	1.35	6.13	4.16	1.26	1.81	0.81
$H_2/4H_1$	0.22	0.19	0.27	0.19	0.17	0.20	0.17	0.17	0.22	0.22	0.22	0.24	0.24	0.17	0.21	0.21	0.22	0.20	0.22	0.24	0.03
$(4DH_1)^{1/2}+F$ / $(4DH_1)^{1/2}-F$	1.52	2.76	2.55	2.36	3.35	0.97	1.95	1.36	0.17	8.72	0.93	1.27	1.21	1.71	0.78	1.12	0.48	0.35	2.14	1.26	2.55
t^2	Ns	Ns	Ns	Ns	Ns	Sig	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Sig	Ns	Sig	Ns	Ns

F_1^+ Diallel conducted during 1997-98 (Experiment I)
F_1^{++} and $F2^{++}$ Diallel conducted during 1998-99 (Experiment II)

considered. The additive genetic variance (D) was significant in F_1 and F_2 generation of Experiment II. The estimates of the dominance components H_1, H_2 and h^2 were significant at 1 per cent level of probability in both F_1 and F_2 generations. The mean degree of dominance over all loci estimated by (H_1/D) ½ were 0.45 and 0.78 in F_1 and F_2 generations, respectively exhibiting partial dominance. The mean value u.v. over all loci (u = proportion of positive genes, v = proportion of negative genes) estimates from H_2/H_1 were 0.17 and 0.22 in F_1 and F_2, respectively indicating unequal proportion of positive and negative genes in the parents. When the genes with positive and negative effects are equal u = v = 0.5 at all loci. The estimate of $H_2/4H_1$ equal to 0.25. The values of the proportion of dominant and recessive genes in the parents estimated by $(4\ HD_1)$ ½ + F / $(4HD_1)1/2$-F were 3.18 and 2.31 in F_1 and F_2 generations, respectively indicated that the excess of dominant gene for this character. The significantly positive value of F in these generations indicated that dominant gene were more than recessive.

4.4.2 Days to maturity

The value of t^2 was significant for days to maturity in Experiment I. Therefore the results obtained from Experiment II only. The values of genetic parameter D, H_1 and F were significant. The value of H_2 was significant only in F_1 generation, whereas not significant in F_2 generation and the value of h^2 significant in F_2 generation not significant in F_1

generation for days to maturity. The estimates obtained from $(H_1/D)1/2$ these generations were 0.57 and 0.53. This indicated partial dominance. The value of $H_2/4H_1$ were 0.13 and 0.04 respectively in F_1 and F_2 generation indicated unequal distribution of genes in the parent. The estimates 3.60 and 43.73 from F_1 and F_2 providing the proportion of dominant and recessive genes. Significantly positive value of F indicated that dominant genes were more as compared to recessive genes.

4.4.3 Plant height

The estimate of additive genetic component for plant height were significant thereby indicating the predominant role of additive component in expression of the characters. The estimate of dominance component was also significant but h^2 was not significant in Experiment I. The value of mean degree of dominance were 0.77 in F_1 of Experiment I and 0.51 in F_1 of Experiment II indicated presence of partial dominance whereas 1.25 in F_2 generation of Experiment II showed presence of over-dominance. The estimate of $H_2/4H_1$ were 0.22 in Experiment I and 0.23 in F_1 and 0.21 in F_2 of Experiment II and thereby indicated that the unequal distribution of gene with positive and negative effects in the parents. The values of estimated proportion of dominant and recessive gene (1.28, 1.44 and 0.87 in the F_1 and F_2 of Experiment II) in the parents and positive estimates of F indicated that dominant gene were more in Experiment I and F_1 generation of Experiment II, but negative estimate of F in F_2 generation of Experiment II indicated that recessive allele out numbered the dominant alleles for this character.

4.4.4 Length of main shoot

The value of t^2 was significant in Experiment I. Therefore, the estimates for genetic component obtained in Experiment II are only presented here. The additive component D was highly significant in both generations of F_1 and F_2 respectively. The dominance component was also significant in both generations while, H_2 were negative in F_2 generation. The dominance genetic variance (h^2) was highly significant in F_1 generation whereas, in F_2 generation were not significant. The estimates of $(H_1/D)1/2$ were 1.08 in F_1 generation show over dominance whereas in F_2 (0.56) generation showed partial dominance. The value of the estimates from $H_2/4H_1$ were 0.22 and 0.20 in F_1 and F_2 generation respectively. This indicated unequal proportion of positive and negative genes in the parents. The values of the proportion of dominant and recessive gene in the parent were 1.93 and 2.85 in the F_1 and F_2 generation respectively. This along with highly significant positive value of F in F_1 and F_2 generation indicated that the dominant genes were more than the recessive genes.

4.4.5 Primary branches per plant

The additive genetic component was highly significant in both Experiment I and II. The dominance component was found highly significant in all the three generations of Experiment I and II. The estimates of h^2 were too significant in Experiment I and F_2 generation of Experiment II. The mean degree of dominance were 0.89, 1.20 and 3.11 in F_1

Experiment I and F_1 and F_2 Generation of Experiment II, respectively indicating over dominance in F_1 and F_2 generation of Experiment II and partial dominance in Experiment I. The proportion of positive and negative genes were unequal in the parents as indicated by the estimated value from F_1 (0.17) of Experiment I and F_1 (0.19) and F_2 (0.23) of Experiment II. The magnitude of the value of estimated for the proportion of dominant and recessive gene were more than 1.00 in both experiments. The dominant gene in excess was evident in both experiments.

4.4.6 Secondary branches per plant

The estimates of additive genetic component D were highly significant in both experiments. The estimates of dominance component H and H_2 were also highly significant in both experiments but H and H_2 were negative in F_2 generation of Experiment II. The estimates from both F_1s of Experiment I and II and F_2 generation of Experiment II for average degree of dominance were 1.83, 1.36 and 4.33, respectively. This indicated manifestation of over dominance for number of secondary branches. The values for the measure of proportion of positive and negative gene estimated from F_1 in Experiment I and F_1 and F_2 generation of Experiment II were 0.15, 0.20 and 0.21, respectively. This indicated that the genes with positive and negative effects were not in equal proportion. The value negative and positive of F in both experiments indicated that excess of dominant and recessive genes in the parents.

4.4.7 Siliquae on main shoot

The value of t^2 was significant for number of siliquae on main shoot in Experiment I, therefore, the result obtained from Experiment II only one described. The genetic parameters (D), (H_1), (H_2), (h^2) and (F) were highly significant for this character in both generation. The estimates from both F_1 and F_2 generation for average degree of dominance were 1.38 and 2.64 respectively. This indicated presence of over dominance for this character. The value of estimated (0.21 in F_1 and 0.22 in F_2) for proportion of positive and negative genes in the parent indicated that in F_1 genes with positive and negative effects are unequally distributed in the parents while in F_2 their distribution was almost equal. The estimates for the proportion of dominant and recessive genes in the parents on the basis of analysis of F_1 (2.12) and F_2 (1.49) indicated that the excess of dominant genes for this character.

4.4.8 Siliqua Length

The analysis of genetic components for the length of siliqua revealed that the additive genetic component D was significant in F_1 and F_2 generation of Experiment I and II, respectively. The dominance component H_1 and H_2 were significant but negative in F_2 generation of Experiment II however, the value of h^2 were highly significant in both experiments. The value of mean degree of dominance was found 0.79, 0.87 and 1.20 in Experiment I and F_1 and F_2 generation of Experiment II, which indicated partial dominance in both F_1 generation and strong over dominance in F_2.

The estimate of the genes in the positive and negative effects was 0.27 in F_2 which indicated that positive and negative genes were nearly equal proportion in the parent. Nevertheless, the estimated value 0.19 and 0.22 in F_1 of both experiments indicated unequal proportion. The positive significant value of F and proportion of dominant and recessive allele in the parent were 1.52, 2.76 and 2.55, respectively in Experiment I and F_1 and F_2 in Experiment II indicated that the excess of dominant genes for this character.

4.4.9 Seeds per siliqua

The value of t^2 was significant for number of seeds per siliqua in the F_2 of Experiment II. Therefore, the result obtained in both F_1 generation of Experiment I and II are presented here. The genetic components D, H_1, H_2, h^2 and F were significant in both F_1 generation of Experiment I and II, while h^2 was not significant in Experiment I. The estimates obtained from $(H_1/D)1/2$ in F_1s (Experiment I and II) were 1.10 and 1.05 indicating prominance of over dominance. The values (0.19) and (0.17) estimates obtained from F_1 of both Experiment I and II indicated that unequal distribution of genes in the parents. The estimates (2.36 and 3.35) from both experiments of F_1 generation providing the proportion of dominant and recessive genes and the significant positive values of F in these indicated that dominant genes were more than the recessive genes.

4.4.10 Biological yield per plant

The estimates of additive genetic component for biological yield per plant were significant thereby indicating the predominant role of additive component in the expression of the characters. The estimates of dominance component was also significant but h^2 was not significant in Experiment I. The values of mean degree of dominance were 0.95, 2.58 and 18.26 in the Experiment I and $F_1$and F_2 of Experiment II indicated that partial dominance in Experiment I, whereas, in F_1 and F_2 generation of Experiment II indicated the presence of strong over dominance. The values estimated (0.17, 0.17 and 0.22 in F_1 and F_2 of Experiment I and II) to measure the proportion of positive and negative genes in the parents were unequally distributed. The values estimated to measure the proportion of dominant and recessive genes in the parents indicating the excess of dominant genes in parents of Experiment II whereas, excess of recessive genes in parents of the Experiment-I.

4.4.11 Seed yield per plant

The additive genetic variance was significant in F_1 of Experiment I and F_2 of Experiment II. The dominance component positive and negative but highly significant in both experiments of F_1 and F_1 and F_2 generation of Experiment I and Experiment II was found. The estimates obtained by $(H_1/D)1/2$ 1.78 in F_1 of Experiment I and 2.98 in F_1 and 2.56 in F_2 of Experiment II. This indicated that presence of over-dominance.

The estimated values (0.22 in F_1 Experiment I and 0.22 in F_1 and 0.24 in F_2 of Experiment II) for proportion of positive and negative genes in the parents indicated that the distribution was almost equal. The estimated values (1.72, 0.93 and 1.27 in F_1 of Experiment I and F_1 and F_2 of Experiment II) to measure the proportion of dominant and recessive genes in the parent and F value indicated the excess of both dominant and recessive genes in the parent.

4.4.12 1000-seed weight

The analysis of genetic components for the 1000-seed weight revealed that the additive genetic component (D) was significant in both experiments I and II. The dominance component H_1 and H_2 are also positive or negative but highly significant. Whereas, h^2 significant only in F_2 generation of Experiment II. The estimates of mean degree of dominance 0.71 and 0.95 and 2.29 in the F_1 of Experiment I and F_1 and F_2 of Experiment II indicated that partial dominance in both experiment of F_1 generation while, in F_2 generation indicated strong over dominance. The calculated values for the proportion of positive and negative genes in the parents were 0.24 in F_1 of Experiment I and 0.17 in F_1 and 0.21 in F_2 of Experiment II indicated that they were unequally distributed in F_1 and F_2 of Experiment II while in Experiment I their distribution was almost equal. The magnitude of the values of estimates for proportion of dominant and recessive genes were more than 1.00 in both experiment. This indicate the excess dominant genes in the parent.

4.4.13 Oil content

The test of t^2 indicated that the F_1 of Experiment I and F_2 of Experiment II fulfill the assumption of **Hayman (1954 b)**. therefore, the results obtained in F_1 of Experiment II which gave significant t^2 were not described for this attribute. The genetic component D, H_1 and H_2 were significant but the magnitude of dominance component H_1 and H_2 was greater than D. The values of h^2 are also highly significant. The mean degree of dominance for over all loci was 1.35 and 4.16 which indicated the presence of strong over-dominance. The estimated values (0.21 in both F_1 and 0.20 in F_2 of Experiment I and II) for proportion of positive and negative genes in the parent indicated that in both experiment positive and negative effect were almost equally distributed. The values estimated to measure the proportion of dominant and recessive gene in the parent indicated excess of recessive genes.

4.4.14 Harvest index

The value of t^2 was significant for harvest index in Experiment I, therefore the results obtained from Experiment II only are described. The additive genetic variance (D) was significant in both generation of Experiment II whereas H_1 and H_2 were significant only in F_1 generation. The estimates of h^2 and F was highly significant in both generations. The mean degree of dominance for overall loci estimates by $(H_1/D)1/2$ were 1.81 and 0.81 in F_1 and F_2 generation, respectively exhibiting over-dominate and partial dominance in F_1 and F_2. The distribution of positive and negative genes in the parent (0.24 F_1 and 0.03 in F_2) indicated that unequal distribution of positive and negative genes in F_2 (Experiment II) and almost equal proportion in F_1 (Experiment II). The estimates for the proportion of dominant and recessive genes in the parents on the basis of analysis of F_1 (1.26) and F_2 (2.55) indicated excess of dominant genes for this character.

4.5 Estimation of extent of heterosis and inbreeding depression

Heterosis was expressed as per cent increase (+) or decrease (-) in the average performance of hybrids (F_1) over the better parent (heterobeltiosis), mid parent (relative heterosis) and check parent (economic or standard heterosis) for fourteen characters viz.- days to 50 per cent flowering, days to maturity, plant height, length of main shoot, number of primary and secondary branches per plant, number of siliquae on main shoot, siliqua length, number of seeds per siliqua, biological yield per plant, seed yield per plant, 1000-seed weight, oil content and harvest index in the Experiment I and II. Inbreeding depression in F_2 for these characters was estimated (in per cent) in Experiment II. Estimates of heterosis and inbreeding depression for various character are presented in Table 4.9 to 4.22 and the results are described below :

4.5.1 Days to 50 per cent flowering

The estimates of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression have been presented in Table 4.9. Heterobeltiosis ranged from –4.50 to 56.90 per cent in the Experiment I and –15.18 per cent to 59.18 per cent in the Experiment II, respectively. 25th and 34th crosses had showed heterobeltiosis. In these crosses the heterobeltiosis was in decreased direction, PHR 2 × Domo (-4.50 per cent) and EC 322090 × Domo (-15.18 per cent) revealed highest heterobeltiosis in Experiment I and II, respectively.

Relative heterosis ranged from –20.50 per cent to 16.27 per cent and –19.34 per cent to 6.88 per cent in Experiment I and II. 24th and 34th hybrids exhibited heterosis over mid parent. Pusa barani × Domo (-20.50 per cent) and Divya × EC 322090 (-19.34 per cent) revealed highest relative heterosis in Experiment I and II, respectively.

Heterosis over Kranti ranged from –22.08 per cent to 43.61 per cent and –17.69 per cent to 64.62 per cent where as 28th and 25th crosses expressed superiority over Kranti in the Experiment I and II, respectively. The best cross observed for economic heterosis was Pusa bold × Divya (-22.08 per cent) in Experiment I and Kranti × Divya (-17.69 per cent) in the Experiment II, respectively.

Table 4.9 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for days to 50 per cent flowering.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	-2.30	-2.89	-2.32	1.23	0.92	0.61	4.85
Kranti× P.barani	2.42	0.29	-1.74	2.43	0.00	2.43	-0.60
Kranti × RLM198	0.59	-0.57	0.59	5.49	-0.29	5.49	-2.31
Kranti × PHR2	12.21**	-5.39*	12.21**	28.04**	-4.55	28.04**	-2.38
Kranti ×Divya	13.83**	-5.08	-18.59**	0.74	-9.48	-17.69**	-3.70
Kranti ×Zeml	15.12**	8.50**	15.12**	20.72**	-11.81**	20.72**	-7.70
Kranti× EC 322090	-1.74	-7.91**	-1.74	15.84**	-16.31**	15.84**	-10.00
Kranti× EC 322092	-1.74	-15.08**	-1.74	21.95**	-8.88*	21.95**	3.5
Kranti × Domo	9.31**	-9.83**	9.31**	31.69**	-5.48	31.69**	5.56
P.bold × P.barani	-1.21	-3.84	-5.23	9.83	6.88	9.14	12.56
P.bold × RLM 198	-1.72	-2.28	-0.58	9.20	2.89	8.52	-2.25
P.bold × PHR2	10.91**	-5.86*	12.21**	17.19**	-12.98*	16.46**	-16.75
P.bold × Divya	8.95	-9.76**	-22.08**	13.43**	2.36	-7.32	-0.65
P.bold × Zeml	2.88	-2.44	4.08	27.61**	-7.15	26.82**	4.33
P.bold × EC323290	4.60	-1.35	5.83	19.64**	-13.91**	18.89**	3.08
P.bold × EC322092	3.45	-15.99**	-2.32	23.93**	-7.77*	23.66**	-2.48
P.bold × Domo	1.72	-15.52**	2.91	28.84**	-7.90*	28.04**	0.00
P.barani × RLM198	-4.06	-7.93**	-8.72**	0.59	-2.53	5.49	-2.31
P.barani × PHR2	21.82**	0.25	16.87**	18.04**	-9.37**	23.78**	-2.96
P.barani × Divya	22.76**	4.85	-12.21**	29.10**	-13.08**	5.48	-5.78
P.barani ×Zeml	3.64	-4.47	-0.58	7.57	-19.03**	12.80**	-9.73
P.barani× EC322090	12.13**	2.78	7.57*	19.78**	-10.81**	25.61**	2.43
P.barani ×EC322092	-3.04	-18.16**	-6.98*	17.44**	-9.62**	23.16**	-2.97
P.barani × Domo	-1.22	-20.50**	-5.23	22.10**	-9.67**	28.04**	15.24
RLM198 × PHR2	11.93**	-4.37	14.55**	16.93**	-6.76	30.47**	-14.95
RLM198 × Divya	46.34**	20.40**	4.66	23.87**	4.72	1.21	7.83
RLM198 × Zeml	8.52**	3.53	11.06**	10.38*	-13.68**	23.16**	-1.49
RLM198 × EC322090	3.41	-1.88	5.83	26.77**	-21.00**	41.45**	8.62
RLM198 × EC322090	10.79**	-2.99	13.38**	21.85**	-2.63	35.96**	9.42
RLM198 × Domo	11.93**	-6.41**	14.55**	30.05**	-0.06	45.11**	9.66
PHR2 × Divya	56.90**	7.51**	12.21**	46.25**	-4.39	20.00**	4.08
PHR2 × Zeml	20.74**	8.63**	35.45**	-10.51**	-11.95	50.59**	5.67
PHR2 × EC322090	1.54	-8.13**	15.12**	-10.14**	-12.37	51.22**	2.82
PHR2 × EC322092	6.20*	3.89	39.54**	12.73*	-12.89**	46.33**	2.08
PHR2 × Domo	-4.50	-2.71	36.05**	-7.61	-10.37**	55.48**	-4.31
Divya × Zeml	35.78**	5.71	-2.90	59.68**	2.14	30.48**	17.29
Divya × EC322090	27.63**	-1.26	-8.72**	27.60**	-19.34**	4.26	9.94
Divya × EC322092	15.44**	-18.63**	-17.44**	50.73**	-1.23	23.16**	18.81
Divya × Domo	30.90**	-12.50**	-6.38	38.06**	-13.35**	12.80**	8.11
Zeml × EC322090	7.26*	6.70**	-20.3**	-12.19**	-17.91**	43.90**	-8.47
Zeml × EC322092	1.55	-6.44**	13.95**	-12.73**	-14.28**	46.33**	-9.17
Zeml × Domo	21.76**	7.30**	36.63**	-9.82**	-11.07**	56.70**	-5.06
EC322090× EC322092	22.57**	13.55**	38.97**	-1.82	-4.43	64.62**	-2.59
EC322090×Domo	26.66**	12.27**	43.61**	-15.18**	-15.61**	49.99**	-8.54
EC322092×Domo	6.29*	1.91	39.54**	-4.36	-7.39**	60.36**	0.76

*,** Significant at 5% and 1% probability levels, respectively.

The maximum and minimum inbreeding depression was observed in crosses Divya × EC 322090 (18.81 per cent) and Pusa bold × PHR 2 (-16.75 per cent). The average value of inbreeding depression for days to 50 per cent flowering was observed to be 6.31 per cent in F_2 of Experiment II.

4.5.2 Days to maturity

Heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for number of days to maturity have been presented in the Table 4.10. Heterosis over better parent ranged from –10.58 per cent to 24.72 per cent in the Experiment I and –3.00 per cent to 27.02 per cent in the Experiment II. 24^{th} and 29^{th} hybrids revealing heterosis over better parent in the Experiment I and II respectively. Pusa barani × Zem 1 (-10.58 per cent) in the Experiment I and PHR 2 × EC 322092 (-3.00 per cent) in the Experiment II exhibited highest heterobeltiosis.

Heterosis over mid parent ranged from –5.80 per cent to 14.62 per cent and –4.39 per cent to 8.70 per cent. While, twenty three and fourteen hybrid expressed heterosis over mid parent in the Experiment I and II, respectively. Pusa bold × Domo (-5.80 per cent) and RLM 198 × Zem 1 (-4.39 per cent) had highest relative heterosis in the Experiment I and II, respectively.

The numbers of hybrid showing heterosis over check parent Kranti was 30^{th} and 38^{th} . whereas, the range of economic heterosis was –9.25 per cent (Pusa bold × Divya) to 17.03 per cent (EC 322090 × Domo) and –0.49

Table 4.10 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for days to maturity. :

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	0.73	0.24	0.73	1.93	0.11	1.93	-0.95
Kranti× P.barani	2.92	2.55	2.92	3.63*	2.03	3.63*	-0.23
Kranti × RLM198	5.46**	4.43**	3.41*	3.15	1.07	3.15	-1.64
Kranti × PHR2	2.19	-4.44**	2.19	8.32**	0.68	8.32**	-2.91
Kranti ×Divya	15.91**	6.95**	-0.73	14.48**	6.47**	-0.49	0.00
Kranti ×Zeml	16.06**	9.16**	16.06**	9.92**	1.68	9.92**	0.88
Kranti× EC 322090	3.16	-4.72**	3.16	7.50**	-0.12	7.50**	-2.48
Kranti× EC 322092	9.73**	1.23	9.73**	7.26**	0.80	7.26**	-1.13
Kranti × Domo	3.65*	-4.48**	3.65*	10.16**	2.71*	10.16**	1.54
P.bold × P.barani	1.69	1.57	2.43	-0.47	-0.71	2.66	1.89
P.bold × RLM 198	2.73	1.23	0.73	1.16	0.93	4.84**	-0.46
P.bold × PHR2	10.37**	3.74**	11.44**	3.97*	-1.44	7.74**	-2.70
P.bold × Divya	5.97**	-2.74	-9.25**	14.48**	4.45**	-0.49	0.00
P.bold × Zeml	9.64**	3.65**	10.71**	3.97*	-1.99	7.74**	0.00
P.bold × EC323290	3.62*	-3.81**	4.62**	3.51*	-1.99	7.26**	-2.03
P.bold × EC322092	2.65	-4.80**	3.65*	2.80	-1.56	6.54**	-2.73
P.bold × Domo	1.69	-5.80**	2.68	3.27*	-1.89	7.02**	-3.17
P.barani × RLM198	1.74	0.37	-0.24	2.59	2.11	5.81**	2.52
P.barani × PHR2	2.90	-3.40**	3.65*	4.93**	-0.78	8.23**	-1.12
P.barani × Divya	24.72**	14.62**	6.81**	17.82**	7.77**	2.42	-2.84
P.barani ×Zeml	-10.58**	-5.59**	0.73	3.75*	-2.43	7.02**	-1.13
P.barani× EC322090	2.66	-4.81**	3.41*	8.45**	2.43	11.86**	2.81
P.barani ×EC322092	2.41	-5.15**	3.16	5.87**	1.12	9.20**	-0.67
P.barani × Domo	3.38*	-4.35**	4.14*	5.40**	-0.11	8.72**	-2.45
RLM198 × PHR2	17.12**	8.38**	14.84**	4.42**	-0.77	8.72**	-2.00
RLM198 × Divya	10.23**	2.78	-5.60**	17.26**	6.72**	1.93	2.85
RLM198 × Zeml	10.68**	3.01*	8.52**	1.17	-4.39**	5.32**	-2.30
RLM198 × EC322090	6.70**	-2.50	4.60**	2.79	-2.43	7.02**	-5.20
RLM198 × EC322090	6.21**	-3.05*	4.14*	7.44**	3.13*	11.86**	1.73
RLM198 × Domo	10.68**	0.91	8.52**	5.58**	0.55	9.92**	-1.54
PHR2 × Divya	15.34**	-0.98	-1.22	20.61**	3.84**	4.84**	-0.92
PHR2 × Zeml	1.94	1.39	14.84**	-1.47	-1.99	13.31**	1.50
PHR2 × EC322090	-1.28	-2.43*	12.41**	-2.74	-2.84*	11.86**	-2.60
PHR2 × EC322092	-0.65	-1.90	13.14**	-3.00*	-3.93**	9.44**	-3.60
PHR2 × Domo	0.43	-0.95	14.36**	-1.26	-1.48	13.08**	-2.57
Divya × Zeml	18.47**	2.33	1.46	27.02**	8.70**	10.41**	2.85
Divya × EC322090	17.34**	-0.60	0.49	24.51**	7.06**	8.23**	0.89
Divya × EC322092	21.03**	2.41	3.65*	23.95**	7.88**	7.74**	0.22
Divya × Domo	19.32**	0.84	2.19	24.79	7.69**	8.47**	1.34
Zeml × EC322090	0.87	-0.85	13.63**	0.63	0.21	15.98**	1.88
Zeml × EC322092	1.73	-0.11	14.60**	3.65*	2.12	16.95**	4.14
Zeml × Domo	1.08	0.85	13.87**	0.21	-0.53	14.77**	0.84
EC322090× EC322092	-4.38**	-4.48**	11.44**	2.80	1.70	15.98**	0.63
EC322090×Domo	0.41	0.21	17.03**	-0.63	-0.95	13.80**	-2.55
EC322092×Domo	-3.75**	-3.85**	12.41**	1.29	0.53	14.28**	-0.64

*,** Significant at 5% and 1% probability levels, respectively

per cent (Kranti × Divya) to 16.95 per cent (Zem 1 × EC 322090) in the Experiment I and II, respectively.

The average value of inbreeding depression for this character was observed to be 1.80 per cent.

4.5.3 Plant height

The estimates of heterosis and inbreeding depression for plant height have been presented in the Table 4.11. 39th hybrids of Experiment I and 20th hybrid of Experiment II expressed heterobeltiosis. Heterobeltiosis ranged from –15.77 per cent to 65.08 per cent in Experiment I and –7.54 per cent to 56.13 per cent in the Experiment II. The highest heterobeltiosis was exhibited by Kranti × Divya (-15.77 per cent) in Experiment I and EC 322090 × Domo (-7.54 per cent) in the Experiment II respectively.

The relative heterosis expressed by 39th and 9th crosses in the Experiment I and II. The relative heterosis ranged from –25.89 per cent to 47.86 per cent in the Experiment I and –6.42 per cent to 24.85 per cent in Experiment II. The best combination with highest negative relative heterosis was Pusa barani × Domo (-25.89 per cent) and RLM 198 × Zem 1 (-6.42 per cent) in the Experiment I and II, respectively.

The economic heterosis over Kranti ranged from –15.77 to 42.89 per cent in the Experiment I and –6.76 to 39.50 per cent in Experiment II respectively. Fortytwo and twentynine hybrids showed heterosis over check

Table 4.11 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for Plant height.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	8.44**	5.30**	2.35	11.15	8.69	6.34	4.26
Kranti× P.barani	1.58	-1.93	-5.20**	7.80	7.15	7.80	11.15
Kranti × RLM198	7.65**	4.90**	7.65**	12.79*	3.06	12.79*	5.42
Kranti × PHR2	25.33**	10.76**	25.33**	14.07*	3.40	14.07*	-2.84
Kranti ×Divya	-15.77**	0.16	-15.77**	7.41	24.85**	7.41	12.62
Kranti ×Zeml	4.80**	-7.57**	4.80**	12.41*	-0.99	12.41*	-1.37
Kranti× EC 322090	25.88**	8.95**	25.88**	14.65*	-0.98	14.65*	-10.96
Kranti× EC 322092	20.57**	0.36	20.57**	21.84**	7.90	21.89**	9.05
Kranti × Domo	19.46**	0.91	19.46**	15.52**	4.17	15.52**	4.13
P.bold × P.barani	1.41	0.84	-5.36**	4.40	1.46	-0.12	-2.74
P.bold × RLM 198	9.49**	3.54**	3.35**	20.07**	7.08	14.87*	6.69
P.bold × PHR2	29.01**	10.35**	21.76**	14.15*	0.98	9.21	-8.34
P.bold × Divya	-8.69**	6.51**	-13.81**	31.09**	12.63*	-5.54	5.23
P.bold × Zeml	26.54**	8.01**	19.43**	22.25**	5.03	16.96**	5.80
P.bold × EC323290	28.44**	7.53**	21.23**	19.06**	0.25	13.90*	-12.67
P.bold × EC322092	17.11**	5.79**	10.53**	16.10**	0.29	11.07	-6.94
P.bold × Domo	29.13	5.46**	21.88**	20.24**	5.80	15.04*	1.41
P.barani × RLM198	13.57	6.76**	5.99**	4.92	-3.51	6.17	-0.67
P.barani × PHR2	28.61	9.30**	20.03**	7.96	-1.49	9.25	-3.24
P.barani × Divya	27.35	47.86**	18.86**	39.87**	16.35**	0.80	-1.67
P.barani ×Zeml	26.54	7.32**	18.10**	7.68	-4.52	8.97	-3.66
P.barani× EC322090	25.76**	4.60**	17.37**	21.12**	5.31	22.56**	6.26
P.barani ×EC322092	10.86**	-11.41**	3.47**	20.27**	7.22	21.71**	3.03
P.barani × Domo	-8.64**	-25.89**	14.73**	15.36**	4.70	16.74**	4.61
RLM198 × PHR2	26.77**	15.24**	33.41**	2.13	1.39	21.41**	-2.22
RLM198 × Divya	26.20**	6.39**	-8.14**	29.40**	-2.33	-6.76	-4.51
RLM198 × Zeml	11.61**	1.25	17.46**	-3.20	-6.42	15.08*	7.07
RLM198 × EC322090	20.92**	7.70**	27.26**	10.23	4.65	31.05**	5.27
RLM198 × EC322090	26.75**	8.67**	33.39**	15.20**	11.92**	36.95**	14.64
RLM198 × Domo	26.15**	9.72**	32.75**	2.30	1.06	21.61**	1.01
PHR2 × Divya	65.08**	14.93**	11.33**	30.24**	-2.5	-6.15	-13.24
PHR2 × Zeml	-0.77	0.95	25.33**	5.27	2.53	26.98**	1.26
PHR2 × EC322090	10.97**	8.91**	40.16**	5.23	0.67	26.94**	-4.22
PHR2 × EC322092	11.75**	5.89**	41.14**	6.33	4.07	28.25**	0.30
PHR2 × Domo	13.14**	8.64**	42.89**	8.94	8.42*	31.41**	1.94
Divya × Zeml	51.66**	5.34**	2.29	47.49**	6.75	6.28	-1.01
Divya × EC322090	42.93**	-2.89**	-3.60**	52.49**	7.92	9.88	5.91
Divya × EC322092	50.13**	-2.50*	1.25	56.13**	13.70**	12.51*	3.99
Divya × Domo	40.01**	-7.52**	-5.57**	49.73**	11.31*	7.89	5.14
Zeml × EC322090	5.80**	4.02**	34.11**	7.53	5.66	36.63**	-1.73
Zeml × EC322092	0.52	4.56**	27.42**	10.16*	9.64*	38.63**	10.07
Zeml × Domo	-1.18	-4.93**	25.27**	2.81	0.64	25.22**	-5.61
EC322090× EC322092	7.82**	4.18**	41.34**	10.85*	8.39*	39.50**	-1.29
EC322090×Domo	5.35**	3.12**	38.09**	-7.54	-3.97	21.65**	-10.33
EC322092×Domo	0.12	-1.15	36.92**	7.38	5.62	30.78**	0.37

*,** Significant at 5% and 1% probability levels, respectively

parent. Kranti × Divya (-15.77 per cent) and PHR 2 × Divya (-6.76 per cent) were showed highest economic heterosis over Kranti in the Experiment I and II, respectively.

The average value of inbreeding depression for plant height was observed to be 5.05 per cent and the highest inbreeding depression recorded in cross RLM 198 × EC 322092 (14.64 per cent) in F_2 of Experiment II.

4.5.4 Length of main shoot

The percentage of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for the length of main shoot have been presented in Table 4.12. The number of crosses showed heterosis over better parent was 16^{th} and 11^{th} in the Experiment I and II, respectively. The heterobeltiosis ranged from –16.27 to 34.84 per cent in Experiment I and –37.73 to 74.20 per cent in Experiment II. Whereas, Divya × Zem 1 (34.84 per cent) and EC 322092 × Domo (74.20 per cent) hybrid were recorded best for heterobeltiosis in the Experiment I and II, respectively.

The heterosis over mid parent ranged from –12.93 to 36.66 per cent in Experiment I and –19.96 to 101.44 per cent in the Experiment II. Thirtythree and twentysix hybrids exhibited heterosis over mid parent. Divya × Zem 1 (36.66 per cent) and Divya × Domo (101.44 per cent) revealed highest relative heterosis in the Experiment I and II, respectively.

Table 4.12 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP)and inbreeding depression for length of main shoot.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	18.60**	18.81**	18.60**	-2.20	-1.43	-2.20	-4.50
Kranti× P.barani	13.56*	11.80*	10.09	1.66	0.65	1.66	4.86
Kranti × RLM198	12.94*	9.81*	6.85	4.31	5.53	6.78	5.41
Kranti × PHR2	3.80	23.35**	3.80	-9.52	16.26	-9.52	-6.71
Kranti ×Divya	-4.86	6.87	-4.86	-6.25	6.74	-6.25	-4.32
Kranti ×Zeml	-1.25	12.23*	-1.25	-0.41	35.86**	-0.41	13.21
Kranti× EC 322090	1.31	21.94**	1.31	7.09	55.36**	7.09	8.39
Kranti× EC 322092	3.03	14.79**	3.03	4.41	33.08**	4.41	12.31
Kranti × Domo	8.22	29.56**	8.22	-0.05	52.57**	-0.05	2.68
P.bold × P.barani	10.13	8.62	6.77	-1.58	0.18	0.41	-3.38
P.bold × RLM 198	17.78**	14.72**	11.42*	0.65	2.61	3.04	10.57
P.bold × PHR2	-1.52	16.86**	-1.87	8.11	38.23**	6.43	14.09
P.bold × Divya	6.31	19.23**	5.94	-12.93	-1.54	-14.29	-0.97
P.bold × Zeml	-0.56	12.84*	-0.91	6.48	44.53**	4.82	-1.59
P.bold × EC323290	-2.44	17.27**	-2.78	3.34	49.27**	1.73	32.83
P.bold × EC322092	0.06	11.31*	-0.30	9.98	39.38**	8.27	10.01
P.bold × Domo	4.94	25.46**	4.57	-5.62	43.53**	-7.09	12.88
P.barani × RLM198	16.96**	15.53**	10.65*	2.74	2.91	5.18	2.21
P.barani × PHR2	3.70	21.68**	0.54	-13.36	12.12	-11.61	-0.20
P.barani × Divya	4.71	16.01**	1.51	-9.45	3.98	-7.63	-5.80
P.barani ×Zeml	15.05**	29.00**	11.54*	-17.38	13.43	-15.71	-17.23
P.barani× EC322090	-4.86	13.10*	-7.76	-31.21**	0.35	-29.82**	-26.80
P.barani ×EC322092	6.92	17.48**	3.65	1.00	29.66**	3.04	12.82
P.barani × Domo	1.71	20.25**	-1.39	7.25	64.48**	9.41	0.82
RLM198 × PHR2	-12.37*	1.77	-17.11**	1.34	31.30**	3.75	26.05
RLM198 × Divya	5.27	15.35**	-0.42	-16.22	-3.65	-14.23	-9.58
RLM198 × Zeml	4.08	15.44**	-1.54	6.75	46.71**	9.29	18.03
RLM198 × EC322090	-9.88	6.07	-14.74	-7.85	34.54**	-5.66	35.27
RLM198 × EC322090	-7.46	0.56	-12.46	-37.73**	-19.96	-36.25**	-38.66
RLM198 × Domo	-1.40	15.40**	-6.72	-23.03*	18.15	-21.20*	-7.18
PHR2 × Divya	25.61**	33.99**	-1.95	16.00	33.61*	-12.27	-6.31
PHR2 × Zeml	7.30	13.01*	-18.48**	59.20**	45.03**	-25.84*	-4.90
PHR2 × EC322090	5.87	7.55	-27.69**	53.99**	83.31**	-14.29	36.67
PHR2 × EC322092	5.74	1.40	-25.06**	65.67**	67.51**	-5.71	40.28
PHR2 × Domo	24.41**	25.55**	-15.03**	44.15**	85.13**	-19.77	34.27
Divya × Zeml	34.84**	36.66**	5.25	28.56*	59.11**	-2.73	0.18
Divya × EC322090	19.68**	29.55**	-6.58	32.24*	76.28**	0.06	1.84
Divya × EC322092	22.53**	23.66**	-2.57	23.04	40.44**	-6.91	8.70
Divya × Domo	25.72**	35.25**	-1.87	42.01**	101.44**	7.45	17.07
Zeml × EC322090	6.91	14.30*	-18.76**	11.23	22.75	-44.16**	-11.48
Zeml × EC322092	-5.30	-3.15	-4.721	-0.44	9.47	-43.34**	-29.20
Zeml × Domo	-3.28	2.76	-26.51**	24.41	49.39**	-42.02**	-3.49
EC322090× EC322092	-13.76*	-5.86	-31.43**	-17.16	-0.61	-52.86**	-22.35
EC322090×Domo	-13.31	-12.73	-41.87**	74.20**	91.50**	-34.05**	33.21
EC322092×Domo	-16.27*	-9.15	-33.42**	16.32	50.57**	-33.81**	23.47

*,** Significant at 5% and 1% probability levels, respectively

The heterosis over check parent Kranti ranged from –41.87 to 18.60 per cent in the Experiment I and –52.86 to 9.41 per cent and the Experiment II. Sixteen and ten crosses showed heterosis over check parent. The best combination with highest economic heterosis was Kranti × Pusa bold (18.60 per cent) in the Experiment I and Pusa barani × Domo (9.41 per cent) in the Experiment II, respectively.

The highest inbreeding depression was recorded in the cross PHR 2 × EC 322090 (40.28 per cent).The average value of inbreeding depression for length of main shoot was observed to be 13.84 per cent in F_2.

4.5.5 Primary branches per plant

The estimates of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for the primary branches per plant have been presented in Table 4.13. 16^{th} crosses showing heterosis over better parent in both experiments. The best cross recorded for heterobeltiosis was RLM 198 × EC 322090 (25.24 per cent) in the Experiment I and Kranti × Divya (23.37 per cent) in the Experiment II.

Twelve and eight hybrids revealing heterosis over mid parent. The range of relative heterosis was from –25.55 per cent (Kranti × Zem 1) to 37.12 per cent (Pusa bold × EC 322090) in the Experiment I and –23.08 per cent (PHR 2 × Domo) to 29.29 per cent (Kranti × Divya) in the Experiment II, respectively.

Table 4.13 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for primary branches/ plant.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
KrantixP.bold	-13.95	-3.48	-13.95	-14.57	-8.93	-2.49	-6.54
Krantix P.barani	-4.08	-0.50	3.36	26.29*	22.68*	26.20*	21.72
Kranti × RLM198	-10.28	-2.84	5.95	0.00	6.86	14.72	5.56
Kranti × PHR2	-16.75*	3.33	36.18**	-17.05*	-0.69	23.71*	23.20
Kranti ×Divya	-4.39	2.21	-4.39	22.37*	29.29**	22.37*	17.71
Kranti ×Zeml	-39.04**	-25.55**	-4.39	-1.03	4.34	10.33	5.20
Krantix EC 322090	1.29	18.28*	42.12**	-17.01	-3.94	14.55	1.68
Krantix EC 322092	-0.59	13.33	31.78**	-9.96	0.68	14.15	20.11
Kranti × Domo	9.35	18.77*	29.97*	-24.74**	-9.90	12.24	11.93
P.bold × P.barani	-8.87	5.56	-1.81	1.01	4.87	15.30	7.18
P.bold × RLM 198	-20.57*	-4.47	-6.20	11.67	11.95	28.11*	23.88
P.bold × PHR2	-33.18**	-9.62	9.30	-17.06*	-6.03	23.71*	22.68
P.bold × Divya	6.83	12.50	-6.98	-10.05	0.94	2.68	-10.56
P.bold × Zeml	-18.78*	8.35	27.39*	-9.05	-7.97	3.82	-10.43
P.bold × EC323290	6.81	37.12**	49.87**	-4.17	4.78	31.93**	14.01
P.bold × EC322092	-8.38	15.20	21.45	-7.54	-2.70	17.21	-6.52
P.bold × Domo	7.17	29.23**	27.39*	-21.41**	-10.97	17.21	14.67
P.barani × RLM198	-10.28	-6.13	5.94	10.50	15.01	26.77*	15.58
P.barani × PHR2	-26.22**	-11.05	20.67	-23.97**	-11.03	13.38	8.43
P.barani × Divya	15.11	27.32**	24.03*	-12.66	-5.29	-7.65	-6.21
P.barani ×Zeml	-17.13*	-1.76	29.97*	-5.66	-3.17	5.16	-19.39
P.baranix EC322090	-3.68	8.96	35.14**	-17.09	-6.21	14.15	-2.23
P.barani ×EC322092	-17.54*	-9.03	9.30	3.62	12.99	31.36**	11.65
P.barani × Domo	-1.52	3.31	17.05	-15.00	-0.53	26.77*	11.06
RLM198 × PHR2	-1.27	7.71	51.68**	-22.69**	-12.61	15.30	0.55
RLM198 × Divya	-5.25	9.07	11.89	13.33	-2.53	-0.57	-5.03
RLM198 × Zeml	--18.78*	-7.33	27.39*	14.50	16.15*	31.36**	22.82
RLM198 × EC322090	25.54*	12.00	44.77**	-4.58	4.09	31.36**	5.83
RLM198 × EC322090	3.31	9.28	36.95**	17.83*	11.96	35.18**	24.06
RLM198 × Domo	23.26*	23.66**	46.51**	-25.64**	-15.94*	10.90	-5.76
PHR2 × Divya	-17.85*	7.22	34.37**	-27.31*	-9.07	8.41	4.12
PHR2 × Zeml	-12.64	-10.81	42.90**	-17.56*	-5.65	22.95	8.29
PHR2 × EC322090	-16.27*	-9.86	36.95**	-16.28*	-12.93	24.86*	2.04
PHR2 × EC322092	-14.69*	-5.76	39.53**	-14.49	-7.56	27.53*	2.50
PHR2 × Domo	1.58	17.66*	66.15**	-23.08**	-23.08**	14.72	-6.67
Divya × Zeml	-20.92**	1.70	24.03*	2.40	13.71	14.15	0.56
Divya × EC322090	-7.92	13.64	29.20*	-20.42*	-3.45	9.56	0.58
Divya × EC322092	0.00	20.71*	32.56**	-12.52	2.66	10.89	11.49
Divya × Domo	16.74	34.76**	38.76**	-10.26	12.27	33.84**	23.33
Zeml × EC322090	-11.53	-6.61	38.76**	-16.67	28.93**	60.61**	22.22
Zeml × EC322092	-18.78*	-11.96	27.39*	10.56	17.66*	40.15**	19.09
Zeml × Domo	-8.24	4.41	43.93**	-13.72	-1.25	28.63*	1.98
EC322090× EC322092	3.68	6.63	45.48**	18.06*	22.92**	62.52**	8.24
EC322090×Domo	14.73	24.23	60.98**	-17.95*	-14.66*	22.37	-8.25
EC322092×Domo	-3.12	2.16	28.42*	-20.13*	-13.65	19.12	6.95

*,** Significant at 5% and 1% probability levels, respectively

Thirty hybrids of Experiment I and eighteen hybrids in Experiment II exhibited heterosis over check parent (Kranti). The best cross observed for the economic heterosis was PHR2 × Domo (66.15 per cent and EC 322090 × EC 322092 (62.52 per cent).

The maximum inbreeding depression was observed in RLM 198 × EC 322090 (24.06 per cent) while the minimum was recorded in Pusa barani × Zem 1 (-19.39 per cent). The average inbreeding depression for this character was observed to be 11.28 per cent.

4.5.6 Secondary branches per plant

The estimates of heterobeltiosis, relative heterosis, standard heterosis and inbreeding depression for secondary branches per plant have been given in Table 4.14. Six, nine and seven hybrids showed heterosis over better parent mid parent and check parent respectively in the Experiment I. In the Experiment II the number of hybrids showing heterosis over better mid and check parent were 13, 9 and 22 respectively. The best heterobeltiotic cross was Divya × Domo (36.29 per cent) and Kranti × Divya (41.78 per cent).

The best cross combination for relative heterosis observed was Divya × Domo (26.29 per cent) in the Experiment I and Pusa bold × Pusa barani (34.50 per cent) in the Experiment II, respectively.

Standard parent heterosis ranged from –31.81 per cent to 62.16 per cent and –14.49 per cent to 72.76 per cent in the Experiment I and II. The

Table 4.14 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for secondary branches/ plant.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
KrantixP.bold	-20.19	-21.45	-22.66*	-3.95	-1.19	1.75	-9.14
Krantix P.barani	-6.76	-9.74	-6.76	4.00	17.91	36.13*	23.93
Kranti × RLM198	-28.70*	-35.00**	-28.70*	27.66	29.85*	32.11	18.50
Kranti × PHR2	10.97	-6.90	10.97	-27.12**	-9.70	18.67	15.69
Kranti ×Divya	0.00	-3.53	0.00	41.78*	34.50*	27.92	21.82
Kranti ×Zeml	-4.94	-12.16	-4.94	-6.44	4.48	19.20	11.71
Krantix EC 322090	15.72	3.34	18.72	11.67	25.65*	43.63**	9.72
Krantix EC 322092	8.41	-14.06	8.41	-18.80	-1.51	25.13	22.79
Kranti × Domo	1.82	-9.21	1.83	-21.28	-5.51	18.15	15.27
P.bold × P.barani	4.34	-0.63	1.10	0.93	11.57	32.11	16.30
P.bold × RLM 198	-17.55	-26.12*	-20.11	32.95*	34.50*	40.83*	9.09
P.bold × PHR2	5.10	-13.44	1.83	-21.76	-5.20	27.40	26.03
P.bold × Divya	-2.45	-6.43	-5.48	-19.28	-12.81	-14.49	2.72
P.bold × Zeml	-2.45	-11.40	-9.48	-18.22	-10.70	4.19	-10.61
P.bold × EC323290	25.85	9.34	21.94	39.54*	26.04*	47.82**	10.24
P.bold × EC322092	11.89	-12.99	8.41	-24.92*	-11.00	15.71	-8.04
P.bold × Domo	30.76*	14.55	26.69*	-9.30	6.34	36.13*	16.67
P.barani × RLM198	-0.52	-6.15	0.03	11.07	24.05	45.38**	21.20
P.barani × PHR2	-4.46	-16.87	1.83	-17.47	-8.50	34.38*	5.19
P.barani × Divya	5.14	4.79	12.07	-25.33*	-11.60	-2.27	-2.98
P.barani ×Zeml	-6.18	-10.33	0.00	-17.81	-18.92	4.71	13.89
P.baranix EC322090	5.14	-3.69	12.07	-5.73	-4.91	23.37	11.79
P.barani ×EC322092	-14.75	-29.80**	-9.14	7.59	16.35	65.79**	16.84
P.barani × Domo	10.97	2.45	18.28	-7.33	-0.99	39.09*	6.28
RLM198 × PHR2	13.78	5.39	35.83**	-20.69*	-3.01	29.15	10.81
RLM198 × Divya	-1.71	-6.94	5.48	3.88	2.70	-0.52	-9.88
RLM198 × Zeml	-25.12*	-26.05**	-12.79	10.96	22.45	41.36*	22.63
RLM198 × EC322090	-13.78	-16.16	2.92	15.74	28.27*	48.87**	13.28
RLM198 × EC322090	-42.88**	-49.80**	-31.81**	7.93	29.13**	66.32**	44.41
RLM198 × Domo	15.93	13.58	38.39**	-8.49	8.33	37.35*	8.05
PHR2 × Divya	0.51	-12.20	7.86	-32.15**	-12.69	10.47	6.32
PHR2 × Zeml	-1.10	-9.61	15.17	-11.79	-1.02	43.63**	23.48
PHR2 × EC322090	-17.12	-21.63*	3.66	-15.01	-5.03	38.39*	16.81
PHR2 × EC322092	-16.38	-20.38*	15.72	-15.33	-13.00	37.87*	-0.84
PHR2 × Domo	30.44**	23.45**	62.16**	14.58	-11.10	39.09*	-1.26
Divya × Zeml	-2.90	-6.86	4.21	4.11	21.90	32.64	0.00
Divya × EC322090	-4.09	-11.83	2.93	-0.54	16.91	27.92	11.36
Divya × EC322092	2.22	-15.49	9.69	-14.27	8.14	32.11	19.82
Divya × Domo	36.29**	26.28*	46.25*	-6.16	17.21	40.84*	21.90
Zeml × EC322090	3.47	-3.54	17.01	-34.33**	34.97**	72.76**	23.57
Zeml × EC322092	0.47	-12.93	17.01	27.40*	15.31	62.30**	21.86
Zeml × Domo	5.18	1.75	22.49	28.36*	17.86	63.53**	22.78
EC322090× EC322092	-5.80	-14.64	18.83	8.38	18.15	66.02**	-1.05
EC322090×Domo	-9.27	-9.93	12.80	-7.79	-0.69	38.39*	-13.45
EC322092×Domo	-6.91	-16.33	15.72	-24.92*	-23.92*	15.71	-11.06

*,** Significant at 5% and 1% probability levels, respectively

best cross combination for standard heterosis was PHR 2 × Domo (62.16 per cent) and Zem1 × EC 322090 (72.76 per cent) in the Experiment I and II, respectively. The average inbreeding depression for number of secondary branches per plant was recorded to be 14.02 per cent. The maximum inbreeding depression was observed in the cross RLM 198 × EC 322092 (44.41 per cent) in F_2 of Experiment II.

4.5.7 Siliquae on main shoot

The percentage of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for siliquae on main shoot have been given in Table 4.15. 17^{th} and 10^{th} crosses exhibited heterobeltiosis in the Experiment I and II. The highest heterobeltiosis was observed in cross Divya × EC 322090 (50.28 per cent and 67.03 per cent in the Experiment I and II, respectively) whereas the lowest in EC 322090 × Domo (-40.53 per cent) and RLM 198 × Divya (-29.62 per cent).

Twentyeight and eighteen hybrids revealing heterosis over mid parent in the Experiment I and II. The crosses showing highest relative heterosis was Divya × EC 322090 (63.15 per cent) and Divya × Domo (63.68 per cent) and the lowest was in EC 322090 × Domo (-23.32 per cent) and EC 322090 × EC 322092 (-11.74 per cent) in the Experiment I and II, respectively.

Table 4.15 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for siliquae on main shoot.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	5.16	11.30	5.16	-8.19	-9.08	-9.95	19.63
Kranti× P.barani	-0.81	4.06	9.43	-2.80	-2.74	-2.80	2.96
Kranti × RLM198	12.39	13.25	12.39	7.71	11.96	16.56	8.77
Kranti × PHR2	1.85	5.15	8.68	6.25	6.34	6.43	-0.97
Kranti ×Divya	3.52	16.88	3.52	-6.27	6.43	-6.26	6.67
Kranti ×Zeml	11.08	11.63	11.08	-7.07	11.49	-7.07	-21.58
Kranti× EC 322090	13.93	38.40**	13.93	8.43	37.18**	8.43	-7.88
Kranti× EC 322092	23.79**	40.67**	23.79**	6.64	21.62*	6.64	9.12
Kranti × Domo	11.96	20.88**	31.35**	6.94	34.53**	6.94	6.04
P.bold × P.barani	-10.12	-0.50	-0.85	-1.52	-2.41	-3.40	4.73
P.bold × RLM 198	10.34	15.95	8.67	-9.17	-4.71	-1.70	4.04
P.bold × PHR2	20.02*	30.90**	28.07**	15.08	16.29	15.28	6.80
P.bold × Divya	2.07	9.34	-9.20	-4.13	7.93	-5.96	-3.59
P.bold × Zeml	11.09	17.03*	9.99	12.36	33.74**	10.22	8.74
P.bold × EC323290	18.95	37.78**	5.82	11.36	39.88**	9.23	27.09
P.bold × EC322092	30.66**	40.92**	16.23	4.56	18.26	2.56	10.16
P.bold × Domo	5.41	19.90**	23.66**	11.15	38.82**	9.03	-1.73
P.barani × RLM198	1.40	7.15	11.86	-0.72	3.26	7.45	2.68
P.barani × PHR2	20.85*	22.87**	33.32**	1.10	1.25	1.28	1.96
P.barani × Divya	3.58	21.92**	14.26	-4.56	8.29	-4.68	-0.10
P.barani ×Zeml	15.97	22.23**	27.93**	-10.02	7.89	-10.13	-12.93
P.barani× EC322090	-2.59	22.84**	7.46	39.85*	2.85	-18.77	-12.54
P.barani ×EC322092	5.75	25.22**	16.66	11.84	27.49**	11.71	16.00
P.barani × Domo	-21.63**	-19.53**	-8.41	5.67	32.87**	5.54	-2.07
RLM198 × PHR2	18.02*	13.29	16.23	-8.89	-5.38	-1.40	-1.81
RLM198 × Divya	14.88	28.26**	13.15	-29.62**	-17.38	-23.83*	-16.30
RLM198 × Zeml	21.57*	21.90**	20.38*	-1.73	21.57*	6.35	12.30
RLM198 × EC322090	6.21	28.24**	4.60	-13.76	12.23	-6.67	14.36
RLM198 × EC322090	21.56*	37.21**	19.71*	-12.00	3.75	-4.77	4.90
RLM198 × Domo	-0.48	8.21	16.76	-0.36	28.99**	7.83	13.90
PHR2 × Divya	-1.42	17.73*	8.21	-15.17	-3.62	-15.01	-29.91
PHR2 × Zeml	21.40*	16.52*	19.85*	-0.09	19.94	0.09	1.98
PHR2 × EC322090	6.16	32.22**	13.28	0.51	27.24*	0.69	11.44
PHR2 × EC322092	9.94	28.09**	16.99	8.92	24.32*	9.12	21.38
PHR2 × Domo	16.25*	21.75**	36.38**	11.42	40.26**	11.62	20.73
Divya × Zeml	28.78**	44.78**	27.51**	52.80**	62.89**	16.38	2.78
Divya × EC322090	50.28**	63.51**	15.91	67.03**	44.53**	-2.80	1.43
Divya × EC322092	49.25**	50.34**	15.12	23.08	23.73	-6.26	2.75
Divya × Domo	-0.09	20.57*	17.22	45.21**	63.68**	10.61	19.84
Zeml × EC322090	-0.43	20.48*	-1.41	37.28*	27.78*	-20.26	-2.99
Zeml × EC322092	-6.51	5.78	-7.43	1.98	8.18	-23.15*	-21.58
Zeml × Domo	-13.73	-6.43	1.22	39.54**	30.95*	-17.69	-6.03
EC322090× EC322092	7.96	16.68	-17.94*	-21.86	-11.74	-41.11**	-46.71
EC322090×Domo	-40.53**	-23.32**	-30.23**	60.96**	62.19**	-5.06	29.60
EC322092×Domo	-28.57**	-13.31	-16.20	37.38**	20.62	-18.98	-27.33

*,** Significant at 5% and 1% probability levels, respectively

Thirteen and three hybrids showed heterosis over check parent (Kranti) in the experiment I and II. The standard heterosis ranged from –30.23 per cent (EC 322090 × Domo) to 36.38 per cent (PHR 1 × Domo) and –41.11 per cent (EC 322090 × EC 322092) to 16.56 per cent (Kranti × Pusa barani) in the Experiment I and II, respectively. In the F_2 the average inbreeding depression for number of siliquae on main shoot was observed to be 11.71 per cent.

4.5.8 Siliqua length

The estimates of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for length of siliqua has been presented in Table 4.16. The number of hybrid expressing heterosis over better parent, mid parent and Kranti were 12, 19 and 11 in the Experiment I and 19, 19 and 37 in the Experiment II. The highest heterobeltiosis value was exhibited by the cross Zem 1 × EC322090 (53.50 per cent) and PHR 2 × EC 322090 (28.81 per cent) and the lowest in Pusa barani × EC 322092 (-13.49 per cent) and Pusa barani × EC 322090 (-19.28 per cent) in the Experiment I and II, respectively.

Relative heterosis ranged from –3.87 per cent (Pusa barani × Divya) to 41.83 per cent (Zem 1 × EC 322090) and –11.08 per cent (Kranti × RLM 198) to 32.35 PHR 2 × EC 322090 in the Experiment I and II, respectively.

Table 4.16 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for siliqua length.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
KrantixP.bold	14.28*	9.59*	14.28*	-10.44	-4.72	-10.44	3.88
Krantix P.barani	16.29**	9.56*	16.29*	-7.83	-5.36	-7.83	6.60
Kranti × RLM198	2.86	5.42	2.86	-17.23**	-11.08*	-17.23**	-7.37
Kranti × PHR2	-2.00	5.54	-2.00	-13.83*	5.43	13.83*	4.04
Kranti ×Divya	11.43*	6.41	11.43*	-19.06**	-10.53	-19.06**	-5.38
Kranti ×Zeml	5.71	16.90**	5.71	-19.84**	2.54	-19.84**	1.09
Krantix EC 322090	-8.57	7.93	-8.57	-13.84*	7.67	-13.84*	8.08
Krantix EC 322092	0.00	14.19**	0.00	-15.67**	7.13	15.67**	4.12
Kranti × Domo	10.57	24.84**	10.57	-18.28**	0.00	-18.28**	-11.70
P.bold × P.barani	-0.76	0.91	11.43*	-6.34	-2.86	-11.23*	-6.86
P.bold × RLM 198	1.84	8.56	10.57	0.00	1.05	-12.01*	-3.96
P.bold × PHR2	-13.16*	-2.94	-5.71	0.00	16.21*	-12.01*	2.97
P.bold × Divya	-2.61	-2.23	6.57	-8.01	-4.17	-19.06**	-16.13
P.bold × Zeml	-5.26	8.60	2.86	-5.94	8.56	-17.23**	-7.37
P.bold × EC323290	-11.32*	8.19	3.71	5.94	25.93**	-6.79	18.69
P.bold × EC322092	6.32	21.31**	11.43*	-1.19	19.57**	-13.06*	5.00
P.bold × Domo	3.42	12.92*	4.86	0.89	17.24**	-11.23*	6.86
P.barani × RLM198	14.11*	4.68	8.57	-0.83	3.90	-6.01	9.26
P.barani × PHR2	-9.16	3.03	2.0	-11.85*	5.61	-16.45**	-1.04
P.barani × Divya	-5.09	-3.87	6.57	-17.36*	-10.85	-12.67**	-11.11
P.barani ×Zeml	-4.07	11.54*	7.71	0.00	19.02**	-5.72	7.34
P.baranix EC322090	-10.94*	10.06	0.00	-19.38**	-1.18	-23.49**	-10.23
P.barani ×EC322092	-13.49**	3.66	-2.86	-13.77*	7.38	-18.28**	2.13
P.barani × Domo	-1.53	16.74**	10.57	-9.92	7.92	-14.62*	1.02
RLM198 × PHR2	-1.80	3.32	-6.57	0.00	15.18*	-13.49*	18.18
RLM198 × Divya	14.11*	6.15	8.57	-0.91	2.19	-14.62*	1.02
RLM198 × Zeml	11.11	20.13**	5.71	3.94	18.89**	-10.44	6.80
RLM198 × EC322090	-3.00	12.15*	-7.71	0.91	18.92**	-13.06*	22.00
RLM198 × EC322090	-10.81	-0.34	15.14**	-12.12	5.46	-24.28**	0.00
RLM198 × Domo	-3.90	6.14	-8.57	-18.18**	-5.76	-29.50**	-11.11
PHR2 × Divya	24.33**	9.22	6.57	-0.97	11.03	-19.84**	5.43
PHR2 × Zeml	22.33**	25.90**	4.86	17.41*	18.37*	-24.28**	-3.45
PHR2 × EC322090	-3.33	6.81	-17.14**	28.81**	32.35**	-18.28**	12.77
PHR2 × EC322092	4.33	11.10	-10.57	23.66**	29.59**	21.67**	6.67
PHR2 × Domo	-1.00	4.21	-15.14**	15.23*	15.23*	-26.89**	-1.19
Divya × Zeml	-3.39	11.11*	5.71	0.97	12.39	-18.28**	5.32
Divya × EC322090	-8.61	11.82*	0.00	13.87*	30.74**	-7.83	15.09
Divya × EC322092	-5.22	12.38*	3.71	0.00	16.98*	-19.06**	4.30
Divya × Domo	-1.57	15.47**	7.71	5.48	18.26**	-14.62*	0.00
Zeml × EC322090	53.50**	41.83**	6.57	4.05	7.76	-32.90**	-16.88
Zeml × EC322092	14.13*	18.32**	-7.71	1.21	7.07	-34.73**	-12.33
Zeml × Domo	18.52*	15.73*	-8.57	18.10*	17.14*	-25.07**	10.47
EC322090× EC322092	1.52	5.53	-23.71**	0.00	2.22	-39.95**	-11.59
EC322090×Domo	1.11	6.43	-22.00**	23.04*	19.66*	-26.11**	18.82
EC322092×Domo	11.11	12.57	-14.29*	15.23	20.95**	-26.89**	-4.76

*,** Significant at 5% and 1% probability levels, respectively

The highest standard heterosis was observed in the cross Kranti × Pusa barani (16.29 per cent) and Kranti × EC 322092 (15.67 per cent) whereas lowest was recorded in the cross EC 322090 × EC 322092 (-23.71 per cent and –39.95 per cent) in the Experiment I and II, respectively.

The maximum inbreeding depression was found in the cross RLM 198 × EC 322090 (22.00 per cent). The range of inbreeding depression from –21.33 per cent (Zem 1 × EC 322090) to 22.00 per cent (RLM 198 × EC 322090). The average value was observed to be 7.98 per cent in F_2 of Experiment II.

4.5.9 Seeds per siliqua

The estimates of heterobeltiosis relative heterosis, economic heterosis and inbreeding depression for number of seeds per siliqua have been presented in Table 4.17. Ten and twentyone crosses are revealing heterosis over better parent in the Experiment I and II. Heterobeltiosis ranged from –23.19 per cent to 16.00 per cent and –23.08 per cent to 15.20 per cent respectively in the Experiment I and II. Divya × EC322092 and PHR 2 × EC 322090 exhibited highest heterobeltiosis of 16.00 per cent and 15.20 per cent respectively in the Experiment I and II.

Four and five hybrids were expressed heterosis over mid parent. PHR 2 × Zem 1 (15.83 per cent) and PHR 2 × EC 322090 (13.36 per cent revealed highest relative heterosis in the Experiment I and II, respectively.

Table 4.17 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for seeds/ siliqua.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	-5.54	-2.36	1.04	-3.68	-1.13	-3.68	-1.53
Kranti× P.barani	1.04	3.65	1.04	-4.36	-3.76	-3.16	-0.76
Kranti × RLM198	-3.19	-3.08	-2.96	-5.66	-4.00	-5.66	-2.86
Kranti × PHR2	10.40	0.31	-10.40	-18.38**	-8.00	-18.38**	2.10
Kranti ×Divya	2.64	7.68	2.64	-13.97**	-6.88	13.97**	-4.27
Kranti ×Zeml	-15.76*	-9.50	-15.76*	-16.91**	-7.49	-16.91**	-0.88
Kranti× EC 322090	-12.80*	-6.44	-12.80*	-20.33**	-11.48*	-20.37**	-7.08
Kranti× EC 322092	-10.64	-0.71	-10.64	-18.38**	-7.11	-18.38**	-0.90
Kranti × Domo	-2.16	10.03	-2.16	-21.84**	-10.30*	-21.84**	-5.33
P.bold × P.barani	-21.47**	-16.80**	-16.00*	-6.83	-3.76	-5.66	-2.08
P.bold × RLM 198	8.98	-6.03	-2.64	-1.22	-0.35	-4.63	-1.29
P.bold × PHR2	-3.29	11.47	3.44	-12.95*	-4.14	-17.43**	-1.19
P.bold × Divya	-11.22	-3.89	-5.04	-9.07	-3.97	-13.75**	-2.27
P.bold × Zeml	-23.19**	-14.91**	-17.84**	-9.85	-1.98	-14.49**	0.29
P.bold × EC323290	-23.19**	-15.02**	-17.84**	-11.09*	-3.50	-15.66**	0.00
P.bold × EC322092	-19.97**	-8.43	-14.40*	-11.63*	-1.72	-16.18**	0.58
P.bold × Domo	-22.44**	-10.22	-17.04**	-12.64*	-2.00	-17.13**	2.07
P.barani × RLM198	-0.48	2.21	-0.24	-7.26	-5.06	-6.10	-4.70
P.barani × PHR2	-0.84	8.48	-5.84	-13.36**	-1.81	-12.28*	3.63
P.barani × Divya	-2.28	0.00	-7.20	-12.35*	-4.59	-11.25*	-3.04
P.barani ×Zeml	-8.17	-3.71	-12.80*	-17.94**	-8.13	-16.91**	-3.83
P.barani× EC322090	-9.60	-5.34	-14.16*	-14.82**	-4.79	-13.75**	3.98
P.barani ×EC322092	-12.97	-5.53	-17.36**	-17.43**	-5.53	-16.40**	-5.28
P.barani × Domo	-9.60	-0.64	-14.16*	-17.21**	-4.49	-16.18**	-3.24
RLM198 × PHR2	-14.61*	-4.29	-14.40*	-13.71*	-4.23	-16.69**	-1.18
RLM198 × Divya	-7.18	-2.52	-6.96	-5.03	1.14	-8.31	0.53
RLM198 × Zeml	-13.25*	-6.70	-13.04*	-12.94*	-4.59	-15.96**	2.62
RLM198 × EC322090	-9.02	-2.28	-8.80	-12.41*	-4.17	-15.44**	-1.74
RLM198 × EC322090	-10.62	-0.58	-10.40	-3.81	7.81	-7.13	8.71
RLM198 × Domo	-11.65	-0.54	-11.44	-23.08**	13.04*	-25.74**	-16.71
PHR2 × Divya	-8.47	-1.98	-17.04**	14.62	9.43	-11.25*	4.96
PHR2 × Zeml	10.77	15.83**	-4.56	5.70	4.21	-18.16**	0.60
PHR2 × EC322090	3.06	7.90	-10.96	15.20*	13.36*	-10.81*	2.20
PHR2 × EC322092	8.70	9.63	-13.04*	7.31	8.50	-16.91**	-0.29
PHR2 × Domo	13.94	14.52*	-10.40	4.46	6.64	-19.21**	2.12
Divya × Zeml	2.38	4.98	-7.20	0.35	3.49	-14.93**	-0.29
Divya × EC322090	-12.89	-10.80	-21.04**	5.55	8.66	-10.52*	10.14
Divya × EC322092	16.00*	8.77	-7.20	8.00	5.63	-15.22**	1.16
Divya × Domo	-6.18	0.95	-14.96*	-0.87	5.69	-15.96**	0.87
Zeml × EC322090	-1.20	-1.07	-14.64*	5.54	5.35	-15.96**	0.87
Zeml × EC322092	3.34	7.17	-10.96	3.14	5.73	-17.87**	1.19
Zeml × Domo	3.11	8.98	-10.64	2.77	6.36	-18.16**	0.60
EC322090× EC322092	3.43	7.40	-10.64	2.76	5.23	-17.86**	5.67
EC322090×Domo	-3.43	1.61	-16.56*	3.31	7.11	-17.43**	0.89
EC322092×Domo	4.70	6.13	-16.24*	6.12	7.16	-19.63**	3.53

*,** Significant at 5% and 1% probability levels, respectively

Twenty and thirtyseven hybrids showed superiority over Kranti in the Experiment I and II. Economic heterosis ranged from –21.04 per cent (Divya × EC 322090) to 3.44 per cent (Pusa bold × PHR 2) in the Experiment I and –25.74 per cent (RLM 198 × Domo) to 13.97 per cent (Kranti × Divya) in the Experiment II.

The maximum and minimum inbreeding depression for this character was observed in the cross Divya × EC 322090 (10.14 per cent) and RLM 198 × Domo (-16.71 per cent) respectively. The average value of inbreeding depression was recorded to be 2.89 per cent.

4.5.10 Biological yield per plant

The percentage of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for biological yield per plant have been presented in the Table 4.18. The number of hybrids exhibited heterosis over better parent, mid parent and check parent were 26, 12 and 11 in the Experiment I and 18, 21 and 23 in the Experiment II, respectively. Heterobeltiosis ranged from –41.74 per cent to 50.00 per cent and –26.96 per cent to 64.30 per cent. The best cross combination for heterobeltiosis was observed Pusa barani × Divya (50.00 per cent) and Pusa bold× Pusa barani (64.30 per cent) in the Experiment I and II, respectively.

The highest relative heterosis was observed in cross Pusa barani × EC 322090 (71.44 per cent) and RLM 198 × EC 322090 (60.52 per cent)

Table 4.18 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for biological yield/ plant.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	-5.25	8.28	-5.24	10.98	11.65	10.98	10.99
Kranti× P.barani	-2.61	8.85	-2.61	6.74	11.12	15.88	26.32
Kranti × RLM198	-19.30	-15.74	-11.84	34.18**	44.77**	34.18**	26.36
Kranti × PHR2	39.48**	27.71**	39.48**	-21.99*	-14.28	-4.87	5.13
Kranti ×Divya	-28.94*	-18.18	-28.94*	31.27**	15.08	2.45	17.86
Kranti ×Zeml	-41.29**	-30.81**	-15.79	-4.43	0.02	4.90	10.47
Kranti× EC 322090	-22.59**	-6.79	17.13	11.48	14.79	18.30	15.46
Kranti× EC 322092	-23.97**	15.12	-3.95	9.68	16.58	24.41*	16.67
Kranti × Domo	-12.37	1.67	21.08	20.90*	27.19**	34.18**	34.56
P.bold × P.barani	0.00	2.56	-21.04	1.11	5.88	9.77	13.33
P.bold × RLM 198	-26.53**	12.88	-19.74	41.96**	52.32**	40.25**	32.17
P.bold × PHR2	2.23	25.18**	21.08	0.00	10.49	21.95*	26.00
P.bold × Divya	15.78	16.08	-13.15	-2.48	8.96	-3.66	6.33
P.bold × Zeml	-15.58*	10.86	21.08	-4.43	0.50	4.90	0.00
P.bold × EC323290	-27.81**	-3.47	9.24	23.44*	19.04*	21.95*	17.00
P.bold × EC322092	-22.91*	-3.25	-2.61	15.07	23.00**	30.52**	20.56
P.bold × Domo	-12.37	13.59	21.08	18.69	25.60**	31.73**	23.15
P.barani × RLM198	-27.72**	-16.09	-21.04	12.34	25.77**	21.95*	23.00
P.barani × PHR2	-6.67	12.00	10.54	-19.98*	-15.33	-2.42	-5.00
P.barani × Divya	50.00**	55.16**	18.44	-26.96**	-15.02	-20.71	-7.69
P.barani ×Zeml	-19.27*	4.14	15.79	-4.43	3.91	4.91	3.49
P.barani× EC322090	30.45**	71.44**	97.39**	-12.37	-11.37	-4.87	-14.10
P.barani ×EC322092	-35.41**	-20.50*	-18.40	23.65*	26.36**	40.25**	39.13
P.barani × Domo	-28.57**	-9.10	-1.30	25.29**	36.67**	39.04**	30.70
RLM198 × PHR2	25.30*	20.24*	36.87**	41.45**	16.49	20.75	19.19
RLM198 × Divya	-12.07	5.01	-3.95	31.27*	25.39*	2.45	1.19
RLM198 × Zeml	-25.68**	-15.63*	6.59	20.00*	35.01**	31.72**	24.07
RLM198 × EC322090	-22.59**	-10.09	17.13	44.83**	60.52**	53.68**	31.75
RLM198 × EC322090	26.03**	-20.66*	-6.55	6.45	21.48*	20.75	20.20
RLM198 × Domo	-17.14*	-7.45	14.49	26.38**	42.86**	40.25**	26.96
PHR2 × Divya	-20.00*	-1.38	-5.25	-24.00**	-7.32	-7.32	-9.21
PHR2 × Zeml	-11.01	-2.51	27.64*	1.02	6.33	23.20*	6.21
PHR2 × EC322090	-13.05	-2.44	31.58**	6.00	13.36	29.27**	22.64
PHR2 × EC322092	2.09	5.39	28.98*	0.00	3.62	21.95*	19.00
PHR2 × Domo	4.77	12.83	44.77**	-12.99	-8.89	6.11	9.20
Divya × Zeml	-31.19**	-9.09	-1.30	7.77	25.97**	18.30	-2.06
Divya × EC322090	-41.74**	-21.65*	11.84	-3.45	11.27	2.45	7.14
Divya × EC322092	-18.75*	2.63	2.65	6.45	26.12**	20.75	28.28
Divya × Domo	-19.06*	5.57	11.84	5.51	23.89*	17.09	25.00
Zeml × EC322090	-31.31**	-29.47**	3.95	33.35**	31.09**	41.49**	24.14
Zeml × EC322092	-14.67	-9.26	22.39*	8.61	10.39	23.20*	11.88
Zeml × Domo	-4.56	-2.76	36.87**	17.61	18.25*	30.52**	17.76
EC322090× EC322092	-22.59**	-15.63*	17.14	10.74	14.43	25.61*	2.91
EC322090×Domo	-15.65*	-11.82	27.64*	19.78*	22.47**	32.93**	17.43
EC322092×Domo	-14.29	-10.45	18.44	26.38**	25.00**	40.25**	23.84

*,** Significant at 5% and 1% probability levels, respectively

and the lowest in Kranti × Zem 1 (-30.81 per cent) and Pusa barani × PHR 2 (-15.23 per cent) in the Experiment I and II, respectively.

Heterosis over check parent (Kranti) ranged from –28.94 per cent to 97.39 per cent and –20.71 per cent to 53.68 per cent. The best cross recorded for economic heterosis was Pusa barani × EC 322090 (97.39 per cent) and RLM 198 × EC 322090 (53.68 per cent)in the Experiment I and II, respectively.

The maximum inbreeding depression was recorded in Pusa barani × EC 322092 (39.13 per cent). The average value for this character was observed to be 17.23 per cent in the F_2 of Experiment II.

4.5.11 Seed yield per plant

The estimate of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for seed yield per plant have been presented in Table 4.19. 18th and 23rd crosses showed heterosis over the better parent. The range of heterobeltiosis was from –46.21 per cent to 86.42 per cent and –40.17 per cent to 71.35 per cent in the Experiment I and II. The best cross combination for heterobeltiosis observed was Pusa barani × Divya (86.42 per cent) and RLM 198 × EC 322090 (71.35 per cent) in the Experiment I and II, respectively.

Nineteen and twentyeight crosses had revealed heterosis over mid parent. The best and poorest cross combination identified for relative

Table 4.19: Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for seed yield/plant.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed. dep (%)
Krantix P.bold	-3.67	8.25	-3.67	24.15	40.84**	24.15	19.25
Krantix P.barani	-43.20**	-27.74*	-43.20**	2.83	7.15	11.84	34.72
Kranti × RLM198	-14.14	-4.51	7.56	46.31**	56.03**	46.31**	35.68
Kranti × PHR2	4.75	19.75	4.75	-20.31	-15.01	-20.31	-7.53
Kranti ×Divya	-43.19**	-17.56	43.19**	-2.46	39.34*	-2.46	22.91
Kranti ×Zeml	-41.69**	-34.23**	-41.19**	-9.23	-6.42	-9.23	9.22
Krantix EC 322090	11.88	30.31**	11.88	-4.00	10.74	-4.00	-1.12
Krantix EC 322092	3.24	16.59	3.24	33.23**	38.56**	33.23**	43.92
Kranti × Domo	-5.40	8.82	-5.40	53.08**	59.07**	53.08**	55.64
P.bold × P.barani	-29.92*	-19.17	-45.36**	-2.69	14.38	5.85	13.96
P.bold × RLM 198	-26.72**	-9.67	-8.21	51.85**	62.25**	32.92**	33.50
P.bold × PHR2	-8.86	-7.06	-28.94*	53.60**	64.13**	34.46**	57.42
P.bold × Divya	-21.61	5.60	-38.88**	4.64	37.30*	-20.15	1.93
P.bold × Zeml	26.59	27.12*	-1.30	-30.77*	-23.56	-34.92**	-12.06
P.bold × EC323290	45.43**	51.52**	13.39	42.54*	45.32**	8.77	24.66
P.bold × EC322092	-10.80	-10.31	-30.45**	30.33*	-42.70**	20.31	37.79
P.bold × Domo	49.86**	53.91**	16.84	55.91**	70.83**	44.15**	39.72
P.barani × RLM198	-52.24**	-34.44**	-40.17**	6.08	17.56	15.38	32.67
P.barani × PHR2	34.58*	52.61**	0.86	-17.26	-8.31	-10.10	0.85
P.barani × Divya	86.42**	124.54**	6.70	-31.54**	0.10	-25.54*	32.18
P.barani ×Zeml	45.24**	66.93**	12.31	-29.14*	-23.98*	-22.92	6.06
P.baranix EC322090	19.88	33.33**	-14.04	-40.17**	-28.55*	-34.92**	-13.95
P.barani ×EC322092	-14.57	-1.93	-34.13**	17.82	27.47*	28.15*	36.68
P.barani × Domo	-2.92	9.39	-28.29*	37.34**	48.47**	49.39**	46.84
RLM198 × PHR2	-9.31	13.48	13.61	27.59	27.59*	11.69	15.10
RLM198 × Divya	-46.21**	-17.35	-32.61**	-12.65	19.90	-23.54	-17.41
RLM198 × Zeml	-36.55**	-21.54*	-20.52	59.74**	65.42**	50.15**	47.51
RLM198 × EC322090	-19.83*	1.97	0.43	71.35**	86.42**	50.00**	29.74
RLM198 × EC322090	-37.93**	-23.16*	-22.25	50.17**	54.15**	38.62**	45.15
RLM198 × Domo	1.12	27.33**	26.78*	24.79	28.21*	15.39	18.35
PHR2 × Divya	-7.49	22.99	-30.67**	-14.06	17.97	-24.77	-4.63
PHR2 × Zeml	48.05**	50.36**	14.47	2.78	6.44	-3.39	-1.59
PHR2 × EC322090	10.66	13.11	-17.06	67.49**	82.22**	46.62**	31.19
PHR2 × EC322092	50.14**	52.27**	15.76	38.33**	42.00**	27.69*	38.10
PHR2 × Domo	5.48	6.24	-20.95	-5.16	-2.56	-12.31	-4.51
Divya × Zeml	-4.19	28.71	-25.92*	33.55*	87.37**	25.54*	16.06
Divya × EC322090	31.02	71.60**	-6.05	-2.52	26.19	-28.46*	19.05
Divya × EC322092	9.52	46.99**	-15.55	-9.50	26.28	-16.46	37.69
Divya × Domo	-3.51	27.66	-28.73*	-25.29	4.30	-30.92*	19.84
Zeml × EC322090	-9.78	-6.38	-30.24**	57.45**	76.84**	48.00**	41.29
Zeml × EC322092	24.02	24.20	-4.01	37.64**	38.89**	29.39*	22.01
Zeml × Domo	36.87*	40.00**	5.83	46.65**	47.86**	37.85**	24.86
EC322090× EC322092	-6.16	-2.76	-27.65*	52.50**	69.92**	40.77**	21.21
EC322090×Domo	7.02	8.61	20.95	29.12*	43.97**	19.39	18.82
EC322092×Domo	-13.48	-11.59	33.26**	19.30	19.40	10.31	25.85

*,** Significant at 5% and 1% probability levels, respectively

heterosis were Pusa barani × Divya (124.54 per cent) and Pusa barani × RLM 198 (-34.44 per cent) in the Experiment I and Divya × Zem 1 (87.37 per cent) and Pusa barani × Zem 1 (-23.98 per cent) in the Experiment II respectively.

Eighteen and twentythree hybrids expressed their seed yield superiority overcheck parent (Kranti). The best cross observed for economic heterosis was Kranti × Divya (43.19 per cent) and Kranti × Domo (53.08 per cent) whereas the poorest cross was Pusa bold × Pusa barani (-45.36 per cent) and Pusa barani × EC 322090 (-34.92 per cent) in the Experiment I and II, respectively.

Out of fortyfive hybrids thirtythree hybrids showed reduction in seed yield in F_2. However the combination Pusa bold × PHR 2 showed reduction of 57.42 per cent. The average value of inbreeding depression for seed yield per plant was observed to be 24.89 per cent in the F_2 of Experiment II.

4.5.12 1000-Seed weight

The estimate of heterobeltiosis, relative heterosis, economic heterosis and in breeding depression have been presented in Table 4.20. In the Experiment I, the number of hybrids exhibited heterosis over better parent, mid parent and check parent were 20th, 10th and 26th in the experiment I and 23rd, 14th and 29th in the experiment II, respectively. The estimates of heterobeltiosis ranged from -28.69 per cent (Pusa bold × EC322092) to

Table 4.20 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for 1000- seed weight.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	2.23	9.39*	17.63**	-7.43	-3.59	0.58	-4.01
Kranti× P.barani	-14.66**	-6.05	4.49	-1.13	-0.29	0.58	-0.86
Kranti × RLM198	3.21	9.15*	3.21	-2.31	-1.45	-2.31	5.91
Kranti × PHR2	-5.13	7.83	-5.13	-16.14**	-6.73	-16.14**	-6.65
Kranti ×Divya	-7.05	0.17	-7.05	-13.83**	-6.56	-13.83**	4.46
Kranti ×Zeml	-10.90*	-1.24	-10.90*	-14.99**	-10.33*	-14.99**	-4.51
Kranti× EC 322090	-13.14**	-8.29*	-13.14**	-7.21	0.31	-7.21	0.62
Kranti× EC 322092	-8.33	-0.35	-8.33	-10.95*	-3.14	-10.95*	-1.30
Kranti × Domo	-13.14**	-1.99	-13.14**	-2.31	10.07*	2.31	15.91
P.bold × P.barani	0.26	3.37	22.76**	0.27	3.56	8.93	4.50
P.bold × RLM 198	-0.28	12.40**	14.74**	-10.61*	-6.13	-2.88	-5.34
P.bold × PHR2	-13.93**	3.69	-0.96	-19.10**	-6.73	-12.10*	-1.31
P.bold × Divya	-15.32**	-2.88	-2.56	-23.34**	-13.73**	-16.72**	-9.24
P.bold × Zeml	-10.31*	5.57	3.21	-19.89**	-12.21**	-12.96**	-2.87
P.bold × EC323290	0.00	12.54**	15.06**	-14.59**	-4.17	-7.21	-4.97
P.bold × EC322092	-28.69**	-17.55**	-17.95**	-20.16**	-9.88*	-13.26**	-7.10
P.bold × Domo	-18.11**	-2.00	-5.77	-12.73**	1.86	-5.19	3.85
P.barani × RLM198	-17.28**	-4.24	1.28	-8.50	-6.92	-6.92	-8.45
P.barani × PHR2	-20.94**	-2.42	-3.21	-15.01**	-4.76	-13.55**	-0.89
P.barani × Divya	-13.35**	2.00	6.09	-9.35*	-0.93	-7.78	-3.75
P.barani × Zeml	-13.61**	4.27	5.77	-7.37	-1.51	-5.76	-2.04
P.barani × EC322090	-21.73**	-9.53*	-4.17	1.13	7.72	0.58	6.49
P.barani ×EC322092	-16.23**	-0.62	2.56	0.57	10.25*	2.31	3.20
P.barani × Domo	-14.40**	4.98	4.81	-8.50	3.86	-6.92	0.82
RLM198 × PHR2	-9.71**	-2.52	-19.55**	-18.77**	-10.36*	-20.17**	-3.32
RLM198 × Divya	4.67	6.79	-6.73	-19.94**	-13.88**	-21.33**	-6.23
RLM198 × Zeml	-5.39	-0.57	-15.71**	-14.08**	-10.12*	-15.56**	-1.36
RLM198 × EC322090	-6.81	-6.64	-16.67**	-16.42**	-10.38*	-17.86**	-13.11
RLM198 × EC322090	-9.35	-6.67	-19.23**	-17.01**	-10.44*	-18.44**	-7.76
RLM198 × Domo	-7.91	-1.35	-17.95**	-15.84**	-5.90	-17.29**	-1.62
PHR2 × Divya	19.41**	12.30*	-9.30*	4.78	7.72	-11.53*	7.61
PHR2 × Zeml	5.98	9.02	-14.74**	-14.71**	-9.86*	-23.63**	-8.31
PHR2 × EC322090	-13.26**	-6.20	-22.44**	-3.39	-0.35	-17.87**	-5.61
PHR2 × EC322092	0.38	5.41	-15.71**	2.75	5.28	-13.83**	0.22
PHR2 × Domo	2.49	3.35	20.83**	12.64*	11.00*	-12.68**	10.35
Divya × Zeml	4.87	8.11	-10.26*	-6.75	-3.97	-16.42**	1.38
Divya × EC322090	-3.58	-1.47	-13.78**	-0.34	0.00	-15.27**	-0.23
Divya × EC322092	-4.12	-3.21	-17.95**	-6.14	-5.82	-20.75**	-0.48
Divya × Domo	-2.25	2.76	-16.35**	-6.83	-2.85	-21.33**	0.49
Zeml × EC322090	-0.72	4.53	-11.22*	-3.22	-0.66	-13.26**	-1.77
Zeml × EC322092	13.36*	15.79**	-4.81	-5.15	-1.99	-14.99**	-7.24
Zeml × Domo	4.78	6.91	-15.71**	-1.29	5.86	-11.53*	-2.93
EC322090× EC322092	1.53	-1.66	-14.74**	11.68*	10.92*	-6.34	4.31
EC322090×Domo	11.62	3.46	-13.78**	-1.56	3.19	-16.14**	4.85
EC322092×Domo	18.26**	13.32**	-8.65	15.61*	11.07*	-10.38*	4.50

*,** Significant at 5% and 1% probability levels, respectively

19.41 per cent (PHR 2 × Divya) in the Experiment I and –23.34 per cent (Pusa bold × Divya) to 15.61 per cent (EC322092 × Domo) in the Experiment II. The best combination for 1000-seed weight was PHR 2 × Divya and EC322092 × Domo in the same Experiment.

The best cross combination for relative heterosis was Zem × EC322092 (15.79 per cent) and EC322092 × Domo (11.07 per cent) whereas the poorest cross combination was Pusa bold × EC322092 (-17.55 per cent) and RLM 198 × Divya (-13.88 per cent) respectively in the Experiment I and II.

The highest value of standard heterosis was 22.76 per cent and 8.93 percent (Pusa bold × Pusa barani) while the lowest values was –22.44 per cent (PHR-2 × EC322090) and –23.63 per cent (PHR 2 × Zem1) in the Experiment I and II respectively.

The range of inbreeding depression was from –13.11% (RLM198 × EC322090) to 15.91 per cent (Kranti × Domo). The average value of inbreeding depression for 1000-seed weight was observed to be 4.51 per cent.

4.5.13 Oil content

The estimates of heterobeltiosis, relative heterosis, standard heterosis and inbreeding depression for oil cont nt have been presented in Table 4.21 fourteen and eight hybrids showed heterosis over better parent. The highest

Table-4.21: Estimate of heterobeltiosis (BP), relative heterosis(MP), economic heterosis (CP) and inbreeding depression for oil content.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreed.dep (%)
Kranti×P.bold	-0.89	0.97	-0.89	-1.39	-0.10	-1.39	-0.44
Kranti× P.barani	0.10	0.40	0.10	-0.53	-0.27	-0.53	1.67
Kranti × RLM198	-2.23	-1.27	-2.23	-3.49	-2.86	-2.22	-2.13
Kranti × PHR2	-0.22	0.50	1.24	-0.58	-0.14	-0.58	-0.58
Kranti ×Divya	1.41	2.02*	1.41	-1.54	-0.08	-1.54	1.80
Kranti ×Zeml	-2.01	-1.32	-2.01	-3.48	-3.36	-3.46	-3.37
Kranti× EC 322090	-1.56	0.22	-1.56	-0.18	1.28	-0.18	1.96
Kranti× EC 322092	0.62	2.64*	0.62	1.58	2.10	2.63	4.36
Kranti × Domo	-1.31	0.70	-1.31	0.98	0.90	0.98	3.48
P.bold × P.barani	-0.40	1.18	-1.00	-2.44	-1.42	-2.95	0.86
P.bold × RLM 198	2.67*	1.74	-1.11	-0.55	1.40	0.76	3.33
P.bold × PHR2	0.03	2.63**	1.49	0.89	1.76	0.00	-0.05
P.bold × Divya	-0.20	1.08	-1.39	0.91	0.73	-2.04	-0.96
P.bold × Zeml	-1.43	0.27	-2.80*	-0.71	0.49	-0.91	2.03
P.bold × EC323290	2.49*	2.41*	-1.29	1.92	2.08	-0.71	0.20
P.bold × EC322092	2.60*	2.47*	-1.44	-3.32	-1.56	-2.32	-1.69
P.bold × Domo	3.18**	3.34**	-0.62	4.22*	2.77	1.54	5.02
P.barani × RLM198	3.08**	2.38*	1.09	-2.37	-1.44	-1.09	-0.83
P.barani × PHR2	0.03	1.05	1.48	-0.33	-0.15	-0.86	-0.81
P.barani × Divya	1.47	1.77	0.87	2.31	1.07	-0.68	1.04
P.barani ×Zeml	-0.33	0.08	-0.92	-5.41**	-5.26**	-5.60**	-5.78
P.barani× EC322090	0.65	2.16*	0.05	1.36	0.14	-1.57	-2.88
P.barani ×EC322092	-0.70	1.00	-1.29	-2.37	1.61	-1.36	-0.41
P.barani × Domo	2.96*	1.18	-1.14	0.76	1.11	0.93	3.60
RLM198 × PHR2	5.25**	3.46**	3.22**	0.57	1.68	1.89	-1.33
RLM198 × Divya	0.28	0.65	-0.92	-6.05**	-4.05*	-4.82*	2.36
RLM198 × Zeml	0.51	0.78	-0.89	-3.64	-2.91	-2.37	-3.03
RLM198 × EC322090	2.69*	1.84	-0.94	5.12*	2.90	2.10	3.54
RLM198 × EC322090	3.32**	2.26*	-0.74	-3.61	-3.48*	-2.35	-2.41
RLM198 × Domo	0.96	2.03*	-0.99	0.18	0.74	1.19	1.28
PHR2 × Divya	0.81	2.14*	2.28*	-0.94	0.09	-1.82	-0.83
PHR2 × Zeml	0.05	1.47	1.51	0.53	0.88	0.33	0.35
PHR2 × EC322090	-1.63	0.85	-0.20	0.89	1.92	0.00	2.28
PHR2 × EC322092	0.10	2.83**	1.56	-2.47	-1.54	-1.46	1.61
PHR2 × Domo	-0.17	2.58*	1.29	2.72	2.18	1.82	2.94
Divya × Zeml	-1.83	-1.93	-3.19**	-6.17**	-4.87*	-6.36**	-4.61
Divya × EC322090	-1.90	-0.72	-3.07**	0.68	0.68	-2.72	0.22
Divya × EC322092	-3.33**	-0.97	-4.48**	-6.00**	-4.12*	-5.03*	-0.19
Divya × Domo	-2.83*	-1.44	-3.98**	-5.39**	-3.90*	-5.23*	-0.55
Zeml × EC322090	0.03	1.13	-1.36	-2.91	-1.59	-3.10	-4.85
Zeml × EC322092	1.51	2.83**	0.10	0.10	0.72	1.14	4.03
Zeml × Domo	3.87**	2.48*	-0.27	1.26	1.45	1.44	1.54
EC322090× EC322092	1.31	1.52	-2.28*	-3.02	-1.11	-2.02	-1.15
EC322090×Domo	2.60*	2.36*	-1.48	-3.83	-2.34	-3.66	-4.85
EC322092×Domo	4.07**	4.04**	-0.08	-6.12**	-5.72*	-5.14*	-4.05

*,** Significant at 5% and 1% probability levels, respectively

values of heterobeltiosis was observed in RLM198 × PHR 2 (5.25 per cent) and RLM198 × EC322090 (5.12 per cent) in the Experiment I and II respectively whereas the lowest value in Divya × EC322092 (-3.33 per cent) and Divya ×Zem1 (-6.17 per cent) respectively.

Eighteen and seven crosses experessed heterosis over mid parent. The relative heterosis ranged from –1.93 per cent (Divya × Zem1) to 4.04 percent (EC322092 × Domo) in the Experiment I and –5.72 per cent (EC322092 × Domo) to 2.90 per cent (RLM198 × EC322090) in the Experiment II.

Eight and six crosses exhibited heterosis over Kranti. The highest positive standard heterosis observed was in RLM198 × PHR2 (3.22 per cent) and Kranti × EC322092 (2.63 per cent) whereas the highest negative was in Divya × EC322092 (-4.48 per cent) and Divya × Zem1 (-6.36 per cent) in the Experiment I and II respectively.

The highest value of inbreeding depression was in Pusa bold × Domo (5.02 per cent) whereas lowest value was in Pusa barani × Zem1 (-5.78 per cent). The average value of inbreeding depression for oil contant was observed to be 2.16 per cent in F_2 of Experiment II.

4.5.14 Harvest index

The estimates of heterobeltiosis, relative heterosis, economic heterosis and inbreeding depression for harvest index have been presented in

Table 4.22 : Estimate of heterobeltiosis (BP), relative heterosis (MP), economic heterosis (CP) and inbreeding depression for harvest index.

Name of crosses	Experiment-I			Experiment-II			
	BP(%)	MP(%)	CP(%)	BP(%)	MP(%)	CP(%)	Inbreedig dep (%)
Kranti×P.bold	-48.62**	-48.14**	-47.66**	21.69**	13.41**	6.17	4.44
Kranti× P.barani	-23.36**	-17.28**	-23.37**	5.81	5.37	4.94	11.63
Kranti × RLM198	3.05	6.65	10.51	11.52*	12.53**	13.58**	14.18
Kranti × PHR2	-5.84	5.50	-5.84	-8.03	-0.78	-8.03	-6.13
Kranti ×Divya	-14.72*	0.41	-14.72*	-2.68	13.29**	-2.68	-0.66
Kranti ×Zeml	-15.42*	-1.75	-15.42*	-6.79	-3.21	-6.79	-0.10
Kranti× EC 322090	-1.87	16.18*	-1.87	-9.67	-1.02	-9.67	-2.06
Kranti× EC 322092	0.00	12.19*	0.00	5.56	10.80*	5.56	19.51
Kranti × Domo	-12.15	0.40	-12.15	8.64	15.92**	8.64	19.76
P.bold × P.barani	-18.35**	-11.11	-16.82**	-0.62	5.74	-1.44	-0.90
P.bold × RLM 198	0.87	3.46	8.18	-4.04	3.37	-2.26	0.89
P.bold × PHR2	-25.23**	-15.54*	-23.83**	20.76**	22.05**	5.35	23.42
P.bold × Divya	-17.89**	-2.59	-16.36*	4.48	14.62**	-8.85	-2.24
P.bold × Zeml	-11.47	3.62	-9.81	-15.11**	-12.59*	-21.40**	-6.00
P.bold × EC323290	0.69	20.11**	2.57	15.21*	12.00*	-4.94	6.01
P.bold × EC322092	-16.28*	-5.32	-14.72*	6.36	8.33	-3.71	9.09
P.bold × Domo	-3.90	10.70	-2.10	20.00**	20.14**	4.94	1.90
P.barani × RLM198	-18.95**	-9.71	-13.08*	-4.04	-2.76	-2.26	6.32
P.barani × PHR2	13.97	18.69**	-2.80	13.01*	4.57	-3.50	1.83
P.barani × Divya	11.23	22.29**	-5.14	-4.56	10.71*	-5.35	18.32
P.barani ×Zeml	15.07*	24.63**	-1.87	13.28**	-10.30*	-13.99**	0.96
P.barani× EC322090	8.22	19.70**	-7.71	-15.35**	-7.59	-16.05**	-3.47
P.barani ×EC322092	5.21	9.71	-10.28	-3.32	1.09	-4.12	-1.33
P.barani × Domo	0.28	6.71	-14.49*	5.18	11.80*	4.32	12.76
RLM198 × PHR2	-15.03*	-1.89	-8.88	-5.05	3.30	-3.29	-7.65
RLM198 × Divya	-21.57**	-5.01	-15.89*	-14.95**	-0.24	-13.37**	-6.86
RLM198 × Zeml	-20.04**	-4.43	-14.25*	5.86	10.90*	7.82	17.38
RLM198 × EC322090	-13.72*	5.04	-7.48	-1.82	8.48	0.00	0.14
RLM198 × EC322090	-15.90**	-2.77	-9.81	5.05	11.23*	7.00	14.58
RLM198 × Domo	-0.87	16.67**	6.31	-10.10**	-3.26	-8.44	-5.02
PHR2 × Divya	8.63	14.96*	-14.72*	6.75	15.97**	8.85	2.83
PHR2 × Zeml	20.54*	25.58**	-5.37	-2.67	1.27	-9.98	-4.16
PHR2 × EC322090	1.76	8.40	-20.09**	25.06**	27.21**	6.79	5.77
PHR2 × EC322092	19.94*	20.12**	-5.84	13.64*	16.96**	2.88	12.25
PHR2 × Domo	-6.25	-4.11	-26.40**	6.99	5.71	-8.64	-7.36
Divya × Zeml	20.07*	22.04**	-13.32*	11.33*	25.41**	3.09	8.98
Divya × EC322090	43.14**	44.11**	0.00	1.50	8.53	-16.25**	7.35
Divya × EC322092	20.00*	26.81**	-6.08	-7.96	2.66	-16.67**	7.85
Divya × Domo	6.23	10.00	-20.33**	-12.47*	-3.88	23.46**	-3.75
Zeml × EC322090	12.30	14.90	-18.93**	12.00*	18.45**	3.71	13.05
Zeml × EC322092	12.24	16.77*	-12.15	11.33*	12.58**	3.09	6.07
Zeml × Domo	21.68*	19.37*	-12.15	11.56*	14.74**	3.92	4.36
EC322090× EC322092	0.59	6.98	-21.26**	17.28**	21.19**	6.58	10.34
EC322090×Domo	4.67	9.09	21.50**	14.21**	10.90*	-5.76	-0.18
EC322092×Domo	-3.28	-1.22	-24.30**	-7.27	-5.67	-16.05**	-10.38

*,** Significant at 5% and 1% probability levels, respectively

Table 4.22. Heterosis over better parent was expressed by the twenty crosses in both Experiment. The best positive heterobeltiosis was shown by the cross Divya × EC322090 (43.62 per cent) and PHR 2 × EC322090 (25.06 per cent). whereas, the cross Kranti × Pusa bold (-48.62 per cent) and Pusa barani × EC322090 (-15.35 per cent) were identified as the best poorest cross combination in the Experiment I and II respectively.

Nineteen and twentyfour hybrids were revealing heterosis over mid parent. The relative heterosis ranged from –48.14 (Kranti × Pusa bold) to 44.11 per cent (Divya × EC322090) in the Experiment I and –12.59 per cent (Pusa bold × Zem1) to 27.21 per cent (PHR 2 × EC322090) in the Experiment II respectively.

Twentyone and nine crosses were showed superiority over Kranti amongst these the best were EC322090 × Domo (21.50 per cent) and Divya × Domo (23.46 percent). The lowest value was recorded in Kranti × Pusa bold (-47.66 per cent) and Pusa bold × Zem1 (-21.40 per cent) in the Experiment I and II respectively.

The hybrid Pusa bold × PHR 2 (23.42) had highest inbreeding depression whereas the EC322092 × Domo (-10.38) per cent) had lowest inbreeding depression. The average value of inbreeding depression for harvest index was recorded to be 7.56 per cent in F_2 of Experiment II.

DISCUSSION

Discussion

The success of any breeding programme primarily depends upon the choice of parents and most appropriate breeding methodology. The common approach of selecting the parents on the basis of *per se* performance and local adaptation does not necessarily lead to much gainful result **(Allard 1960),** because of the fact that the ability of parents to combine well depends upon the complex interaction among genes and the genotype ×environment interaction. Hence, genetic worth of the parents may not be judged by mere performance test. In accomplishing this synthesis of superior genotypes, the plant breeders often need the best available parental material and try to choose the most appropriate breeding methodology for the purpose. In choosing the right type of parents for marshalling them into the recombination breeding approach, information on the combining ability of the parental populations and their hybrids are required. In handling the advanced generations of the material, they also need basic information on the type of gene action involved in the expression of the characters under study, the extent of heritability, heterosis and inbreeding depression are needed for useful selection. Therefore, present investigation was conducted together these information which may help in selecting the superior parents and designing the most appropriate breeding methodology. The present investigation was carried out during winter (rabi) season 1997-98 and 1998-99. Combining ability, gene action, heritability, heterosis and inbreeding depression were studied using F_1 and F_2 diallel excluding reciprocals. The salient features of the result obtained have been discussed here.

5.1 Analysis of variance

Results on analysis of variance in the present investigation revealed that the treatments differed significantly from each other for all the 14 characters. Partitioning of treatment mean sum of squares indicated that parents in experiment –II and crosses were significant for all the characters except for oil content among parents and number of seed per siliqua among crosses in the Experiment I. It was concluded that population development by diallel mating of 10 parents (excluding reciprocal) produced sufficient variability for all characters except oil content and number of seed per siliqua.

5.2 Combining ability analysis

Information on general combining abiliy are required for selection of the best general combining parent for various characters which may be used in hybridization programme to accumulate the favourable gene combinations for higher expression of economic characters. The biometrical information on *sca* is frequently utilized to spot out the most productive heterotic cross combination that could be profitably exploited in a hybrid breeding programme. In genetic sense, the *gca* is considered as indicator of the extent of the additive type of gene action while, *sca* is usually considered to be indicator of non-additive type of gene action.

In the present investigation, the *gca* and *sca* variances were analysed for yield and its component characters including oil content. The results obtained have already been presented in Table 4.3.The analysis of variance for combining ability were significant for all the characters in experiment I except seeds per siliqua and for days to 50 per cent flowering, days to maturity, length of main shoot, siliqua length, seed yield per plant and harvest index in F_1 and F_2 of experiment II whereas for primary and secondary branches per plant sliquae on main shoot biological yield per plant 1000 seed weight in F_1 experiment II. These significant mean square results indicate the importance of additive and non-additive gene effects in the inheritance of these characters. The importance of both additive as well as non- additive variance have been reported by **Paul** ***et al.*** **(1976), Yadava and Yadava (1976), Trivedi (1980) Yadava** ***et al.*** **(1981) Singh (1986) Jindal** ***et al.*** **(1985) and Thakral** ***et al.*** **(1995).** The additive genetic variances were significant for seeds per siliqua in both the experiments; for plant height and oil content in experiment II and for primary and secondary branches per plant, sliquae on main shoot, biological yield per plant and 1000- seed weight in F_2 of experiment II. The significant value of *gca* indicate the importance of additive gene effect for these characters. These results were in agreement with those of **Singh** *et al.* **(1986), Yadav (1990), Malkhondale (1993)** and **Luczkiewez (1996)**. It therefore, appears that the forces of artificial selection have not exhausted the additive genetic variance in the Indian mustard.

The value of an individual cross combination is judged by specific combining ability effects, a measure of the breeding potentialities, that can not be always associated with its individual performance. A proper understanding of the *gca* effect of the parents and *sca* effect of the crosses that indirectly indicate the nature of gene action is necessary for identifying suitable combinations for development of hybrids further, *sca* effect reflects the role of genetic diversity in the manifestation of heterosis.

The general combining ability effects of the parent are expressed in terms of 'G' for for good general combiners 'A' for average and 'P' for poor general combiners. The *gca* effects are summerised in Table 5.1. The result revealed that none of the parents had desirable *gca* effect for all the characters.

Kranti was found to be good general combiner for length of mainshoot, number of siliquae on main shoot, length of siliqua, number of seeds per siliqua, seed yield per plant, oil content and harvest index. It was average general combiner for 1000-seed weight.

Table 5.1 : Ranking of parental lines for their general combining ability effect with respect to various characters.

Characters	Varieties/lines									
	Kranti	Pusa bold	Pusa barani	RLM198	PHR2	Divya	Zem1	EC322090	EC322092	Dono
Days to 50% flowering	P	P	P	P	G	P	G	G	G	G
Days to maturity	P	P	P	P	G	P	G	G	G	G
Plant height	P	P	P	A	G	P	G	G	G	G
Length of main shoot	G	G	G	G	P	G	P	P	P	P
Primary branches/plant	P	P	P	A	G	P	A	G	G	G
Secondary branches/plant	P	P	P	P	G	P	A	G	G	G
Siliquae on main shoot	G	G	G	G	G	A	A	P	P	P
Siliqua length	G	G	G	A	P	A	P	P	P	P
Seeds/siliqua	G	G	G	G	P	A	P	P	P	P
Biological yield	P	P	P	P	G	P	G	G	G	G
Seed yield/plant	G	A	P	G	P	P	A	A	P	A
1000-seed/weight	A	G	G	A	P	P	P	P	P	P
Oil content	G	A	A	G	G	P	A	A	A	A
Harvest index	G	A	P	G	P	P	A	P	P	P
G	7	5	5	6	8	1	4	6	6	6
A	1	3	1	4	-	3	6	2	1	2
P	6	6	8	4	6	10	4	6	7	6

Pusa bold and Pusa barani were good general combiners for 1000-seed weight, length of main shoot, siliquae on mainshoot, length of siliqua and seeds per siliqua. These two were an average general combiner for seed yield per plant, oil content and harvest index.

The lines Domo, EC322090 and EC322092 expressed good general combining ability for days to 50 per cent flowering, days to maturity, plant height, primary and secondary branches per plant and total biological yield per plant; average *gca* for seed yield per plant and oil content and poor *gca* for length of mainshoot, number of siliquae on mainshoot, length of siliqua, number of seeds per siliqua , 1000-seed-weight and harvest index.

Zem1 was good general combiner for days to 50 per cent flowering, maturity, plant height and total biological yield per plant. It was poor general combiner for 1000- seed weight, length of siliqua, seeds per siliqua and length of mainshoot. Its general combining ability with respect to number of other characters was average.

Divya expressed good general combining ability for length of mainshoot; average for number of siliquae on mainshoot, length of siliqua and number of seeds per siliqua. PHR2 was good general combiner for eight characters none of the characters showed average *gca* effect. RLM198 proved to be good general combiner for seed yield per plant, seeds per siliqua, siliquae on main shoot, length of main shoot, oil content and harvest index. It was an average general combiner for plant height, number of primary and secondary branches, length of siliqua and 1000- seed weight.

Significant negative *gca* effect of Divya for flowering, maturity and harvest index indicated that it could be used as parent in the hybridization programme for development of early maturing dwarf varieties.

A summary of best parents, best 'F_1's based on mean performance, best general combiners and best specific cross combinations for various characters studied have been presented in Table 5.2. It was observed that parents showing best *per se* performance were not the best general combiner for most of the characters. However, for five characters there was a perfect correspondence between *gca* and *per se* performance of the parents in both experiments while four other parents were observed best for perfect correspondence between *gca* and *per se* performance in each experiment. The parent, showing best *per se* performance alongwith high *gca* were Pusa bold for 1000-seed weight; Pusa barani for 1000-seed weight, length siliqua and number of seed per siliqua; RLM 198 for seed yield, oil content and harvest index; Kranti for length of main shoot and length of siliqua; PHR2 for primary and secondary branches per plant and oil content and EC322092 for secondary branches per plant.

Table 5.2 : Correspondence of mean performance of the best parent best general combiner, best hybrids and the best specific combination for different characters.

Characters	Best parent (mean performance)		Best hybrids (mean)			Best general combiner			Best specific combination		
	Expt-I	Expt.II	Expt. F_1	Expt.II F_1	Expt. II F_2	Expt.I F_1	Expt.II F_1	Expt.II F_2	Expt.I F_1	Expt II F_1	Expt II F_2
Days to 50% flowering	Divya	Divya	P.bold × Divya	Kranti × Divya	Krantix Divya	PHR-2	Domo	Domo	EC322090× EC322092	Divyax Zem1	P.baranix Divya
Days to maturity	Divya	Divya	P.bold × Divya	P.bold × Divya	RLM198× Divya	Zem1	Zem1	EC322090	P.baranix Divya	Divyax Zem1	P.baranix Divya
Plant height	Divya	Divya	Kranti × Divya	P.bold × Divya	P boldx Divya	PHR2	EC322090	EC322090	P.baranix Divya	Krantix Divya	P.baranix Divya
Length of main shoot	Kranti	RLM198	Kranti × P.bold	P.barani × Damo	Krantix Zem1	Kranti	Kranti	Kranti	Divyax Zem1	Divyax Domo	Divyax EC322090
Primary branches/plant	PHR-2	PHR-2	PHR-2 × Damo	Zem1 × EC322090	EC322090× EC322092	PHR-2	EC322090	EC322090	P.boldx EC322090	Zem1× EC322090	EC322090× EC322092
Secondary branches/plant	EC322092	PHR-2	Divya × Damo	Zem1 × EC322090	EC322090× EC322092	PHR-2	EC322092	EC322090	Divyax Domo	Krantix Divya	Divyax Zem1
Siliquae on main shoot	Domo	RLM198	PHR-2 × Damo	Kranti × RLM198	Krantix Zem1	PHR-2	PHR-2	Kranti	Divyax EC322090	Divyax Zem1	P.boldx Domo
Siliqua length	P. barani	Kranti	Kranti × P. barani	Kranti × P. barani	P. boldx P. barani	P.barani	Kranti	P.barani	Zem1× EC322090	Divyax EC322090	Krantix Domo
Seeds/siliqua	P. bold	P. barani	P.bold × PHR-2	Kranti × P. barani	P.baranix RLM178	Kranti	P.barani	P.barani	P.bold × PHR-2	RLM198× EC322090	PHR2× EC322090
Biological yield/plant	EC322090	PHR-2	P.baranix EC322090	RLM198× EC322090	EC322090× EC322092	PHR-2	Domo	Zem1	P.baranix Divya	RLM198× EC322090	Divyax Zem1
Seed yield/plant	RLM198	P. barani	Kranti × EC322090	RLM198× EC322090	RIM198× EC322090	RLM198	RLM198	RLM198	P.baranix Divya	Divyax Zem1	Divyax Zem1
1000-seed/weight	P.barani	P. bold	P.bold × P.barani	P.bold × P.barani	Krantix P.bold	P.barani	P.barani	P.bold	P.boldx EC322090	Krantix Domo	Zem1× Domo
Oil content	PHR-2	RLM198	P.bold × PHR-2	RLM198× PHR-2	RLM198× PHR-2	PHR-2	PHR-2	RLM198	Krantix Divya	Krantix EC322092	RLM198× PHR-2
Harvest index	RLM198	RLM198	Krantix RLM198	Kranti × P. barani	Krantix P.bold	RLM198	Kranti	RLM198	Divyax EC322090	Divyax Zem1	Krantix Divya

The crosses with highest mean did not possess highest *sca* effect for most of the characters. The six crosses that showed highest mean performance with highest *sca* effect were Zeml × EC322090 and EC 322090 ×EC 322092 for number of primary branches per plant in F_1 and F_2 of experiment II, Divya × Domo for secondary branches per plant in F_1 of experiment I, Pusa bold ×PHR2 for seeds per siliqua in Experiment I, RLM 198 ×EC322090 for total biological yield per plant and RLM 198 ×PHR-2 for oil content in F_1 and F_2 of Expt. II. The crosses with high *sca* effects did not have parent with high *gca* parent also reported by **Singh 1973** and **Sheikh and Singh 1998.**

The *sca* estimates represent dominance and epistatic effects and can be correlated with heterosis. On the basis of per se performance we can use Zeml × EC322090, EC322090 × EC322092, Divya × Domo, Pusa bold × PHR2, RLM198 × EC322090 and RLM 198 × PHR2 for heterosis breeding. However, additive × additive type interaction component is also fixable in later generations. If the crosses showing high *sca* effect involved one parents are good general combiner and other showed poor one, these crosses could be exploited for breeding programme. However, if the crosses having high *sca* has parent of one of which is good and other poor or average general combiner. These results were in agreement with the report of **Sheikh and Singh (1998)**. Such crosses are likely to throw good segregants only if additive genetic system are present in the good general combiner and epistatic effect in the cross act in the same direction so as to maximize the desirable plant characteristics. With regard to the *sca* effects, the following broad interference may be drawn from the present study.

The crosses exhibiting high *sca* did not always involved highest *gca* parents two crosses were EC322090×EC322092 for days to 50% flowering and secondary branches per plant and RLM198×PHR2 for oil content revealed the high *gca* with high *sca* effects.

The *sca* effect of yield were not closely associated with those of other characters, hence, component characters may not be used effectively in sorting out better crosses. The result of different generation for *sca* effect did not bear striking similarity. It indicate the occurrence of high *sca* ×generation interaction.

5.3 Gene action

In plant breeding programmes, the diallel analysis has frequently been utilized for obtaining information on gene action. For this analysis the approach suggested by **Hayman (1954) and Jinks (1954)** is frequently utilized for obtaining the basic genetic parameters on types of gene action governing the quantitative characters. In the present study yield and yield components including oil content characters influencing the expression of yield were put to detailed genetic analysis utilizing the diallel mating approach and information obtained from the numerical estimates of gene action, gene effect and heritability estimates were obtained and the same have been presented in Table 4.7 and 4.8, respectively.

In the present study both additive (D) and non-additive (H_1 & H_2) gene action were important for the expression of all the characters in both experimental generations except the D in F_1 and F_2 for seed yield per plant and biological yield per plant in the Experiment II; H_1 and H_2 for harvest index and days to maturity in F_2 and Expt. II; More or less similar result have been reported by **Rawat (1975), Paul (1976), Yadava *et al.* (1981), Sachan and Singh (1988), Diwaker and Singh (1993), Thakur and Bhateria (1993), Malkhandale (1993) and Thukral *et al.* (1995).**

The significant values of H_1 and H_2 indicated the existence of considerable non-additive component variance due to heterozygosity. Considerable amount of non- additive gene action was found for number of siliquae on main shoot, length of siliqua and harvest index in both experiments. The F_1 and F_2 experiments revealed significant value for days to 50 per cent flowering, plant height, seeds per siliqua, biological and seed yield per plant and only in F_2 of experiment II for days to maturity and 1000-seed weight. While, in F_1 of Expt. I and F_2 Expt. II for primary and secondary branches per plant and oil content and only in F_1 generation which showed the considerable amount of non-additive gene action for length main shoot. Similar findings have been reported by **Jindal (1986), Gupta (1987), Yash Pal and Singh (1991) and Sheikh and Singh (1998).**

The ratio of $H_2/4H_1$ which gives the proportion of positive and negative genes and the mode of gene distribution, was less than 0.25 as should be for the most of the characters. This showed that dominant and recessive genes were not equally distributed in the parents. These results were in agreement with the reports of **Paul (1976)** and **Rawat (1980)**. The estimated value of $H_2/4H$ (0.24) being close to 0.25 indicate that the genes with positive and negative effects were about equally distributed in parents for seed yield per plant and length of siliqua in F_2 and for harvest index in F_1 generation of Expt. II and for 1000-seed weight in F_1 and Expt. I. Similar result have been reported by **Singh (1984).**

The ratio of dominant and recessive gene [(4DH)1/2+F/(4DH)1/2-F], suggested that proportion of dominant gene was more than recessive genes for days to 50% flowering, maturity, primary branches per plant, siliquae on mains shoot, siliqua length, seeds per siliqua and harvest index in both experiments. The proportion of recessive gene were more than the dominant gene for plant height, secondary branches per plant, seeds per siliqua biological yield per plant, oil content and 1000-seed weight in F_2 and seed yield per plant in the F_1 of experiment II and for length of main shoot in F_1 of Expt. I More or less similar results were in agreement with result of **Paul *et al.* (1976) Rishpal *et al.* (1981) and Singh (1984).**

The ratio of mean degree of dominance (H_1/D) 1/2 indicated partial dominance for days to maturity, days to 50 per cent flowering, plant height and length of siliqua, while partial to over dominance was evident for length of main shoot. Similar results have been reported by **Singh *et al.* (1970), Singh (1971), Chauhan and Singh (1973) Rawat (1975).** It was complete to over dominance for number of primary branches per plant, seeds per siliqua biological yield per plant, 1000-seed weight and harvest index, while; over-dominance was evident for siliquae on main shoot seed yield per plant and oil content. These results were in agreement with those of **Singh (1971), Singh and Singh 1972, Chauhan and Singh (1979)** and **Singh (1984).**

Heritability estimate gives an idea; whether, the selection in early generation would be effective are not. The early generation selection should be used only if the proportion of genetic variance was additive. Most of the characters showed moderate to high heritability except seeds per siliqua in both experiments; oil content in Experiment II and the biological and seed yield only in F_2 of Expt. II. In all the cases values for broad sense heritability were higher than narrow sense estimates, as expected. More or less similar result have been reported by **Singh (1970), Bagrecha *et al.* (1972), Zuberi *et al.* (1973), Paul (1978), Wang and Wang (1986), Malil *et al.* (1995) and Hussain *et al.* (1998).**

5.4 Estimation of heterosis

Exploitation of heterosis in crop plants is regarded as one of the major break through in the field of plant breeding. Heterosis is now being commercially exploited in an array of economically important cross and often cross pollinated crop plants and to lesser extent in self pollinated crops.

The extent of heterosis reported in most of the self pollinated crops is of moderate to high order. In general, exploitation of heterosis in self pollinated crops is linked with the problem of large scale commercial seed production. However, in some of the autogamus crops male sterility has been reported. The availability and use of male sterility and fertility restoration system usually enable commercial exploitation of hybrid vigour in self pollinated crops. But in order to take up such programme, it becomes necessary and *a priori* to know whether the manifestation of heterosis is sufficient in magnitude or not. But in practical breeding programme the expression of heterosis could be considerably useful only when it exceeds the local check or national check variety. With this in view the mustard variety Kranti was also included for the comparison of the study.

The experimental results revealed that the hybrids expressed significant heterosis for various characters studied. A summary of heterosis for highest value in the desired direction with respect to each character studied is presented in Table 5.3.

For the development of early genotypes, negative heterosis is desirable for number of days to 50 per cent flowering. The cross combination PHR2 × Domo and EC322090 × Domo emerged as best cross combination for heterobeltiosis, while, Pusa barani × Domo and Divya × EC322090 for relative and Zem1 × EC322090 and Kranti × Divya for standard exhibited highest negative heterosis **Rawat (1975). Chaudhary and Sharma (1982) and Verma *et al.* (1998)** also observed heterosis for earlyness in *B. juncea*.

The cross combinations EC322090×EC322092 and PHR-2 ×EC322090 showed highest heterobeltiosis for days to maturity. Whereas, cross Pusa bold × Divya and EC322090 × Domo showed heterosis over check parent. The importance of negative heterosis for this character was previously reported by **Agrawal (1976), Singh and Singh (1983), Singh (1983), Singh (1984), Hirve and Tiwari (1991) and Varshney and Rai (1997).**

Negative heterosis for plant height is desirable for development of dwarf varieties. The cross Pusa barani × Domo and RLM198 × Zemi showed high negative relative heterosis. Kranti × Divya and EC322090 × Domo showed highest negative heterobeltiosis while Kranti × Divya and

Table 5.3 : Summary table showing highest heterotic cross combination and extent of heterosis for different character in desired direction and average inbreeding depression in 45 crosses of F_2 in experiment II.

Characters	Highest heterotic cross combination						Average inbreeding depression(%)
	Experiment I			Experiment II			
	BP	MP	CP	BP	MP	CP	
Days to 50% flowering	P.bold × PHR-2	P.barani × Domo	Zem1 × EC322090	EC322090 × Domo	Divya × EC322090	Kranti × Divya	6.31
Days to maturity	EC322090 × EC322092	P.bold× Domo	P.bold × Divya	PHR-2 × EC322090	RLM198× Zem1	EC322090 × Domo	1.80
Plant height	Kranti × Divya	P.barani× Domo	Kranti × Divya	EC322090 × Domo	RLM198× Zem1	PHR-2× Divya	5.05
Length of main shoot	Divya × Zem1	Divya × Zem1	Kranti × P.bold	EC322090 × Domo	Divya × Domo	Pbarani × Domo	13.84
Primary branches/plant	RLM198 × EC322090	P.bold × EC322090	PHR2 × Domo	Kranti × Divya	Kranti × Divya	EC322090× EC322092	11.28
Secondary branches/plant	Divya× Domo	Divya × Domo	PHR-2× Domo	Kranti × Divya	Zem1 × EC322090	Zem1× EC322090	14.02
Siliquae on main shoot	Divya × EC322090	Divya × EC322090	PHR-2× Domo	Divya × EC322090	Divya × Domo	Kranti × RLM198	11.71
Siliqua length	Zem1 × EC322090	Zem1 × EC322090	Kranti× P.barani	PHR-2 × EC322090	PHR-2 × EC322090	Kranti × EC322092	7.98
Seeds/siliqua	Divya × EC322092	PHR-2 × Zem1	P.bold × PHR-2	PHR2 × EC322090	PHR-2 × EC322090	Kranti × divya	2.89
Biological yield/plant	P.barani× Divya	P.barani × EC322090	P.barani × EC322090	P.bold × RLM198	RLM198 × EC322090	RIM198 ×EC322090	17.23
Seed yield/plant	P.barani× Divya	P.barani × Divya	Kranti× Divya	RLM198 × EC322090	Divya× Zem1	Kranti× Domo	24.80
1000-seed/weight	PHR-2 × Divya	Zem1 × EC322092	P.bold × P.barani	EC322092× Domo	EC322092× Domo	P.bold × Pbarani	4.51
Oil content	RLM198 × PHR-2	EC322092 × Domo	RLM198× PHR-2	RLM198 × EC322090	RLM198 × EC322090	Kranti × EC322092	2.16
Harvest index	Divya × EC322090	Divya × EC322090	EC322090 × Domo	PHR-2 × EC322090	PHR-2 × EC322090	Divya × Domo	7.56

PHR2 × Divya emerged as best cross for economic heterosis. The result obtained for this character are in agreement with the **Singh *et al.* (1985), Kumar *et al.* (1990), Thakur and Bhateria (1993) and Sood *et al.* (2000).**

For the length of main shoot, Kranti × Pusa bold in experiment I and Pusa barani × Domo in experiment II recorded highest economic heterosis. These crosses had at least one parent with high *gca* effect. In experiment I, Divya × Zem1 recorded highest relative heterosis and heterobeltiosis. However, in experiment II, the maximum relative heterosis and heterobeltiosis was recorded in Divya × Domo and EC322090 × Domo for this character. **Banga and Labana (1984) and Singh and Singh (1985)** also reported heterosis for length of main shoot in mustard.

In case of primary branches per plant, RLM198 × EC322090 and Pusa bold× EC322090 expressed highest heterobeltiosis and relative heterosis in experiment I. However, Pusa bold × EC322090 and Kranti × Divya emmerged best cross in respect of relative heterosis and heterobeltiosis in experiment II. The maximum economic heterosis was found in PHR2 × Domo and EC322090 × EC322092 in the experiment I & II, respectively. These two crosses had both the parent with high *gca* effects. For secondary branches per plant, Divya × Domo was found best in respect of relative heterosis and heterobeltiosis while PHR2 × Domo expressed highest economic heterosis in the experiment I. In experiment II, Zem1 × EC322090 recorded highest economic and relative heterosis while Kranti × Divya expressed maximum heterobeltiosis. Heterosis for primary and secondary branches per plant in mustard has also been reported by **Trivedi (1980), Hirve and Tiwari (1991), Pradhan *et al.* (1991), Thakur and Bhateria (1993), Varshney and Rai (1997) and Sood *et al.* (2000).**

For siliquae on main shoot, Divya × EC322090 expressed maximum heterobeltiosis in both experiments. In experiment I, PHR2 × Domo and in experiment II Kranti × RLM198 were found best for economic heterosis. But Divya × EC322090 and Divya × Domo recorded highest to relative heterosis. The parents Kranti, Divya and RLM198 were also found to be good combiner for this character. **Banga and labana (1984) and Singh and Singh (1985)** also reported heterosis for this character in mustard.

In experiment I, Zem1 × EC322090 and in experiment II PHR2 × EC322090 expressed maximum heterobeltiosis and relative heterosis for siliqua length. However, Kranti × Pusa barani and Kranti × EC322092 recorded greater economic heterosis in experiment I & II, respectively. For seeds per siliqua, Divya × EC322092 in experiment I and PHR2 × EC322090 in experiment II showed maximum heterobeltiosis. PHR2 × Zem1 and PHR2 × EC322090 expressed highest relative heterosis in the experiment I & II, respectively. Maximum economic heterosis was recorded in Pusa bold × PHR2 in experiment I and Kranti × Divya in experiment II, respectively. In mustard heterosis for siliqua length and seeds per siliqua has been reported by **Agrawal (1976), Kumar** ***et al.*** **(1990), Hirve and Tiwari (1991), Thakur and Bhateria (1993) and Sood** ***et al.*** **(2000).**

For biological yield per plant, Pusa barani × EC322090 and RLM198× EC322090 were found promising in respect of economic and relative heterosis in experiment I & II, respectively. In experiment I, Pusa barani × Divya and in experiment II, Pusa bold × RLM198 recorded maximum heterobeltiosis. **Varshney and Rao (1997) and Singh** ***et al.*** **(1997)** reported heterosis for this character in mustard.

For the commercial success of hybrid must outyield than the best available cultivar. In the present study a high yielding variety Kranti one of the best parent was used for the calculation of economic heterosis. Majority of the crosses exhibited moderate to high heterosis for seed yield per plant. Pusa barani × Divya was found best cross in respect of heterobeltiosis and relative heterosis in experiment I. In experiment II, RLM198 × EC322090 and Divya × Zem1 were found promising in respect of heterobeltiosis and relative heterosis for this character. Kranti × Divya in experiment I and Kranti × Domo in experiment II showed maximum economic heterosis for seed yield per plant. These crosses had atleast one parent (Kranti) with high *gca* effect. **Singh and Mehta (1954), Kumar** ***et***

***al.* (1990) Pradhan *et al.* (1991), Thakur and Bhateria (1993), Varshney and Rao (1997), Agrawal and Badwal (1998) and Sood *et al.* (2000)** also reported heterosis for seed yield in mustard.

For 1000 seed weight, Pusa bold × Pusa barani expressed maximum economic heterosis is both experiments. It was also observed that both the parent had high *gca* effect. In experiment I, PHR2 × Divya and in experiment II, EC322092 × Domo recorded highest heterobeltiosis. But Zem1 × EC322092 and EC322092 × Domo showed highest relative heterosis for this character in experiment I & II, respectively. Low heterosis in mustard was reported by **Patnaik and Murty (1978) and Shuster *et al.* (1978)** while, **Yadava and Gupta (1975)** reported non significant heterosis for this character. **Singh *et al.* (1985) and Kumar *et al.* (1990)** reported significant heterosis for 1000- seed weight.

For oil content, in experiment I, RLM198 × EC322092 and in experiment II, RLM198 × EC322090 recorded highest heterobeltiosis. But EC322092 × Domo and RLM198× EC322090 expressed maximum relative heterosis in experiment I & II, respectively. Only two crosses RLM198 × PHR2 (experiment I) and PHR2 × Divya (experiment II) showed significant positive economic heterosis for this character. **Singh *et al.* (1985), Kumar *et al.* (1990) and Varma *et al.* (1998)** reported significant heterosis for this character while non significant heterosis reported by **Yadava and Gupta (1975) and Shuster *et al.* (1978).**

In case of harvest index, Divya × EC322090 expressed highest heterobeltiosis and relative heterosis while EC322090 × Domo was expressed highest economic heterosis in experiment I. In experiment II, PHR2 × EC322090 emerged best cross in respect of heterobeltiosis and relative heterosis for this character. However Divya × Domo was found best for economic heterosis in experiment II. Heterosis for harvest index in mustard was reported by **Thakur *et al.* (1988)** also.

An over view of all the results suggested that the line Divya can be of potential use as a parent in breeding programmes aimed at developing early and dwarf varieties. For plant height Divya, Kranti, Pusa bold, Pusa barani and RLM198 could be used as parent for the development varieties with medium height. The Kranti, RlM198, Pusa barani and Kranti, as a parent, is suggested for the development of high yielding varieties. Similar suggestion was given by **Singh and Mital (1993)**. It is also suggested that *per se* performance of the parent may serve as reliable guide for selection of best general combiner for all the characters studied .

Most of the crosses exhibiting high heterosis in desired direction involved at least one good general combiner for most of the characters but not necessarily high *per se* performance of the parents. In most of the crosses high heterosis did not involve parents with high mean. This indicates the genetic diversity among the parents.

5.5 Extent of inbreeding depression

The utilization of hybrid varieties for the commercial production primarily rests on promise of the exploitation of non-additive type of gene action present in the expression of yield. The hybrid vigour expresses in F_1 and usually breaks down in the F_2 or latter generation due to segregation of the favourable gene complexes which govern the expression of the vigour. As a result, there is genetically a decline in production. Therefore, for maintaining the yield status, the fresh hybrid seed has to be produced and supplied every year. To asses this decline in the performance, the extent of inbreeding depression was estimated for various characters, studied and the some has already been presented in the preceding chapter. The average inbreeding depression in per cent for all the character has been presented in Table 5.3.

As could be visualised in this table, there was negligible inbreeding depression for in case of days to maturity (1.80 per cent), oil content (2.16 per cent), seed per siliqua (2.89 per cent). 1000-Seed weight (4.51 per cent), Plant height (5.05 per cent), days 50 per cent flowering (6.31 per cent) harvest index (7.56 per cent) and length of siliqua (7.98 per cent). This would, therefore, suggested that these characters could be basically controlled by additive gene action. More or less similar results have been reported by **Doloi and Rai (1981), Rai (1997) Singh and Rai (1997), Verma *et al.* (1998).** Seed yield per plant (24.80 per cent), biological yield per plant (17.23 per cent), secondary branches (14.02 per cent) length of main shoot (13.84 per cent), siliquae on main shoot (11.78 per cent) and number of primary branches per plant (11.28 per cent)revealed high inbreeding depression in present investigation. Similar inbreeding depression reported by **Damgard and Leoschcks (1994) and Singh and Rai (1995).**

The high inbreeding depression in seed yield and consequent reduction in yield and other above characters shows that there could be a biological balance between seed yield and biological yield, length of mainshoot, siliquae on main shoot, primary & secondary branches per plant.

Inbreeding depression in F_2 considered together can give idea about the genetic control of character and these help in isolating high yielding pure lines from the promising crosses. An examination of data on inbreeding depression for seed yield per plant and other character indicated that in general mean expression of F_2 was lower than that of F_1 may be due to dominance and epistatic interaction involving dominance. Parallel relationship between heterosis in F_1 and inbreeding in F_2. **Gupta (1976), Kanshi Ram *et al.* (1976) and Banga and Labana (1984)** suggested the importance of non-additive gene action for controlling the characters.

SUMMARY

Summary

The Present investigation was undertaken with a view to study (i) combining ability, (ii) type of gene action involved (iii) the extent of heritability, (iv) heterosis and inbreeding depression in Indian-mustard (*Brassic juncea* (L.) Czern & Coss). F_1 and F_2 diallel crosses involving 10 mustard varieties/ lines viz., Kranti, Pusa bold, Pusa barani, RlM198, PHR-2, Divya, Zem1, EC322090, EC322092 and Domo, showing considerable variation for different characters were evaluated in two sets of trials. The first set comprised of 10 parents and their 45 F_1s and the second comprised of 10 parents, 45 F_1s and 45 F_2s, in compact family block design with three replications during the rabi season 1997-98 and 1998-99, at the Crop Research Centre of G.B.Pant University of Agriculture and Technology, Pantnagar, India. The observations were recorded on days to 50 per cent flowering , days to maturity, plant height, length of main shoot, primary and secondary branches per plant, number of siliquae on main shoot, siliqua length, seeds per siliqua, biological yield per plant, seed yield per plant, 1000-seed weight, oil content and harvest index. Parent Kranti a commercial variety, was used to calculate economic (standard) heterosis. The statistical analysis was carried out according to model 1 and method 2 of **Griffing (1956)**. The salient findings from the investigations are summarized below:

1. The analysis of variance revealed significant differences between treatments for all the characters studied.

2. The variance due to general combining ability was highly significant for all the characters, and specific combining ability variances were also significant for all the characters, except for number of seeds per siliqua in both the experiments and for plant height and oil content in experiment II.

3. The combining ability analysis revealed that both additive and non-additive genetic variances were important for most of the characters.

4. On the basis of *gca* effects parents were classified as good average and poor general combiners. Kranti and RLM 198 were identified as good general combiner for length of main shoot, siliquae on main shoot, seeds per siliqua, seed yield per plant, oil content and harvest index. Whereas, Pusa bold and Pusa barani were found good general combiner for length of main shoot, siliquae on main shoot, length of siliqua, seeds per siliqua and 1000-seed weight. Divya was identified good combiner for length of main shoot and for days to 50% flowering, days to maturity and dwarf height in negative direction. PHR2, Zem1, EC322090, EC322092 and Domo were found good general combiner for days to 50% flowering, days to maturity, plant height, primary and secondary branches per plant and biological yield

per plant. The parents Kranti, Pusa bold, Pusa barani, RLM198, and Divya may be used in hybridization programme for early maturing, high yield and high test weight.

5. On the basis of *per se* performance and specific combining ability Zem1 × EC322090, EC322090 × EC322092, Divya × Domo, Pusa bold × PHR-2, RLM198 × EC322090 and RLM198 × PHR-2 were found best cross combinations for primary branches per plant, secondary branches per plant, seeds per siliqua and oil content. The crosses showing high *per se* performance did not possess high *sca* effect for most of the characters. This might be attributed to the poor performance of the parents of the crosses.

6. Majority of the crosses showing high *sca* did not always involve good general combiners as parents, revealing the importance of non-additive genetic variance. It is observed that cross combinations involving low *gca* parents can also show high *sca* effect.

7. The estimates of genetic parameters obtained from diallel analysis indicated that involvement of additive type of gene action was more important in the expression of most of the characters except length of main shoot, secondary branches per plant, siliquae on main shoot, seed yield per plant and harvest index in F_1 of both experiments. The characters like days to 50 per cent flowering, days to maturity, plant

height, and siliqua length, showed partial dominance. The gene controlling length of main shoot showed partial to over dominance. The primary branches per plant, seeds per siliqua, biological yield per plant, 1000-seed weight and harvest index were in the range of complete to over dominance, whereas, other characters fell in the range of over dominance. The parental varieties/lines showing higher number of dominant alleles were more than the recessive ones for most of the characters. However, the plant height, secondary branches, seeds per siliqua, biological yield per plant and 1000-seed weight in F_1 and for oil content and seed yield per plant in F_2, the contribution of recessive alleles was higher

8. The broad sense heritability was higher for all the characters. Most of the characters showed moderate to high heritability except seeds per siliqua in both experiments; oil content in experiment II and the biological yield and seed yield per plant in F_2 of experiment II.

9. The outstanding F_1 hybrids were Pusa barani × Divya, Kranti × Divya, RLM198 × EC322090, Divya × Zem1 and Kranti × Domo for seed yield per plant. The highest value of heterosis over check parent was observed for secondary branches per plant in the cross Zem1 × EC322090 (72.76 per cent) for primary branches per plant in the cross PHR2 × Domo (66.15 per cent). The standard heterosis for seed

yield per plant ranged from -34.92 per cent (Pusa barani ×EC322090) to 53.08 per cent (Kranti × Domo). It is suggested that crosses exhibiting high standard heterosis for yield and its component characters may be used in the breeding programme for developing high yielding varieties

10. The highest average inbreeding depression was observed for seed yield per plant 24.08 per cent, total biological yield per plant (17.23 per cent) and number of secondary branches per plant (14.02 per cent).

The implication of these findings in designing the effective breeding methodology have also been discussed.

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APPENDICES

Appendix 1 :Weekly weather data at Pantnagar during crop period

Period			Meteorological Data					
Month	Week	Date	Mean temperature °C		Relative Humidity (%)		Total rain fall (mm)	Sunshine (hours)
			Max	Min.	07-12 am	14-12 am		
Oct. 1997	1	15-21	29.8	16.4	89	41	003.2	09.3
	2	22-28	26.5	14.4	90	52	005.2	07.2
	3	29-4/11	26.5	13.1	87	50	038.2	08.6
Nov 1997	1	5-11	27.5	13.0	85	49	005.2	08.0
	2	12-18	27.5	13.0	92	40	0.000	09.0
	3	19-25	24.5	11.6	87	52	0.000	05.7
	4	26-2/12	20.1	11.0	93	70	022.0	03.6
Dec 1997	1	3-9	23.0	9.9	90	58	005.0	07.2
	2	10-16	17.5	10.1	96	73	070.8	01.8
	3	17-23	14.6	7.4	93	77	0.000	01.9
	4	24-31	15.7	5.9	95	70	004.8	03.4
Jan 1998	1	1-7	13.1	7.6	98	84	0.000	01.7
	2	8-14	15.5	8.2	96	82	0.000	02.1
	3	15-21	18.1	4.4	95	61	0.000	05.4
	4	21-28	20.6	5.1	90	50	0.000	07.3
	5	29-4/2	21.8	9.3	94	61	007.2	04.9
Feb. 1998	1	5-11	21.7	5.5	94	48	0.000	08.9
	2	12-18	25.8	12.0	88	54	002.6	07.1
	3	19-25	23.3	9.8	89	55	000.6	06.8
	4	26-4/3	22.5	9.2	94	58	0005.6	05.7
Mar. 1998	1	5-11	22.7	8.8	90	50	009.0	08.0
	2	12-18	25.3	11.6	89	46	020.8	08.9
	3	19-25	27.1	12.3	88	49	0.000	08.2
	4	26-1/4	27.5	13.5	82	44	002.8	08.9
April 1998	1	2-8	31.5	16.2	85	45	005.6	09.7
	2	9-15	32.8	16.7	74	25	000.2	10.2
	3	16-22	35.8	17.4	69	26	0.000	11.4
	4	23-29	35.0	20.9	74	40	038.0	09.7
	5	30-6/5	38.3	20.7	69	31	0.000	11.3

Source : Meteorological observatory (Crop Research Center) G.B. Pant University of Agriculture and Technology, Pantnagar.

Appendix 2 : Weekly weather data at Pantnagar during crop period

Period			Meteorological Data					
Month	Week	Date	Mean temperature °C		Relative Humidity (%)		Total rain fall (mm)	Sunshine (hours)
			Max.	Min.	07-12 am	14-12 am		
Oct. 1998	1	15-21	27.6	19.6	91	74	283.4	03.7
	2	22-28	30.5	18.2	90	52	000.0	09.1
	3	29-4/11	29.2	14.6	89	59	000.0	09.9
Nov 1998	1	5-11	27.3	16.6	87	60	007.6	07.1
	2	12-18	27.7	13.1	91	48	0.000	09.5
	3	19-25	27.3	12.0	92	52	0.000	08.4
	4	26-2/12	26.1	8.7	96	47	0.000	09.4
Dec 1998	1	3-9	25.0	8.8	93	47	0.000	09.3
	2	10-16	24.5	8.2	93	44	0.000	07.6
	3	17-23	23.2	6.7	94	45	0.000	06.6
	4	24-31	17.5	5.0	97	70	0.000	04.0
Jan 1999	1	1-7	20.0	6.3	94	59	055.6	04.1
	2	8-14	15.4	7.7	96	73	0.000	02.8
	3	15-21	13.5	6.8	97	84	0.000	01.5
	4	22-28	22.0	8.6	93	58	036.4	05.6
	5	29-4/2	19.4	6.9	95	51	0.000	07.0
Feb. 1999	1	5-11	23.3	8.5	93	55	0.000	06.3
	2	12-18	25.6	10.1	95	53	0.000	06.3
	3	19-25	24.9	9.6	92	53	0.000	04.6
	4	26-4/3	26.3	9.5	94	50	0.000	08.9
Mar. 1999	1	5-11	29.8	12.1	88	36	0.000	09.5
	2	12-18	28.7	9.1	88	37	0.000	10.3
	3	19-25	30.7	10.8	84	26	0.000	10.2
	4	26-1/4	33.6	14.2	74	26	0.000	10.2
April 1999	1	2-8	36.2	16.2	73	20	0.000	09.9
	2	9-15	37.0	18.3	62	27	0.000	10.5
	3	16-22	37.8	15.4	65	20	0.000	09.7
	4	23-29	41.3	17.4	62	20	0.000	10.6
	5	30-6/5	31.1	22.5	63	27	0.000	10.2

Source : Meteorological observatory (Crop Research Center) G.B. Pant University of Agriculture and Technology, Pantnagar.

Appendix-III : Mean performance of parents and crosses (F_1s) for different characters of Experiment I

Genotypes	Characters studied													
	Days to 50% flowering (No)	Days to maturity (No)	Plant height (cm)	Length of main shoot (cm)	Primary branches / plant (no.)	Secondary branches per plant (no.)	Siliquac on main shoot (no.)	Length of siliquac (cm)	Seeds/ siliqua (no.)	Biological yield/ plant (g)	Seed yield/ plant (g)	1000 seed weight (g)	Oil content (%)	Harvest index (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Kranti	57.33	137.00	167.40	48.17	3.87	5.47	30.43	3.50	12.50	25.33	4.63	3.12	40.43	18.34
Pusa bold	58.00	138.33	158.00	48.00	3.03	5.30	27.07	3.80	13.37	19.00	3.61	3.59	38.94	19.07
Pusa barani	55.00	138.00	156.23	46.70	4.17	5.83	33.57	3.93	11.87	20.00	2.65	3.82	40.19	13.44
RLM 198	58.67	134.33	176.17	45.57	4.57	6.53	29.97	3.33	12.53	27.67	5.80	2.78	39.65	21.09
PHR-2	78.67	156.00	211.43	32.90	6.33	7.57	32.47	3.00	9.83	30.00	3.47	2.37	41.02	11.33
Divya	41.00	117.33	112.90	37.60	3.37	5.87	23.47	3.83	11.33	18.67	1.75	2.67	39.95	9.00
Zem1	64.33	154.33	212.20	36.60	6.07	6.37	30.13	2.83	10.77	36.33	3.58	2.51	39.87	9.61
EC 322090	65.00	159.67	219.43	31.87	5.43	6.90	19.67	2.43	10.80	38.33	3.32	2.79	39.00	8.70
EC322092	75.33	160.00	234.80	38.30	5.13	8.33	23.13	2.63	10.00	32.00	3.57	2.62	38.84	11.31
Domo	81.67	160.33	228.93	42.30	4.60	6.80	35.70	2.70	9.73	35.00	3.42	2.41	38.82	10.32
Kranti×P.bold	56.00	138.00	171.33	57.13	3.33	4.23	32.00	4.00	12.63	24.00	4.46	3.67	40.07	18.02
Kranti×P.barani	56.33	141.00	158.70	53.03	4.00	5.10	33.30	4.07	12.63	24.67	2.63	3.26	40.47	10.82
Kranti×RLM198	57.67	141.67	180.20	51.47	4.10	3.90	34.20	3.60	12.13	22.33	4.98	3.22	39.53	22.44
Kranti×PHR2	64.33	140.00	209.20	50.00	5.27	6.07	33.07	3.43	11.20	35.33	4.85	2.96	40.93	16.41
Kranti×Divay	46.67	136.00	141.00	45.83	3.70	5.47	31.50	3.90	12.83	18.00	2.63	2.90	41.00	13.36
Kranti×Zeml	66.00	159.00	175.43	47.57	3.70	5.20	33.80	3.70	10.53	21.33	2.70	2.78	39.62	13.39
Kranti×EC322090	56.33	141.33	210.73	48.80	5.50	6.33	34.67	3.20	10.90	29.67	5.18	2.71	39.80	17.73
Kranti×EC322092	56.33	150.33	201.83	49.63	5.10	5.93	37.67	3.50	11.17	24.33	4.78	2.86	40.68	18.38
Kranti × Domo	62.67	142.00	199.97	52.13	5.03	5.57	39.97	3.87	12.23	30.67	4.38	2.71	39.90	14.17
P.bold × barani	54.33	140.33	158.43	51.43	3.80	5.53	30.17	3.90	10.50	20.00	2.53	3.83	40.03	12.68
P.bold × RLM 198	57.00	138.00	173.00	53.67	3.63	4.37	33.07	3.87	12.17	20.33	4.25	3.58	39.98	21.78
P.bold × PHR2	64.33	152.67	203.83	47.27	4.23	5.57	38.97	3.30	12.93	30.67	3.29	3.09	41.03	10.88
P.bold × Divya	44.67	124.33	144.27	51.03	3.60	5.17	27.63	3.73	11.87	22.00	2.83	3.04	39.87	12.84
P.bold × Zeml	59.67	151.67	199.93	47.73	4.93	5.17	33.47	3.60	10.27	30.67	4.57	3.22	39.30	14.88
P.boldl × EC323290	60.67	143.33	202.93	46.83	5.80	6.67	32.20	3.37	10.27	27.67	5.35	3.59	39.91	19.41
P.bold × EC322092	56.00	142.00	185.03	48.03	4.70	5.93	35.37	3.90	10.70	24.67	3.22	2.56	39.85	13.36

Contd…

Contd....

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P.bold × Domo	59.00	140.67	204.03	50.37	4.93	6.93	37.63	3.67	10.37	30.67	5.41	2.94	40.18	17.61
P.barani × RLM198	52.33	136.67	177.43	53.30	4.10	6.50	34.03	3.80	12.47	20.00	2.77	3.16	40.87	13.83
P.barani × PHR2	67.00	142.00	200.93	48.43	4.67	5.57	40.57	3.57	11.77	28.00	4.67	3.02	41.03	17.36
P.barani × Divya	50.33	146.33	198.97	48.90	4.80	6.13	34.77	3.73	11.60	30.00	4.94	3.31	40.78	16.54
P.barani × Zeml	57.00	138.00	197.70	53.73	5.03	5.47	38.93	3.77	10.90	29.33	5.20	3.30	40.06	17.73
P.barani × EC322090	61.67	141.67	196.47	44.43	5.23	6.13	32.70	3.50	10.73	25.00	3.98	2.99	40.45	15.63
P.barani × EC322092	53.33	141.33	173.20	49.33	4.23	4.97	35.50	3.40	10.33	20.67	3.05	3.20	39.91	14.75
P.barani × Domo	54.33	142.67	142.73	47.50	4.53	6.47	27.87	3.87	10.73	25.00	3.32	3.27	39.97	13.47
RLM198 × PHR2	65.67	157.33	223.33	39.93	5.87	7.43	35.37	3.27	10.70	34.67	5.26	2.51	41.73	15.32
RLM198 × Divya	60.00	129.33	153.77	47.97	4.33	5.77	34.43	3.80	11.63	24.33	3.12	2.91	40.06	13.06
RLM198 × Zeml	63.67	148.67	196.63	47.43	4.93	4.77	36.63	3.70	10.87	27.00	3.68	2.63	40.07	13.57
RLM198 × EC322090	60.67	143.33	213.03	41.07	5.60	5.63	31.83	3.23	11.40	29.67	4.65	2.60	40.05	15.70
RLM198 × EC322090	65.00	142.67	223.30	42.17	5.30	3.73	36.43	2.97	11.20	23.67	3.60	2.52	40.13	15.03
RLM198 × Domo	65.67	148.67	222.23	44.93	5.67	7.57	35.53	3.20	11.07	29.00	5.87	2.56	40.03	20.78
PHR2 × Divya	64.33	135.33	186.37	47.23	5.20	5.90	32.93	3.73	10.37	24.00	3.21	2.83	41.35	13.39
PHR2 × Zeml	77.67	157.33	209.80	39.27	5.53	6.30	36.47	3.67	11.93	32.33	5.30	2.66	41.04	16.46
PHR2 × EC322090	66.00	154.00	234.63	34.83	5.30	5.67	34.47	2.90	11.13	33.33	3.84	2.42	40.35	11.78
PHR2 × EC322092	80.00	155.00	236.27	36.10	5.40	6.33	35.60	3.13	10.87	32.67	5.36	2.63	41.06	16.30
PHR2 × Domo	78.00	156.67	239.20	40.93	6.43	8.87	41.50	2.97	11.20	36.67	3.66	2.47	40.95	9.95
Divya × Zeml	55.67	139.00	171.23	50.70	4.80	5.70	38.80	3.70	11.60	25.00	3.43	2.80	39.14	13.75
Divya × EC322090	52.33	137.67	161.37	45.00	5.00	5.63	35.27	3.50	9.87	22.33	4.35	2.69	39.19	18.39
Divya × EC322092	47.33	142.00	169.50	46.93	5.13	6.00	35.03	3.63	11.60	26.00	3.91	2.56	38.62	16.30
Divya × Domo	53.67	140.00	158.07	47.27	5.37	8.00	35.67	3.77	10.63	28.33	3.30	2.61	38.82	11.65
Zeml × EC322090	69.00	155.67	224.50	39.13	5.37	6.40	30.00	3.73	10.67	26.33	3.23	2.77	39.88	12.25
Zeml × EC322092	65.33	157.00	213.30	36.27	4.93	6.40	28.17	3.23	11.13	31.00	4.44	2.97	40.47	14.23
Zeml × Domo	78.33	156.00	209.70	35.40	5.57	6.70	30.80	3.20	11.17	34.67	4.90	2.63	40.32	14.19
EC322090 ×EC322092	79.67	152.67	236.60	33.03	5.63	6.50	24.97	2.67	11.17	29.67	3.35	2.66	39.51	11.36
EC322090 × Domo	82.23	160.33	231.17	28.00	6.23	6.17	21.23	2.73	10.43	32.23	3.66	2.69	39.83	11.31
EC322092 × Domo	80.00	154.00	229.20	32.07	4.97	6.33	25.50	3.00	10.47	30.00	3.09	2.85	40.40	10.58
M	62.17	145.26	193.25	44.75	4.86	5.79	32.82	3.45	11.23	27.46	3.95	2.91	40.09	14.63
Em±	1.89	2.20	6.31	2.58	0.49	0.73	2.71	0.91	0.79	2.82	0.53	0.14	0.46	2.08

\ppendix-IV : Mean performance of parents and crosses (F_1s & F_2s) for different characters of Experiment II

Genotypes	Characters studied													
	Days to 50% flowering (No)	Days to maturity (No)	Plant height (cm)	Length of main shoot (cm)	Primary branches / plant (No.)	Secondary branches per plant (No.)	Siliquae on main shoot (No.)	Siliqua length (cm)	Seeds/ siliqua (No.)	Biological yield/ plant (g)	Seed yield/ plant (g)	1000- seed weight (g)	Oil content (%)	Harvest index (%)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
<ranti	54.67	137.67	164.73	56.0	5.23	5.73	33.57	3.83	13.60	27.33	6.50	3.47	39.62	23.69
'usa bold	54.33	142.67	157.60	55.13	5.97	6.07	32.93	3.37	12.90	27.00	4.96	3.77	38.60	18.17
'usa barani	57.33	142.00	166.70	57.13	5.53	7.50	33.53	3.63	13.77	29.67	7.07	3.53	39.41	23.34
ιLM 198	61.0	143.33	195.83	57.33	6.00	5.93	36.33	3.30	13.13	23.33	5.69	3.41	40.14	24.59
'HR-2	92.00	158.33	198.70	31.17	7.80	9.33	33.63	2.43	10.53	33.33	5.69	2.77	39.37	17.42
)ivya	44.67	119.67	118.10	42.37	4.67	5.17	25.57	3.10	11.53	21.33	2.60	2.93	38.46	12.20
:eml	95.00	160.00	209.30	26.10	5.83	7.30	22.40	2.47	10.83	30.00	6.11	3.11	39.54	20.31
.C 322090	96.67	158.67	216.73	21.20	7.20	7.37	19.50	2.30	10.87	29.00	4.77	2.95	38.48	16.09
C322092	91.67	155.33	207.30	31.87	6.63	8.83	25.30	2.20	10.30	31.00	6.00	2.91	40.03	19.39
'omo	97.67	157.67	200.63	17.37	7.80	8.60	19.80	2.43	10.10	30.33	6.01	2.69	39.69	18.06
rantixP.Bold	55.00	140.33	175.17	54.77	5.10	5.83	30.23	3.43	13.10	30.33	8.07	3.49	39.07	26.69
rantixP.Barani	56.00	142.67	177.57	56.93	6.60	7.80	32.63	3.53	13.17	31.67	7.27	3.49	39.41	26.01
rantixRLM198	57.67	142.00	185.80	59.80	6.00	7.57	39.13	3.17	12.83	36.67	9.51	3.39	38.74	30.52
rantixPHR2	70.00	149.00	187.90	50.67	6.47	6.80	35.73	3.30	11.10	26.00	5.18	2.91	39.39	20.03
rantixDivay	45.00	137.00	176.93	52.50	6.40	7.33	31.47	3.10	11.70	28.00	6.34	2.99	39.01	22.45
rantixZeml	66.00	151.33	185.17	55.77	5.77	6.83	31.20	3.07	11.30	28.67	5.90	2.95	38.25	20.55
rantixEC322090	63.33	148.00	188.87	59.97	5.97	8.23	36.40	3.30	10.83	32.33	6.24	3.32	39.55	19.29
'antixEC322092	66.67	147.67	200.70	58.47	5.97	7.17	35.80	3.23	11.10	34.00	8.66	3.09	40.66	26.38
'anti × Domo	72.00	151.67	190.30	55.97	5.87	6.71	35.90	3.13	10.63	36.67	9.95	3.39	40.01	27.99
oold × P. barani	59.67	141.33	164.53	56.23	6.03	7.57	32.43	3.40	12.83	30.00	6.88	3.78	38.45	22.92
oold × RLM 198	59.33	144.33	189.23	57.70	6.70	8.07	33.00	3.37	12.97	38.33	8.64	3.37	39.91	22.60
oold × PHR2	63.67	148.33	179.90	59.60	6.47	7.30	38.70	3.37	11.23	33.33	8.74	3.05	39.61	26.30
oold × Divya	50.67	137.00	155.60	48.00	5.37	4.90	31.57	3.10	11.73	26.33	5.19	2.89	38.81	19.65
oold × Zeml	69.33	148.33	192.67	58.70	5.43	5.97	37.00	3.17	11.63	28.67	4.23	3.02	39.26	14.68
oold × EC323290	65.00	147.67	187.63	56.97	6.90	8.47	36.67	3.57	11.47	33.33	7.07	3.22	39.34	21.32
oold × EC322092	67.33	146.67	182.97	60.63	6.13	6.63	34.43	3.33	11.40	35.67	7.82	3.01	38.70	21.92
oold × Domo	70.00	147.33	189.50	52.03	6.13	7.80	36.60	3.40	11.27	36.00	9.37	3.29	40.23	26.05
oarani × RLM198	57.67	145.67	174.90	58.90	6.63	8.33	36.07	3.60	12.77	33.33	7.50	3.23	39.19	22.68
arani × PHR2	67.67	149.00	179.97	49.50	5.93	7.70	34.00	3.20	11.93	26.67	5.85	3.00	39.28	22.01
arani × Divya	57.67	141.0	166.03	51.73	4.83	5.60	32.00	3.00	12.07	21.67	4.84	3.20	39.35	21.16

Contd…

Contd…

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P.barani × Zeml	61.67	147.33	179.50	47.20	5.50	6.00	30.17	3.60	11.30	28.67	5.01	3.27	37.40	17.48
P.barani × EC322090	68.67	154.00	201.90	39.30	5.97	7.07	27.27	2.93	11.73	26.00	4.23	3.49	39.00	16.68
P.barani × EC322092	67.33	150.33	200.50	57.70	6.87	9.50	37.50	3.13	11.37	38.33	8.33	3.55	39.08	21.76
P.barani × Domo	70.00	149.67	192.30	61.27	6.63	7.97	35.43	3.27	11.40	38.00	9.71	3.23	39.99	25.83
RLM198 × PHR2	71.33	149.67	200.00	58.10	6.03	7.40	33.10	3.30	11.33	33.00	7.26	2.77	40.37	22.15
RLM198 × Divya	55.33	140.33	153.60	48.03	5.20	5.73	25.57	3.27	12.47	28.00	4.79	2.73	37.71	17.89
RLM198 × Zeml	67.33	145.00	189.57	61.20	6.87	8.10	35.70	3.43	11.43	36.00	9.76	2.93	38.68	27.54
RLM198 × EC322090	77.33	147.33	215.87	52.83	6.87	8.53	31.33	3.33	11.50	42.00	9.75	2.85	40.45	23.80
RLM198 × EC322090	74.33	154.00	225.60	35.70	7.07	9.53	31.97	2.90	12.63	33.00	9.01	2.83	38.69	27.16
RLM198 × Domo	79.33	151.33	200.33	44.13	5.80	7.87	36.20	2.70	10.10	38.33	7.50	2.87	40.21	19.86
PHR2 × Divya	65.33	144.33	154.60	49.13	5.67	6.33	28.53	3.07	12.07	35.33	4.89	3.07	38.90	19.66
PHR2 × Zeml	82.33	156.00	209.17	41.53	6.43	8.23	33.60	2.90	11.13	32.67	6.28	2.65	39.75	19.28
PHR2 × EC322090	82.67	154.00	209.10	48.00	6.53	7.93	33.80	3.13	12.13	35.33	9.53	2.85	39.62	26.96
PHR2 × EC322092	80.00	150.67	211.27	52.80	6.67	7.90	36.63	3.00	11.30	33.33	8.30	2.99	39.04	25.00
PHR2 × Domo	85.00	155.67	216.47	44.93	6.00	7.97	37.47	2.80	11.00	29.00	5.70	3.03	40.34	19.91
Divya × Zeml	71.33	152.00	175.07	54.47	5.97	7.60	39.07	3.13	11.57	32.33	8.16	2.90	37.10	25.12
Divya × EC322090	57.00	149.00	181.00	56.03	5.77	7.33	32.57	3.53	12.17	28.00	4.65	2.94	38.72	16.62
Divya × EC322092	67.33	148.33	185.33	52.13	5.80	7.57	31.47	3.10	11.53	33.00	5.43	2.75	37.63	16.48
Divya × Domo	61.67	149.33	177.73	60.17	7.00	8.07	37.13	3.27	11.43	32.00	4.49	2.73	37.55	13.98
Zeml × EC322090	78.67	159.67	225.07	29.03	8.40	9.90	26.77	2.57	11.43	38.67	9.62	3.01	38.39	25.51
Zeml × EC322092	80.00	161.00	228.37	31.73	7.33	9.30	25.80	2.50	11.17	33.67	8.41	2.95	40.07	25.10
Zeml × Domo	85.67	158.00	206.27	32.47	6.73	9.37	27.63	2.87	11.13	35.67	8.96	3.07	40.19	25.18
EC322090× C322092	90.00	159.67	229.80	26.40	8.50	9.57	19.77	2.30	11.17	34.33	9.15	3.25	38.82	26.94
EC322090×Domo	82.00	156.67	200.40	36.93	6.40	7.93	31.87	2.83	11.23	36.33	7.76	2.91	38.17	21.09
EC322092×Domo	87.67	157.33	215.43	37.07	6.23	6.63	27.20	2.80	10.93	38.33	7.17	3.11	37.58	16.67
Kranti×P.bold	52.23	141.67	167.70	57.23	5.43	6.31	36.17	3.30	13.30	27.00	6.52	3.63	39.24	24.30
Kranti×P.barani	56.33	143.00	157.77	54.17	5.17	5.93	31.67	3.30	13.27	23.33	4.74	3.52	38.76	20.41
Kranti×RLM198	59.00	144.33	175.57	56.57	5.67	6.17	35.70	3.40	13.20	27.00	6.12	3.19	39.57	22.50
Kranti×PHR2	71.67	153.33	193.23	54.07	4.97	5.73	35.80	3.17	10.87	24.67	5.57	3.10	39.62	22.57
Kranti×Divay	46.67	137.00	154.60	54.77	5.27	5.73	29.37	3.27	12.20	23.00	4.89	2.85	38.31	22.72
Kranti×Zeml	70.67	150.00	187.70	63.13	5.47	6.03	37.93	3.03	11.40	25.67	5.33	3.09	39.54	20.71
Kranti×EC322090	69.67	151.67	209.57	54.93	5.87	7.43	33.53	3.03	11.60	27.33	6.31	3.20	38.78	20.13
Kranti×EC322092	64.33	149.33	182.53	51.27	4.77	5.53	32.53	3.10	11.20	28.33	4.86	3.13	38.89	17.12
Kranti × Domo	68.00	149.33	182.43	54.47	5.17	5.73	33.73	3.50	11.20	24.00	4.41	2.85	38.62	18.22
P.bold × barani	52.00	138.67	169.03	58.13	5.60	6.33	30.90	3.63	13.10	26.00	5.92	3.61	38.12	23.34
P.bold × RLM 198	60.67	145.00	176.07	51.60	5.10	7.33	31.67	3.50	13.13	26.00	5.74	3.55	38.59	22.28

Contd

Contd....

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
P.bold × PHR2	74.33	152.33	194.90	51.20	5.00	5.40	36.07	3.27	11.37	24.67	3.72	3.09	39.63	15.47
P.bold × Divya	51.00	137.00	147.47	48.47	5.93	4.77	32.70	3.60	12.00	24.67	5.09	3.15	39.18	20.59
P.bold × Zeml	66.33	148.33	181.50	59.63	6.00	6.60	33.77	3.40	11.60	28.67	4.74	3.11	38.47	16.43
P.bold × EC323290	63.00	150.67	211.40	38.27	5.93	7.60	26.73	2.90	11.47	27.67	5.20	3.38	39.26	18.83
P.bold × EC322092	69.00	150.67	195.67	54.57	6.53	7.17	30.93	3.17	11.33	28.33	4.87	3.22	39.35	18.14
P.bold × Domo	70.00	152.00	186.83	45.33	5.23	6.50	37.23	3.17	11.03	27.67	5.65	3.17	38.21	20.20
P.barani × RLM198	59.00	142.00	176.07	57.60	5.60	6.57	35.10	3.27	13.37	25.67	5.05	3.51	39.51	19.88
P.barani × PHR2	69.67	150.67	185.80	49.60	5.43	7.30	33.33	3.23	11.50	28.00	5.90	3.03	39.60	21.23
P.barani × Divya	61.00	145.00	168.73	54.73	5.13	5.77	32.03	3.33	12.43	23.33	3.28	3.32	38.94	14.12
P.barani × Zeml	67.67	149.00	186.07	55.33	6.57	6.83	34.07	3.37	11.73	27.67	4.70	3.34	39.56	17.17
P.barani × EC322090	67.00	149.67	189.27	49.83	6.10	6.23	30.70	3.23	11.27	29.67	4.82	3.27	40.12	17.96
P.barani × EC322092	69.33	151.33	194.43	50.30	6.07	7.90	31.50	3.07	11.97	23.33	5.28	3.43	39.24	22.44
P.barani × Domo	59.33	153.33	183.43	61.71	5.90	7.47	36.17	3.23	11.67	26.33	5.16	3.21	38.55	19.66
RLM198 × PHR2	82.00	152.67	204.43	42.97	6.00	6.60	33.70	2.70	11.47	26.67	6.17	2.86	40.91	25.61
RLM198 × Divya	51.00	136.33	160.53	52.63	5.47	6.30	29.73	3.23	12.40	27.67	5.62	2.90	36.82	20.34
RLM198 × Zeml	68.33	148.33	176.17	50.17	5.30	6.27	31.30	3.20	11.73	27.33	5.12	2.97	39.85	18.84
RLM198 × EC322090	70.67	155.00	204.50	34.20	6.47	7.40	26.83	2.60	11.70	28.67	6.85	3.22	39.01	23.61
RLM198 × EC322090	67.33	151.33	192.57	49.50	5.37	5.30	33.53	2.90	11.53	26.33	4.94	3.05	39.62	19.78
RLM198 × Domo	71.67	153.67	198.30	47.30	6.13	7.23	31.17	3.00	11.73	28.00	6.13	2.92	39.70	21.88
PHR2 × Divya	62.67	145.67	175.07	52.23	5.43	5.93	37.07	2.90	11.47	27.67	5.12	2.83	39.22	18.57
PHR2 × Zeml	77.67	153.67	206.53	43.57	5.90	6.30	32.93	3.00	11.07	30.67	6.28	2.87	39.61	20.90
PHR2 ×EC322090	80.33	158.00	217.93	30.40	6.40	6.60	29.93	2.73	11.87	27.33	6.56	3.01	38.72	23.95
PHR2 ×EC322092	78.33	156.33	210.63	31.53	6.50	7.97	28.80	2.80	11.33	27.00	5.14	2.98	38.42	19.24
PHR2 × Domo	88.67	159.67	212.27	29.53	6.40	8.07	29.70	2.83	10.77	26.33	5.95	2.71	39.15	22.76
Divya × Zeml	59.00	147.67	176.87	54.37	5.93	7.60	31.07	3.30	11.60	33.00	6.85	2.86	38.81	20.86
Divya × EC322090	51.33	147.67	170.30	55.00	5.73	6.50	32.10	3.00	10.93	26.00	3.77	2.95	38.64	14.27
ɔivya × EC322092	54.67	148.00	177.73	47.60	5.13	6.07	30.60	2.97	11.40	23.67	3.38	2.77	37.70	14.22
ɔivya × Domo	56.67	147.33	168.60	49.90	5.37	6.30	29.77	3.27	11.33	24.00	3.60	2.71	37.75	15.02
ʼeml × EC322090	85.33	156.67	228.97	32.37	6.53	7.57	27.57	3.00	11.33	29.33	5.65	3.07	40.25	19.25
ʼeml × EC322092	87.33	154.33	205.37	41.00	5.93	7.7	31.37	3.03	11.03	29.67	6.56	3.16	38.45	22.17
ˌeml × Domo	90.00	156.67	217.83	33.60	6.60	7.23	29.30	2.57	11.07	29.33	6.73	3.16	39.57	23.04
C322090× C322092	92.33	158.67	232.77	32.30	7.80	9.67	29.00	2.57	10.53	33.33	7.21	3.11	39.26	21.58
C322090× Domo	89.00	160.67	221.10	24.67	6.97	9.00	22.43	2.30	11.13	30.00	6.30	3.05	39.92	21.11
C322092× Domo	87.00	158.33	214.63	45.71	5.80	7.37	34.63	2.93	10.57	29.33	5.32	2.97	39.11	20.32
M	69.03	149.24	189.82	48.36	6.07	7.17	32.09	3.10	12.11	29.69	6.26	3.10	39.11	21.02
ΞM	3.18	2.21	9.63	5.74	0.63	0.95	3.56	0.22	0.65	2.91	0.82	0.17	0.81	2.21

VITA

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ABSTRACT

Rapeseed-mustard comprising traditionally of grown indigenous species namely *Brassica juncea, B. compestis, B. napus and B. carinala* is the second most important group of oil seed crops after groundunt. Indian mustard (*Brassica juncea* (L.) *Czern & coss*) account for about 90 per cent of the total area under rapeseed-mustard. The present investigation was carried out during winter (rabi) season 1997-98 and 1998- 99, at the Crop Research Centre, of G.B. Pant University of Agriculture and Technology, Pantnagar. India.

The inheritance of fourteen quantitative characters was studied utilizing F_1 and F_2 10 × 10 diallel excluding reciprocals. The study was carried out under the head : General statistics, combining ability analysis, gene action, heritability, heterosis and inbreeding depression.

The analysis of variance revealed that significant differences existed between treatments for all the characters. The results revealed that variances due to general combining ability were higher than that of specific combining ability for all the characters studied. Kranti and PHR2 were identified best general combiners with respect to characters studied. The other good general combiners were Pusa bold; Pusa barani; RLM198 and Kranti for test weight, seed yield length of main shoot, number of siliquae on main shoot, length of siliqua and seeds per siliqua. The Zem1and Divya were observed poorest whereas, Divya was good general combiner for flowering and maturity in negative direction. The majority of crosses showing high sca did not always involved good general combiners as parent, revealing the importance of non additive genetic variance. It may be concluded that cross combinations showing low gca parent can also show high sca effect. The crosses EC322090 × EC322092 for flowering, number of secondary branches per plant and RLM198 × PHR2 for oil content showed high sca with high gca effect. The estimates of genetic parameters obtained from numerical diallel analysis indicated that the major contribution of additive type of gene action in the inheritance of most of the characters and some of the characters showed non-additive type of gene action in the expression of yield and yield component characters.

The broad sense heritability was higher for all the characters as compared to narrow sence heritability, as expected. Most of the characters showed moderate to high heritability. The outstanding hybrids were Pusa barani × Divya, RLM198 × EC322090, Kranti × Divya and Kranti × Damo for yield per plant. The highest value of heterosis over check parent was observed by cross Zem1 × EC322090 and EC322090 × EC322092 for number of secondary and primary branches per plant. The highest average in breeding depression was noticed for seed yield per plant, total biological yield per plant and secondary branches per plant.

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