STUDY OF GENETIC PARAMETERS OF YIELD AND ITS COMPONENTS AND QUALITY TRAITS IN *Brassica juncea* (L.) Czern. & Coss

THESIS
Submitted

FOR

Partial fulfilment of the requirement
For the degree of

DOCTOR OF PHILOSOPHY

IN

GENETICS AND PLANT BREEDING

BY

AJIT PRATAP SINGH
Id. No. CA-4740/2000

DEPARTMENT OF GENETICS & PLANT BREEDING
CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY,

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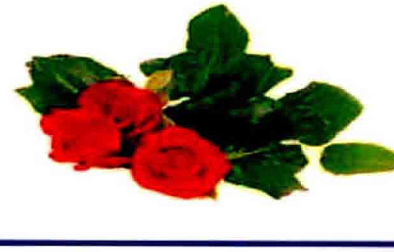
Dedicated To Tsunami Victims



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CERTIFICATE

This is to certify that **Sri Ajit Pratap Singh**, Id. No. CA/4740/2000 of College of Agriculture, C.S. Azad University of Agriculture and Technology, Kanpur 208 002, a candidate for the degree of **Doctor of Philosophy** in Agriculture with major in **Genetics and Plant Breeding**, has worked under my guidance and supervision during the course of the programme and the thesis entitled "**Study of Genetic Parameters of yield and its components and quality traits in *Brassica juncea* (L.) Czern. & Coss.**" he has submitted, is his genuine work"

Dated : 11th August, 2005
Place : Kanpur

(Prakash Singh)

CHANDRA SHEKHAR AZAD UNIVERSITY OF AGRICULTURE AND TECHNOLOGY, KANPUR 208 002

Date : 11/08/05

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Sri Ajit Pratap Singh,** Id. No. CA/4740/2000, a candidate for the degree of **Doctor of Philosophy** in Agriculture with **Genetics and Plant Breeding**, agree that the thesis entitled, **"Study of Genetic Parameters of yield and its components and quality traits in *Brassica juncea* (L.) Czern. & Coss."**, may be submitted by him in partial fulfilment of the requirements for the degree.

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Acknowledgement

My debts are great and too many, especially like the debt of God, which I cannot repay and who bestowed upon me the courage to carry out this piece of research work.

It is a golden opportunity and proud privilege to work under the talented and inspiring guidance of **Dr. Prakash Singh,** Ex.- Professor, Department of Genetics and Plant Breeding, **C.S. Azad University of Agriculture and Technology, Kanpur** and Chairman of my Advisory Committee. His untiring supervision, persistent encouragement, unending zeal, conspicuous ability and constructive criticism have always been a constant source of my achievements. I am extremely indebted to him for being meticulous throughout the investigation and preparation of this manuscript.

I also extend my heartfelt thanks and gratitude to Dr. Ranjeet, Associate Professor, Department of Genetics and Plant Breeding; Dr. R.S. Yadav, Associate Professor, Department of Plant Physiology; Dr. P.S. Kendurkar, Associate Professor, Department of Agricultural Biochemistry and Dr. R.N. Prasad, Associate Professor, Department of Agricultural Economics and Statistics, C.S. Azad University of Agriculture and Technology, Kanpur, who are the members of my advisory committee, for their guidance and creative suggestions during the tenure of the present study.

Words can never express the indebtedness, but I dare take this opportunity to pay my sincere appreciation to Dr. Shankar Lal, Ex-Director, IIPR and Dr. Munish Gangwar, Associate Professor/ Officer In-charge, ARIS Cell, C.S. Azad University of Agriculture and Technology, Kanpur, who have not only helped me but also took keen interest throughout the course of this investigation. Had they not taken painstaking efforts and inspiring attitude, the research work would have not been accomplished.

I am equally obliged and express my veneration to Dr. R.K. Dixit, Professor and Head; Late Dr. S.L. Katiyar, Dr. P. Singh, Dr. R. Mishra, Dr. Z. Ahmad and Dr. Ram Krishna, Professors; Dr. S.B. Lal Srivastava, Associate Professor and Dr. D.N. Bharadwaj, Dr. H.L. Singh, Dr. R.K. Yadav and Dr. Sanjay Singh, Asstt. Professors, Department of Genetics and Plant Breeding; Dr. Kaushal Kumar, Asstt. Professor, Department of Forestry; Dr. Arvind Srivastava, Oil Seed Section and Dr. Om Prakash, Ebr. Section C.S. Azad University of Agriculture and Technology, Kanpur, who directly or indirectly cooperated and helped me during my study period.

I also extend my thanks to Dr. K.D. Upadhyaya, Dean, College of Agriculture, and Dr. R.S. Bisen, Registrar, C.S. Azad University of Agriculture and Technology, Kanpur, for his solemn cooperation and liberal contribution in the research work.

From the core of my heart, uncountable words of cordial veneration and gratitude are dedicated to the pious feet of my grand father Sri R.P. Singh, my grand mother Smt. Parwati Singh, my father, Sri B.P. Singh and my mother Smt. Malti Singh for their love, affection, good wishes, blessings, constant encouragement and inspiration. I also express my warm appreciation to my brother-in-laws, Mr. Anand Singh and Er. Ram Singh and sisters Manju and Anju for their never-ending love and best wishes. I am also thankful to my younger brothers Anil, Udai and Mohit who extended moral support, timely help and constant inspiration to me during the entire period of my study.

I will fail in my duty if I do not express my everlasting gratitude to my beloved friend Summi, without whose encouragement, affection, moral support and constant love it would have been impossible for me to complete this voluminous task. Without her timely criticism and valuable suggestions I would have not achieved this destination of arduous journey.

I am getting short of words to express my special thanks to my loving cousins who cooperated in my bad times and helped me to overcome my mental tiredness and distress

From the very special corner of my heart, I wish to record my indebtedness to my friends Mrs. and Mr. Manoj, Sunil, Upadhyaya, Satish and Achal, Saroj Singh, Saleem Khan, Dr. Bipin Kumar, Dr. P.K. Mishra, Ikhalaq Bhai, Govind Lal, Yogesh Yadav, Vinod, Pawan, Riyaz, Rawat, Upesh, Pal, Vineet, Vivek, Upendra and Vinod Verma for their kind help and timely support

Date : July, 2005

Place : Kanpur

(Ajit Pratap Singh)

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INTRODUCTION

INTRODUCTION

The oilseed crops occupy an important place in the economy of Indian agriculture. Next to food grains, they hold a sizeable share of the country's gross cropped area (13%) contribute around 5% of its gross national product and 10% of the value of all agricultural products.

In the oilseed scenario of the world India ranks first for groundnut, sesame, rapeseed and mustard second for castor and fifth for linseed. Rape seed and mustard comes next to groundnut covering an area of 26.80 mha with production of 21.47 mt in the world. In the country it occupies an area of 4.40 m ha and production of 3.97 mt (Anionymous 2002). Being second after Rajastan, the area and production of mustard in Uttar Pradesh is 1.17 mha and 0.85 mt, respectively (Anonymous, 2002).

The different oileferous Brassicae grown in India have been divided into two groups i.e., rapeseed and mustard. Rapeseed includes *Brassica campestris* (L.) var. brown *sarson*, *Brassica campestris* (L.) var, *toria*, *Brassica campestris* (L.) var. yellow *sarson*, *Brassica napus* (*Gobhi sarson*), mustard includes *Brassica junciea* (L.) Czern. and Coss. *Brassica carinata* (Abyssinian mustard).

The Indian mustard, *Brassica juncea* (L.) *Czern. and Coss.* is commonly known as *rai* or *raya*. Although it is a naturally autogamous species, yet there occurs frequent outcrossing which varies from 20 to 30 per cent, depending upon the environmental conditions and random visitation of pollinating insects.

Cytologically, Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] is an amphidiploid (2n=36), derivative of *Brassica campestris* (2n=20) and *Brassica nigra* (2n=16).

Being important, rapeseed and mustard is utilized in variety of ways. The seeds are used as medicine spices and as component in the preparation of *salad*, sauces, juices, curries and pickles.

The mustard is mainly grown for oil, the cake obtained after oil extraction is widely used for cattle feeding. The unrefined oil is used for edible purpose in a number of countries. There is increasing interest in the preparation of detoxified high functional rapeseed flour, which is a good source of protein and minerals. Fatty acid composition of Indian mustard is unfavorable from nutritional point of view. Its fatty acid profile is fairly complex. It contains palmitic, stearic, arachidic, behenic, linoleic, linolenic, eicosenoic and erusic acid. Erusic acid, antinutritional fatty acid, is present in highest concentration in Indian mustard (about 50%). The oil consumed in greater amount could be dangerous by causing damage to heart muscle. Literature is scantly on the aspect of oil, fatty acid, amino acid, glucosinolate and detoxification of mustard flour and its use for feeding purpose for human being.

Inspite of diverse uses of rapeseed and mustard its productivity level (~10.12 q/ha) in the country is very low. Among the several factors responsible for low yield of the crop in the country, non-adoption of the improved agronomic practices by the farmers, cultivation of the crop under mixed cropping system, lack of breakthrough in the varietal status of the required level and the susceptibility of the crop to diseases and insect-pests are the major ones. Further, the quality of Indian mustard becomes poor due to the presence of very high level of erucic acid in the oil and glucosinolates in its meal.

For improving yield and quality parameters an insight knowledge of genetic mechanism involved in the inheritance of various quantitative and quality traits is essential.

The choice of parents for hybridization is a confronting problem before a plant breeder at the time of formulating the breeding programme. The clear understanding of genetic system involved in the inheritance of characters, the knowledge about nature and magnitude of gene action, correlation among various characters heritability and genetic advance is essential in deciding the most appropriate breeding procedure in order to increase the genetic potentiality and to make a break-though in the productivity of the crop.

Several mating designs namely, diallel, partial diallel, line x tester, biparental crosses and triple test cross have been used in different crop plants for selection of suitable parents and deriving information on various genetic parameters. The diallel, biparental and triple test crosses techniques have the limitations of using fewer parents thus leaving many superior parents untested. The diallel cross also results in biased estimation of combining ability variance due to large sampling error. On the other hand, partial diallel cross does not give the idea about specific combining ability effects and study is confined only to a selected No. of crosses. In such situations, line tester technique suggested by Kempthorne (1957) appears to be an effective one to evaluate a large number of genotypes for their combining ability and ultimately their utilization in hybridization programme for the genetic improvement of yield and quality parameters.

Keeping in view the fact that very meagre genetical research work has been done on yellow seeded Indian mustard, the present investigation "**study of genetic parameters of yield and it components and quality traits in brassica juncea (l.) Czern. & Coss".** with 24 parents (20 females and 4 males) along with their 80 F_1s and 80 F_2s generation by line x tester mating design, was undertaken with the following objectives:

1. To estimate the components of variance
2. Estimate the general and specific combining ability variances and their effects
3. To estimate heterosis in F_1 hybrids
4. To estimate inbreeding depression in F_2 generation
5. To estimate heretability and expected genetic advance
6. To find out correlation among yield and its components and quality traits

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The recent development in biometrical genetics has played a significant role in providing basic information and developing procedures for utilizing the germplasm for selecting desirable genotypes which would give maximum food, feed and fiber. The theoretical basis of quantitative genetics was established by **Fisher (1918)**, **Wright (1921)** and **Haldane (1932)**. Biometrical genetics gained momentum when the concepts on various parameters were developed by **Sprague** and **Tatum (1942)**, **Comstock** and **Robinson (1948)**, **Comstock** ***et al.*** **(1949)** and **Mather (1949)**. Various models were formulated to estimate various genetic parameters. Among them, generation mean analysis **(Mather, 1949; Hayman** and **Mather, 1955; Hayman, 1958; Jinks** and **Jones, 1958; Mather** and **Jinks, 1971)**, biparental mating **(Comstock** and **Robinson (1948,1952)**, diallel cross analysis **(Jinks and Hayman, 1953; Hayman, 1954** a, b; **Griffing, 1956; Eberhart, 1964; Gardner** and **Eberhart, 1966; Jensen, 1970)**, line x tester analysis **(Kempthorne, 1957; Arunachalam, 1976)**, partial diallel cross analysis **(Kempthorne** and **Crunow, 1961; Fyfe** and **Gilbert, 1963; Federer, 1967; Frey, 1971** and **Ponnuswamy, 1972)** and triple test cross analysis **(Kearsey and Jinks, 1968)** were the major techniques which have received considerable attention of plant breeders and geneticists to ascertain the genetic architecture of metric traits.

Keeping in view the above the literature on various parameters, related to present investigation has been reviewed hereunder.

2.1 Line x Tester analysis

The line x tester analysis has been used for estimating general and specific combining abilities of parents and crosses, respectively. **Kempthorne (1957)** precisely defined the gca and the sca in terms of covariance of half-sibs (Cov.H.S.) and full-sibs (Co.F.S.), respectively, which is analogous to design II.

2.2 Nature and number of testers

Federer and **Sprague (1947)** indicated that an increase in number of testers in many cases would have greater value than more extensive replications and the use of single tester. **Keller (1949)** made a comparison involving number and relationship between tester in evaluating the inbred lines of maize and concluded that high and low combining lines were on an average, of equal value.

Matzinger (1953) defined a desirable tester as one that combines the greatest simplicity in use with the maximum information on the performance to be expected from the tested lines when used in other combinations.

Studies on the nature and number of testers to be used were also made by **Sprague (1966), Hull (1947), Burton (1948, 1959), Grogan** and **Zuber (1975), Vahtin (1964)** and **Singh** and **Joshi (1966).**

In general, most of the workers agreed that for initial evaluation of large collections of inbred lines, more than one tester with good gca and possessing high additive genetic components and with broad genetic base should be used.

2.3 Components of genetic variance

Most of the characters of economic importance are quantitatively inherited. They are governed by a large number of genes, with small and additive effects and are characterized by exhibiting continuous variation. They are also influenced by environmental factors. Knowledge about the nature and magnitude of genetic variation in a crop species is, therefore, essential for efficient breeding programme.

Gardner (1963) postulated the following genetic parameters which are useful to plant breeders:

1. Additive genetic variance (δ^2A) which results from the additive effects of the genes at all the segregating loci.
2. Dominance variance (δ^2D) which results from the intra-allelic interaction of genes at segregating loci.

3. Epistatic variance which results from the inter-allelic interaction of the genes at two or more segregating loci and which is divisible, additive x additive (δ^2AA), additive x dominance (δ^2AD) and dominance x dominance (δ^2DD) for two loci situation and into additive x additive x additive (δ^2AAA), etc. for three loci and so on.
4. Average degree of dominance determined by the ratio of dominance variance to additive genetic variance.
5. Genotype x environment interaction which may be divided into additive genetic variance x environmental effects and non-additive genetic variance x environmental effects.
6. Genotypic correlation among important quantitative characters.

2.4 Combining ability

The concept of general and specific combining abilities was proposed by **Sprague** and **Tatum (1942)**. According to them, general combining ability (gca) is an average performance of line (s) in a series of hybrid combinations, while specific combining ability (sca) refers to those cases in which certain combinations do relatively better or worse than would be expected on the basis of an average performance of the line involved. They concluded that gca is primarily due to additive effects of genes, while sca is a consequence of intra-allelic interactions or dominance and inter-allelic interaction or epistasis. **Henderson (1952)** also defined gca as the average merit of the large number of progenies of an individual or line when mated with a random sample, whereas sca was defined as a deviation of an average value of a cross from the value which would be expected on the basis of known general combining ability of two lines. Sca, on the other hand, is attributed primarily to deviations from the additive scheme caused by dominance and epistasis **(Sprague** and **Tatum, 1942)**. This fact is also apparent from the formula developed by **Griffing (1956a)**, in which δ^2gca is the variance due to gca, δ^2 A is the additive genetic variance and δ^2 AA is the additive x additive types of inter-allelic interactions.

Similarly, δ^2 sca is the variance due to sca, δ^2 D is the dominance vairance, δ^2 AD is additive x dominance and δ^2 DD is dominance x dominance types of interactions. **Kempthorne (1957)** defined the general and specific combining ability variances as δ^2 gca and δ^2 sca, respectively, in terms of half and full-sibs as δ^2 gca=Cov. (Half-sibs) and δ^2 sca=Cov. (Full -sibs)-2 Cov. (Half-sibs)

2.5 Degree of dominance

In polygenic inheritance, the effect of individual genes can not ordinarily be differentiated from one another consequently it is not possible to determine the mode of action of individual genes. By studying their combined effects in segregating populations, however, one can gain some insight into their behaviour and can draw inferences about the average level of dominance involved in the expression of a particular quantitative character.

Fisher *et al.* (1932) presented a method for estimating the degree of dominance. **Mather (1949)** gave a formula for estimating the degree of dominance according to which if the value of degree of dominance is greater than zero but less than unity or more than unity a certain degree of dominance in the action of genes conditioning the expression of characters is indicated. If the value is greater than unity, there is an over dominance of genes at one or more loci, but if this value is less than one, there is either no dominance or partial dominance. If the value of degree of dominance is zero the dominance is absent **(Comstock** and **Robinson, 1948).**

Robinson *et al.* (1949) and **Gardner (1963)** recognised that the estimates of degree of dominance in over dominance range for yield could be obtained as a result of a repulsion phase linkage, even though none of the genes involved was more than complementary or partially dominant to its alleles. **Garnder** and **Lonnquist (1959)**, and **Moll *et al.* (1964)** have provided experimental evidence for linkage bias in the results.

2.6 Work done on Indian mustard

Govil *et al.* (1981) reported that sca was more important than gca for seed yield and oil content.

Singh *et al.* (1981) reported that additive gene action was lower and predominant for days to flower. Both additive and non-additive gene effects for number of primary branches showed equal importance. Epistatic gene effect contributed to most of the characters, particularly to those showing higher magnitude of dominance effects.

Yadav *et al.* (1981) observed the importance of both additive and non-additive gene effects in controlling the inheritance of oil content.

Singh *et al.* (1982) estimated the components of variance and degree of dominance. They found that number of secondary branches and yield per plant showed over dominance. Number of primary branches showed partial dominance, whereas for days to flower, incomplete dominance was observed. Oil content was influenced by both additive and non-additive gene actions.

Dixit *et al.* (1983) reported that both additive and non-additive gene actions influenced the inheritance of oil content.

Govil *et al.* (1983) reported that additive and dominance components of variation were highly significant in F_1 and F_2 generations. Dominance variance was much larger than that of additive genetic variance. Average degree of dominance tended towards over dominance.

Chander *et al.* (1985) observed high value of gca for seed yield, number of secondary branches, plant height and 1000- seed weight. RC 1262 was found to be a good general combiner for most of the characters.

Singh *et al.* (1985) reported that both additive and non-additive gene effects were important for siliquae per plant and siliqua length in Indian mustard, although non-additive gene effects were predominant.

The *per se* performance of the parents was associated with their gca effects. Prakash and Laha 101 were good general combiners for seed yield. Most of the crosses showing significant sca effects involved both low x low or low x high general combiners. **Singh *et al.* (1985)** observed that variances due to gca and sca were highly significant for plant height, number of primary branches, days to maturity and seed yield.

Kumar *et al.* (1986) observed that selection in early segregating generations for high yield could be appropriate for simultaneous exploitation of additive and non-additive genetic components.

Pal and **Singh (1986)** reported that additive gene effects were important for days to maturity and flower.

Singh *et al.* (1986a) through combining ability analysis indicated the preponderance of additive and additive x additive gene actions for days to flower and maturity, number of primary branches per plant and length of main shoot, whereas preponderance of non-additive gene action was observed only for 1000-seed weight, secondary branches and seed yield per plant with small amount of additive gene effects.

Badwal and **Labana (1987)** revealed that both gca and sca variances were significant for seed size and protein content, but sca variance was significant only for oil content and non additive gene effects were important for all the three traits. For oil content and seed yield, sca variance was higher than gca variance, indicating that dominance was possibly predominant for these traits.

Gupta *et al.* (1987) reported additive gene effects for seed yield per plant and non-additive gene effects for number of primary branches and siliquae on main raceme.

Kumar and **Sinha (1987)** reported the preponderance of additive gene effects for seed yield.

Jain *et al.* (1988) reported that both additive and non-additive gene actions were important in controlling days to flower and maturity, plant height, number of primary and secondary branches, number of siliquae per plant, 1000-seed weight and seed yield per plant. Epistatic effects of gene action were predominant over additive and dominance effects with an important role of duplicate type of epistasis for most of the traits and suggested that for exploitation of additive and non-additive gene effects, recurrent crossing can give desired results.

Liv and **Liv (1989)** in *Brassica juncea* revealed that erucic acid was controlled by two pairs of additive genes with dominance effects. Genetic behaviour of erucic acid was fitted to additive-dominance model with additive effect being predominant.

Podkolzina and **Shpota (1989)** found that seed oil content was mainly controlled by non-additive gene action.

Singh *et al.* (1989) noted the gca and sca variances significant for all the 11 quantitative characters studied.

Thakur *et al.* (1989) found that the combining ability variance indicated the predominance of non-additive gene action for seed yield, primary branches, plant height and 1000-seed weight, whereas additive gene action for secondary branches, siliquae per plant and days to maturity.

Wani and **Srivastava (1989)** derived information on combining ability from the data on seven characters in 23 lines and their F_1s and F_2s. They found that parents RK 8202, KR 5610, RK 1418, RH 30, V10 and B 30 were good general combiners for seed yield.

Chauhan *et al.* (1990) reported than when crosses and their 15 parents were tested, there were significant differences for seed yield between genotypes. NDR 8602, Krishna, Pusa Bold and TM 9 had good general combining ability.

Dhillion *et al.* (1990a) in Indian mustard studied five agronomic traits viz., seed yield, number of primary and secondary branches, plant height and main raceme length. gca and sca variances were important for all the characters. Variety RLM 198 was found to be the best general combiner for all the traits except seed size.

Yadav *et al.* (1990) reported that genetic control of seed yield was mainly through dominant gene effects and epistatic of the additive x additive and dominance x dominance types.

Gupta *et al.* (1991) observed that a relationship did exist between the genetic diversity of the parents and sca effects. It was suggested that selection of parents for breeding should be based on diversity estimates coupled with combining analysis.

Pal and **Kumar (1991)** studied the type of gene action involved in the inheritance of oil content in Indian mustard. They reported the presence of both additive and non-additive gene actions. Recurrent selection might be used to exploit both the types of gene actions for improving oil content.

Singh and **Yashpal (1991)** studied seven *Brassica juncea* lines from India, four from USSR and one from Canada and developed 66 F_1s. Non-additive genetic variance was found predominant for controlling oil content.

Verma *et al.* (1991) gave an information on the predominance of additive gene effects for 1000-seed weight and oil content, non-additive gene action for primary and secondary branches and both additive and non-additive types of gene effects for plant height and seed yield.

Yadav *et al.* (1992) evaluated 45 F_1s of Indian mustard along with their 10 parents. They reported that all the traits (seed yield, its components and oil content) were governed by both additive and non-additive genetic variances. Parents Varuna, Kranti, RLC 1359 and RLC 1357 were identified as good general combiners for earliness, siliqua length, seeds per siliqua, 1000- seed weight, primary and secondary branches and oil content.

Diwakar and **Singh (1993)** derived the information on combining ability of 7 yield components and oil content in parents and their hybrids. K_2 and K_4 were superior for gca. Crosses K_7 x K_8, K_2 x K_4 and K_4 x K_5 had the highest sca for seed yield per plant.

Malkhandale (1993) reported significant variation in gca and sca for all the traits studied. Both additive and non-additive gene actions were involved in controlling the traits. Among all the traits, number of branches pre plant played the most important role in the improvement of seed yield.

Patel ***et al.*** **(1993)** observed that inheritance of seed yield was mainly governed by non-additive gene effects.

Rishipal ***et al.*** **(1993)** concluded that gene effects were considerably influenced by environment and cross. The expression of number of primary branches, seeds per siliqua. 1000-seed weight and seed yield were governed by additive and non-additive effects, the later, however, being the most important. A duplicate type of epitasis was observed for most of the traits.

Baisakha ***et al.*** **(1994)** reported that the oppressed mutant genotypes were best general combiners.

Sharma and **Singh (1994)** observed that additive gene action was predominated for seed volume, whereas for remaining traits, non-additive gene action was important.

Bharteria ***et al.*** **(1995)** reported predominance of non-additive gene action through line x tester analysis. The cross RLM 198 x Varuna has high sca effects for several characters and was also high yielder.

Patel ***et al.*** **(1996)** found that variances due to gca and sca were significant for most of the traits except number of seeds per siliqua for gca variance and 1000-seed weight for sca variance. Non-additive gene action appeared to be predominant for all the characters except days to maturity, which was governed by additive gene action.

Singh ***et al.*** **(1996)** reported high magnitude of variance for sca for days to flower, number of secondary branches, seeds per siliqua, seed yield and oil content. However, estimates of gca variance were high for plant height.

Chaudhary ***et al.*** **(1997)** found that both additive and non-additive gene actions were important in most of the characters studied. Hybridization system such as multiple or reciprocal recombinant crossing, which exploit both additive and non-additive gene effects simultaneously were recommended for the improvement of such characters.

Khulbe *et al.* (1998) reported that significant differences existed for gca and sca for all the traits and were important for all the characters, indicating the presence of both additive and non-additive gene effects in controlling the expression of various traits. Yield was found to be controlled predominantly by non- additive gene action. The crosses with high sca effects did not have parents with good gca effects.

Sheikhe and **Singh (1998)** observed the predominance of non-additive gene action for most of the traits including the seed yield and oil content.

Verma and **Kushwaha (1999)** found the significant differences for the combining ability variances for all the characters. Variance due to sca was greater than gca, indicating the predominance of non-additive gene effects in the expression of seed quality traits.

Chauhan *et al.* (2000) reported significant differences for days to maturity and oil content in males and for all the characters in females except for secondary branches and seed yield per plant.

Basudev *et al.* (2001) observed the presence of gca and sca variances for seed yield per plant, days to 50 percent flowering, days to maturity, early vigour, plant height, number of primary branches, number of siliquae on main axis, length of siliqua, seeds per siliqua, oil content and 1000-seed weight. Reciprocal cross effects were also significant for all the traits except early vigour and length of siliqua.

Rao and **Gulati (2001)** reported the predominance of the non-additive component for majority of the yield contributing characters.

Singh *et al.* (2001) found higher degree of dominance in all the traits studied except plant height and protein content in two generations.

Ghose *et al.* (2002) reported that both additive and non-additive gene actions were of prime importance through studies carried out on line x tester analysis involving 29 female and 7 male parents.

2.7 Heterosis

The term heterosis was first coined by **Shull (1914)** for the superiority in vigour of certain F_1s over parents. **Hayes *et al.* (1955)** defined heterosis as increased vigour of F_1 over the mean of parents or over the superior parent. **Abercrombie *et al.* (1961)** described heterosis as increased vigour or growth, fertility, etc. in the cross between two genetically different lines as compared with either of parental lines.

Initially, hybrid vigour was reported by **Koelreuter (1763)** in artificial plant crosses. **Knight (1799), Darwin (1877)** and **Focke (1881)** described hybrid vigour in various crosses. Genetic basis of heterosis has been reported by **East (1908)** and **Stringfield (1950)**.

Whaley (1944) reported that the hybrid vigour is the manifestation of the effect of heterosis and two terms were synonyms. **Gowen (1952)** reviewed the researches directed towards explaining and utilizing the vigour of hybrids.

Jinks (1955) suggested that non-allelic interactions might be the cause of heterosis rather than relation between the genes at the same locus. **Mather (1955)** observed heterosis to be an expression of genetic balance, which depends upon adjustment and integration of polygenes. **Allard (1960)** considered heterosis as hybrid vigour such that an F_1 hybrid falls out side the range of the parents with respect to some traits. Heterosis in common use represents percent increase/decrease in the mean value of the F_1 hybrid over its mid parental value.

Jinks and **Jones (1958)** also stated that heterosis is a complex genetical phenomenon which depends upon the additive, dominance and interaction of homozygous/homogeneous and homozygous/ heterogeneous components as well as on the contribution of the genes in the parental lines.

Deskalov (1963) concluded that heterosis in F_1 is a combined expression of genetical, cytoplasmic, biochemical and physiological factors and may be attributed to stimulation, resulting from the interaction of different heritable factors of the parents in F_1. **Grafius (1964)** pointed out that such studies of individual yield components could lead to simplification in genetic explanation of heterosis.

Coyne (1965) stated that the heterosis could possibly be explained on the basis of dominance rather than on overdominance.

Mather and **Jinks (1971)** defined heterosis as the amount by which the F_1 hybrid mean exceeds over its better parent. In plant breeding programmes, heterosis refers to the expression of increased vigour of the hybrid over the better parent.

Nowadays it is realized that the heterosis is of no practical value unless the performance of hybrid exceeds that of well-adapted variety of the region. This kind of heterosis expressed over the commercial cultivar is generally designated as the economic heterosis.

Genetic basis of heterosis for complex characters could be explained by multiplicative interaction at phenotypic level of the component traits. It was suggested that the heterosis could possibly be explained on the basis of dominance rather than over dominance

2.8 Heterosis in Indian mustard

Singh *et al.* (1983) reported that heterosis for seed yield was mostly due to number of siliquae per plant, primary and secondary branches and siliqua length. Six crosses showed high heterosis over better parent. All heterotic crosses involved low x low general combiners.

Banga and **Labana (1984)** found greatest hetero-beltiosis for seed yield per plant, number of siliquae on main shoot and number of secondary branches.

Singh *et al.* (1985) observed that the progenies of eight crosses were superior to Indian x Indian cross progenies in respect of number of siliquae on main shoot, number of secondary branches and number seeds per siliqua. Highest heterosis for plant height, seed yield and number of secondary branches was recorded in RLK 78-6-1 x *Pahadi Rai* (82.76%), *PahadiRai* x Blase (89.66%) and Indian x exotic crosses. Varuna x Domo (84.4%) showed highest heterosis for seed yield.

Lefort Buson *et al.* (1987) reported the heterosis and F_1 performance differed among the crosses for all the traits. Heterosis was greatest when parental lines were unrelated and come from different geographical pools.

Verma *et al.* (1989) observed significant heterotic effects over standard variety for days to flowering, primary and secondary branches per plant, 1000 seed weight, seed yield per plant and oil content.

Dhillon *et al.* (1990b) reported highest heterosis (113.6%) for seed yield in the cross RLM 198 x RK 2. Heterosis for yield was mainly attributed to increased branch number.

Kumar *et al.* (1990) found positive heterosis for seed yield, primary and secondary branches, siliqua length and seeds per siliqua.

Hirve and **Tiwari (1991)** reported highest heterosis over better parent for seed yield and significant heterosis for seed yield contributing traits.

Rai (1993) found 4.9 to 24.6 per cent heterosis in the crosses of rape seed and also reported that heterosis breeding is now recognized as potent genetic tool for exploiting the presence of considerable amount of non-additive gene action inherent in the expression of seed yield through the development of superior performing hybrids in *Brassicas*.

Patel *et al.* (1993) corssed six lines of Indian mustard with four testers and found that only three crosses viz., RC 1277 x Kranti (41.4%), RH 7811 x Krnati (27.9%) and RSK2 x Krnati (25.9%) had significant heterosis for seed yield over better parent.

Rai and **Singh (1994)** reported heterosis over the better parent and commercial check for seed yield; oil content and some yield components in 28 inter varietal crosses of *Brassica campestris*. The average heterosis over better parents for seed yield and oil content was 21.3 and 32 percent, respectively and the highest being 78.8 percent for seed yield and 11.4 percent for oil content, while number of primary branches exhibited 36.2% only.

Singh *et al.* (1996) recorded heterosis over better parents in the tune of 77.6 per cent for seed yield and 13.1 percent for oil content.

Agarwal and **Badwal (1998)** noted that 18 hybrids outyielded the best control variety RLM 18. Three of them viz., MS x Pant Rai 1002, MS x RH 818 and MS x RLC 1017 were superior over the best control in seed yield by 81.18 50.56 and 64.65 percent, respectively. Over all heterosis for seed yield was very high (59.69%).

Khulbe *et al.* (1998) reported that heterosis was high for length of main shoot, number of primary branches, seeds per siliqua, seed yield per plant and 1000-seed weight. The range of heterosis was quite low for days to maturity and oil content. A large number of crosses exhibited significant negative heterosis for days to maturity and oil content.

Verma *et al.* (1998) reported significant positive heterosis for seed yield and oil content. Crosses RK 8801 x Kranti and JGM 88-A x Kranti exhibited the best hybrid vigour.

Patel and **Sharma (1999)** observed that there was no appreciable increase in oil content due to hybridization (mean parental oil content 36.68% and hybrid oil content 35.66%)

Chauhan *et al.* (2000) found heterotic responses in single and three way crosses in Indian mustard. They observed highest heterotic response for seed yield, followed by number of primary and secondary branches over better parent, when compared with standard check highest being 78 per cent for seed yield.

Katiyar *et al.* (2000) reported that seven combinations exhibited>30 per cent heterosis and 11 crosses showed 31.3 to 71.3% heterosis. It is concluded that there should be adequate genetic divergence among lines to support a successful hybrid breeding programme.

Sood *et al.* (2001) noted that none of the hybrids was consistently good with regard to high heterosis and sca effects. The highest heterosis for seed yield was observed in the cross NDR 860 x RLM619 (141%)

Tyagi *et al.* (2000) revealed that desirable significant and negative heterosis for plant height was observed in seven crosses, with Varuna x SKNM 90-14 exhibiting the negative value (14%). Maximum positive heterosis was recorded for seed yield per plant with crosses PCR-7 x 5 KNM-13, RH 30 x TM 18-18 and PCR 7 x JM90-12, giving values of 93.13, 81.3 and 77.31 per cent, respectively. In general, positive heterosis for seed yield was accompanied with positive heterosis for siliqua length, seeds per siliqua, 1000-seed weight, biological yield and harvest index.

Verma *et al.* (2000) revealed that hybrids RK8902 x DLM-2, PR 8903 x RK 8902 and RSK 28 x DLM 2 had desirable heterosis for seedling vigour, seed yield, days to 50 per cent flowering, oil content and 1000-seed weight.

Sheikh and **Singh (2001)** reported the manifestation of higher degree of heterosis for seed yield and other component characters in mustard.

Singh *et al.* (2003a) found that heterobeltiosis is Indian mustard for seed yield per plant was observed in eight crosses, namely KR-5610x PR-15 (58.38%), YRT-3 x PR-15 (54.33%),RK-1467x T-6342 (52.60%). Varun x YRT-3 (35.83%), KRV-Tall x T- 6342 (33.81%), RLM-198 x RT-3(34.10%), Varuna x RLM- 198 (31.50%) and KR-5610 x KRV-Tall (36.70%). Inbreeding depression in all the above crosses was very low i.e. 10.35, 8.32, 10.15,-16.54, -7.28,-20.05,-12.56, and-8.08%, receptively. The hybrid showed a wide range of heterosis effect for each character. In the F_2 generation, most of the high heterotic cross combinations for different characters showed low inbreeding depression.

Singh *et al.* (2003b) observed that high heterosis for seed yield in Varuna x Rohini (56.74%), Vardan x Rohini (53.43%), Varuna x RK-9501 (52.68%), Vardan x NDR 8501 (36.73%), Pusa Boald xRohini (37.68%) and

Varuna x NDR 8501 (32.54%). The Inbreeding depression in there hybrids were very low (11.06,8.25, 10.04, -16.43, -7.26 and –12.48%), respectively.

Kumar *et al.* (2002) reported that five hybrids with the highest heterosis for seed yield were RN-505 x RN-440 RN-505 xPER-43, RN-393xRN-481, RN- 393 x RN-453 and RN-505 x RN-481, and these crosses offer the best possibilities of further exploitation for the development of high yielding varieties.

Tyagi *et al.* (2001) reported that the selative heterosis was desirable for plant height, number of primary branches and secondary branches per plant, seed per siliqua, number of siliqua on main shoots biological and seed yields and oil content. Heterobiltiosis was desirable for primary and secondary branches per plant, siliqua on main shoots and biological and seed yields.

Standard heterosis was desirable for the number of primary and secondary per plant, siliqua length, seeds per siliqa number of siliqua on main shoots, biological yield, seed yields and oil content. The mean level of heterosis was highest for biological yield. The highest standard heterosis (206.14%) and heterobiltiosis (240.56%) for seed yield per plant was recorded in the cross. BIO 772x Rohini.

Kumar D and Rathore Neetu (2004) to studied Heterosis on yield and its components in Indian mustard. The crosses NDR-9501 x RH-30 and Kranti x NDR-9501 (29.8%) and NDR-9501 x RK-30 (23.02%) showed the highest heterosis effect for seed yield. There was no cross showing significant positive heterosis for seed yield.

Singh and Lallu (2004) Found that economic heterosis and inbreeding depression of P_1 and P_2 were significant for most of the character studies. Their 8 crosses also had high economic heterosis and comparatively and low inbreeding depression of seed yield

2.9 Selection parameters

2.9.1. Heritability and genetic advance: Heritability is an index of transmissibility of traits from parents to offsprins. The concept of heritability is important to determine whether phenotypic differences observed among various individuals are due to genetic changes or due to the effects of environmental factors.

According to **Lush (1940, 1943,1949)** the broad sense heritability is the ratio of total genetic variance to phenotype variance. In narrow sense, it is the ratio of additive genetic variance to phenotypic variance. **Robinson *et al.* (1949)** stated narrow-sense heritability as the additive variance in per cent of total variance.

Smith (1952) reported heritability as the ratio expressed in percent of variance component due to additive fixable gene effects (δ^2g) to sum $\delta^2g+\delta^2D+\delta^2E$ where δ^2g, δ^2D and δ^2E are additive, dominance and environmental variances, respectively.

Comstock and **Robinson (1952)** and Johnson *et al.* (1955) have reported that the estimates of heritability and prediction of genetic advance becomes biased by genotypic- environmental interactions.

According to **Dudley** and **Moll (1969)** plant breeding comprises of (i) assembly or creation of pool of variable germplasm, (ii) selection of superior individuals from the pool and (iii) utilization of the selected individuals to develop superior variety. Estimates of genetic variance and heritability are important in all these three statges.

Genetic advance or genetic gain is still a more useful estimate. It is the value which indicates improvement in genotypic value in the new population in contrast to past population. The genetic gain depends upon.

1. The amount of genetic variability in the base population,
2. The magnitude of the masking effects of environment and interaction components of variability on the genetic variability, and
3. Intensity of selection

The genetic gain is the product of the heritability and selection differential expressed in terms of phenotypic standard deviation of that character. Heritability and genetic advance both are the components of direct selection. It is, necessary to utilize heritability estimates in conjunction with selection deferential which would indicate the expected genetic gain.

Robinson (1949) placed the heritability estimates (in narrow sense) in three categories viz., low heritability (upto 10%), medium heritability (10-30%) and high heritability (above 30%)

2.10.9 The work done on heritability and genetic advance in Indian mustard:

Labana *et al.* (1980) observed that heritability was high for number of primary branches and moderate for number of days to flower along with high genetic advance for plant height.

Yadav *et al.* (1981) observed high heritability estimates for yield and earliness.

Chaudhary and **Sharma (1982)** reported high heritability for number of primary branches per plant.

Govil *et al.* (1983) reported higher values of heritability in F_1 than in F_2 generation for oil content.

Wan and **Hu (1983)** observed high heritability values for flowering period and primary branches as well as effective secondary branches. The highest genetic advance was reported for days to flower.

Yadav (1983) reported high heritability with genetic advance for days to flower.

Banga *et al.* (1986) elucidated that broad sense heritability was high for days to flower, seed yield and plant height. For raceme length and total number of branches, it was moderately high.

Singh (1986b) reported higher heritability estimates for secondary branches and number of seeds per siliqua.

Kumar and **Sinha (1987)** found 83 percent heritability for seed weight on the other hand, Badwal and Labana (1988)found low heritability value (20%) for seed yield.

Podhilzina and **Shpota (1989)** found that heritability for seed oil and erucic acid was low. To obtain high oil content free to erucic acid, recurrent selection and reciprocal interspecific hybrid developments were recommended.

Chaudhary and **Goswami (1991)** recorded high heritability (broad-sense) and genetic advance for number of siliquae per plant and plant height. **Dhillon *et al.* (1992)** noticed high heritability and genetic advance for the traits they studied.

Sharma *et al.* (1992) reported that the narrow sense heritability for seedling traits was high in the F_2 generation and moderate in the F_1 generation, but it was low for germination percentage and 1000-seed weight.

Diwakar and **Singh (1993)** observed narrow sense heritability and genetic advance high for days to flower and plant height.

Surendar *et al.* (1994) found high levels of genetic advance and broad sense heritability. Yield improvement was thought to be possible through selection for seed yield per plant, harvest index, siliquae per plant, number of secondary branches and 1000-seed weight.

Sharma and **Singh (1994)** observed high heritability for seed volume, whereas other traits had low heritability estimates.

Uddin *et al.* (1995) reported that heritability values were generally high for 1000-seed weight and were moderately high for other traits except branches per plant, seed size and siliquae per plant, but high values for genetic advance were expressed as percentage of mean.

Yadav *et al.* (1996) found broad sense heritability highest for days to flower, 1000- seed weight and seed yield.

Ram Bhajan *et al.* (1997) noted that heritability in narrow sense was high for seed yield per plant (43.62%).

Das *et al.* (1998) noted high heritability coupled with high genetic advance for siliquae per plant, number of secondary branches per plant, 1000- seed weight and plant height.

Lekh Raj *et al.* (1998) observed the highest genotypic coefficient of variation for secondary branches. High heritability estimates were observed for all the traits under all environments except harvest index and biological yield. Highest genetic advance was recorded for days to 50 per cent flowering.

Sheikh and **Singh (1998)** reported high estimates of heritability and genetic advance for length of siliqua.

Khulbe *et al.* (2000) reported that all the traits except oil content exhibited high heritability with high/ moderate genetic advance.

Larik *et al.* (2000) revealed that heritability showed high estimates for all characters, indicating the involvement of additive gene action. Seeds per siliqua and plant height exhibited low genetic advance irrespective of their high heritability estimates, probably due to non-additive, gene effects (dominance and epistasis).

Mandal and **Khajuria (2000)** observed that days to maturity and 1000-seed weight showed high heritability and genetic advance.

Ghose and **Gulati (2001)** noted high heritability coupled with high genetic advance for oil content, harvest index, number of primary branches, number of siliquae on main shoot, main raceme length and number seeds per siliqua.

Rao and **Gulati (2001)** classified the estimates of narrow sense heritability as low, medium and high in two generations and showed shifts in the magnitude from F_1 to F_2 into low to medium, medium to high, high to medium and medium to low directions. It was low to medium for number of secondary branches, medium to high for number primary branches and 1000- seed weight, high to medium for plant height and oil content and medium to low for seed yield per plant. For the traits, days to 50 per cent flowering, days to maturity and number of seeds per siliqua, the magnitude of heritability was medium and remained unchanged in both the generations.

2.11 Correlation coefficients

The Knowledge about genotypic, phenotypic and environmental inter-relationships among various agronomic traits is important with respect to both theoretical and practical points of view. Selection is usually concerned with changing two or more traits simultaneously. This information may be used for the expression of correlated response to directional selection, in the construction of selection indices and in the detection of some characters which may have no values by themselves, but are useful as indicators of the more important one under consideration **(Johnson *et al.*, 1955; Robinson *et al.*, 1951; Falconer, 1960; Searle, 1965)**

Phenotypic correlation may be of genotypic and environmental origin and provides information about association between two characters. For selection purposes, phenotypic correlation is of little practical utility unless genetic and environmental correlations between pairs of characters are in the same direction when estimated separately.

Genetic correlation provides a measure of genetic association between characters and is generally used for selecting one character for the improvement of another. Such correlation coefficient provides information by themselves **(Miller *et al.*, 1959)**. It may also be helpful to breeders since the associations are based on transmissible genetic variance.

Phenotypic correlation is the net effect of segregating genes that affect the character, some causing positive and some negative correlations. The major causes underlying genetic correlations are pleiotropy, linkage and developmentally included relationship **(Adams, 1967; Stebbins, 1950)**.

The genetic architecture of yield can be better resolved through its components rather than yield *per se* as the yield is the end product of multiplicative interaction between various yield components **(Grafius, 1959)**.

2.12 Correlation in Indian mustard

Ahmad (1980) reported that seed yield per plant had positive correlation with siliqua length, number of siliquae per plant, number of seeds per siliqua and 1000-seed weight.

Singh *et al.* (1980) explained that number of secondary branches and plant height were the most important components of seed yield.

Yadav (1982) observed seed yield significantly and positively correlated with number of primary and secondary branches, total siliquae number and days to flowering.

Varshney and **Singh (1983)** worked out the correlation of yield with other characters and reported that yield was positively correlated with primary branches, number siliquae per plant and 1000- seed weight.

Wan and **Hu (1983)** reported association of seed weight with siliquae number per plant.

Yadav *et al.* (1983) reported that 1000-seed weight and oil contents were positively correlated with seed yield. However, they also reported association of seed yield with number of primary branches, siliquae per plant and 1000-seed weight.

Kumar *et al.* (1984) reported significant correlation of yield with 1000-seed weight.

Bang *et al.* (1986) found high negative association between seed yield and flowering date.

Badwal and **Labana (1987)** reported that seed yield was positively correlated with primary and secondary branches and siliqua length.

Gupta *et al.* (1987) elucidated that seed yield and oil percentage showed significant positive correlation with oil yield at genotypic and phenotypic levels, with higher genotypic correlation coefficients than respective phenotypic ones. Seed yield and oil percentage had the highest direct effect on oil yield.

Kumar *et al.* (1987) reported that yield had high significant positive correlation with secondary branches, days to first flowering, days to 50 per cent flowering and plant height.

Chaudhary *et al.* (1988) observed that yield per plant showed a significant genotypic correlation with days to maturity, plant height, number or primary branches, number of siliquae on main raceme and lateral branches.

Kumar *et al.* (1988) found that yield was positively and significantly correlated with number of primary and secondary branches and siliquae per plant.

Reddy (1991) found positive and significant association of yield with leaf area index, number of siliquae per plant, number of seeds per siliqua and seed weight. Primary branches showed a positive correlation with siliquae per plant as well as seed weight per plant. He found stability of these associations year after year

Behl (1992) observed that phenotypic correlation coefficient of oil yield with siliquae per plant and seed yield was positive and significant.

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

Singh *et al.* (1996) reported that oil content was positively associated with 1000- seed weight and seed yield, indicating the possibility of simultaneous improvement of these characters.

Tyagei *et al.* (1996) reported that plant height, siliquae per plant, siliqua length, seed yield per plant and seed weight had a positive and significant effects on seed yield.

Das *et al.* (1998) noted high positive genotypic correlation of siliqua length and seeds per siliqua with seed yield per plant.

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

Basudeb *et al.* (2001) revealed that there was a significant positive correlation between *per se* performance of the parents and gca of the parents for days to 50 per cent flowering, plant height, seed yield per plant and 1000-seed weight.

Gose and **Gulati (2001)** observed that seed yield exhibited significant positive association with yield contributing traits like days to 50 per cent flowering, days to maturity, plant height, number of secondary branches, number of siliquae on main shoot and oil content. These components, in turn, exhibited significant positive correlation with one an other. The results indicated that selection for one of these characters might automatically combine them.

Singh *et al.* (2003a) stated that the varietal differences were highly significant for plant height, days to 50% flowering, siliqua per plant, seeds per siliqua, days to maturity, 1000-seed weight and seed weight per plot. They also found the coefficient of genotypic and phenotypic variations higher for 1000-seed weight and minimum for days to maturity. The highest genetic advance was obtained with 1000-seed weight (39.08), followed by seed yield/plant (20.18), days to 50% flowering (16.79) and siliquae per plant (16.49).

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

Swarnkar *et al.* (2002) recorded moderate heritability with low genetic advance was in majority of the characters, indicating the effect of non-additive gene action. Days to flowering, 1000-seed weight, oil content and protein content characterized by high heritability with low genetic advance, may be beneficial for selection.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Materials

3.1.1. Selection of parents:- The present investigation was comprised of 20 female lines and four testers of Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] selected on the basis of variability for different characters and maintained by selfing in the Oil Seed Section, of Department of Genetics and Plant Breeding, C.S. Azad University of Agriculture and Technology, Kanpur. The salient features and source of these parents are given in Table 1.

Table 1: Details of parents used in the experiment

S. No.	Parents	Source	Salient Features
1	Sanjukta	Barahampur. W.B.)	Plant height: 75.85cm,maturity: 95-100, oil content: 38%, seed weight: 2.5-3.0g,average yield: 1000-1200Kg/ha, suitable for mix cropping in rain fed condition
2	Pusa Basant	IARI, (New Delhi)	Plant height: 180cm,maturity: 108 days, oil content: 42%, seed weight: 3.2-3.7g,average yield: 1100Kg/ha
3	Pusa Jaikisan	NRC on Plant Biotech IARI, (NewDelhi)	Plant height: 189cm,maturity: 112-135 days, oil content: 40%, seed weight: 6.8g,average yield: 1600-2200Kg/ha, semi compact plant type, resistant to lodging and shattering.
4	Pusa Bahar	IARI, (New Delhi)	Plant height: 140-150cm, maturity: 108 days, oil content: 43%, seed weight: 4.5-5.0g,average yield: 1000Kg/ha
5	Krishna	GBPUA&T, Pantnagar	Plant height: 160cm,maturity: 132 days, oil content: 40%, seed weight: 5.2g,average yield: 1380Kg/ha, less susceptible to aphid and saw fly as compared to Varuna tolerant to frost.
6	Urvashi	CSAUA&T,Kanpur	Plant height: 140cm,maturity: 125 days, oil content: 42%, seed weight: 5.2-5.5g,average yield: 2200-2500Kg/ha.better tolerant to high temperature at seedling stage.

7	Sita	Barahampur, W.B.)	Plant height: 95-100cm,maturity: 90-100days, oil content: 38%, seed weight: 2-2.5g,average yield: 1200-1400Kg/ha. Tolerant to aphids and alternaria blight, early maturing.
8	RK-9901	CSAUA&T,Kanpur	Plant height: 140-150cm,maturity: 125-128days, oil content: 39%, seed weight: 5.5g,average yield: 2200-2500Kg/ha.
9	RK-9902	CSAUA&T,Kanpur	Plant height: 160-165cm,maturity: 110-115days, oil content: 38/, seed weight: 3.5-4.0g,average yield: 1500 Kg/ha.
10	RK-2007	CSAUA&T,Kanpur	Plantheight: 125-130cm,maturity: 125days, oil content: 37-38%, seed weight: 3.5g,average yield: 1400 Kg/ha.
11	RK-9807	CSAUA&T,Kanpur	Plant height: 115-120cm,maturity: 125-130days, oil content: 39%, seed weight: 3.0-3.5g,average yield: 1500 Kg/ha.
12	Basanti	CSAUA&T,Kanpur	Plant height: 165-170cm,maturity: 135-140days, oil content: 40%, seed weight: 3.5-4.0g,average yield: 2000-2200 Kg/ha.
13	Jawahar-1	JNKV Campus Morena (M.P.)	Plant height: 185-190cm,maturity: 125-127days, oil content: 42%, seed weight: 5.0g, average yield: 2000-2100Kg/ha, resistant to white rust.
14	Vaibhav	CSAUA&T,Kanpur	Plant height: 140-145cm,maturity: 120-125days, oil content: 38%, seed weight: 4.5g,average yield: 1300-1500 Kg/ha.
15	Pusa Bold	IARI, (New Delhi)	Plant height: 170-180cm,maturity: 110-115days, oil content: 42%, seed weight: 6.0-7.0g,average yield: 1800Kg/ha.
16	RK-2001	CSAUA&T,Kanpur	Plant height: 125-130cm,maturity: 125-130days, oil content: 37%, seed weight: 3.5g,average yield: 1200Kg/ha
17	RK-2002	CSAUA&T,Kanpur	Plant height: 120-125cm,maturity: 130-135days, oil content: 36%, seed weight: 3.3g,average yield: 1200 Kg/ha
18	RK-2003	CSAUA&T,Kanpur	Plant height: 125-130cm,maturity: 120days,oil content:38%,seed weight:3-3.5g,average yield:1500 Kg/hac

19	RK-9803	CSAUA&T,Kanpur	Plant height: 120-125cm,maturity: 130-135days, oil content: 39%, seed weight: 3.5g,average yield: 1600Kg/ha.
20	RK-9804	CSAUA&T,Kanpur	Plant height: 125-130cm,maturity: 130days, oil content: 38%, seed weight: 3.5g,average yield: 1700Kg/ha.
21	Kranti	GBPUA&T, Pantnagar	Plant height: 155-175cm,maturity: 125-130days, oil content: 40%, seed weight: 4.5g,average yield: 1500-1800 Kg/ha, tolerant to alternaria blight and frost, resistant to downey mildew and white rust.
22	Rohini	CSAUA&T,Kanpur	Plant height: 150-155cm,maturity: 125-130days, oil content: 43%, seed weight: 5.0-5.2g,average yield: 2200-2800Kg/ha, appressed siliqua, resistant to shattering.
23	Varuna	CSAUA&T,Kanpur	Plant height: 145-155cm,maturity: 125-130days, oil content: 43%, seed weight: 5.0-6.5g,average yield: 2000-2200Kg/ha, moderately resistant to alternaria blight and aphids.
24	Vardan	CSAUA&T,Kanpur	Plant height: 140-145cm,maturity: 120-125days, oil content: 40%, seed weight:4.5g,average yield:1000-1600Kg/ha,suitable for late sown and intercropping.

3.1.2. Building up of the material: - Twenty females and four males were sown during *rabi* 2000-2001 at Oil Seed Research Farm of the University at Kalyanpur, Kanpur. All the females were crossed with each of the four males to produce sufficient amount of seed of 80 crosses. During *kharif* 2001 their F_1s were advanced to F_2 as Off Season Nursary, Palampur (H.P.) and fresh crosses were also made.

3.2 Methods

3.2.1. Plan of layout: - The material consisting of 24 parents and 80 each F_1s and 80 F_2s were grown during *rabi*: 2001-2002 in a randomized block design with three replications at Oil Seed Research Farm, of C.S. Azad University of Agriculture and Technology, Kanpur. Each population was planted in two rows, each 3 m long and 45 cm apart. The plant-to-plant distance was maintained at 15 cm by thinning. All the recommended agronomic practices were adopted for raising a good crop.

3.2.2. Recording of observations: - Data were recorded on ten randomly selected plants in each population in each replication on 14 characters except for trait oil and protein contents and 1000-seed weight where samples were drawn from bulk harvest of each population per replication as per details given below.

1. **Days to flower:-** It was recorded as the period from the seed sowing to opening of the first flower on the main raceme of the randomly selected plants.
2. **Days to maturity:-** It was recorded when the most of siliquae on the plant turned yellow and days from sowing to maturity were counted.
3. **Plant height:-** The height was measured from base to top of the plant in cm at maturity.
4. **Length of main raceme:**- Length of main raceme was measured in each selected plant at maturity.
5. **Number of primary branches:**- Number of first order branches designated as primary branches arising on the main shoot was counted on each selected plant at maturity.
6. **Number of secondary branches:**- Second order branches arising from the primary branches were counted at maturity.
7. **Number of siliquae on main raceme:**- The number of siliquae was counted from main raceme in each selected plant at maturity.
8. **Number of seeds per siliqua:**- Ten randomly selected siliquae were taken from each selected plant and total number of seeds were counted and the average number of seeds per siliqua was worked out.
9. **Biomass:**- Total weight of the plant was recorded at maturity.
10. **Harvest index:**- Harvest index was worked out by using the following formula

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

11. **1000-seed weight:-** 1000-seeds were counted from the bulk yield of each population and weighed in g on electronic balance.
12. **Yield per plant:-** The seeds were sun dried and yield per plant was recorded by weighing in g on electronic balance.
13. **Oil content:-** It was determined in percent by using Pulsed Nuclear Magnetic Resonance Spectrometer (NMR) technique from the three randomly drawn samples of each population.
14. **Protein content:-** The residue obtained after oil extraction was subjected to semi-micro Kjeldahl's method of nitrogen estimation. The protein in percentage of the meal was obtained by multiplying the nitrogen content by 6.25.

3.3 Statistical Analyses

The data recorded on above characters were subjected to the following statistical analyses.

3.3.1. Analyses of variance: Analyses of variance was carried out according to the usual procedure of **Panse** and **Sukhatme (1967)** as detailed in Table 2.

3.3.2. Combining ability analyses: The analyses of variance for combining ability was carried out according to the method outlined by **Kempthorne (1957).** The partitioning of populations was done into males, females and males x females for F_1 generation. The skeleton of analysis for combing ability is as per details given in Table 3

Table 2 : ANOVA for combing ability

Source	d.f.	m.s.	Expected .m.s.
Replications	(r-1)		
Hybrids	(mf-1)		
Males	(m-1)	m_1	σ^2+r[Cov(F.S.)-2Cov(H.S.)]+fr Cov (H.S.)
Females	f-1	m_2	δ^2+r[cov (F.S)-2 cov (H.S.)]+ mr Cov (H.S.)
Males x Females	(m-1)(f-1)	m_3	δ^2+r [Cov (F.S.)-2 Cov (H.S.)]
Error	(r-1)(mf-1)	m_4	δ^2
Total	(mfr-1)		

Kempthorne (1957) advocated general combining ability (gca) and specific combining ability (sca) in form of covariances of half- sibs (H.S.) and full- sibs (F.S.) as, respectively as

δ^2 gca = Cov. (H.S.)

δ^2 sca = Cov. (F.S.)-2 Cov. (H.S.)

Where,

Cov. (H.S.) = $[(m_1-m_3)+(m_2-m_3)]/r\,(f+m)$

Cov. (F.S.) = $[m_1-m_4)+(m_2-m_4)+(m_3-m_4)+6r$ Cov (H.S.)-r (f+m) Cov. (H.S.)] 3r

3.3.3. Estimates of components of variance:

$\delta^2 gm = (m_1-m_3)/fr$

$\delta^2 gf = (m_2-m_3)/mr$

$\delta^2 g = [(m_1-m_3)+(m_2-m_3)]\ r(f+m)$

$\delta^2 s = (m_3-m_4)/\ r$

Where,

δ^2gm = variance due to gca of males

δ^2gf = variance due to gca of females

δ^2g = variance due to pooled gca

δ^2s = variance due to sca

3.3.4. Estimates of general and specific combining ability effects:-

The following mathematical model was applied to estimate the general and specific combining ability effects of ijkth observation

$X_{ijk} = \mu + gi + gj + sij + eijk$

μ = population mean

g_i = general combining ability effect of the ith male parent

g^j = general combining ability effect of thejth female parent

s_{ij} = specific combining ability effect of ijth combination

e_{ijk} = error associated with the X_{ijk} observation

i = number of male parents (1,2,--------m)

j = number of female parents (1,2,..........f.)

k = number of replications (1,2..............r.)

The individual effects were estimated with the help of following relationship

μ = $(X.../mfr)$.

Where,

$(X...$ = Total of all hybrid combinations)

g_i = $(X_1../fr)-(X../mfr)$,

Where,

$(X_i..$ = Total of i^{th} male parent over all the females and replications)

g_j = $(X_{ij}../mr)-(X.../mfr)$,

Where,

$(X_{ij}..$ = (Total of j^{th} female parent over all the males and replications)

s_{ij} = $[X_{ij}/r-K_i../fr)-[X_{ij}/mr+X.../mfr]$,

Where,

Xij = $(ij)^{th}$ combination over all the replications.

The significance of general and specific combining ability effects was tested through standard errors of their effects which were computed by taking the square root of variance as follows:

S.E. (g_i) = $\sqrt{\delta^2{}_e/fr}$

S.E. (g_j) = $\sqrt{\delta^2{}_e/mr}$

S.E. (s_{ij}) = $\sqrt{\delta^2{}_e/r}$

Standard errors of differences between the values of two general and specific combining ability effects were calculated as follows:

S.E. $(g_i\text{-}gi)$ = $\sqrt{2\delta^2{}_e/fr}$

S.E. $(g_i\text{-}g_i)$ = $\sqrt{2\delta^2{}_e/mr}$

S.E. $(s_{ij}\text{-}s_{ij})$ = $\sqrt{2\delta^2{}_e/r}$

3.3.5. Degree of Dominance:- The degree of dominance was calculated using the following formula given by **Kempthorne** and **Curnow (1961).**

Degree of dominance = $(\delta^2 s/\delta^2 g)^{0\ 5}$

Where,

$\delta^2 s$ = estimated variance due to sca

$\delta^2 g$ = estimated variance due to gca

Heterosis : It was estimated as percent increase or decrease in the mean values of F_1 hybrids over commercial cultivar as follows

$$\text{Heterosis (\%)} = \frac{(F_1\text{-}CC)}{CC} \times 100$$

Where,

F_1 = mean of hybrid

CC = mean value of commercial cultivar

3.3.7 Inbreeding depression: - Inbreeding depression refers decrease in fitness and vigour due to inbreeding. It was estimated as follows

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

Where,

F_1 and F_2 are the mean values of F_1 and F_2 progenies, respectively of the same cross for a given character.

3.3.8. Heritability:- Heritability was calculated by the formula proposed by **Burton** and **Devane (1953)**

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Where,

h_2 = Heritability

vg = Genotypic variance

vp = Phenotypic variance

3.3.9 Genetic Advance: The Genetic advance was calculated by the following formula suggested by **Johnson *et al.* (1955a).**

GA = H x σph x k

where,

H = Heritability

σph = Phenotypic standard deviation

K = Selection differential at 5% Selection intensity (k= 2.06)

3.3.10 Genetic advance in percentage of mean: It was calculated as follows:

$$Gs(\%)\ [G_s/X] \times 100\ Gs \frac{GA}{x} \times 100$$

Where,

Gs = expectation of genetic advance

X = mean of the character

3.3.11. Correlation coefficient : The environmental genotypic and phenotypic coefficients of correlation were worked out as suggested by **Al- jibouri *et al.* (1958)**

(a) Environmental correlation $rxy(e) = \frac{Cov_{xy}(e)}{[vx(e)vy(e)]^{0.5}}$

(b) Phenotypic correlation $rxy(p) = \frac{Cov_{xy}(p)}{[vx(p)vy(p)]^{0.5}}$

(c) Genotypic correlation $rxy(g) = \frac{Cov._{xy}(g)}{[v_x(g)v_y(g)]^{0.5}}$

Where.

$Cov._{xy}(e)$ = Environmental covariance between characters x and y

$Cov._{xy}(p)$ = Phenotypic covariance between characters x and y

$Cov._{xy}(g)$ = Genotypic covariance between characters x and y

The significance of phenotypic correlation coefficient was tested against 'r' values from r-table of **Fisher** and **Yates (1938)** for (n-2) degree of freedom where. in is the number of population.

EXPERIMENTAL FINDINGS

EXPERIMENTAL FINDINGS

The present investigation comprised of 24 parental lines of 20 x 4 line x tester analysis design and each of their 80 F_1 and F_2 populations. These were raised in a randomized block design with three replications. The data were recorded on 10 characters namely, days to flower and maturity, plant height, length of main raceme, number of primary and secondary branches per plant, number of siliqua on main raceme, number of seeds per siliquae, biomass, harvest index, 1000-seed weight, seed yield per plant and oil and protein content. These data were subjected to various statistical and biometrical methods and the results obtained have been described under the following heads

4.1 Analysis of Variance of the experiment

4.2 Mean and Variability among parents, F_{1s} and F_{2s}

4.3 Combining ability analysis

4.3.1 Analysis of variance for combining ability

4.3.2 Components of variance and degree of dominance

4.3.3 General combining ability (gca) effects

4.3.4 Specific combining ability (sca) effects

4.4 Heterosis

4.5 Inbreeding depression

4.6 Heritability and Genetic advance

4.7 Correlation

4.1 Analysis of variance of the experiment

The m.s.s. obtained through the analysis of the data of the experiment having 184 genotypes viz., 24 parents and their 80 all possible crosses of the 20 x 4 line x tester design, excluding reciprocals and their 80 F_2 population are given in Table 3. The variance due to replications was found non-significant for all the 14 characters. This suggested that the environmental conditions obtaining in the site where the experiment was laid down were uniform and homogeneous. On the other hand, the m.s.s. due to 24 parents were found highly significant for 10 characters, significant for two characters and not significant only for number of secondary branches and 1000-seed weight. This suggested that the parental lines were a group of highly genetically divergent strains. The 24 parental lines were again partitioned into females, males and females vs. males. The m.s.s. due to latter were found highly significant for all the characters, except number of seeds per siliqua and 1000-seed weight. This suggested that the two groups of genotypes viz., females and males, as a whole, were distinct. Again, 20 female parents were genetically different from one another in respect of all the characters except 1000-seed weight. Similarly, the males were found statistically different from one another for as many as 8 characters.

Except for plant height, a set of 80 F_1 crosses was found statistically different from one another for all the characters under study. When these crosses were compared with their parents, these two groups (F_{1s} and parents) as a whole were also found statistically different for as many as 12 characters. This suggested that the F_{1s} exhibited significant superiority or inferiority over their parental populations. Similar 80 F_{1s} and 80 F_2 populations, as a whole, were found distinct for 12 characters. This suggests that F_2 population is exhibiting inbreeding depression, irrespective of the direction over the F_1 performance.

4.2 Mean and range among parents, F_{1s} and F_{2s}

4.2.1 Parents

Though the variability among parents (females and males) together and individually has been assessed through analysis of variance of the experiment (Table 3), but through mean values and the range, the precise assessment can be made. The mean performance of 24 parents in respect of 14 characters has been given in Table 4 and the character-wise presentation is given below-

4.2.1.1 Days to flower: The days taken from sowing to emergence of first flower have ranged from 43 (Sanjukta and Sita) to 55 (Kranti).

4.2.1.2 Days to maturity: Very wide range for days to maturity was recorded among the parents, the earliest being Sita (115 days), and Basanti had longest (135 days) duration. All the 24 parental lines took more than 100 days to mature.

4.2.1.3 Plant height: Very wide range in the mean plant height could be recorded, RK 9807 being the dwarfest (113 cm) and RK 9901, Rohini the tallest (183 cm). It is interesting to mention here that the lines that took more days to flower were invariably tall and vice-versa.

4.2.1.4 Length of main raceme: The length of main raceme is the most important character, as larger the raceme more will be the number of siliquae and ultimately the seed yield. The range in this character was recorded from 31.17 cm (Vaibhav) to 87.40 cm (Pusa Bold). There appears to be association between plant height and the length of main raceme, i.e., taller the plant longer would be the main raceme and vice-versa.

4.2.1.5 Number of primary branches: From yield point of view, this is a very important character as the number and the length of raceme depends mainly upon the primary branches. A very wide range in the number of primary branches was observed among 24 parents. The shy branching was noted in the strain RK 9901 (4.40), where as RK 9807 recorded profused branching (9.0). Majority of the parental lines gave primary branches between 6.00 and 8.00. It is very interesting to report here that the tall (RK 9901) and dwarf (RK 9807) varieties produced very poor and high number of primary branches, respectively.

4.2.1.6 Number of secondary branches: Tremendous variability among the 24 parental lines was observed in terms of this trait. It ranged from 1.17 (Basanti) to 17.33 (RK 2001). As many as 13 parental lines had 7-13 secondary branches. The number of primary branches appears to be related to number of secondary branches, i.e., higher the number of primary branches, greater will be the number of secondary branches and vice-versa.

4.2.1.7 **Number of siliquae on main raceme:** This is the most important yield component in mustard. Similar to number of primary branches, the variability for number of siliquae on main raceme was very high, ranging from 27 in the parent Sita to 71 in Vardan. The length of the main raceme appears to be positively associated with the number of siliquae on the main raceme. As many as 13 parents had more than 50 siliquae on main raceme.

4.2.1.8 **Number of seeds per siliqua:** This is another important yield component. The range for this character was recorded from 9.10 (RK 9804) to 13.30 (Rohini). It has also been observed that wherever the number or siliquae for main raceme was higher the number of seeds for siliqua was less and vice-versa.

4.2.1.9 **Biomass:** Sum total dry matter of the plant is called biomass. Very wide range from 8.33 g in Urvashi to 91.00 g in Varuna was recorded for this character. Most of the ruling varieties like Rohini, Varuna and Pusa Bold had very high biomass

4.2.1.10 **Harvest index:** This parameter indicates the proportion of seed yield out of the total biomass. The range for this character was recorded from 20.14% in RK 9807 to 32.72% in Varuna. The latter is a top yielding national variety, which has highest harvest index. It has high biomass also.

4.2.1.11 **1000-seed weight:** The seed weight among the parents ranged from 3.10 g in Sanjukta to 4.31 g in Varuna. It has also been observed that higher the number of seeds per siliqua, lighter is the seed and vice-versa.

4.2.1.12 **Seed yield per plant:** Very wide range in seed yield was recorded (from 13.96 g in Sita to 29.78 g in Varuna). Again, Varuna which is a national variety and has highest seed yield.

4.2.1.13 Oil content: Marginal variability among the parents was recorded for oil content, i.e., only from 37.00% in RK 9901 to 39.83% in Varuna. In general, it could be established that bolder the seeds lower is the oil content and vice-versa.

4.2.1.14 Protein content: Similar to oil content for protein content also very narrow variability could be recorded among the parents, Sita (23.35%) being the poorest and RK 2007 (29.80%) the richest.

4.2.2 F_1 Population

The mean performance of 80 F_1 crosses for 14 characters under study has been worked out and the same has been given in Table- 5 and the results described below character-wise.

4.2.2.1 Days to flower: The range for this character was recorded from 41.33 days in RK 2003 x Rohini to 56.67 days in Pusa Jaikisan x Rohini. In other crosses not much variability could be observed.

4.2.2.2 Days to maturity: For this character very wide variability was recorded, which ranged from 128 days in RK 2007 x Kranti to 142 days in Basanti x Varuna. No relationship between days to flowering and maturity could be observed.

4.2.2.3 Plant height: Tremendous variability among the crosses was observed for plant height. The cross Sita **x** Varuna proved to be dwarfest (114.33 cm) and on the other hand, RK 2003 x Rohni the tallest (177 cm).

4.2.2.4 Length of main raceme: Narrow variability was recorded among 80 crosses for this character (38.73 cm in Urvashi x Varuna to 56.73 cm in RK 9901 x Kranti). Plant height and length of the main raceme appeared to be positively associated.

4.2.2.5 Number of primary branches: The number of primary branches was found, in general, very shy (besides narrow variability among the crosses).

4.2.2.6 Number of secondary branches: The variability for this character among the crosses was found very marginal, i.e., from 9.00 in the cross Sita x Varuna to 20.60 in Vaibhav x Kranti.

4.2.2.7 Number of siliquae on the main raceme: Huge variability was recorded among 80 F_1 crosses in respect of number of siliquae on the main raceme. The crosses Sita x Varuna had minimum (36) siliquae and the cross Basanti x Varuna had maximum (93) siliquae on the main raceme. The crosses in which either Sanjukta or Sita were involved the siliquae number was low and on the other hand, the crosses involving Varuna as one of the parents had, in general, large number of siliquae.

4.2.2.8 Number of seeds per siliqua: Tremendous variability among the F_1 crosses for number of seeds per siliqua was observed, and the range being from 9.33 in the crosses Krishna x Rohini to 13.6 in the cross RK 2007 x Varuna. For this character also, the crosses involving Varuna as one of the parents had, invariably, large number of seeds per siliqua.

4.2.2.9 Biomass: The total biomass per plant among the F_1 crosses ranged from 73.00 g in Sita x Vardan to 104.33 g in Pusa Bahar x Varuna. Wherever Varuna is involved, the crosses gave high value of biomass. on the other hand the crosses having Sita as one of the parents gave low biomass.

4.2.2.10 Harvest index: This parameter among the F_1 crosses ranged from 22.00% (Sita x Kranti) to 50.84% (Urvashi x Varuna). The parents Urvashi and Sita gave high and low harvest indices, respectively wherever they were involved in the crosses as one of the parents.

4.2.2.11 1000-seed weight: Tremendous variability among the F_1 crosses for seed weight was recorded. It was minimum (1.81g) and maximum (6.14) in the crosses Vaibhav x Varuna and RK 2001x Varuna, respectively. Pusa Bold being bold seeded parent could not influence the seed size of its F_1 crosses. On the other hand, Vardan and Varuna, the most popular varieties of the country, increased the seed size of their crosses.

4.2.2.12 Seed yield per plant: High variability in the seed yield per plant was observed among 80 F_1 crosses, the lowest (18.70 g) and highest (27.19 g) was obtained from the crosses Sita x Kranti and Pusa Bold x Vardan, respectively. Again, the high yielding varieties Vardan and Varuna influenced the yield of their crosses in positive direction.

4.2.2.13 Oil content: Not much variability could be noted for oil content among the F_1 crosses. It ranged from low values in the cross RK 2001 x Kranti to very low in the cross RK 9803 x Rohini.

4.2.2.14 Protein content: Unlike oil content, the F_1 crosses were found highly variable for protein content, the range was recorded from 24.53 % in the cross RK 2001 x Rohini to 33.00 % in the cross RK 9804 x Vardan. Most of the crosses where Vardan was involved gave high protein content in >50 crosses.

4.2.3 F_2 Population

A set of 80 F_2 populations of 20 x 4 line x tester crosses was also studied for their performance in respect of 14 characters. The mean values of these populations have been given in Table 6 and described below character-wise.

4.2.3.1 Days to flower: The range for this character among the 80 F_{2s} was recorded from 41.00 days in RK 2001 x Varuna, to 57.33 days in RK 9902 x Varuna and Vardan.

4.2.3.2. Days to maturity: Almost all the F_2 populations took more than 100 days to mature, however, the range was recorded from 103.00 days in the crosses RK 2003 x Vardan to 164.33 days in the cross RK 2002 x Kranti .

4.2.3.3 Plant height: Tremendous variability for plant height was recorded, though it was more than 100 cm in all the populations. The minimum (115.6 cm) and maximum (183.00 cm) plant height was noted in the F_2 population of the crosses

Pusa jai kishan x vauna and Urvashi x Rohni, respectively.

4.2.3.4. Length of main raceme: Similar to plant height, substantial variability was noted for this character. In majority of the populations the height of the main raceme was more then 40 cm, however, the range being from 37.87 cm in the cross Sita x Kranti to 59.83 cm in Sita x Varuna. Variety Varuna increased the length of the main raceme in almost all the crosses where it was one of the parents.

4.2.3.5 Number of primary branches: Very wide range for number of primary branches was recorded, the lowest (5.03) and the highest (12.13) being in the crosses RK 9804 x Varuna and Pusa Bahar x Vardan, respectively.

4.2.3.6 Number of secondary branches: Here also a very wide range was recorded, the lowest (9.17) and highest (18.17) number being in the crosses Basanti x Kranti and Pusa Bahar x Vardan, respectively.

4.2.3.7 Number of siliquae on main raceme: In majority of the cases the number of siliquae ranged between 40 and 50. However, the range was noted from 27.50 in Jawahar-1 x Vardan to 15.63 in RK 2002 x Vardan.

4.2.3.8 Number of seeds per siliqua: A very wide range in the number of seeds per siliqua was recorded among the F_2 populations (from 5.07 in the cross Urvashi × Rohini to 15.63 in the cross RK 2002×Vardan).

4.2.3.9 Biomass: Wide range from 67.67g in the Sita × Kranti to 101.33 g in the cross Sanjukta × Vardan and RK 9804 × Rohini was recorded for this character .The crosses involving Vardan and Pusa Jaikisan as one of the parents produced high biomass.

4.2.3.10 Harvest index: Tremendous variability has been observed in this secondary character. Minimum and maximum harvest index has been recorded with the crosses RK 9804 × Varuna (11.48%) and RK 9803 × Rohini (31.64 %), respectively.

Wherever RK 9803 was used as one of the parents, the resulting F_2 population gave high harvest index. Likewise Pusa Bold produced F_2 population with poor harvest index.

4.2.3.11 **1000-seed weight:** Being one the potent yield component, it exhibited very. high variability, the range being from 1.79 g in the cross Sita × Kranti to 5.21 g in the cross RK 9902 × Vardan. The strains Pusa Bold, Vardan and Varuna had contributed to high seed weight.

4.2.3.12 **Seed yield per plant:** Similar to test weight for seed yield also very high variability has been recorded. The F_2 populations of the crosses Krishna × Kranti and Basanti × Varuna gave lowest (13.92 g) and highest (27.01g) seed yield per plant, respectively.

4.2.3.13 **Oil content:** Most of the populations were found concentrated between the oil content range of 35 and 40%. However, the F_2 populations of the crosses RK 2001 × Rohini (35.70%) and Pusa Basant ×Varuna (41.63%) gave lowest and highest oil content, respectively.

4.2.3.14 **Protein content**: Similar to oil content, for protein content also most of the populations were concentrated between 25 and 30% range. However, the poorest and richest populations in respect of protein content were Pusa Jaikisan × Vardan (23.4%) and RK 2007 × Varuna (31.61%), respectively.

4.3 Combining ability analysis

4.3.1 Analysis of variance for combining ability: The analysis of variance for combining ability in respect of 14 characters has been carried out for 20 x 4 line x tester analysis and variance due to males, females and males x females have been given in Table 7.Variance due to females (20) and, males (4) for all the characters except number of seeds per siliqua and protein content and interactions between females and males for all the characters except protein contents were found highly significant.

4.3.2. Estimates of components of variance and degree of dominance:

The estimates of components of variance, i.e., variance g (σ^2 g) and variance r (σ^2 s) were calculated from the variance of all the characters. The ratio of σ^2 g/σ^2 s and degree of dominance (σ^2 s/σ^2g)$^{0.5}$ were also worked out. The estimates of genetic components, their ratio and degree of dominance have been given in Table 8.

The ratio of 1:1 between σ^2 g and σ^2 s indicates an equal importance of both additive and non-additive genetic variances for the expression of the characters, whereas the deviation from this ratio (1:1) indicates more importance of either σ^2 g orσ^2 s, depending upon the magnitude of the ratio. The magnitude of gca variance was found higher than sca variance for days to flowering and maturity, plant height, length of main raceme, number of primary and secondary branches, number of siliquae on main raceme and 1000-seed weight. On the other hand, sca variance was found greater than its gca counter part for number of seeds per siliqua, biomass, harvest index and oil content. However, both these variances were almost equal in magnitude for seed yield and protein content.

The average degree of dominance indicates the magnitude of dominance. In case the value of degree of dominance is more than one the over-dominance is indicated, when this value is 0 and one, no dominance and complete dominance, respectively are indicated. Accordingly, the over-dominance has been expressed for days to flower and maturity, plant height, length of main raceme, number of primary and secondary branches, number of siliquae on main raceme and 1000-seed weight. For number of seeds per siliqua, biomass, harvest index and oil content, partial dominance was indicated. On the other hand, for seed yield and protein content no dominance was indicated.

4.3.3 Estimates of combining ability effects

4.3.3.1 General combining ability effects: The estimates of gca effects of 24 parents, comprising of 20 females and 4 testers of line x tester analysis designed for 14 quantitative characters and their mean performance have been given in Table 9 and results described character-wise below.

1. **Days to flower:** Irrespective of decline, the gca effects for this character were found highly significant for all the females and testers in both F_1 and F_2 generations. The negative values indicated the additive genetic variance for earliness, therefore, such estimates are desirable. Therefore, among the females RK 2003 (-8.34) followed by RK 9803 (-7.09) and RK 2001 (-6.34) and among the testers none gave high and negative estimates in F_1 generation.
2. **Days to maturity:** For this character also the negative estimates were desirable. In both F_1 and F_2 populations a large number of female lines gave highly significant and negative gca effects, higher being - 15.22 (RK 9804) in F_1 and -17.50 (Sita) in F_2 population.
3. **Plant height:** Irrespective of the sign, all the 20 female lines gave highly significant gca effects. Among the males only in F_2 generation they gave highly significant estimates of gca effects.
4. **Length of main raceme:** In both the generations a large number of female lines and males exhibited highly significant gca effects, majority of them were of positive sign. Pusa Bold in F_1 generation gave higher value (24.96) of positive gca effects.
5. **Number of primary branches:** Highly significant gca effects were displayed by 24 parents in both the generations. In F_1 generation, a large number of gca effects were negative.
6. **Number of secondary branches:** The gca effects of all the parents, though highly significant, but marginal in magnitude as estimated through F_1 and F_2 generations were recorded.

7. **Number of siliquae on main raceme:** All the 24 parents exhibited highly significant gca effects. However, the magnitude of these effects has been found higher in F_1 generation. Among the females RK 9804 and among the males Varuna gave higher gca effects.

8. **Number of seeds per siliqua:** Among the females Vaibhav and among the males Rohini gave highest and highly significant gca effects.

9. **Biomass:** Barring two females parents and one male parent all gave highly significant gca effects.

10. **Harvest index:** Except one each in females and males, all have given highly significant gca effects. Pusa Bold gave highest value.

11. **1000-seed weight:** In this character also, except one each in females and males (F_1) all have been found associated with highly significant gca effects.

12. **Seed weight:** Most of the parents gave significant gca effects, the highest negative estimate has been given by Sita in both the generations.

13. **Oil content:** Almost all the females and two males in F_1 and fairly a large number of parents in F_2 have been found associated with significant gca effects.

14. **Protein content:** Out of 20 females, 19 in F_1 and 15 in F_2 have been found having highly significant gca effects. On the other hand, only Vardan has given significant gca effect in F_1.

4.3.3.2 Specific combining ability effects

The sca effects for 80 crosses have been worked out through F_1 and F_2 generation separately. These estimates along with mean values for 14 characters have been given in Tables 10 and 11 and the results described character-wise below.

A. F_1:

1. **Days to flower:** Out of 80 crosses, 49 exhibited highly significant sca effects, most of them were positive, the cross Pusa Bold x Varuna gave high value (- 3.35) of this parameter in negative direction.

2. **Days to maturity:** A set of 55 crosses manifested highly significant sca effects. The cross Urvashi x Rohini gave highest value (-6.08) of this parameter with negative sign.
3. **Plant height:** 47 crosses were found associated with highly significant sca effects. Maximum negative (-20.91) and positive (6.77) and significant sca effects were displayed by the crosses Vaibhav x Kranti and RK 9803 x Varuna, respectively.
4. **Length of main raceme:** Irrespective of sign, 41 crosses were found having highly significant sca effects. Highest positive (12.96) and negative (2.46) values were recorded with the crosses Pusa Bold x Kranti and Pusa Jai Kisan x Rohini, respectively.
5. **Number of primary branches:** As many as 64 crosses exhibited highly significant sca effects of both positive and negative signs.
6. **Number of secondary branches:** A set of 58 crosses was found associated with highly significant sca effects having both negative and positive signs
7. **Number of siliquae on main raceme:** A set of 46 crosses showed highly significant sca effects. The highly significant and positive (8.23) and negative (8.37) values of this parameter were noted with the crosses Vaibhav x Rohini and Vaibhav x Kranti, respectively.
8. **Number of seeds per siliqua:** As many as 72 crosses out of 80 exhibited highly significant sca effects. Most of these estimates were found positive with high value of 8.23 in the cross Vaibhav x Varuna.
9. **Number of seeds per siliqua:** Most of the crosses were found associated with highly significant and positive sca effects.
10. **Biomass:** 53 crosses were found associated with highly significant sca effects.
11. **Harvest index:** Except 14 crosses, all exhibited highly significant sca effects. The cross RK 9803 x Varuna gave highly positive estimate (9.6) of this parameter.

12. **Seed yield:** As many as 76 crosses were found associated with highly significant sca effects. The cross Basanti x Vardan gave highly significant and positive estimate of this parameter (6.58).

13. **Oil content:** Only about 50% of the crosses were found having significant sca effects. However, most of the values were negative.

14. **Protein content:** A set of 66 crosses had highly significant sca effects.

B. F_2:

1. **Days to flower:** Only a limited number of crosses displayed highly significant sca effects, that too with most of them negative.

2. **Days to maturity:** As many as 48 crosses gave highly significant sca effects. Majority of these effects were positive.

3. **Plant height:** Most of the crosses gave highly significant and positive sca effects. The maximum positive estimate was given by the cross Krishna x Kranti (25.57).

4. **Length of main raceme:** Barring one cross (Krishna x Vardan) all the crosses gave highly significant sca effects. High estimates of positive sign were given by the crosses where one of the parents was Sita.

5. **Number of primary branches:** A set of 65 crosses was found with highly significant sca effects of both positive and negative signs.

6. **Number of secondary branches:** The same trend as in case of number of primary branches was observed for this character.

7. **Number of siliquae on main raceme:** As many as 64 crosses gave highly significant sca effects. The highly positive (10.3) and negative (-8.43) values were noted with the crosses RK 9803 x Vardan and RK 9803 x Kranti, respectively.

8. **Number of seeds per siliqua:** A very large number of crosses were found associated with highly significant sca effects. Highly significant sca effect of negative sign were found with the cross RK 2002 x Kranti.

9. **Biomass:** A limited number of crosses were found having highly significant sca effects. However, the cross RK 9807 x Kranti gave high value (8.09) of this parameter of positive sign.

10. **Harvest index:** As many as 20 crosses gave highly significant sca effects. The high positive (96.1) value of this parameter was shown by the cross RK 9803 x Rohini.

11. **1000-seed weight:** Almost all the crosses gave highly significant sca effects, though the magnitude of the estimates was marginal.

12. **Seed yield:** Here also almost all the crosses exhibited high significant sca effect. The high estimates of positive (6.58) and negative (-9.66) signs were observed with the crosses Basanti x Varuna and Krishna x Kranti, respectively.

13. **Oil content:** Only a limited number of crosses showed highly significant sca effects, that too with marginal values.

14. **Protein content:** For this quality trait a very large number of crosses showed highly significant sca effects. The magnitude of the values was also found respectable. The high positive (3.20) negative (4.52) values were noted with the crosses Pusa Bahar x Varuna and Jaikisan x Vardan, respectively.

4.4 Heterosis

The performance of F_1 crosses vis-a-vis to commercial variety grown in the country has been assessed. Varuna, a ruling variety of Uttar Pradesh and which has also covered entire Rajasthan has been considered as the commercial cultivar. The estimates of the difference in the performance of the F_1 crosses and that of this variety have been worked out and expressed in percent of mean value of this commercial variety have been given in Table 12 and results described below character-wise.

4.4.1 Days to flower: Out of 80 crosses 34 for late flowering and 32 for early flowering compared to commercial variety have exhibited heterosis. Earliness is a desirable character. Therefore, the progenies of these 32 crosses may throw early flowering genotypes.

4.4.2 Days to maturity: Similar to days to flowering, early maturity is also a desirable trait. A set of 23 F_1 crosses was found significantly early over the commercial variety. On the other hand, as many as 41 crosses were significantly late maturing.

4.4.3 Plant height: As many as 44 crosses were significantly taller and 36 dwarfer than the commercial variety.

4.4.4 Length of main raceme: Length of main raceme is the part of plant height. There were a large number of crosses (54) that exhibited positive heterosis for this trait. Only 14 crosses showed negative heterosis.

4.4.5 Number of primary branches: For this trait, 48 crosses showed significantly positive heterosis and the magnitude of heterosis was found as high as 50.46% in the cross RK 2007 x Rohini. Only 18 crosses showed negative heterosis, the magnitude of which was not high.

4.4.6 Number of secondary branches: For this character also as high as 54 F_1 crosses showed significantly positive heterosis and the magnitude of increase in the number of secondary branches was as good as 54.55% in the cross RK 2002 X Rohini. Only a limited number of crosses (9) showed significantly decreased number of secondary branches over the commercial cultivar.

4.4.7 Number of siliquae on main raceme: Large number of crosses showed negative heterosis than the positive one. This suggested that the crosses were shy in fruiting compared to commercial cultivar.

4.4.8 Number of seeds per siliqua: Out of 80 crosses, 65 exhibited the siliqua having large number of seeds than that of the commercial variety.

4.4.9 Biomass: Highest number of crosses (70) exhibited positive heterosis for higher production of biomass over the commercial variety. Only three crosses gave biomass lower than the commercial variety.

4.4.10 Harvest index: For this trait 68 crosses gave higher harvest index than the commercial variety. Only few crosses produced biomass lower than the test variety.

4.4.11 1000-seed weight: For test weight also 69 crosses produced seed heavier than the commercial variety and the increase has been recorded as high as 73.49% (RK 9804 x Varuna). Only nine crosses produced lighter seeds than the commercial variety.

4.4.12 Seed yield: Among all the characters, for seed yield highest number of crosses (80) gave higher yield than the commercial variety and the highest increase of 41.05% was recorded in the cross RK 9901 x Varuna.

4.4.13 Oil content: Only a limited number of crosses (16) showed positive heterosis and the increase in oil content has been noted only marginal. The cross Pusa Bahar x Vardan showed negative heterosis of the order of 100%. It is to mention here that both the parents of this cross are bold seeded.

4.4.14 Protein content: A set of 42 crosses produced seeds having protein content higher than that of the commercial variety. Similarly, a large number of crosses also exhibited negative heterosis and the maximum reduction in protein value (100%) was noted in the cross RK 9804 X Kranti.

4.5 Inbreeding depression

The decrease (inbreeding depression) and increase (increase in vigour) in the mean performance of F_2 population over its F_1 parents have been worked out in percent and the estimates have been given in Table 13 and described character-wise below.

4.5.1 Days to flower: Only 16 F_2s showed significant inbreeding depression, i.e., F_2 population flowered earlier than their respective F_1 crosses. On the other hand, a large number of crosses flowered later than their corresponding F_1 population.

4.5.2 Days to maturity: A set of 38 F_2 population matured significantly earlier than their respective F_1s, thus exhibited inbreeding depression, the maximum depression being 49.42% in the cross RK 9804 X Kranti. Also, a fairly large number of crosses matured later than the corresponding F_1s.

4.5.3 **Plant height:** A fairly large (28) F_2 populations showed reduction (inbreeding depression) in height over their F_1s. Also, equally a large number of F_2 populations produced plants taller than their corresponding F_1 population.

4.5.4 **Length Of main raceme:** As many as 53 F_2 populations gave main raceme significantly larger than that of the respective F_1 population. On the other hand, inbreeding depression in the expression of this character has been exhibited by 25 F_2 populations.

4.5.5 **Number of primary branches:** A set of 29 F_2 populations exhibited inbreeding depression. The highest magnitude of 92.53% was exhibited by Pusa Bahar X Vardan. A fairly large number of populations gave higher number of primary branches than what was recorded in their respective F_1s.

4.5.6 **Number of secondary branches:** A moderate number of F_2 populations (21) exhibited significant inbreeding depression. The maximum of 60.08% was recorded in the cross RK 2001 x Varuna. A fairly large number of crosses expressed positive vigour for this character.

4.5.7 **Number of siliquae on main raceme:** A set of 45 crosses exhibited inbreeding depression. The increase in number of secondary branches was also showed by fairly large number of crosses.

4.5.8 **Number of seeds per siliqua:** As many as 30 F_2 populations exhibited inbreeding depression. Also, an equal number of crosses showed increased vigour over their corresponding F_1s.

4.5.9 **Biomass:** Twenty-nine F_2 populations showed inbreeding depression. A sizeable number of crosses manifested increase in the performance and the maximum increase of 20.38% was noticed with the cross Sita X Kranti.

4.5.10 Harvest index: Only 16 crosses manifested inbreeding depression. On the other hand, 47 crosses showed increase in vigour. The maximum vigour was noted with the cross Urvashi x Rohini (64.06%).

4.5.11 1000-seed weight: In general, the magnitude of inbreeding depression was higher than the increase in the performance. Only 23 crosses showed inbreeding depression with the maximum value of 128.7% in the cross Vaibhav x Vardan. A sizeable number of crosses showed increase in vigour, but the maximum increase of only 54.42% would be noted with Pusa Basant x Rohini.

4.5.12 Seed yield: Only 21 F_2 populations exhibited inbreeding depression. The maximum reduction of 27.32% was shown by the cross RK 9807 x Rohini. On the other hand, as many as 45 crosses showed vigour over their respective F_1s. However, the increase in the performance has been as high as 61.58% in the cross RK 9803 X Varuna.

4.5.13 Oil content: Only 14 crosses showed inbreeding depression for oil content that too only marginal. On the other hand, as many as 35 crosses exhibited increase in oil content over their respective F_1s.

4.5.14 Protein content: A set of 21 crosses exhibited inbreeding depression, which was as marginal as in case of oil content. However, the increase in oil content was displayed by 35 crosses and maximum increase of 21.23% was registered with the cross Pusa Jaikisan X Vardan.

4.6 Heritability and genetic advance

Heritability in a broad sense and genetic advance both in absolute terms and percentage of mean, have been estimated in parents F_1s and F_2s and the values have been given in Tables 14,15, &16 and results have been described population wise.

4.6.1 Parents: Heritability among 14 characters ranged from 40% for oil content to 99% for plant height, length of main raceme and number of siliquae on main raceme. Most of the characters fell in high heritability range. Genetic advance in percentage of mean varied from 2.4 for oil content to 52.9 for number of siliquae on main raceme (Table 14).

4.6.2 F_1 Population: The heritability and genetic advance estimated in F_1s for 14 characters have been given in Table 15 for all the characters. Very high heritability (>90%) values were recorded. On the other hand, very wide range was observed for genetic advance in percentage of mean, the minimum being 6.31% for oil content and the maximum of 50% for 1000-seed weight.

4.6.3 F_2 Population: Similar to F_1 population, the heritability estimates in F_2 population were very high. Days to flower and oil content gave slightly low values. Similar trend was recorded for genetic advance in percentage of mean. Again, oil content and 1000-seed weight gave lowest (7.11%) and highest (49.41) values of this parameter, respectively (Table 16).

4.7 Correlation

Correlation at environmental, phenotypic and genotypic levels have been worked out among 14 traits including seed yield in parents, F_1s and F_2s and the values have been given in Tables 17,18 and 19 and results presented below.

4.7.1 In Parents

The coefficients of correlation worked out at environmental, phenotypic and genotypic levels have been presented in Table 17 and 18. The former and latter have been placed above and below the diagonals of the above tables, respectively and interpretation has been made below.

4.7.1.1 Environmental correlation: The values of coefficient of correlation in the parents have been given in Table 17. Except days to maturity with number of secondary branches per plant, number of siliquae on main raceme and oil content; length of raceme with number of siliquae on main raceme, number of seeds per siliqua and seed yield per plant; number of primary branches per plant with number of siliquae on main raceme, number of seeds per siliqua and oil content; number of siliquae on main raceme with number of seeds per siliqua, biomass, harvest index, seed yield and oil content; number of siliquae on main raceme with 1000-seed weight and seed yield; number of seeds per siliqua with oil content; biomass with harvest index and seed yield; harvest index with seed yield; 1000-seed weight with oil and protein contents; and seed yield with oil content. Other character combinations exhibited not significant correlation at environmental level. Also, among the significant correlation, the level of significance was mostly at 5%.

4.7.1.2 Phenotypic correlation: Days to flower with days to maturity, plant height, number of secondary branches, oil content and protein content; days to maturity with length of main raceme and number of siliquae on main raceme; plant height with number of primary branches; number of primary branches with harvest index; number of secondary branches with biomass, harvest index and seed yield; number of siliquae on main raceme; and number of seeds per siliqua with none of the traits; biomass with seed yield; harvest index, 1000-seed weight and seed yield; and 1000-seed weight with seed yield have exhibited strong correlation at phenotypic level.

4.7.1.3 Genotypic correlation: Days to flower with days to maturity and plant height, number of secondary branches; days to maturity with length of main raceme and number of siliquae on main raceme; plant height with number of primary branches, length of raceme with number of primary branches and 1000-seed weight; number of secondary branches with number of primary branches, biomass, harvest index and seed yield; biomass with yield per plant; harvest index with 1000-seed weight and seed yield; and 1000-seed weight with seed yield had exhibited highly significant positive correlation at genotypic level. None of the combinations showed negative correlation.

4.7.2 Correlation in F_{1s}

The correlation coefficients at environmental, phenotypic and genotypic levels were worked out and the same have been given in Tables 19 and 20 and the results presented below category wise.

4.7.2.1 Environmental correlation: None of the characters showed significant and positive correlation with seed yield. However, 1000-seed weight exhibited significant and negative correlation with seed yield. Only one more character combination, i.e., number of primary branches with number of siliquae on main raceme showed highly significant positive correlation.

4.7.2.2 Phenotypic correlation: A large number of character combinations exhibited significant correlation at 5% level of significance. However, at 1% level of significance 20 character combinations showed positive correlation. On the other hand, highly significant and negative correlation was observed for 10 character combinations. The seed yield was found significantly correlated with days to flowering, number of primary branches and biomass in positive direction.

4.7.2.3 Genotypic correlation: A large number of character combinations showed significant positive (26) and negative (12) correlation. It is also to mention here that the genotypic correlations were higher than their phenotypic counterparts. Seed yield per plant exhibited highly significant positive correlation with days to flower, number of primary branches per plant and biomass. None of the characters showed negative correlation with seed yield. Number of primary branches per plant showed correlation with large number of characters, including seed yield. Protein content showed negative correlation with as many as two characters.

4.7.3 Correlation in F_2 population

In F_2 populations the coefficients of correlation at environmental, phenotypic and genotypic levels were worked out and the same has been given in Tables 21 and 22 and the results presented below category wise.

4.7.3.1 Environment correlation: Highly significant and positive, and negative correlation at environmental level was exhibited by two and one character combinations, respectively. Seed yield per plant showed significant and negative correlation with 1000-seed weight.

4.7.3.2 Phenotypic correlation: Glancing through the values given in the above diagonal of Table 22 suggested that days to flower with two, days to maturity with one, plant height with three, length of main raceme with three, number of siliquae on main raceme with two, number of seeds per siliqua with one, biomass with one, seed yield with one, and oil and protein content with one, each character had significant and positive correlation at phenotypic level. Highly significant and negative correlation was exhibited by few character combinations. Seed yield has shown highly significant and positive correlation with five characters. None of the characters showed negative correlation with seed yield

4.7.3.3 Genotypic correlation: Only a few character combinations exhibited highly significant and positive correlation. Seed yield with number of primary and secondary branches per plant, number of seeds per siliqua, biomass and harvest index has exhibited highly significant and positive correlation. The two quality traits, i.e., oil and protein content also exhibited positive association.

DISCUSSION

DISCUSSION

For launching any sound breeding programme it is essential to have information on genetic constitution and magnitude and kind of genetic variability in the base material in respect of the characters for which improvement has to be effected. In the present investigation mustard is the test crop where improvement not only in seed yield but also the oil content, which is both quality and economic character is desirable. Both these characters are complex and are dependent on several components and influenced by the environment, as they are polygenic in genetic constitution. On the other hand, **Grafius (1964)** suggested that there is no way in which yield can be changed/improved without changing/improving one or more of the components. He has also pointed out that "while all changes in yield might be accompanied by changes in one or more of the components, however, all changes in the components need not be expressed in changes in yield". This is due to varying degrees of negative and positive correlations between yield and its components, on one hand and between the components themselves, on the other. This results in gains made through selection in favour of one component are offset by reduction in others.

The knowledge about type of variability available in the material, type of gene action, magnitude of heritability, breeding value of the material in the form of general combining ability, correlation between yield and its components is essential for successful exploitation of available and created variability. Various mating designs such as diallel cross, triallel cross, partial diallel and line x tester analysis have been used in several crops to understand the genetic value of the material. Except the later all mating designs have one or more limitations. Line x tester design developed by **Kempthorne (1957)** is useful, as it can evaluate a large number of lines at a time. Due to this merit, this technique has been used in a large number of crops including mustard (**Lal and Singh, 1974; Pandey, 1974; Badwal *et al.*, 1976 and Labana *et al.*, 1978).**

Wide genetic variability is available in Indian mustard, probably due to autogamous nature of reproduction. The information available on various genetic parameters could not be exploited for improvement purpose as this information has been derived due to evaluation of a few lines at a time in isolation. It is therefore, essential to evaluate a large number of lines for deriving genetic information. With this objective in view, the present investigation on line x tester analysis involving 20 females and 4 testers has been undertaken. To derive information on combining ability, components of variance, degree of dominance, heritability, genetic advance, heterosis and correlation in respect of 14 quantitative characters, the results obtained on these aspects have been discussed here.

The analysis of variance exhibited highly significant variability for 14 characters among 20 females, 4 males, 80 F_1s and 80 F_2s, which suggested adequate divergence among them. The parents and F_1s as a whole were found distinct which suggested that F_1s displayed heterosis. Similarly, the F_1 and F_2 were also found distinct thus the suspect of the inbreeding depression in F_2 was observed.

5.1 Combining ability analysis

The combining ability analysis through line x tester technique was carried out using the method developed by **Kempthorne (1957)**. This technique involves the estimation of covariance of full- sibs and half-sibs to get the estimates of gca and sca variances and their effects. The estimates of combining ability variances were translated into genetic variance, to understand the nature and magnitude of gene action and to provide a guideline for adoption of appropriate breeding procedures for effective quick improvement.

The additive genetic variance results mostly from additive gene action, whereas non-additive genetic variance is the result of dominance and epistatic variances. The dominance variance diminishes by half with each generation of selfing and therefore, is unexploitable in the development of pure or fixed lines. The epistatic variance also declines on sefling, but some portion of it like additive x additive, additive x additive x additive, etc is fixable.

The analysis of variance for combining ability indicated significant differences each among 20 females and 4 males in respect of gca for almost all the 14 traits under study. The interaction between females and males in respect of sca was also highly significant for all these traits. The significant differences with reference to gca and sca reflected the importance of both additive and non-additive gene actions in the inheritance.

As far as gene action is concerned, the estimate of $\sigma^2 g$ (pooled) and $\sigma^2 s$ indicated the predominant role of non-additive gene action in the inheritance of nine out of fourteen characters. The predominance of non-additive gene action has also been observed by **Chaudhary *et al.* (1997), Kulbe *et al.* (1998), Sheikh** and **Singh (1998), Verma** and **Kushwaha (1999), Rao** and **Gulati (2000)** and **Parmar** and **Patel (2003)** in mustard for various traits.

Another genetic parameter, i.e., average degree of dominance is of great importance to plant breeders. This parameter has been estimated by the formula $\sqrt{\sigma 2s/\sigma 2g}$, which is based on the assumption that the genes are isodirectionally distributed among the parents and all the increments have the same sign **(Kempthorne and Curnow, 1961)**. Thus this method measures only the degree of dominance irrespective of the direction. If the dominance variance is in the plus or minus direction they tend to cancel each other, and then F_1 may be equal to its better parent.

The degree of dominance was in the order of over dominance for 8 out of 14 characters. This over dominance observed, might not be an index of real dominance at genetic level because combination of positive and negative genes or complementary type of gene interaction of simply correlated gene distribution, might seriously inflate the mean degree of dominance and also convert partial dominance into perceptible over dominance **(Hayman, 1954)**. The average degree of dominance in the range of over dominance results from repulsion phase linkage of genes in the partial or complete dominance range. The linkage bias was also proved by **Comstock *et al.* (1957), Robinson (1960), Moll *et al.* (1964), Singh *et al.* (1982), Govil *et al.***

(1983), Liv and Liv (1989) and **Yadava *et al.* (1990)**. The over dominance for most of the traits under this study was also reported by **Singh *et al.* (2001)**.

Most of the traits under study except days to flower and maturity, plant height, length of main raceme, number of primary and secondary branches, number of siliquae on main raceme, 1000-seed weight and protein content exhibited prevalence of additive gene action, showed pre-ponderance of non-additive genetic variance. These results indicate that the genetic gain in these characters would be difficult by selection and that non-additive genetic variance should be exploited through heterosis breeding. Since male sterility has been introduced in Indian mustard from alien species, there is every chance to exploit this phenomenon in future. Indian Council of Agricultural Research has included this crop in a special mission mode project" Exploitation of heterosis in selected crops".

Till the dream of exploitation of hybrid vigour through the use of male sterility happens true, the non-additive genetic variability can be exploited by recurrent and modified recurrent selection methods. Though these procedures pore difficulties, particularly in self-pollinated crops, but have promised to furnish encouraging results. The recurrent selection has been used in many cross-pollinated crops like sugarcane. The main problem in using this mythology in self-pollinated crops is difficult in making sufficient crosses to initiate recombination portion in real cycle. However, with the development of male sterility, this difficulty will be resolved.

The additive portion of variability observed in days to flowering and maturity, plant height, length of main raceme, number of primary and secondary branches, number of siliqua on main raceme, 1000-seed weight and protein content in the present study suggests that improvement in these characters can be affected by simple breeding procedures, such as pedigree method or modified pedigree method involving selection based on progeny performance. However, it has been observed that additive genetic variance in self-pollinated crops rapidly fixes after F_2 generation resulting in restricted recombinations.

The major limitation in Indian mustard is the difficulty of infusing massive gene flow during recombination phase and the limitation of having sufficient quantity of seed required for multi-location testing under several environmental conditions. However, these difficulties can be overcome by increasing the rapidity and efficiency of manual hybridization, promoting some kind of out- crossing through genetic male sterility with specific respect, delayed dehiscence or protogyny into the population and reducing seed number and plot size required for testing. Alternatively, seed production can be made possible by the use of induced male sterility, self incompatibility, advanced stigma or other system which ensure hybrid seed production.

In Indian mustard, **Singh (1972)** suggested the use of selected procedures that may allow intermating of improved genotypes in successive generation. **Singh (1973)** suggested that in Indian mustard rapid progress could be made by family selection, involving occasional intermating in subsequent generation. This might prove more effective than the conventional procedure of mass or pedigree selection, both in fixing and increasing the frequency of pleiotropic genes and chromosomes both of favourably linked genes in superior lines.

5.2 Performance of parents and their crosses in respect of combining ability effects

The information about the performance of the parents and their crosses along with their combining ability is of paramount importance to the breeders for isolation of better combining lines to be used in subsequent breeding programmes.

The parents used in the present study were found to differ significantly in their gca effects. Also, none of them was found to be a good general combiner for all the 14 traits. However, among females Urvashi, Sita, RK 9901, RK 9902, Basanti, RK 2003, RK 9803, RK 2003 and RK 9804 and among males Varuna and Vardan were found good combiners for majority of the traits. Therefore, these lines may be used in multiple crossing. It has been observed that the mean performance of the parents was associated with their gca effects.

The gca effects for different characters of economic importance are useful for selecting parents with favourable genes for different components of yield, such as number of primary and secondary branches, length of main raceme and number of siliquae on main raceme. It is bare fact that gca effects are governed by additive and additive x additive components of gene action which are fixable in action. Therefore, additive effects of parents, which are measured, by gca effects are of practical use to the breeders. On the other hand, non-additive interactions are not predictable as they are not fixable and this cannot be easily manipulated.

The sca effects normally do not contribute towards the improvement of self-pollinated crops, as they are not fixable, the exception is the situation where possibility of commercial exploitation of heterosis exists. The breeder's interest in self-pollinated crops is, involving of parents of high gca effects and ultimately to produce homozygous lines. **Jinks and Jones (1958)** emphasized that the superiority of the hybrid in terms of mean might not indicate its ability to produce transgressive segregants due to non-fixable portion of variance. Therefore, in segregating generations, sca would be important in self-pollinated crops like Indian mustard.

Critical review of results on specific combining ability of the crosses clearly showed that none of the 80 crosses was associated with high sca effects for all the characters. However, the crosses which exhibited significant and desirable sca effects are Krishna x Kranti, Krishna x Varuna, Sita x Varuna , Sita x Vardan, Urvashi x Rohini, Urvashi x Varuna, Urvashi x Vardan and all the crosses involving RK 9901 as one of the females as assessed through F_1 population. However, in F_2 population also, the above crosses were found associated with significant and desirable values of sca effects. Among all the crosses Jawahar I x Varuna was found showing high performance both for seed yield and oil content and also exhibited highly significant desirable sca effect. This cross could be utilized for exploiting heterosis. It is to mention here that both these parents of this cross-exhibited highly significant and positive gca effects for seed yield and oil content. Therefore, the major portion of sca effects might be governed by additive and additive x additive type of gene actions. Hence, the segregating population of this cross would be quite useful in isolating high yielding and high oil possessing pure lines. Also, these lines can also be utilized in hybridization programme. This cross and other crosses where these parents are involved could also be utilized for the production of desirable segregants by adopting bi-parental progeny selection as suggested by **Andrus (1963)** on the model of **Comstock** and **Robinson (1948)** of Design III. **Singh (1972)** also advocated intermating among selected genotypes in a bi-parent fashion in early generation and then bulking of the best families to produce phenotypically uniform but genetically buffered variety.

The two crosses viz., Krishna x Varuna and Krishna x Vardan showed positive and significant sca effects, for seed yield and oil content. Each of these crosses involve one of the parents as positive (desirable) and other with negative (undesirable) for high x low general combiners. The desirable positive sca effects might have been resulted due to additive component in good combiner and complementary epistatic effects present in poor combiner acted in complementary fashion to minimize plant attributes, which could be exploited further in an appropriate, breeding programme. Such specific combinations could produce desirable transgressive segregants as reported by **Jenson (1970)** in self-pollinated crops. The *inter se* crossing of the crosses in all possible combinations for multiple parents into a central pool would help in facilitating the recombinations by breaking the undesirable genetic block **(Jenson, 1970)**.

5.3 Heterosis

In general, the term heterosis refers to the increased vigour of F_1 over the mean of its parents or even better parent or economic parent and it may not be due to any single genetic cause. **Hayes (1946)** considered that heterosis and dominance were different degrees of expression, of the same physiological genetic phenomenon. According to **Griffting (1956)**, the expression of heterosis was due to accumulation of desirable genes in a hybrid plant through crossing of parents in their genetic makeup and it was very much related to the magnitude of genetic diversity. **Moll *et al.* (1964)** were of the view that heterosis was mostly dependent on genetic diversity present in the parental stock.

In the present investigation, the degree of heterosis has been measured as superiority of F_1s over the best variety recommended. Unless the hybrid is superior to the existing best variety, it cannot be economically exploited. Keeping this point in mind the heterosis has been worked out over the best variety, Varuna.

Yield is the interaction of many direct and indirect components. Thus, it may be of great interest to discuss the results obtained in the light of recent concept of genetic basis of yield. **Grafius (1959)** and **Whitehouse *et al.* (1958)** have suggested that there may not be any gene system for yield *per se* which largely an artefact is. Several investigators (**Keeble** and **Pellow, 1970; Grafius, 1956** and **1959; Williams** and **Gilbert, 1960, Durarte and Adams, 1963; Coyne, 1965)** concluded that the genetic basis of heterosis for a complex trait like yield could be explained by the multiplicative interaction on the phenotypic level of component traits.

The results presented in Table 12 revealed that none of the crosses exhibited economic heterosis for all the traits. Out of 80 crosses, as many as 77 exhibited significant heterosis, which ranged from 12.95 % by the cross Sanjukta x Rohini to 87.04 % by the cross Pusa Basant x Rohini. The later cross also exhibited respectable amount of heterosis for a number of primary and secondary branches, number of seeds per siliqua, biomass and seed weight, which are strong components of yield. The preponderant role of dominance in the magnitude of over dominance in the crosses exhibiting highly significant and positive heterosis for seed yield could be the reason for maximum heterosis for seed yield. **Grafius (1959)** suggested that there might not be any gene system for yield, as it is an end product of multiplicative interaction between different components. Thus, this would suggest that heterosis for yield should be through heterosis for individual yield components or alternatively due to multiplicative factors, prevailing partial dominance of component characters. Therefore, it is desirable to understand the relationship between heterosis for yield components. It has been observed that in most of the crosses displaying heterosis for yield the heterosis has also been manifested for yield components like primary and secondary branches, length of main raceme, number of siliquae on main raceme, number of seeds per siliqua and seed weight. Similar findings were reported by **Singh (1973), Singh *et al.*(1975), Banga and Labana (1984), Dhillon *et al.* (1990), Hirve and Tewari (1991), Verma *et al.* (1998), Agrawal and Badwal (1998), Tyagi *et al.* (2000), Katiyar *et al.* (2000), Verma *et al.* (2000) and Patel *et al.* (1999)**.

In Indian mustard, hybrid seed production can be made feasible by the use of induced male sterility, self-incompatibility **(Singh *et al.* 1961)** and advance stigma **(Asthana** and **Singh, 1964)** or other genetic systems which ensure hybrid seed production.

A combination of good general combiners did not ensure the best specific crosses. For instance, a high x low general combiners resulted in heterosis and high x high general combiners failed to exhibit this phenomenon.

5.4 Inbreeding depression

A large number of crosses displaying heterosis exhibited sizeable magnitude of inbreeding depression. This suggested that heterosis was the result of dominance and epistatic gene actions. On the other hand, some of the crosses showed superiority of F_2 over its F_1 generation. This clearly suggested that the heterosis was manifested by the epistatic gene action of additive x additive nature. Such crosses are useful for isolating the superior pure lines.

5.5 Heritability and genetic advance

Heritability is the index of transmissibility of characters from parents to offsprings and it helps the breeders in selection process. **Hansen (1963)** reviewed the utility of heritability estimates in biometrical studies and pointed out that the heritability estimates are influenced by method of estimation, generation of study, sample size and environmental factors. The heritability estimates coupled with genetic advance may provide a better picture to the plant breeders for exercising selection effectively. **Robinson (1966)** classified heritability as low (<10%), medium (10-30%) and high (> 30%). In the present investigation high to very high heritability estimates were recorded for all the characters as estimated through parents, F_1s and F_2s. However, both heritability and genetic advance of high magnitude were observed for number of primary branches, number of siliquae on main branches, 1000-seed weight and seed yield. Oil and protein content showed low genetic advance which reflected the role of non-additive gene action which support the earlier reports of **Labana *et al.* (1980), Jindal *et al.* (1985), Podlkolzina** and **Shopta (1989), Chawdhary** and **Goswami (1991), Mandal** and **Khajuria (2000), Ghose** and **Gulati (2001)** and **Rao** and **Gulati (2001).**

5.6 Correlation

The knowledge of nature and magnitude of genetic association of yield components is of economic value which can help in improving the efficiency of selection by making possible use of suitable combinations of characters for such selection. **Adams (1967)** pointed out that yield components and other plant characteristics are determined at different stages in the ontogeny of the plant, they are affected differentially by the environmental factors. At the same time compensation between yield components may lead to variation in correlation pattern and therefore, stressed the need for centennial investigation of inter-relationship between yield components.

Johnson *et al.* (1955) emphasized the importance of genotypic environment *interactions* and their *contribution* to genetic slippage in the selection of complex characters. Therefore, the studies under different environments might give clear and reliable picture of association, which can effectively be utilized for selecting yield components. **Dewey and Lu (1959)** emphasized to recognize the nature of population under consideration as the magnitude of correlation could be included by choice of individuals upon which the observations are made.

In the present investigation correlation at environmental, phenotypic and genotypic levels each among 24 parents, 80 F_1s and 80 F_2s were estimated separately. In general, the genotypic correlation coefficients were higher in magnitude than their phenotypic counterparts. Also, the phenotypic correlations were same in direction revealing the pleiotropic effect rather than the linkage for these associations.

Seed yield was found significantly and positively associated with plant height, number of secondary branches, number of seeds per siliqua, biomass, harvest index and 1000-seed weight among the parents both at phenotypic and genotypic levels. Among different characters, days to flowering was associated with days to maturity, likewise, plant height with length of main raceme, oil content was found positively associated with days to flowering.

In F_1s seed yield was found positively and significantly associated with number of primary branches, biomass and oil content both at phenotypic and genotypic levels. On the other hand, among F_2 population seed yield has shown positive and highly significant association with days to maturity, number of primary and secondary branches, number of seeds per siliqua and harvest index both at phenotypic and genotypic levels

The above findings are in agreement with those of **Thakral (1982), Yadav (1982, 1983), Labana *et al* (1980), Richards and Thuking (1987b), Ahmed (1980), Singh *et al.* (1980), Kumar *et al,* (1987),Badwal and Labana (1987), Chaudhary *et al.* (1980) and Chaudhary *et al.* (1994).**

SUMMARY

SUMMARY OF THE THESIS

The present investigation "Study of genetic parameters of yield and its components and quality traits in *Brassica juncea* (L.) Czern. & Coss. Was carried out during 2002 at CSAUA&T, Kanpur and the results obtained on above aspects have been summarized below:

6.1. The variance due to replications was found non-significant for all the 14 characters, which suggested that the environmental conditions in the site of the experiment were uniform and homogeneous.

6.2. In the present study 20 female lines and 4 testers were used they are significantly different from one another for almost all the characters.

6.3. A set of 80 F_1 crosses was found statistically different from one another for 13 out of 14 characters.

6.4. These crosses were also found significantly different from their parents, thus suggested the existence of heterosis, irrespective of direction.

6.5. The 80 F_2 populations were also found significantly distinct from one another. Also, the F_2 populations as a whole were statistically different from F_1 crosses as a whole, which suggested that the F_2 population were exhibiting inbreeding depression, irrespective of the direction over F_1.

6.6. For mean performance the parents were statistically variable from one another in respect of all the characters, thus fulfilled the requirement of line x tester analysis technique.

6.7. In most of the cases the performance of F_1s was exceeded to the parents and the range was also widened in almost all the characters.

6.8. High range in the performance of 80 F_2 populations was recorded for 11 characters, exception being number of siliquae on main raceme and oil and protein content.

6.9. Through combining ability analysis it has been observed that variances due to females, males and interaction between females and males were found highly significant for almost all the characters, except protein content.

6.10. The gca variance was found higher than sca variance for days to flowering and maturity, plant height, length of main raceme, number of primary and secondary branches, number of siliquae on main raceme and 1000-seed weight. On the other hand, sca variance was found greater than gca counterpart for number of seeds per siliqua, biomass, harvest index and oil content. However, for seed yield and protein content both the variances were found almost equal in magnitude.

6.11. According to the estimates of degree of dominance, over dominance has been expressed for days to flower and maturity, plant height, length of main raceme, number of primary and secondary branches, number of siliquae on main raceme and 1000-seed weight.

6.12. Partial dominance was observed for number of seeds per siliqua, biomass, harvest index and oil content.

6.13. No dominance was recorded for seed yield and protein content.

6.14. None of the 24 parents was found to be a good general combiner for all the 14 characters. However, among the females Urvashi, Sita, RK 9901, RK 9902, Basanti, RK 2003, RK 9803, and RK 9804 and among males Varuna and Vardan were found good general combiners for majority of the traits.

6.15. None of the 80 crosses evaluated was found associated with significant sca effects for all the characters. However, about 50% of the crosses showed highly significant sca effects for a large number of characters in both the populations.

6.16. The crosses Basanti x Vardan in F_1 and Basanti x Varuna in F_2 gave highly significant and positive sca effects for seed yield.

6.17. Heterosis in F_1 population was estimated over most popular variety Varuna. A large number of crosses expressed superiority over this variety for length of main raceme, number of primary and secondary branches, number of seeds per siliqua, biomass, harvest index, seed weight and seed yield.

6.18. Inbreeding depression i.e., reduced performance of F_1 vis-a-vis its F_1 progenitor was recorded for variable number of crosses in all the characters.

6.19. On the other hand, in some cases F_2 showed superiority over F_1 such as for length of main raceme, number of primary and secondary branches, number of siliquae on main raceme, number of seeds per siliqua, biomass, harvest index, seed weight, seed yield and oil and protein contents.

6.20. For seed yield the F_2 population of the cross RK 9803 x Varuna showed 61.58% superiority over its F_1.

6.21. Heritability in a broad sense estimated in parents was found having high range for most of the characters. However, it ranged from 40% for oil content to 99% for plant height, length of main raceme and number of siliquae on main raceme.

6.22. In F_1 population, very high (>90%) values of heritability were expressed by all the characters.

6.23. In F_2 population also similar trend for heritability was recorded, as was found in F_1 population.

6.24. Among parents, a very wide range in the estimates of genetic advance was recorded, from 2.4% for oil content to

6.24. In F_1 also, very wide range, from 6.31% for oil content to 50% for 1000-seed weight was recorded for genetic advance.

6.25. In F_2 population also, oil content and 1000-seed weight exhibited lowest (7.11%) and highest (49.4%) estimates of genetic advance, respectively.

6.26. In general, genotypic correlation was found higher than the phenotypic ones.

6.27. For most of the character combinations the environmental correlation was found non-significant.

6.28. Among parents, days to flower with 5; days to maturity with 2; plant height with 1; number of primary branches with 1; number of secondary branches with 3; number of siliquae on main raceme with 1; biomass with 1; harvest index with 2; and seed weight with 1 characters showed positive and significant correlation.

6.29. At genotypic level also, similar trend was observed as for phenotypic correlation recorded among the parents.

6.30. In F_1 population, none of the characters showed significant and positive correlation at environmental level.

6.31. At phenotypic level a large number of character combinations exhibited significant correlation at 5%, on the other hand, 20 character combinations showed positive correlation significant at 1% level.

6.32. As many as 26 character combinations exhibited positive and 12 negative and significant correlation at genotypic level in F_1 crosses.

6.33. In F_2 population, days to flower with 2; days to maturity with 4; plant height with 3; length of main raceme with 2; number of primary and secondary branches with 3 each; number of siliquae on main raceme with 2; number of seeds per siliqua and biomass, harvest index, oil and protein content with 1 each have exhibited positive and significant correlation at phenotypic level.

6.34. Only a few character combinations exhibited highly significant and positive correlation at genotypic level in F2 populations.

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TABLES

Table: 3 : ANOVA for 14 characters involving parents and F_1s in Indian mustard- MSS

Source of variety	d.f	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Replication	2	14.153	3.179	21.046	-0.371	0.062	0.040	3.846	0.667	16.871	0.483	0.052	0.201	0.435	-0.076
Population	183														
Parents	23	36.907*	81.184*	1402.02**	394.22**	3.301**	6.610	484.46**	5.494**	214.83**	22.838**	0.357	33.343**	2.169**	4.531*
Females	19	38.495*	95.062**	1519.73**	466.44**	3.505**	5.730**	426.64**	5.152**	219.76**	18.932**	0.343	23.399**	2.190**	5.178*
Males	3	20.750**	8.750**	462.75	61.568	1.227	2.49**	214.75**	9.116**	89.554**	38.139**	0.503	60.354**	0.207	0.404
Female x Male	1	55.218**	34.812**	1983.37**	20.082**	5.679**	35.68**	2392.17**	1.114	497.02**	40.789**	0.194	141.24**	7.656**	4.613*
F_1s	79	63.664**	218.86**	1404.85	188.10**	10.602**	15.778**	135.83**	11.212**	154.09**	30.999**	3.258**	12.143**	4.721**	7.180*
F1Vs Parents	1	59.625**	369.25**	353.00	223.40	123.82**	324.42**	1105.64**	189.32**	2815.00**	16.960**	11.239**	268.87**	122.50**	25.015
F_2s	79	62.743**	93.054**	864.72	115.14	9.453**	42.317**	121.54**	9.175**	159.02**	69.234**	2.828**	53.160**	7.208**	9.057*
F_2 vs F_1s	1	259.648**	1931.02**	526.61	572.97	12.500**	61.080**	274.11**	220.63**	6.30**	771.31**	5.905**	1948.3**	6.044**	11.855
Error	206	0.940	1.189	2.291	0.296	0.094	0.195	0.820	0.176	1.949	0.613	0.022	0.168	0.246	0.10[illegible]

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table-4 : Mean performance of 24 parents of 20 x 4 line x tester cross in *B. juncea* (L.) Czern. & Coss. for 14 characters.

PARENTS	CHARACTERS													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sanjukta	43.00	125.00	111.00	36.07	9.40	12.07	26.00	13.23	80.00	27.66	3.10	22.13	38.33	27.89
Pusa Basant	51.00	139.00	147.00	49.30	6.87	13.50	67.00	11.60	69.33	24.10	4.12	16.71	38.00	27.49
Pusa jaikisan	50.00	135.00	176.00	59.77	5.67	12.00	60.00	10.53	84.00	27.99	3.72	23.51	37.67	28.55
Pusa Bahar	50.00	125.67	148.00	44.07	6.53	12.20	48.00	10.47	75.67	27.58	3.67	20.87	38.72	28.92
Krishna	53.00	126.00	174.00	39.87	6.17	13.87	40.00	11.67	76.00	27.63	3.42	21.00	38.00	29.67
Urvashi	51.00	128.00	130.00	35.03	6.63	12.77	38.00	11.43	08.33	30.12	4.23	26.60	38.50	29.10
Sita	43.00	115.00	132.33	35.43	6.90	8.50	27.00	10.63	58.33	23.93	3.25	13.96	37.80	23.35
RK-9901	51.00	132.00	183.33	56.53	4.40	13.97	41.00	10.60	83.00	27.82	3.75	23.13	37.00	26.04
RK-9902	48.00	133.67	163.33	51.57	5.70	10.60	67.67	11.00	83.00	24.41	4.07	20.26	38.30	29.45
RK-2007	43.00	125.00	122.67	47.60	6.83	12.27	54.00	9.30	90.33	21.63	3.84	19.54	37.17	29.80
RK-9807	53.00	130.00	113.00	44.67	9.00	12.17	54.00	9.13	90.67	20.14	3.35	18.25	39.00	29.56
Basant	53.00	135.33	166.67	49.80	6.80	1.17	38.00	12.33	83.33	25.74	3.91	22.74	39.07	29.67
Jawahar-1	50.00	129.00	162.00	47.33	6.80	1.50	35.00	11.63	81.67	24.72	3.73	20.18	39.00	29.24
Vaibhav	46.00	123.00	125.00	31.17	5.97	10.50	35.00	9.33	63..67	28.28	3.92	18.01	37.30	26.61
Pusa Boald	49.00	128.00	145.00	87.40	6.67	13.23	54.00	12.23	86.67	27.18	4.30	23.56	37.90	28.56
RK-2001	47.00	130.00	119.00	60.90	6.17	17.33	53.33	12.63	82.33	28.06	4.10	23.10	36.17	25.22
RK-2002	46.00	133.67	123.00	52.57	7.00	13.50	45.67	10.00	74.67	27.79	3.31	20.75	36.83	27.84
RK-2003	45.00	120.00	133.00	44.63	6.63	13.13	47.00	11.53	78.67	26.38	3.82	20.75	37.20	28.88
RK-9803	54.00	127.67	120.00	38.77	7.67	13.67	42.00	9.10	75.00	26.14	3.73	19.60	39.33	28.15
RK-9804	52.00	131.33	161.00	53.90	6.67	13.33	61.00	13.03	76.00	29.16	4.02	22.15	38.33	30.07
Kranti	55.00	125.00	156.00	50.90	7.20	13.83	67.00	9.33	86.33	26.19	3.83	20.60	39.10	29.57
Rohini	51.00	126.00	174.00	49.23	6.83	14.50	59.00	13.30	89.33	29.67	4.11	26.51	39.69	28.80
Varuna	50.00	127.00	155.00	40.57	8.33	15.20	52.00	10.23	91.00	32.72	4.31	29.78	39.83	29.20
Vardan	49.00	129.00	144.00	46.77	7.53	13.07	71.00	10.17	78.67	24.80	3.32	19.51	39.74	29.56

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

Table-5 : **Mean performance of F_1s of 20 x 4 line x tester cross in *B. juncea* (L.) Czern. & Coss. for 14 characters**

Cross Combination	1	2	3	4	5	6	7
Sanjukta x Kranti	43.00	140.00	123.67	55.03	7.70	13.93	38.00
Sanjukta x Rohini	44.67	137.00	123.33	54.00	10.47	16.43	41.00
Sanjukta x Varuna	44.33	134.67	126.00	49.80	7.40	10.93	40.00
Sanjukta x Vardan	45.00	134.33	123.00	52.50	7.70	15.20	47.00
Pusa Basant x Kranti	50.33	132.33	165.33	52.13	6.97	14.33	66.00
Pusa Basant x Rohini	48.67	133.67	161.00	52.37	9.00	13.73	61.00
Pusa Basant x Varuna	51.33	129.00	171.64	47.40	7.50	12.57	60.00
Pusa Basant x Vardan	49.33	129.67	163.00	51.27	9.10	14.70	68.33
PusaJaikisan x Kranti	54.33	138.00	169.67	56.50	8.40	14.10	63.33
Pusa Jaikisan x Rohini	56.67	131.67	159.00	58.77	7.70	14.63	57.00
Pusa Jaikisan x Varuna	53.33	136.00	183.00	53.47	6.40	12.53	56.67
Pusa Jaikisan xVardan	50.00	135.00	161.33	55.83	6.40	12.60	68.00
Pusa Bahar x Kranti	54.00	138.00	164.67	49.83	8.30	15.23	56.67
Pusa Bahar x Rohini	53.33	135.00	159.33	49.23	8.20	17.40	54.00
Pusa Bahar x Varuna	54.00	131.67	135.00	44.30	6.03	11.37	50.00
Pusa Bahar x Vardan	53.67	130.00	131.00	45.87	6.30	12.83	58.00
Krishna x Kranti	56.00	136.00	135.33	47.50	5.60	12.97	53.33
Krishna x Rohini	53.00	130.00	132.00	44.77	7.60	12.27	50.00
Krishna x Varuna	50.67	129.00	127.00	40.90	7.33	12.97	46.00
Krishna x Vardan	52.33	129.00	136.00	45.30	7.10	13.40	54.00
Urvashi x Kranti	54.00	136.00	133.33	45.23	7.30	13.43	51.00
Urvashi x Rohini	51.00	131.00	160.00	44.40	5.63	12.10	47.00
Urvashi x Varuna	51.33	143.00	175.67	38.73	6.23	12.67	45.33
Urvashi x Vardan	50.00	139.00	159.00	42.27	6.70	16.00	52.33
Sita x Kranti	40.00	131.00	111.67	45.27	5.10	10.70	
Sita x Rohini	43.00	133.00	111.00	44.97	9.10	13.00	42.67
Sita x Varuna	48.00	130.00	110.33	40.37	4.80	9.00	36.33

Sita x Vardan	48.00	132.67	111.33	42.80	8.10	12.87	46.00
RK-9901 x Kranti	50.00	130.00	165.67	56.73	6.30	14.30	52.00
RK-9901 x Rohini	51.00	129.00	159.00	57.00	6.60	14.37	50.00
RK-9901 x Varuna	52.00	133.00	170.33	51.27	5.20	13.90	46.00
RK-9901 x Vardan	54.00	133.00	173.67	55.93	6.03	15.83	56.33
RK-9902 x Kranti	56.70	139.00	165.67	54.03	5.23	14.27	64.00
RK-9902 x Rohini	55.00	140.33	164.00	52.37	8.73	15.90	62.00
RK-9902 x Varuna	52.67	138.00	161.00	47.10	6.23	11.80	58.33
RK-9902 x Vardan	51.67	136.00	163.67	49.30	6.30	13.40	67.33
RK-2007 x Kranti	47.00	120.00	119.00	50.63	8.97	15.93	61.33
RK-2007 x Rohini	50.00	122.33	119.00	49.70	11.33	16.37	56.33
RK-2007 x Varuna	47.33	120.00	118.67	44.60	9.10	15.77	54.00
RK-2007 x Vardan	49.33	120.00	121.00	49.37	10.00	15.47	60.33
RK-9807 x Kranti	43.00	118.33	133.00	51.17	9.63	15.63	61.00
RK-9807 x Rohini	41.00	116.33	130.00	48.67	10.93	17.50	58.00
RK-9807 x Varuna	45.00	120.67	132.00	45.30	9.10	13.77	53.00
RK-9807 x Vardan	47.00	118.32	130.00	47.33	10.10	14.77	61.00
Basanti x Kranti	49.67	138.67	174.67	52.50	7.40	15.20	50.00
Basanti x Rohini	52.00	139.00	173.67	52.37	10.30	15.23	47.00
Basanti x Varuna	47.00	142.33	179.00	47.70	8.77	11.50	93.00
Basanti x Vardan	51.00	140.00	173.67	49.77	10.33	16.10	53.67
Jawahar-1 x Kranti	51.67	139.00	160.33	50.77	8.00	11.50	59.00
Jawahar-1 x Rohini	48.00	126.00	149.00	48.57	6.10	11.97	54.33
Jawahar-1 x Varuna	51.00	130.00	163.00	45.83	7.03	12.60	54.00
Jawahar-1 x Vardan	53.00	125.33	158.00	48.57	8.20	11.83	60.00
Vaibhav x Kranti	51.00	127.67	151.33	43.70	8.50	20.60	44.00
Vaibhav x Rohini	47.00	131.33	175.33	41.53	8.97	18.57	47.00
Vaibhav x Varuna	50.00	129.00	173.33	39.20	7.27	16.73	56.00
Vaibhav x Vardan	51.00	131.00	170.33	40.50	7.30	18.47	57.00
Pusa Bold x Kranti	50.00	125.00	173.67	71.20	7.60	15.60	48.33

Pusa Bold x Rohini	51.00	123.67	174.00	70.47	9.30	19.30	46.00
Pusa Bold x Varuna	44.00	120.00	177.67	69.73	9.23	14.87	54.00
Pusa Bold x Vardan	47.00	124.00	162.00	60.30	8.77	16.73	50.00
RK-2001 x Kranti	41.32	144.00	122.00	57.38	8.40	17.40	60.00
RK-2001 x Rohini	41.33	147.00	122.00	57.50	10.00	17.97	54.00
RK-2001 x Varuna	42.00	140.67	123.33	54.03	7.10	13.93	54.33
RK-2001 x Vardan	43.00	144.00	136.00	56.30	8.37	16.37	60.00
RK-2002 x Karnti	42.67	146.67	138.33	52.67	9.03	18.57	57.00
RK-2002 x Rohini	45.00	144.33	134.00	54.63	10.07	20.20	51.00
RK-2002 x Varuna	42.00	147.00	139.67	49.40	11.03	18.72	48.67
RK-2002 x Vardan	47.00	164.33	130.33	52.30	10.47	16.27	55.33
RK-2003 x Kranti	39.00	127.00	129.00	51.27	8.73	17.23	57.33
RK-2003 x Rohini	41.33	128.33	177.67	49.30	10.87	17.30	55.00
RK-2003 x Varuna	40.33	129.00	130.00	43.57	10.47	16.30	50.00
RK-2003 x Vardan	39.00	126.00	139.00	47.70	10.70	16.63	57.33
RK-9803 x Kranti	43.33	119.67	143.00	47.50	9.13	15.97	54.00
RK-9803 x Rohini	42.33	120.67	139.00	46.97	10.83	18.07	50.00
RK-9803 x Varuna	39.33	116.67	149.00	42.00	10.70	17.23	48.00
RK-9803 x Vardan	39.67	119.00	159.67	43.47	10.81	16.97	56.00
RK-9804 x Kranti	50.67	116.00	159.67	5.10	7.10	15.17	61.00
RK-9804 x Rohini	51.33	114.67	166.33	51.70	10.13	16.82	59.00
RK-9804 x Varuna	46.33	118.00	153.67	47.63	9.07	13.20	55.33
RK-9804 x Vardan	48.00	114.00	161.00	53.23	8.43	15.17	63.00

Cross Combination	8	9	10	11	12	13	14
Sanjukta x Kranti	12.17	82.33	27.78	3.53	22.77	38.83	29.62
Sanjukta x Rohini	12.60	84.00	30.06	2.89	25.22	39.80	29.90
Sanjukta x Varuna	12.47	80.33	30.80	3.45	24.75	40.50	29.76
Sanjukta x Vardan	11.43	85.00	29.04	20.49	24.69	40.10	29.87
Pusa Basant x Kranti	12.30	86.00	26.59	4.32	23.01	39.53	30.45
Pusa Basant x Rohini	12.40	97.67	23.44	6.21	22.89	38.33	30.29
Pusa Basant x Varuna	10.30	94.67	20.74	5.09	19.63	39.37	30.37
Pusa Basant x Vardan	12.57	70.00	22.58	5.62	20.32	39.20	30.95
Pusa Jaikisan x Kranti	9.70	101.00	26.25	4.74	26.51	39.00	30.58
Pusa Jaikisan x Rohini	10.23	83.00	31.11	4.07	25.82	39.37	30.20
Pusa Jaikisan x Varuna	9.87	85.00	31.51	5.07	26.78	39.43	29.46
Pusa Jaikisan x Vardan	11.67	87.00	29.92	3.67	26.04	39.87	29.71
Pusa Bahar x Kranti	12.03	92.33	25.01	3.13	23.09	40.00	28.20
Pusa Bahar x Rohini	11.80	103.67	22.03	3.83	22.84	39.87	28.25
Pusa Bahar x Varuna	11.70	104.33	22.06	5.04	23.02	40.43	30.48
Pusa Bahar x Vardan	10.80	98.00	23.45	4.50	22.99	90.65	28.33
Krishna x Kranti	9.23	99.00	23.72	4.17	23.48	40.07	29.78
Krishna x Rohini	9.33	103.00	22.12	3.14	22.79	39.43	28.65
Krishna x Varuna	12.17	100.33	22.37	4.36	22.34	39.90	28.50
Krishna x Vardan	9.63	95.67	23.68	4.54	22.66	39.30	29.42
Urvashi x Kranti	11.67	83.00	28.65	4.42	23.78	38.30	28.01
Urvashi x Rohini	9.77	88.00	50.84	4.39	27.14	39.37	29.61
Urvashi x Varuna	13.37	77.67	32.08	5.34	24.92	38.57	2935
Urvashi x Vardan	12.80	72.67	34.69	5.82	25.39	39.43	27.94
Sita x Kranti	10.90	85.00	22.00	3.82	18.70	36.50	30.10
Sita x Rohini	11.70	80.00	26.17	3.69	20.28	40.33	30.10
Sita x Varuna	11.10	77.00	26.07	5.05	20.07	39.90	28.57
Sita x Vardan	11.60	73.00	28.87	3.02	21.08	36.67	30.51

RK-9901 x Kranti	9.63	79.00	32.05	3.41	24.65	40.17	27.36
RK-9901 x Rohini	13.30	82.00	30.91	3.88	25.34	39.57	30.15
RK-9901 x Varuna	10.30	95.00	29.02	4.03	27.52	39.13	28.19
RK-9901 x Vardan	9.97	92.00	27.33	4.8	25.13	40.73	30.10
RK-9902 x Kranti	13.37	96.67	23.77	4.30	22.98	39.77	30.08
RK-9902 x Rohini	12.60	85.00	27.32	5.51	23.23	39.70	30.39
RK-9902 x Varuna	12.77	87.00	29.97	3.95	26.08	39.53	30.50
RK-9902 x Vardan	12.53	99.00	23.48	4.38	23.25	41.90	30.54
RK-2007 x Kranti	12.07	84.00	25.82	2.93	21.69	39.40	30.17
RK-2007 x Rohini	12.70	85.00	24.82	4.82	21.10	39.23	30.34
RK-2007 x Varuna	13.60	83.00	26.63	3.80	22.10	39.57	30.20
RK-2007 x Vardan	12.90	80.00	24.55	5.04	19.49	39.70	30.27
RK-9807 x Kranti	12.60	88.00	25.61	4.86	22.54	39.20	30.36
RK-9807 x Rohini	12.80	91.00	22.24	4.49	20.24	40.60	30.41
RK-9807 x Varuna	12.90	93.67	22.05	5.02	20.64	41.43	30.27
RK-9807 x Vardan	12.40	95.00	22.42	5.45	21.30	39.30	30.51
Basanti x Kranti	11.80	87.00	25.84	5.79	22.48	39.777	30.26
Basanti x Rohini	12.53	85.00	29.48	4.87	25.06	39.83	31.18
Basanti x Varuna	12.33	83.00	29.24	5.13	24.27	40.43	30.80
Basanti x Vardan	12.53	87.33	30.33	2.69	26.49	38.87	30.60
Jawahar-1 x Kranti	10.00	95.00	24.34	3.15	23.13	39.57	30.10
Jawahar-1 x Rohini	10.33	85.00	26.69	2.78	22.69	39.27	30.58
Jawahar-1 x Varuna	12.20	89.00	26.89	4.77	23.91	41.00	30.53
Jawahar-1 x Vardan	12.50	86.67	27.52	5.63	23.85	40.23	29.00
Vaibhav x Kranti	12.90	77.00	25.96	3.74	19.99	39.73	30.32
Vaibhav x Rohini	12.83	94.67	24.20	3.06	22.74	40.23	29.47
Vaibhav x Varuna	12.40	99.00	22.09	2.24	21.78	40.60	29.86
Vaibhav x Vardan	12.20	80.33	29.35	1.81	23.58	41.80	28.41
Pusa Bold x Kranti	12.30	80.00	31.55	2.57	25.21	40.77	28.76
Pusa Bold x Rohini	12.63	79.67	32.35	2.45	25.77	40.63	30.78

Pusa Bold x Varuna	12.70	87.67	30.82	3.17	27.02	41.63	30.56
Pusa Bold x Vardan	13.40	92.00	29.55	4.62	27.19	40.33	29.48
RK-2001 x Kranti	11.90	86.00	27.68	3.48	23.81	36.30	25.76
RK-2001 x Rohini	11.57	80.00	28.86	5.13	23.09	38.37	24.53
RK-2001 x Varuna	12.73	80.00	28.79	6.14	23.03	38.47	26.59
RK-2001 x Vardan	11.90	80.00	30.02	3.69	24.02	40.23	26.93
RK-2002 x Karnti	12.10	85.00	39.42	2.54	25.01	36.90	27.88
RK-2002 x Rohini	12.93	85.00	29.86	3.47	24.71	39.80	25.51
RK-2002 x Varuna	12.73	87.67	27.08	3.98	23.74	37.27	28.25
RK-2002 x Vardan	12.77	85.33	27.82	4.90	23.74	36.77	28.56
RK-2003 x Kranti	11.97	91.00	25.82	4.70	23.50	37.23	25.91
RK-2003 x Rohini	12.93	93.00	24.92	4.53	24.86	37.13	26.91
RK-2003 x Varuna	12.40	87.00	26.30	5.09	22.88	39.23	25.19
RK-2003 x Vardan	11.90	89.00	27.05	2.89	24.08	38.67	26.48
RK-9803 x Kranti	12.23	87.33	29.63	5.08	25.88	41.00	30.91
RK-9803 x Rohini	12.50	77.67	33.25	3.84	25.82	42.23	30.89
RK-9803 x Varuna	12.80	90.00	29.76	4.48	26.79	40.20	30.08
RK-9803 x Vardan	11.70	92.00	28.35	4.95	26.08	30.90	31.04
RK-9804 x Kranti	11.07	83.00	28.67	3.71	23.81	42.17	3.74
RK-9804 x Rohini	11.23	82.00	29.22	5.25	23.96	40.63	30.76
RK-9804 x Varuna	12.23	87.33	28.51	5.76	24.90	40.00	30.48
RK-9804 x Vardan	11.90	86.33s	28.85	5.05	24.39	41.13	30.83

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

Table-6 : Mean performance of F_2s of 20 x 4 line x tester cross in *B. juncea* (L.) Czern. & Coss. for 14 characters

Cross combination	1	2	3	4	5	6	7
Sanjukta x Kranti	41.33	129.00	128.33	43.17	7.33	12.57	52.33
Sanjukta x Rohini	51.67	127.00	150.00	46.83	11.23	17.07	59.67
Sanjukta x Varuna	39.33	135.67	145.67	46.06	10.37	16.47	55.00
Sanjukta x Vardan	43.00	132.33	150.33	43.57	12.07	16.40	51.33
Pusa Basant x Kranti	37.33	134.00	131.00	41.10	8.40	12.17	49.33
Pusa Basant x Rohini	48.33	151.67	151.00	41.43	11.07	16.10	55.00
Pusa Basant x Varuna	45.00	133.67	145.33	57.00	7.03	16.17	45.00
Pusa Basant x Vardan	46.33	132.67	144.67	50.43	10.20	15.40	61.00
Pusa Jaikisan x Kranti	42.33	134.67	130.00	47.23	6.33	13.23	57.33
Pusa Jaikisan x Rohini	54.00	136.33	147.00	50.20	9.23	14.37	65.33
Pusa Jaikisan x Varuna	45.00	142.67	143.67	56.33	9.10	14.73	60.33
Pusa Jaikisan x Vardan	47.00	139.00	135.67	56.20	10.30	16.17	58.00
Pusa Bahar x Kranti	44.00	138.33	126.33	50.93	8.23	13.07	53.00
Pusa Bahar x Rohini	53.67	139.67	146.33	53.50	9.13	14.17	61.00
Pusa Bahar x Varuna	46.00	141.00	149.33	51.53	11.07	16.13	54.67
Pusa Bahar x Vardan	48.00	138.00	142.33	51.77	12.13	18.17	54.33
Krishna x Kranti	47.00	140.33	131.33	45.81	8.60	15.33	47.67
Krishna x Rohini	52.00	134.33	153.33	50.00	10.23	17.03	57.00
Krishna x Varuna	41.67	132.00	141.00	46.40	9.17	17.03	57.00
Krishna x Vardan	44.67	130.33	140.67	48.97	10.03	17.23	61.33
Urvashi x Kranti	46.33	138.00	145.67	42.50	8.07	14.17	53.00
Urvashi x Rohini	53.67	132.67	167.00	45.57	8.17	15.27	61.33
Urvashi x Varuna	46.67	133.33	141.00	42.00	6.17	15.07	59.33
Urvashi x Vardan	46.00	129.63	140.67	40.10	8.17	14.03	48.33
Sita x Kranti	42.00	128.33	126.67	37.87	7.23	10.07	45.00
Sita x Rohini	53.33	130.00	146.33	40.90	8.17	12.23	51.00
Sita x Varuna	45.67	142.00	143.33	59.83	7.53	20.23	62.67

Sita x Vardan	47.00	138.00	131.00	59.27	8.30	20.40	56.00
RK-9901 x Kranti	42.67	142.00	131.67	55.20	6.17	24.17	53.00
RK-9901 x Rohini	53.33	136.00	152.00	57.20	9.47	21.17	60.33
RK-9901 x Varuna	49.67	140.00	142.67	47.60	8.17	16.23	64.00
RK-9901 x Vardan	51.00	135.00	140.33	48.27	11.07	16.23	59.67
RK-9902 x Kranti	46.00	134.00	126.67	43.93	9.23	14.07	54.00
RK-9902 x Rohini	56.00	132.00	149.67	46.53	10.17	16.17	61.00
RK-9902 x Varuna	57.33	140.67	158.00	49.97	9.20	14.20	56.67
RK-9902 x Vardan	53.33	138.33	158.00	49.65	10.00	15.17	47.00
RK-2007 x Kranti	46.67	138.00	141.67	44.17	7.37	13.07	46.00
RK-2007 x Rohini	50.33	137.00	162.67	46.97	9.07	15.25	51.67
RK-2007 x Varuna	45.67	136.00	163.00	48.67	7.27	18.27	62.33
RK-2007 x Vardan	50.00	136.67	160.33	46.43	10.30	16.07	56.33
RK-9807 x Kranti	45.00	131.67	157.00	45.63	6.70	13.37	50.00
RK-9807 x Rohini	53.67	135.67	157.67	50.17	7.23	18.00	56.00
RK-9807 x Varuna	45.67	140.33	150.67	48.77	6.10	12.50	65.00
RK-9807 x Vardan	46.67	133.67	160.33	46.90	8.23	14.43	63.33
Basanti x Kranti	46.67	138.00	146.67	42.43	6.27	9.17	60.00
Basanti x Rohini	53.67	137.00	147.00	46.90	6.10	13.83	62.67
Basanti x Varuna	41.00	133.33	142.33	49.87	7.07	15.17	62.00
Basanti x Vardan	43.00	131.00	141.67	47.60	10.17	16.50	58.00
Jawahar-1 x Kranti	41.67	132.33	127.00	42.83	5.03	11.27	55.33
Jawahar-1 x Rohini	51.00	132.00	143.00	45.90	8.03	14.27	60.67
Jawahar-1 x Varuna	52.33	139.33	145.33	43.63	9.07	18.23	52.00
Jawahar-1 x Vardan	42.00	135.00	144.00	41.87	8.07	20.40	50.00
Vaibhav x Kranti	39.23	132.33	129.67	37.90	7.13	17.00	46.00
Vaibhav x Rohini	46.00	132.67	148.00	41.50	8.03	16.93	57.33
Vaibhav x Varuna	43.00	134.33	130.00	54.87	4.07	13.60	48.33
Vaibhav x Vardan	44.233	126.33	128.33	52.93	7.10	12.33	45.67
Pusa Bold x Kranti	41.33	128.33	115.67	48.90	5.23	8.33	40.00

Pusa Bold x Rohini	51.00	127.67	136.33	52.97	5.10	11.07	48.00
Pusa Bold x Varuna	46.00	140.67	153.00	49.83	6.17	19.17	60.33
Pusa Bold x Vardan	47.00	135.67	141.00	48.23	7.03	20.37	52.00
RK-2001 x Kranti	47.00	136.33	153.00	48.80	6.07	11.07	58.33
RK-2001 x Rohini	54.00	135.67	140.67	53.50	8.17	16.23	61.67
RK-2001 x Varuna	41.00	136.00	154.00	48.13	7.17	22.30	41.00
RK-2001 x Vardan	43.33	132.33	151.00	47.80	10.13	19.40	52.00
RK-2002 x Karnti	41.67	131.33	137.00	41.77	7.17	14.67	57.33
RK-2002 x Rohini	52.33	131.00	160.00	43.90	8.17	18.30	56.33
RK-2002 x Varuna	46.33	140.00	160.00	44.53	6.30	19.43	55.00
RK-2002 x Vardan	50.00	135.33	146.33	44.17	8.33	20.30	51.67
RK-2003 x Kranti	47.00	134.33	151.33	40.93	7.13	18.23	45.33
RK-2003 x Rohini	53.33	133.67	160.67	42.43	7.17	19.17	56.00
RK-2003 x Varuna	43.32	136.33	140.33	49.77	7.23	15.03	48.33
RK-2003 x Vardan	45.00	103.00	139.67	51.17	9.17	15.07	41.00
RK-9803 x Kranti	41.33	132.00	124.33	46.83	7.57	10.07	39.33
RK-9803 x Rohini	42.00	133.33	142.00	48.73	7.07	12.10	45.67
RK-9803 x Varuna	45.67	142.00	151.00	50.17	5.10	12.30	81.67
RK-9803 x Vardan	50.67	137.00	152.00	49.47	8.10	15.07	81.00
RK-9804 x Kranti	47.33	173.33	138.00	-43.47	5.07	9.07	61.33
RK-9804 x Rohini	53.33	133.67	156.00	47.77	8.10	11.07	64.67
RK-9804 x Varuna	47.33	140.67	165.67	55.17	5.07	17.17	64.67
RK-9804 x Vardan	49.33	133.33	161.00	56.07	7.03	15.07	61.67

Cross Combination	8	9	10	11	12	13	14
Sanjukta x Kranti	17.27	97.00	23.22	4.14	22.51	36.40	26.34
Sanjukta x Rohini	14.00	92.00	23.33	4.97	21.46	35.37	24.82
Sanjukta x Varuna	14.60	95.00	23.50	3.06	22.41	36.50	29.90
Sanjukta x Vardan	12.30	101.33	23.08	3.75	23.37	40.90	30.20
Pusa Basant x Kranti	12.53	76.67	26.72	4.09	20.47	40.20	30.33
Pusa Basant x Rohini	14.00	86.67	23.57	2.83	20.41	38.90	30.50
Pusa Basant x Varuna	11.60	89.67	21.24	3.87	19.00	41.63	30.72
Pusa Basant x Vardan	14.57	85.00	23.50	5.03	19.94	40.83	30.26
Pusa Jaikisan x Kranti	15.00	91.00	27.09	4.75	24.62	39.43	30.31
Pusa Jaikisan x Rohini	14.33	100.67	16.45	4.82	16.54	40.13	30.31
Pusa Jaikisan x Varuna	13.80	101.00	24.09	4.09	24.33	36.63	27.12
Pusa Jaikisan x Vardan	14.23	95.33	20.46	5.06	19.48	37.87	23.40
Pusa Bahar x Kranti	15.30	82.33	30.62	4.84	25.20	36.70	24.24
Pusa Bahar x Rohini	14.90	91.67	27.42	5.32	25.12	37.23	27.00
Pusa Bahar x Varuna	14.37	92.00	27.70	3.24	25.48	37.90	30.54
Pusa Bahar x Vardan	13.80	84.00	26.58	4.14	22.32	36.53	27.24
Krishna x Kranti	10.13	83.00	16.76	3.15	13.92	37.50	29.83
Krishna x Rohini	14.40	92.33	28.76	4.70	26.55	36.20	28.87
Krishna x Varuna	13.47	96.00	25.41	4.16	24.39	38.20	25.13
Krishna x Vardan	14.00	90.67	28.06	2.00	25.42	36.53	28.83
Urvashi x Kranti	15.30	97.00	25.64	4.10	24.87	40.60	30.45
Urvashi x Rohini	5.07	96.00	18.27	4.21	17.54	39.40	27.75
Urvashi x Varuna	14.20	81.00	28.87	4.70	23.38	39.67	30.69
Urvashi x Vardan	14.60	87.00	28.75	2.93	25.01	39.97	31.40
Sita x Kranti	10.97	67.67	20.81	1.79	14.07	40.90	29.65
Sita x Rohini	14.67	72.00	20.13	4.14	14.49	39.00	28.82
Sita x Varuna	14.63	75.67	20.90	4.36	15.79	40.27	34.15
Sita x Vardan	12.23	69.67	23.78	2.80	16.55	40.80	30.70

RK-9901 x Kranti	13.30	86.67	28.76	1.85	24.39	39.87	30.54
RK-9901 x Rohini	11.70	93.33	25.55	3.59	23.68	41.60	30.61
RK-9901 x Varuna	9.73	86.00	19.15	4.19	16.47	35.60	30.07
RK-9901 x Vardan	13.03	90.00	26.51	4.45	23.86	39.70	30.49
RK-9902 x Kranti	12.47	91.00	29.27	3.96	26.65	39.17	30.16
RK-9902 x Rohini	12.90	81.67	32.32	4.15	26.39	33.90	30.86
RK-9902 x Varuna	5.20	89.00	17.25	4.43	15.36	41.23	30.05
RK-9902 x Vardan	12.90	84.00	29.55	5.21	24.82	40.37	30.51
RK-2007 x Kranti	11.97	86.00	32.00	3.80	27.52	39.30	30.16
RK-2007 x Rohini	14.30	91.00	28.48	3.10	25.59	37.93	29.03
RK-2007 x Varuna	14.30	87.00	22.48	5.36	19.56	30.90	31.61
RK-2007 x Vardan	11.90	92.00	22.21	2.46	20.43	31.63	29.22
RK-9807 x Kranti	10.17	95.33	25.55	5.06	24.27	40.67	27.61
RK-9807 x Rohini	14.23	88.00	31.31	2.94	25.77	41.17	30.00
RK-9807 x Varuna	12.17	86.00	25.28	2.72	21.76	37.90	30.44
RK-9807 x Vardan	14.23	88.00	25.94	5.19	22.44	38.77	30.45
Basanti x Kranti	14.53	83.00	31.60	4.92	26.33	39.33	30.57
Basanti x Rohini	12.70	83.00	16.41	4.72	13.62	40.47	30.43
Basanti x Varuna	15.37	92.00	27.35	4.40	27.01	38.90	30.14
Basanti x Vardan	13.47	90.00	17.65	4.83	15.89	41.33	30.80
Jawahar-1 x Kranti	11.43	89.67	26.90	3.76	24.06	41.37	30.89
Jawahar-1 x Rohini	13.90	97.67	24.93	5.20	24.09	39.00	31.07
Jawahar-1 x Varuna	11.30	93.67	27.09	3.96	25.82	41.17	28.75
Jawahar-1 x Vardan	14.87	81.00	28.94	4.13	23.44	39.60	27.52
Vaibhav x Kranti	13.77	72.67	29.71	4.56	21.57	40.73	30.49
Vaibhav x Rohini	7.80	82.33	25.81	3.77	21.24	36.70	26.57
Vaibhav x Varuna	14.90	81.33	26.23	2.08	21.34	38.90	30.05
Vaibhav x Vardan	12.90	77.33	27.75	4.14	21.45	36.40	31.30
Pusa Bold x Kranti	11.50	93.00	24.19	3.75	22.49	37.90	29.29
Pusa Bold x Rohini	13.37	99.00	14.65	3.67	14.51	39.09	30.37

Pusa Bold x Varuna	13.53	89.00	28.45	5.36	25.32	41.27	28.68
Pusa Bold x Vardan	13.57	96.33	14.45	3.79	13.91	39.60	30.19
RK-2001 x Kranti	12.80	86.00	26.25	5.18	22.57	41.53	30.15
RK-2001 x Rohini	15.03	92.00	20.82	4.17	19.15	35.70	30.11
RK-2001 x Varuna	12.57	88.00	24.59	2.96	21.49	40.27	29.37
RK-2001 x Vardan	10.60	89.00	25.10	5.14	22.34	39.90	29.84
RK-2002 x Karnti	9.27	92.00	28.55	4.26	26.27	40.17	31.09
RK-2002 x Rohini	13.30	89.00	15.14	2.82	13.48	39.10	29.38
RK-2002 x Varuna	14.90	85.67	28.36	3.50	24.30	40.87	28.65
RK-2002 x Vardan	15.63	80.00	24.30	4.26	19.44	39.80	30.86
RK-2003 x Kranti	13.30	86.00	28.33	5.06	24.37	38.70	30.14
RK-2003 x Rohini	7.77	89.00	12.65	4.23	11.26	38.87	30.52
RK-2003 x Varuna	14.90	82.00	23.89	3.10	19.59	39.67	27.64
RK-2003 x Vardan	13.17	79.00	31.30	2.75	23.73	39.67	28.32
RK-9803 x Kranti	13.20	95.67	20.98	3.28	19.96	38.90	28.97
RK-9803 x Rohini	15.20	87.67	31.64	2.10	25.08	38.87	29.25
RK-9803 x Varuna	14.57	92.00	11.48	4.15	10.56	39.77	30.53
RK-9803 x Vardan	14.03	89.00	29.87	3.29	26.58	40.50	30.25
RK-9804 x Kranti	12.63	97.67	22.13		22.21	39.60	30.26
RK-9804 x Rohini	13.30	101.33	27.25	3.32	27.61	35.73	30.28
RK-9804 x Varuna	14.53	85.00	29.92	5.10	25.43	38.90	30.56
RK-9804 x Vardan	15.27	98.00	25.48	3.45	24.97	39.90	30.78

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

Table-7 : Analysis of variance for combing ability and estimates of variance due to general (δ^2g) and specific (δ^2s) combining abilities for 14 characters in 20 x 4 parents-line x tester crosses of F_1 generation of *Brassica juncea*

Source of variation	d.f.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lines	19	228.25**	856.01**	5211.23**	640.61**	29.28**	43.26**	425.68**	25.58**	371.55	94.22**	5.95**	40.11**	10.91**	24.47**
Testers	3	12.82**	17.35**	28.81**	446.45**	37.60**	60.08**	539.06**	0.98	19.35**	5.87**	4.23**	3.68**	4.61**	0.47
Line x Tester	57	11.50**	17.09**	200.48**	23.67**	2.95**	4.28**	18.00**	5.95**	88.7**	11.24**	2.30**	3.26**	2.66**	1.77
Error	158	0.83	1.14	2.30	0.21	0.036	0.10	0.81	0.03	2.08	0.58	0.02	0.12	0.07	0.08

Table-8 : Estimates of genetic components its ratio (δ^2g/δ^2s) and degree of dominance $[\delta^2g/\delta^2s]^{0.5}$

Source of variation	1	2	3	4	5	6	7	8	9	10	11	12	13	14
δ^2f	18.06	69.91	416.90	51.41	2.19	3.25	33.97	1.89	23.57	6.91	2.16	3.07	0.69	1.89
δ^2m	0.01	0.00	-2.99	7.05	0.58	0.93	8.68	-0.08	-1.66	-0.09	3.55	0.01	0.03	-0.02
δ^2pooled	6.04	24.27	133.97	28.88	1.69	2.63	25.80	0.49	5.93	2.16	0.15	1.04	0.28	-0.59
δ^2far	3.56	5.32	68.73	7.82	0.97	1.39	5.73	1.97	28.87	3.55	1.87	1.05	0.86	0.56
δ^2g/δ^2s	1.69	4.56	1.93	3.69	1.74	1.89	4.50	0.002	0.20	0.60	1.97	0.99	0.32	1.05
$[\delta^2g/\delta^2s]^{0.5}$	2.13	2.13	1.38	1.92	1.31	1.37	2.12	0.04	0.44	0.77	1.40	0.99	0.56	1.02

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table-9 : Estimates of General combining ability (gca) and mean performance for 14 characters in *Brassica juncea* (L.) Czern.& Coss.

Parents	1			2			3			4			5			6			7		
		gca			gca			gca			gca			gca			gca			gca	
	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2
Sanjukta	43.00	-4.00**	-3.12**	125.00	5.61**	-3.91**	111.00	-24.04**	-2.20**	36.07	2.37**	-3.35**	9.40	-0.03	2.23**	12.07	-0.87**	-0.21	26	-12.33**	-0.75*
Pusa Basant	51.00	1.66**	-2.70**	139.00	0.28	3.09**	147.00	17.21**	-2.78**	49.30	0.33**	-2.26**	6.87	-0.20**	1.15**	13.50	-1.16**	-0.75	67	10.00**	2.25**
Pusa jaikisan	50.00	5.33**	0.13	135.00	4.28**	3.26**	176.00	20.21**	-6.70**	59.77	5.68**	4.29**	5.67	-1.12**	0.72**	12.00	-1.53**	-1.08	60	6.67**	4.91**
Pusa Bahar	50.00	5.50**	0.97*	125.67	2.78**	4.34**	148.00	-0.54	-4.70**	44.07	-3.16**	3.68**	6.53	-1.14**	2.12**	12.20	-0.79**	-0.32	48	0.84**	0.41
Krishna	53.00	4.75**	-0.62	126.00	0.11	-0.66	174.00	-15.45**	-29.20**	39.87	-5.85**	-0.44**	6.17	-1.44**	1.49**	13.87	-1.60**	0.80	40	-3.00**	-1.42**
Urvashi	51.00	3.33**	1.22**	128.00	6.36**	-1.49**	130.00	8.96**	2.80**	35.03	-7.81**	-5.71**	6.63	-1.88**	-0.38**	12.77	-1.45**	-1.07	38	-4.91**	0.16
Sita	43.00	-1.75**	0.05	115.00	0.78**	-0.33	132.33	-36.95**	-8.95**	35.43	-7.11**	6.22**	6.90	-1.57**	-0.21**	8.50	-3.10**	3.53	27	-10.16**	-1.67**
RK-9901	51.00	3.50**	2.22**	132.00	0.36	3.34**	183.33	19.13**	-4.12**	56.53	4.77**	8.82**	4.40	-2.31**	0.69**	13.97	-0.40**	5.24	41	-2.75**	3.91**
RK-9902	48.00	5.25**	4.72**	133.67	7.45**	1.42**	163.33	15.63**	2.30**	51.57	0.24**	-0.69**	5.70	-1.72**	1.63**	10.60	-1.15**	-0.81	67.67	9.09**	-0.67
RK-2007	43.00	0.16	3.72**	125.00	-10.30**	0.76	122.67	-28.62**	11.13**	47.60	-1.89**	-1.69**	6.83	1.51**	0.48**	12.27	0.89**	-0.05	54	4.171**	-1.25**
RK-9807	53.00	-4.25**	0.80	130.00	-12.47**	1.67**	113.00	-16.79**	18.13**	44.67	-2.35**	-0.38**	9.00	2.10**	-0.96**	12.17	0.42**	-1.13	54	4.42**	3.25**
Basanti	53.00	1.66**	-0.87	135.33	9.11**	-0.08	166.67	27.21**	3.63**	49.80	0.12	-1.35**	6.80	0.86**	-0.62**	1.17	-0.49**	-2.04	38	-5.41**	5.33**
Jawahar-1	50.00	2.66**	-2.70**	129.00	-3.30**	-0.24	162.00	9.55**	-5.95**	47.33	-2.03**	-4.69**	6.80	-1.01**	-0.47**	1.50	-3.02**	0.34	35	3.00**	-0.86*
Vaibhav	46.00	1.50**	-3.87**	123.00	-1.14**	-3.49**	125.00	24.55**	1.78**	31.17	-9.23**	-1.45**	5.97	-0.34**	-1.44**	10.50	3.60**	-0.74	35	-2.85**	-7.50**
Pusa Bold	49.00	-0.25	-0.62	128.00	-7.72**	-1.83**	145.00	28.80**	3.22**	87.40	24.96**	1.73**	6.67	-0.38**	-2.14**	13.23	1.63**	-0.97	54	-4.25**	5.25**
RK-2001	47.00	-6.34**	-.62	130.00	13.03**	0.17	119.00	-25.62**	11.4**	60.90	5.95**	1.31**	6.17	.12**	-0.14**	17.33	1.42**	1.54	53.33	3.25**	2.75**
RK-2002	46.00	-4.09**	-0.63	133.67	15.20**	-0.49	123.00	-11.04**	11.55**	52.57	1.79**	-4.66**	7.00	2.81**	-0.53**	13.50	3.45**	2.47	45.67	-0.83**	-0.2
RK-2003	45.00	-8.34**	0.22	120.00	-3.30**	-8.08**	133.00	-18.79**	4.72**	44.63	-2.51**	-2.17**	6.63	2.35**	-0.35**	13.13	1.87**	1.17	47.00	1.09**	-7.6**
RK-9803	54.00	-7.09**	-2.03**	127.67	-11.89**	1.17**	120.00	-5.54**	-3.85**	38.77	-5.48**	0.55**	7.67	2.29**	-1.56**	13.67	2.06**	-3.32	42	-1.83**	-3.1**
RK-9804	52.00	0.83**	2.38**	131.33	-15.22**	1.34**	161.00	12.13**	10.88**	53.90	1.20**	2.37**	6.67	0.34**	-1.71**	13.33	0.23**	-2.61	61	5.75**	7.7**
Kranti	55.00	0.38**	-3.25**	125.00	0.73**	-0.12	156.00	-0.34*	-10.82**	50.90	2.82**	-3.18**	7.20	0.67**	-1.01**	13.83	0.21**	-2.51	67	1.37**	-4.1**
Rohini	51.00	0.08	5.38**	126.00	-0.17	-0.44*	174.00	-0.60**	4.5**	49.23	1.50**	-0.10	6.83	1.05**	0.43**	14.50	1.06**	0.05	59	-1.61**	2.01**
Varuna	50.00	-0.65**	-2.07**	127.00	0.00	3.09**	155.00	0.98**	4.28**	40.57	-3.35**	1.97**	8.33	-0.54**	-0.60**	15.20	-1.35**	1.15	52	-3.23**	3.4**
Vardan	49.00	0.20*	-0.07	129.00	-0.55**	-2.53**	144.00	-0.04	2.48**	46.77	-0.97**	1.31**	7.53	0.17**	1.17**	13.07	0.08*	1.30	71	3.47**	-1.2**

Parents	8			9			10			11			12			13			14		
		gca			gca			gca			gca			gca			gca			gca	
	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2	Mean	F_1	F_2
Sanjukta	13.23	0.28**	0.79**	80.00	-4.67**	8.03	27.66	2.20**	-1.40**	3.10	-1.15**	-0.04	22.13	0.68**	0.74	38.33	0.19**	-2.10**	27.89	0.40**	-1.79**
Pusa Basant	11.60	-0.50**	0.69**	69.33	4.50**	-3.80	24.10	-3.88**	-0.94	4.12	1.07**	-0.06**	16.71	-2.21**	-1.74	38.00	-0.51**	1.00**	27.49	1.13**	0.85**
Pusa jaikisan	10.53	-2.52**	0.59	84.00	1.41**	8.70	27.99	2.48**	-2.68**	3.72	0.15**	0.65**	23.51	2.62**	-0.46	37.67	-0.20**	-0.88**	28.55	0.60**	-1.81**
Pusa Bahar	10.47	-1.31**	0.87**	75.67	12.00**	-0.80	27.58	-4.08**	3.38**	3.67	-0.12**	0.37**	20.87	-0.69**	2.83**	38.72	0.62**	-2.30**	28.92	-0.57**	-2.35**
Krishna	11.67	-2.60**	0.75**	76.00	11.91**	2.20**	27.63	-4.27**	0.05	3.42	-0.19**	-0.57**	21.00	-0.85**	0.87**	38.00	0.06	-2.29**	29.67	-0.30**	-1.44**
Urvashi	11.43	-0.91**	.54**	08.33	-7.25**	1.95**	30.12	9.35**	0.68	4.23	0.75**	0.03	26.60	1.64**	1.00**	38.50	-0.70**	0.51**	29.10	-0.65**	0.47**
Sita	10.63	-1.56**	-0.87**	58.33	-8.84**	-17.50**	23.93	-1.44**	-3.30**	3.25	-0.35**	-0.74**	13.96	-3.64**	-6.48**	37.80	-1.27**	0.85**	23.35	0.43**	1.23**
RK-9901	10.60	-2.09**	-0.06	83.00	-0.59	0.70	27.82	2.61**	0.14	3.75	-0.21**	-0.49**	23.13	1.99**	0.40**	37.00	0.28**	0.80**	26.04	-0.44**	0.82**
RK-9902	11.00	1.43**	0.12*	83.00	4.33**	-1.89**	24.41	-1.08**	2.40**	4.07	0.29**	0.42**	20.26	0.21**	1.60**	38.30	0.61**	0.77**	29.45	0.99**	0.79**
RK-2007	9.30	0.68**	-1.13*	90.33	-4.59**	0.70	21.63	-1.81**	1.59**	3.84	-0.09*	-0.34**	19.54	-2.57**	1.58**	37.17	-0.14*	-0.03	29.80	0.86**	1.15**
RK-9807	9.13	1.04**	-0.55**	90.67	4.33**	-0.22	20.14	-4.14**	2.21**	3.35	0.71**	0.84**	18.25	-2.49**	1.86**	39.00	0.52**	0.23	29.56	1.00**	0.02
Basanti	12.33	0.16**	1.02**	83.33	-2.00**	-1.30**	25.74	1.51**	-1.45**	3.91	0.38**	0.70**	22.74	0.91**	1.01**	39.07	0.11	0.61**	29.67	1.32**	0.88**
Jawahar-1	11.63	-1.63**	0.13**	81.67	1.33**	2.20**	24.72	-0.85**	2.26**	3.73	-0.16**	0.25**	20.18	-0.28**	2.65**	39.00	0.40**	0.89**	29.24	0.67**	-0.05
Vaibhav	9.33	2.44**	0.59**	63.67	0.16*	-9.89**	28.28	1.86**	2.67**	3.92	-1.53**	-0.38**	18.01	-1.62**	-0.30**	37.30	0.98**	0.04	26.61	0.13	0.03
Pusa Bold	12.23	0.12**	1.26**	86.67	-2.75**	6.03**	27.18	3.85**	-4.27**	4.30	-1.04**	0.30**	23.56	2.63**	-2.64**	37.90	1.23**	-0.46**	28.56	0.51**	0.03
RK-2001	12.63	1.39**	-1.50**	82.33	-6.09**	0.45	28.06	1.62**	-0.51*	4.10	0.37**	0.47**	23.10	-0.18*	-0.31*	36.17	-1.27**	1.38**	25.22	-3.43**	0.26**
RK-2002	10.00	0.99**	-0.97**	74.67	-1.84**	-1.64**	27.79	1.33**	-0.61**	3.31	-0.52**	-0.36**	20.75	8.63**	-0.83**	36.83	-1.93**	0.61**	27.84	-1.84**	0.39**
RK-2003	11.53	0.91**	0.54**	78.67	2.41**	-4.30**	26.38	-1.19**	-0.66**	3.82	0.07	-0.23**	20.75	0.16	-1.96**	37.20	-1.55**	-0.14	28.88	-3.44**	-0.45**
RK-9803	9.10	1.42**	0.10	75.00	-0.84*	2.78**	26.14	3.03**	-1.21**	3.73	0.35**	-0.06*	19.60	2.47**	-1.15**	39.33	1.22**	0.11	28.15	1.34**	0.15
RK-9804	13.03	1.47**	-0.31**	76.00	-2.92**	7.20**	29.16	1.60**	1.64**	4.02	1.20**	0.20**	22.15	0.59**	3.36**	38.33	1.37**	0.39**	30.07	1.31**	0.87**
Kranti	9.33	-0.13**	-1.01**	86.33	-0.20	-0.84**	26.19	-0.41*	1.55**	3.83	-0.32**	0.02	20.60	-0.37**	1.21**	39.10	-0.41**	0.10	29.57	-0.12**	0.03
Rohini	13.30	0.15**	1.25**	89.33	-0.37**	1.76**	29.67	0.27**	-1.46**	4.11	-0.07**	-0.08**	26.51	0.11**	-1.02**	39.69	0.07	-0.13	28.80	0.02	-0.07
Varuna	10.23	0.06**	0.38**	91.00	0.85**	0.05	32.72	-0.08	-0.53**	4.31	0.31**	-0.05**	29.78	0.44**	-0.26**	39.83	0.21**	-0.16*	29.20	.01	0.07
Vardan	10.17	-0.08**	-0.63**	78.67	-0.27	-0.97**	24.80	0.22**	0.44**	3.32	0.09**	0.11**	19.51	0.12	0.07	39.74	.12**	0.29**	29.56	0.09**	0.12

Table-10 : Estimates of specific combining ability (sca) effects and mean of F_1s for 14 characters in *Brassica juncea* (L.) Czern. & Coss.

CROSS COMBINATION	Days to flowering		Days to maturity		Plant height		Length of main raceme		Number of Primary branches		Number of Secondary branches		Number of siliquea on main raceme	
	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca
Sanjukta x Kranti	43.00	-1.63**	140.00	2.77**	123.67	0.30	55.03	-0.62**	7.70	0.06	13.93	-0.40**	38.00	-4.87**
Sanjukta x Rohini	44.67	0.34	137.00	0.67	123.33	-0.06	54.00	-0.33	10.47	1.10**	16.43	1.25**	41.00	1.11**
Sanjukta x Varuna	44.33	0.74	134.67	-1.83**	126.00	1.02	49.80	0.33	7.40	-0.37**	10.93	-1.84**	40.00	1.73**
Sanjukta x Vardan	45.00	0.55	134.33	-1.61**	123.00	-0.96	52.50	0.31	7.70	-0.79**	15.20	0.99**	47.00	2.03**
Pusa Basant x Kranti	50.33	0.04	132.33	0.44	165.33	0.42	52.13	0.64**	6.97	-0.50**	14.33	0.29*	66.00	0.80*
Pusa Basant x Rohini	48.67	-1.33**	133.67	2.67**	161.00	-3.65**	52.37	-1.47**	9.00	-0.19*	13.73	1.16**	61.00	-1.22**
Pusa Basant x Varuna	51.33	2.07**	129.00	-2.16**	171.64	5.44**	47.40	0.08	7.50	-0.10	12.57	0.08	60.00	-0.60
Pusa Basant x Vardan	49.33	-0.78	129.67	-0.95*	163.00	-2.21**	51.27	-0.04	9.10	0.79**	14.70	0.78**	68.33	1.03**
Pusa Jaikisan x Kranti	54.33	0.37	138.00	2.10**	169.67	1.75**	56.50	0.44*	8.40	1.85**	14.10	0.43**	63.33	1.46**
Pusa Jaikisan x Rohini	56.67	3.00**	131.67	-3.33**	159.00	-8.65**	58.77	-2.46**	7.70	-0.57**	14.63	0.10	57.00	0.11
Pusa Jaikisan x Varuna	53.33	0.40	136.00	0.84	183.00	13.77**	53.47	1.13**	6.40	-0.28**	12.53	0.42**	56.67	-0.60
Pusa Jaikisan xVardan	50.00	-3.78**	135.00	0.39	161.33	-6.88**	55.83	0.67**	6.40	-0.99**	12.60	0.95**	68.00	-0.97**
Pusa Bahar x Kranti	54.00	-0.13	138.00	3.60**	164.67	17.50**	49.83	0.66**	8.30	1.77**	15.23	0.82**	56.67	0.63
Pusa Bahar x Rohini	53.33	-0.50	135.00	1.50**	159.33	12.44**	49.23	-0.29	8.20	0.06	17.40	2.13**	54.00	0.95*
Pusa Bahar x Varuna	54.00	0.90*	131.67	-2.00**	135.00	-13.48**	44.30	0.43*	6.03	-0.63**	11.37	-1.49**	50.00	-1.44**
Pusa Bahar x Vardan	53.67	-0.28	130.00	-3.11**	131.00	-16.46**	45.87	0.34	6.30	-1.08**	12.83	-1.46**	58.00	-0.14
Krishna x Kranti	56.00	2.62**	136.00	4.27**	135.33	3.09**	47.50	-0.47*	5.60	-0.63**	12.97	-0.64**	53.33	1.13**
Krishna x Rohini	53.00	-0.08	130.00	-0.83	132.00	0.02	44.77	0.07	7.60	-0.36**	12.27	-0.20	50.00	0.78*
Krishna x Varuna	50.67	-1.68**	129.00	-2.00**	127.00	-6.56**	40.90	-1.35**	7.33	0.99**	12.97	0.92**	46.00	-1.60**
Krishna x Vardan	52.33	-0.86*	129.00	-1.45**	136.00	3.45**	45.30	-0.37	7.10	0.02	13.40	-0.08	54.00	-0.30

Urvashi x Kranti	54.00	2.04**	136.00	-1.98**	133.33	-23.33**	45.23	1.65**	7.30	1.51**	13.43	-0.32*	51.00	0.71
Urvashi x Rohini	51.00	-0.66	131.00	-6.08**	160.00	3.60**	44.40	-0.24	5.63	-1.88**	12.10	2.51**	47.00	-0.30
Urvashi x Varuna	51.33	0.40	143.00	5.75**	175.67	17.69**	38.73	0.24	6.23	0.31**	12.67	0.47**	45.33	-0.35
Urvashi x Vardan	50.00	-1.78**	139.00	2.30**	159.00	2.04**	42.27	-0.58**	6.70	0.06	16.00	2.37**	52.33	-0.05
Sita x Kranti	40.00	0.12	131.00	-1.40**	111-67	0.92	45.27	0.58**	5.10	-1.00**	10.70	0.34	52.20	-0.02
Sita x Rohini	43.00	-3.58**	133.00	1.50**	111.00	0.52	44.97	-0.12	9.10	1.28**	13.00	0.05**6	42.67	0.61
Sita x Varuna	48.00	2.15**	130.00	-1.66**	110.33	-1.73**	40.37	0.36	4.80	-1.43**	9.00	-1.54**	36.33	-1.10**
Sita x Vardan	48.00	1.30**	132.67	1.55**	111.33	0.29	42.80	0.42*	8.10	1.16**	12.87	0.89**	46.00	-1.14**
RK-9901 x Kranti	50.00	-2.13**	130.00	-1.98**	165.67	-1.16	56.73	-1.32**	6.30	0.94**	14.30	-0.51**	52.00	-0.45
RK-9901 x Rohini	51.00	-0.83*	129.00	-2.08**	159.00	-7.56**	57.00	0.27	6.60	-0.48**	14.37	-1.30**	50.00	0.53
RK-9901 x Varuna	52.00	0.90*	133.00	1.75**	170.33	2.19**	51.27	-0.62**	5.20	-0.29**	13.90	0.65**	46.00	-1.85**
RK-9901 x Vardan	54.00	2.05**	133.00	2.30**	173.67	6.54**	55.93	1.67**	6.03	-0.17*	15.83	1.15**	56.33	1.78**
RK-9902 x Kranti	5.67	0.79*	139.00	-0.06	165.67	2.34**	54.03	0.52**	5.23	-0.72**	14.27	0.22	64.00	-0.29
RK-9902 x Rohini	55.00	1.42**	140.33	2.17**	164.00	0.99	52.37	0.17	8.73	1.06**	15.90	1.00**	62.00	0.70
RK-9902 x Varuna	52.67	-0.18	138.00	-0.33	161.00	-3.31**	47.10	-0.25	6.23	0.15	11.80	-0.69**	58.33	-1.35**
RK-9902 x Vardan	51.67	-2.03**	136.00	-1.78**	163.67	0.04	49.30	-.043*	6.30	-0.49**	13.40	-0.53**	67.33	0.95*
RK-2007 x Kranti	47.00	-1.80**	120.00	-1.31**	119.00	0.08	50.63	-0.76**	8.97	-0.21**	15.93	-0.16	61.33	1.96**
RK-2007 x Rohini	50.00	1.50**	122.33	1.92**	119.00	0.19	49.70	-0.37	11.33	0.43*	16.37	-0.58**	56.33	-0.05
RK-2007 x Varuna	47.33	-0.43	120.00	-0.58	118.67	-1.73**	44.60	-0.63**	9.10	-0.21*	15.77	1.23**	54.00	-0.77*
RK-2007 x Vardan	49.33	0.72	120.00	-0.03	121.00	1.62*	49.37	-0.76**	10.00	-0.02	15.47	-0.50**	60.33	-1.14**
K-9807 x Kranti	43.00	-1.38**	118.33	-0.81	133.00	2.09**	51.17	0.23	9.63	-0.13*	15.63	0.01	61.00	1.38**
RK-9807 x Rohini	41.00	-3.08**	116.33	-1.91**	130.00	-0.65	48.67	-0.95**	10.93	0.44**	17.50	1.02**	58.00	1.36**

RK-9807 x Varuna	45.00	1.65**	120.67	2.25**	132.00	-0.23	45.30	0.53**	9.10	-0.80**	13.77	-0.30**	53.00	2.02**
RK-9807 x Vardan	47.00	2.80**	118.32	0.47	130.00	-1.21	47.33	0.19	10.10	0.49**	14.77	-0.73**	61.00	-0.72
Basanti x Kranti	49.67	-0.63	138.67	-2.06**	174.67	-0.25	52.50	-0.90**	7.40	-1.13**	15.20	0.48**	50.00	0.21
Basanti x Rohini	52.00	2.00**	139.00	-0.83	173.67	-0.98	52.37	0.28	10.30	0.05	15.23	-0.34*	47.00	0.20
Basanti x Varuna	47.00	-2.26**	142.33	2.34**	179.00	2.77**	47.70	0.46*	8.77	0.11	11.50	-1.66**	93.00	-2.19**
Basanti x Vardan	51.00	0.89*	140.00	0.55	173.67	-1.55**	49.77	0.15	10.33	0.96**	16.10	1.51**	53.67	1.78**
Jawahar-1 x Kranti	51.67	0.37	139.00	0.69	160.33	3.09**	50.77	-0.48*	8.00	1.34**	11.50	-0.68**	59.00	0.80*
Jawahar-1 x Rohini	48.00	-3.00**	126.00	-1.41**	149.00	-7.98**	48.57	-1.37**	6.10	-2.28**	11.97	-1.07**	54.33	-0.89*
Jawahar-1 x Varuna	51.00	0.74	130.00	2.42**	163.00	4.94**	45.83	0.57**	7.03	0.24**	12.60	1.98**	54.00	0.40
Jawahar-1 x Vardan	53.00	1.89**	125.33	-1.70**	158.00	0.45	48.57	1.10**	8.20	0.70**	11.83	-0.23	60.00	-0.30
Vaibhav x Kranti	51.00	0.87**	127.67	-2.81**	151.33	-20.91**	43.70	-0.35*	8.50	1.17**	20.60	1.80**	44.00	-8.37**
Vaibhav x Rohini	47.00	-2.83**	131.33	1.75**	175.33	3.35**	41.53	-1.20**	8.97	-0.09	18.57	-1.09**	47.00	-2.39**
Vaibhav x Varuna	50.00	0.90*	129.00	-0.75	173.33	-0.33	39.20	1.31**	7.27	-0.20**	16.73	-0.51**	56.00	8.23**
Vaibhav x Vardan	51.00	1.05**	131.00	1.80**	170.33	17.79**	40.50	0.24	7.30	-0.88**	18.47	-0.21	57.00	2.53**
Pusa Bold x Kranti	50.00	1.62**	125.00	1.10**	173.67	17.17**	71.20	12.96**	7.60	-0.45**	15.60	-1.23**	48.33	-2.62**
Pusa Bold x Rohini	51.00	2.92**	123.67	0.67	174.00	-2.23**	70.47	3.54**	9.30	-0.47**	19.30	1.61**	46.00	-1.97**
Pusa Bold x Varuna	44.00	-3.35**	120.00	-3.16**	177.67	-0.15	69.73	-2.34**	9.23	1.05**	14.87	-0.41**	54.00	7.65**
Pusa Bold x Vardan	47.00	-1.20**	124.00	1.39**	162.00	-14.80**	60.30	-14.16**	8.77	-0.13	16.73	0.02	50.00	-3.05**

K-2001 x Kranti	41.32	-0.96*	144.00	-0.65	122.00	-0.08	57.38	-1.40**	8.40	0.61**	17.40	0.78**	60.00	1.55**
RK-2001 x Rohini	41.33	-0.66	147.00	3.25**	122.00	0.52	57.50	-0.42*	10.00	0.48**	17.97	0.49**	54.00	-1.47**
RK-2001 x Varuna	42.00	0.74	140.67	-3.25**	123.33	-1.40*	54.03	0.96**	7.10	-0.82**	13.93	-1.13**	54.33	0.48
RK-2001 x Vardan	43.00	0.89*	144.00	0.64	136.00	0.95	56.30	0.85**	8.37	0.27**	16.37	-0.13	60.00	-0.55
RK-2002 x Kranti	42.67	-1.88**	146.67	-0.15**	138.33	-0.66	52.67	-2.40**	9.03	-1.44**	18.57	-0.09	57.00	2.63**
RK-2002 x Rohini	45.00	0.75	144.33	-1.58**	134.00	1.94**	54.63	0.88**	10.07	0.87**	20.20	0.69**	51.00	-0.39
RK-2002 x Varuna	42.00	-1.51**	147.00	0.92*	139.67	-3.98**	49.40	0.50*	11.03	0.43**	18.72	1.67**	48.67	-1.10**
RK-2002 x Vardan	47.00	2.64**	164.33	0.80	130.33	2.70**	52.30	1.02**	10.47	0.15*	16.27	-2.27**	55.33	-1.14**
RK-2003 x Kranti	39.00	-1.30**	127.00	-1.31**	129.00	1.42*	51.27	0.49*	8.73	-1.28**	17.23	0.16	57.33	1.05**
RK-2003 x Rohini	41.33	1.34**	128.33	0.92*	177.67	0.35	49.30	-0.16	10.87	1.13**	17.30	-0.63**	55.00	1.70**
RK-2003 x Varuna	40.33	1.07**	129.00	1.42**	130.00	-2.56**	43.57	-1.04	10.47	0.32**	16.30	0.78**	50.00	-1.69**
RK-2003 x Vardan	39.00	-1.11**	126.00	-1.03**	139.00	0.79	47.70	0.71**	10.70	-0.16*	16.63	-0.32**	57.33	-1.05**
RK-9803 x Kranti	43.33	1.79**	119.67	-0.06	143.00	-3.16**	47.50	-0.30	9.13	-0.83**	15.97	-1.30**	54.00	0.63
RK-9803 x Rohini	42.33	1.09**	120.67	1.84**	139.00	1.10	46.97	0.48*	10.83	-0.85**	18.07	-0.05	50.00	-0.39
RK-9803 x Varuna	39.33	-1.18**	116.67	-2.33**	149.00	-4.48**	42.00	0.36	10.70	0.61**	17.23	1.53**	48.00	-0.77*
RK-9803 x Vardan	39.67	-1.70**	119.00	0.55	159.67	6.54**	43.47	-0.55**	10.81	1.06**	16.97	-0.18	56.00	0.53
RK-9804 x Kranti	50.67	1.26**	116.00	-0.40	159.67	-0.16	5.10	-0.38	7.10	-0.91**	15.17	-0.27*	61.00	0.05
RK-9804 x Rohini	51.33	-2.17**	114.67	-0.83	166.33	6.77**	51.70	-1.77**	10.13	0.40**	16.82	0.58**	59.00	1.03**
RK-9804 x Varuna	46.33	-2.10**	118.00	2.34**	153.67	-7.48**	47.63	-0.69**	9.07	0.93**	13.20	-0.17	55.33	-1.02**
RK-9804 x Vardan	48.00	-1.28**	114.00	-1.11**	161.00	0.87	53.23	2.54**	8.43	-0.42**	15.17	-0.14	63.00	-0.05

CROSS COMBINATION	Number of seeds/ siliqua		Biomass (g)		Harvest Index (%)		1000-seed weight (g)		Seed yield/plant		Oil content		Protein content	
	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca
Sanjukta x Kranti	12.17	1.13**	82.33	-0.38	27.78	-1.24**	3.53	0.76**	22.77	-1.22**	38.83	-0.57**	29.62	-0.05
Sanjukta x Rohini	12.60	1.29**	84.00	1.45*	30.06	0.37	2.89	-0.13	25.22	0.75**	39.80	-0.08	29.90	0.09
Sanjukta x Varuna	12.47	-0.76**	80.33	-3.43**	30.80	1.46**	3.45	0.05	24.75	0.25	40.50	0.48**	29.76	-0.04
Sanjukta x Vardan	11.43	-1.65**	85.00	2.35**	29.04	-0.60	20.49	-0.69**	24.69	0.22	40.10	0.17	29.87	-0.01
Pusa Basant x Kranti	12.30	0.04	86.00	-5.88**	26.59	3.66**	4.32	-0.67**	23.01	1.92**	39.53	0.83**	30.45	0.06
Pusa Basant x Rohini	12.40	0.86**	97.67	5.95**	23.44	-0.17	6.21	0.98**	22.89	1.32**	38.33	-0.85**	30.29	0.25
Pusa Basant x Varuna	10.30	-2.16**	94.67	1.74**	20.74	-2.51**	5.09	-0.57**	19.63	-1.97**	39.37	0.04	30.37	-015
Pusa Basant x Vardan	12.57	1.26**	70.00	-1.81**	22.58	-0.98**	5.62	0.22**	20.32	-1.20**	39.20	-0.03	30.95	0.35**
Pusa Jaikisan x Kranti	9.70	-0.54**	101.00	12.20**	26.25	-3.04**	4.74	0.68**	26.51	0.59**	39.00	-0.01	30.58	0.71**
Pusa Jaikisan x Rohini	10.23	-0.28**	83.00	-5.63**	31.11	1.14**	4.07	-0.25**	25.82	-0.58**	39.37	0.12	30.20	0.19
Pusa Jaikisan x Varuna	9.87	-0.56**	85.00	-4.85**	31.51	1.90**	5.07	0.37**	26.78	0.35**	39.43	-0.20*	29.46	0.54**
Pusa Jaikisan x Vardan	11.67	1.38**	87.00	-1.73**	29.92	0.01	3.67	-0.81**	26.04	-0.37**	39.87	0.33**	29.71	-0.37**
Pusa Bahar x Kranti	12.03	0.58**	92.33	-7.05**	25.01	2.28**	3.13	-0.67**	23.09	0.48**	40.00	0.17	28.20	-0.49**
Pusa Bahar x Rohini	11.80	0.07	103.67	4.45**	22.03	-1.38**	3.83	-0.22**	22.84	-0.25	39.87	-0.44**	28.25	-0.59**
Pusa Bahar x Varuna	11.70	0.05	104.33	3.90**	22.06	-1.00**	5.04	0.61**	23.02	-0.11	40.43	-0.01	30.48	1.66**
Pusa Bahar x Vardan	10.80	-0.70**	98.00	-1.31*	23.45	0.10	4.50	0.29**	22.99	-0.11	90.65	0.00	28.33	-0.57**
Krishna x Kranti	9.23	-0.73**	99.00	-0.30	23.72	1.18**	4.17	0.44**	23.48	1.03**	40.07	0.80**	29.78	0.81**
Krishna x Rohini	9.33	-0.91**	103.00	3.87**	22.12	-1.10**	3.14	-0.84**	22.79	-0.14	39.43	-0.31**	28.65	-0.46**
Krishna x Varuna	12.17	2.01**	100.33	-0.01	22.37	-0.60	4.36	0.00	22.34	-0.62**	39.90	0.01	28.50	-0.60**
Krishna x Vardan	9.63	-0.37**	95.67	-3.56**	23.68	0.52	4.54	0.40**	22.66	-0.27	39.30	-0.50**	29.42	0.25

Urvashi x Kranti	11.67	0.12	83.00	2.87**	28.65	-2.51**	4.42	-0.25**	23.78	-1.16**	38.30	-0.31**	28.01	-0.61**
Urvashi x Rohini	9.77	-2.36**	88.00	8.04**	50.84	-1.00**	4.39	-0.25**	27.14	1.72**	39.37	0.38**	29.61	0.91**
Urvashi x Varuna	13.37	1.33**	77.67	-3.51**	32.08	0.60	5.34	0.04	24.92	-0.53**	38.57	-0.56**	2935	0.59**
Urvashi x Vardan	12.80	0.91**	72.67	-7.40**	34.69	2.91**	5.82	0.74**	25.39	-0.03	39.43	0.39**	27.94	-0.89**
Sita x Kranti	10.90	-0.30**	85.00	6.45**	22.00	-3.37**	3.82	0.24**	18.70	-0.96**	36.50	-1.44**	30.10	0.40**
Sita x Rohini	11.70	0.23**	80.00	1.62**	26.17	0.12	3.69	-0.13	20.28	0.14	40.33	1.91**	30.10	0.25
Sita x Varuna	11.10	-0.29**	77.00	-2.60**	26.07	0.37*	5.05	0.85**	20.07	-0.10	39.90	1.34**	28.57	-1.26**
Sita x Vardan	11.60	0.36**	73.00	-5.48**	28.87	2.88**	3.02	-0.96**	21.08	0.93**	36.67	-1.81**	30.51	0.61**
RK-9901 x Kranti	9.63	-1.04	79.00	-7.80**	32.05	2.63**	3.41	-0.30**	24.65	-0.64**	40.17	0.67**	27.36	-1.47**
RK-9901 x Rohini	13.30	2.35**	82.00	-4.63**	30.91	0.81*	3.88	-0.70**	25.34	-0.43**	39.57	-0.40**	30.15	1.18**
RK-9901 x Varuna	10.30	-0.56**	95.00	7.15**	29.02	-0.73*	4.03	-0.31**	27.52	0.71**	39.13	-0.98**	28.19	-0.77**
RK-9901 x Vardan	9.97	-0.75**	92.00	5.27**	27.33	-2.71**	4.80	0.69**	25.13	-0.65**	40.73	0.71**	30.10	1.06**
RK-9902 x Kranti	13.37	-0.82**	96.67	4.95**	23.77	-1.96**	4.30	0.09	22.98	-0.53**	39.77	-0.05	30.08	-0.18
RK-9902 x Rohini	12.60	1.14**	85.00	6.55**	27.32	0.92**	5.51	1.05**	23.23	-0.77**	39.70	-0.60**	30.39	-0.01
RK-9902 x Varuna	12.77	-1.61**	87.00	-5.76**	29.97	3.92**	3.95	-0.89**	26.08	2.05**	39.53	-0.91**	30.50	0.11
RK-9902 x Vardan	12.53	1.30**	99.00	7.35**	23.48	-2.88**	4.38	-0.24**	23.25	-0.75**	41.90	1.55**	30.54	0.08
RK-2007 x Kranti	12.07	0.63**	84.00	1.20**	25.82	0.82*	2.93	0.90**	21.69	0.96**	39.40	0.33**	30.17	0.04
RK-2007 x Rohini	12.70	-1.10**	85.00	2.37**	24.82	-0.85	4.82	0.75**	21.10	-0.10	39.23	-0.31**	30.34	0.07
RK-2007 x Varuna	13.60	-0.03	83.00	-0.85	26.63	1.30**	3.80	-0.65**	22.10	0.86**	39.57	-0.12	30.20	-0.06
RK-2007 x Vardan	12.90	0.42**	80.00	-2.73**	24.55	-1.27**	5.04	0.81**	19.49	-1.72**	39.70	0.10	30.27	-0.06

RK-9807 x Kranti	12.60	-1.20**	88.00	-3.71**	25.61	2.94**	4.86	0.22**	22.54	1.73**	39.20	-0.53**	30.36	0.09
RK-9807 x Rohini	12.80	1.73**	91.00	-0.55	22.24	-1.11**	4.49	-0.39**	20.24	1.05**	40.60	0.40**	30.41	0.00
RK-9807 x Varuna	12.90	0.91**	93.67.	0.90	22.05	-0.95**	5.02	-0.25**	20.64	-0.68**	41.43	1.09**	30.27	-0.13
RK-9807 x Vardan	12.40	-1.44**	95.00	3.35**	22.42	-0.88**	5.45	0.41**	21.30	0.00	39.30	-0.96**	30.51	0.04
Basanti x Kranti	11.80	-1.12**	87.00	1.62**	25.84	-2.48**	5.79	1.49**	22.48	-1.73**	39.77	0.45**	30.26	-0.33**
Basanti x Rohini	12.53	-0.66**	85.00	-0.21	29.48	0.49	4.87	0.32**	25.06	0.38**	39.83	0.04	31.18	0.04
Basanti x Varuna	12.33	1.22**	83.00	-3.43**	29.24	0.00	5.13	0.20**	24.27	-0.45**	40.43	0.49**	30.80	0.08
Basanti x Vardan	12.53	0.57**	87.33	2.02**	30.33	1.39**	2.69	-2.02**	26.49	1.80**	38.87	-0.98**	30.60	-0.19
Jawahar-1 x Kranti	10.00	-1.13**	95.00	6.29**	24.34	-1.61**	3.15	-0.61**	23.13	0.10	39.57	-0.04	30.10	0.17
Jawahar-1 x Rohini	10.33	-1.07**	85.00	-3.55**	26.69	0.06	2.78	-1.22**	22.69	-0.81**	39.27	-0.82**	30.58	0.50**
Jawahar-1 x Varuna	12.20	0.88**	89.00	-0.76	26.89	0.61	4.77	0.38**	23.91	0.37**	41.00	0.77**	30.53	0.46**
Jawahar-1 x Vardan	12.50	1.33**	86.67	-1.98**	27.52	0.94**	5.63	1.46**	23.85	0.34**	40.23	0.09	29.00	-1.14**
Vaibhav x Kranti	12.90	3.69**	77.00	-10.55**	25.96	1.01**	3.74	1.35**	19.99	-1.68**	39.73	-0.45**	30.32	0.93**
Vaibhav x Rohini	12.83	-2.65**	94.67	7.29**	24.20	-1.61*	3.06	0.42**	22.74	0.58**	40.23	-0.43**	29.47	-0.07
Vaibhav x Varuna	12.40	0.00	99.00	10.40**	22.09	-3.18**	2.24	-0.78**	21.78	-0.32**	40.60	-0.21	29.86	0.34*
Vaibhav x Vardan	12.20	-1.05**	80.33	-7.15**	29.35	3.78**	1.81	-0.99**	23.58	1.41**	41.80	1.09**	28.41	-1.19**
Pusa Bold x Kranti	12.30	0.42**	80.00	-4.63**	31.55	0.89**	2.57	-0.31**	25.21	-0.72**	40.77	0.33**	28.76	-1.01**
Pusa Bold x Rohini	12.63	1.48**	79.67	-4.80**	32.35	1.02**	2.45	-0.68**	25.77	-0.64**	40.63	-0.28**	30.78	0.86**
Pusa Bold x Varuna	12.70	-1.37**	87.67	1.99**	30.82	-0.17	3.17	-0.34**	27.02	0.58**	41.63	0.58**	30.56	0.66**
Pusa Bold x Vardan	13.40	-0.52**	92.00	7.44**	29.55	-1.74**	4.62	1.33**	27.19	0.78**	40.33	-0.63**	29.48	0.50**

RK-2001 x Kranti	11.90	-0.25**	86.00	4.70**	27.68	-0.75*	3.48	-0.81**	23.81	0.69**	36.30	-1.64**	25.76	-0.07
RK-2001 x Rohini	11.57	-0.86**	80.00	-1.13*	28.86	-0.24	5.13	0.59**	23.09	-0.50**	38.37	-0.05	24.53	-1.45**
RK-2001 x Varuna	12.73	0.39**	80.00	-2.35**	28.79	0.03	6.14	1.23**	23.03	-0.60**	38.47	-0.09	26.59	0.62**
RK-2001 x Vardan	11.90	0.71**	80.00	-1.23	30.02	0.96**	3.69	-1.01**	24.02	0.41**	40.23	1.77**	26.93	0.89**
RK-2002 x Karnti	12.10	0.34**	85.00	-0.55	39.42	1.28**	2.54	-0.80**	25.01	1.08**	36.90	-0.38**	27.88	0.45**
RK-2002 x Rohini	12.93	1.90**	85.00	-0.38	29.86	1.04**	3.47	-0.18	24.71	0.30**	39.80	2.05**	25.51	-2.06**
RK-2002 x Varuna	12.73	-1.21**	87.67	1.07	27.08	-1.38**	3.98	-0.05	23.74	-0.70**	37.27	-0.63**	28.25	0.69**
RK-2002 x Vardan	12.77	-1.03**	85.33	-0.15	27.82	-0.94**	4.90	1.09	23.74	-0.68**	36.77	-1.04**	28.56	0.93**
RK-2003 x Kranti	11.97	0.29**	91.00	1.20	25.82	0.20	4.70	0.71**	23.50	0.04	37.23	-0.43**	25.91	0.09
RK-2003 x Rohini	12.93	-1.01**	93.00	3.37**	24.92	-1.37**	4.53	0.31**	24.86	0.92**	37.13	-1.00**	26.91	0.23
RK-2003 x Varuna	12.40	0.54**	87.00	-3.85**	26.30	0.36	5.09	0.47**	22.88	-1.09**	39.23	0.95**	25.19	-0.76**
RK-2003 x Vardan	11.90	0.18**	89.00	-0.73	27.05	0.81*	2.89	-1.50**	24.08	0.13	38.67	0.48**	26.48	0.45**
RK-9803 x Kranti	12.23	1.05**	87.33	0.79	29.63	-0.21	5.08	0.81**	25.88	0.10	41.00	0.57**	30.91	0.30*
RK-9803 x Rohini	12.50	1.04**	77.67	-8.71**	33.25	2.73**	3.84	-0.67**	25.82	-0.43**	42.23	1.33**	30.89	0.14
RK-9803 x Varuna	12.80	-1.57**	90.00	2.40**	29.76	-0.40	4.48	-0.41**	26.79	0.50**	40.20	-0.85**	30.08	-0.66**
RK-9803 x Vardan	11.70	-0.52**	92.00	5.52**	28.35	-2.12**	4.95	0.27**	26.08	-0.18	30.90	-1.06	31.04	0.23
RK-9804 x Kranti	11.07	-1.16**	83.00	-1.46**	28.67	0.28	3.71	-1.41**	23.81	-0.09	42.17	1.59**	3.74	0.16
RK-9804 x Rohini	11.23	-1.27**	82.00	-2.30**	29.22	0.13	5.25	0.88**	23.96	-0.42**	40.63	-0.42**	30.76	0.03
RK-9804 x Varuna	12.23	2.81**	87.33	1.82**	28.51	-0.22	5.76	0.01	24.90	0.49**	40.00	-1.20**	30.48	-0.23
RK-9804 x Vardan	11.90	-0.37**	86.33	1.94**	28.85	-0.18	5.05	0.52**	24.39	0.00	41.13	0.03	30.83	0.04

Table-11 : Estimates of specific combining ability (sca) effects and mean of F_2s for 14 characters in *B. juncea* (L.) Czern. Coss.

CROSS COMBINATION	Days to flowering		Days to maturity		Plant height		Length of main raceme		Number of Primary branches		Number of Secondary branches		Number of siliquea on main raceme	
	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca
Sanjukta x Kranti	41.33	0.75	129.00	-1.88*	128.33	-4.43**	43.17	1.44**	7.33	-1.91**	12.57	-0.62	52.33	1.90**
Sanjukta x Rohini	51.67	2.45**	127.00	-3.56**	150.00	2.27*	46.83	2.04**	11.23	0.55**	17.07	1.51	59.67	3.07**
Sanjukta x Varuna	39.33	-2.43**	135.67	1.58	145.67	-2.20*	46.06	-0.83**	10.37	0.72**	16.47	-0.48	55.00	-2.98**
Sanjukta x Vardan	43.00	-0.77	132.33	3.86**	150.33	4.27**	43.57	-2.64**	12.07	0.64**	16.40	-0.40	51.33	-2.00**
Pusa Basant x Kranti	37.33	-3.67**	134.00	-3.88**	131.00	-1.18	41.10	-1.72**	8.40	0.23**	12.17	-0.28	49.33	-4.10**
Pusa Basant x Rohini	48.33	-1.30	151.67	14.11**	151.00	3.95**	41.43	-4.45**	11.07	1.46**	16.10	1.09	55.00	-4.60**
Pusa Basant x Varuna	45.00	2.82**	133.67	-2.42**	145.33	-1.95	57.00	3.04**	7.03	-1.54**	16.17	0.06	45.00	4.02**
Pusa Basant x Vardan	46.33	2.15*	132.67	-2.81**	144.67	-0.82	50.43	3.13**	10.20	-0.15	15.40	-0.86	61.00	4.67**
Pusa Jaikisan x Kranti	42.33	-1.50	134.67	-3.38**	130.00	1.73	47.23	-2.13**	6.33	-1.40**	13.23	1.12	57.33	1.24**
Pusa Jaikisan x Rohini	54.00	1.53	136.33	-1.39	147.00	3.87**	50.20	-2.24**	9.23	0.06**	14.37	-0.31	65.33	3.07**
Pusa Jaikisan x Varuna	45.00	-0.02	142.67	1.41	143.67	0.30	56.33	2.03**	9.10	0.96**	14.73	-1.04	60.33	-3.31**
Pusa Jaikisan xVardan	47.00	-0.02	139.00	3.36**	135.67	-5.90**	56.20	2.35**	10.30	0.38**	16.17	0.24	58.00	-1.00**
Pusa Bahar x Kranti	44.00	-0.67	138.33	-0.79	126.33	-3.93**	50.93	2.18**	8.23	-0.90**	13.07	0.19	53.00	1.40**
Pusa Bahar x Rohini	53.67	0.37	139.67	0.86	146.33	1.20	53.50	1.67**	9.13	-1.44**	14.17	-1.27	61.00	3.24**
Pusa Bahar x Varuna	46.00	0.15	141.00	-1.34	149.33	3.97**	51.53	-2.37**	11.07	1.53**	16.13	-0.40	54.67	-4.48**
Pusa Bahar x Vardan	48.00	0.15	138.00	1.28	142.33	-1.23	51.77	-1.48**	12.13	0.82**	18.17	1.48	54.33	-0.16
Krishna x Kranti	47.00	3.92**	140.33	6.21**	131.33	25.57**	45.81	1.23**	8.60	0.10	15.33	1.33	47.67	-2.10**
Krishna x Rohini	52.00	0.28	134.33	0.53	153.33	-67.30**	50.00	2.30**	10.23	0.29**	17.03	-0.63	57.00	-0.31
Krishna x Varuna	41.67	-2.60**	132.00	-5.34**	141	20.13**	46.40	-3.37**	9.17	0.26**	17.03	-0.63	57.00	-0.31
Krishna x Vardan	44.67	-1.60	130.33	-1.39	140.67	21.60**	48.97	-0.15	10.03	-0.65**	17.23	-0.58	61.33	3.87**

Urvashi x Kranti	46.33	1.42	138.00	4.71**	145.67	7.90**	42.50	3.13**	8.07	1.43**	14.17	2.04	53.00	1.65*
Urvashi x Rohini	53.67	0.12	132.67	-0.31	167.00	14.37**	45.57	3.13**	8.17	0.09	15.27	0.58	61.33	3.82**
Urvashi x Varuna	46.67	0.57	133.33	-3.18**	141.00	-11.82**	42.00	-2.51**	6.17	-0.87**	15.07	-0.72	59.33	0.44
Urvashi x Vardan	46.00	-2.10*	129.63	-1.22	140.67	-10.40**	40.10	-3.25**	8.17	-0.65**	14.03	-1.90	48.33	-5.91**
Sita x Kranti	42.00	-1.75*	128.33	-6.12**	126.67	0.65	37.87	-13.42**	7.23	0.43**	10.07	-6.66	45.00	-4.51**
Sita x Rohini	53.33	0.95	130.00	-4.14**	146.33	5.45**	40.90	-13.46**	8.17	-0.07	12.23	-7.05	51.00	-4.68**
Sita x Varuna	45.67	0.73	142.00	4.33**	143.33	2.22*	59.83	13.40**	7.53	-0.33**	20.23	7.85	62.67	5.60**
Sita x Vardan	47.00	0.07	138.00	5.94**	131.00	-8.32**	59.27	13.49**	8.30	-0.68**	20.40	5.86	56.00	3.59**
RK-9901 x Kranti	42.67	-3.25**	142.00	3.88**	131.67	0.82	55.20	11.31**	6.17	-1.54**	24.17	5.73	53.00	-2.10**
RK-9901 x Rohini	53.33	-1.22	136.00	-1.81*	152.00	6.28**	57.20	10.24**	9.47	0.32**	21.17	6.16	60.33	-0.93
RK-9901 x Varuna	49.67	2.57**	140.00	-1.34	142.67	-3.28**	47.60	-11.43**	8.17	0.05	16.23	-5.87	64.00	1.35*
RK-9901 x Vardan	51.00	1.90*	135.00	-0.72	140.33	-3.82**	48.27	-10.11**	11.07	1.18*	16.23	-6.02	59.67	1.67*
RK-9902 x Kranti	46.00	-2.42**	134.00	-2.21**	126.67	-10.60**	43.93	-0.50**	9.23	0.59**	14.07	1.68	54.00	3.49**
RK-9902 x Rohini	56.00	-1.50	132.00	-3.56**	149.67	-2.47*	46.53	-0.97**	10.17	0.08	16.17	1.21	61.00	4.32**
RK-9902 x Varuna	57.33	1.73*	140.67	1.24	158.00	5.63**	49.97	0.39**	9.20	0.15	14.20	-1.85	56.67	-1.40**
RK-9902 x Vardan	53.33	1.73*	138.33	4.53**	158.00	7.43**	49.34	1.09**	10.00	-0.82**	15.17	-1.04	47.00	-6.41**
RK-2007 x Kranti	46.67	-0.75	138.00	2.46**	141.67	-4.43**	44.17	0.78**	7.37	-0.13	13.07	-0.08	46.00	-3.93**
RK-2007 x Rohini	50.33	4.28**	137.00	1.78*	162.67	1.70	46.97	0.51**	9.07	0.13	15.25	-0.48	51.67	-4.43**
RK-2007 x Varuna	45.67	-2.93**	136.00	-2.76**	163.00	1.80	48.67	0.14	7.27	-0.63**	18.27	1.46	62.33	4.85**
RK-2007 x Vardan	50.00	-0.60	136.67	-1.47	160.33	0.93	46.43	-1.44**	10.30	0.63**	16.07	-0.90	56.33	3.50**

RK-9807 x Kranti	45.00	0.50	131.67	0.21	157.00	0.90	45.63	0.94**	6.70	0.64**	13.37	1.30	50.00	-4.43**
RK-9807 x Rohini	53.67	0.53	135.67	-0.47	157.67	9.70**	50.17	2.40**	7.23	-0.27**	18.00	3.37	56.00	-4.60**
RK-9807 x Varuna	45.67	-0.02	140.33	0.66	150.67	-7.53**	48.77	-1.07**	6.10	-0.36**	12.50	-3.23	65.00	3.02**
RK-9807 x Vardan	46.67	-1.02	133.67	-0.39	160.33	-6.07**	46.90	-2.28**	8.23	-0.01	14.43	-1.45	63.33	6.00**
Basanti x Kranti	46.67	3.83**	138.00	3.29**	146.67	8.07**	42.43	-1.09**	6.27	-0.10	9.17	-1.99	60.00	8.49**
Basanti x Rohini	53.67	2.20**	137.00	2.61**	147.00	13.53**	46.90	0.30*	6.10	-1.73**	13.83	0.11	62.67	-0.01
Basanti x Varuna	41.00	-3.02**	133.33	-4.59**	142.33	-11.37**	49.87	12.0**	7.07	0.27**	15.17	0.35	62.00	-2.06**
Basanti x Vardan	43.00	-3.02**	131.00	-1.31	141.67	-10.23**	47.60	-0.41**	10.17	1.59**	16.50	1.53	58.00	-1.41*
Jawahar-1 x Kranti	41.67	0.67	132.33	-2.21**	127.00	-2.02	42.83	2.45**	5.03	-1.51**	11.27	-2.27	55.33	4.94**
Jawahar-1 x Rohini	51.00	1.37	132.00	-2.22**	143.00	-0.88	45.90	2.45**	8.03	0.05	14.27	-1.83	60.67	4.15**
Jawahar-1 x Varuna	52.33	0.15	139.33	1.57	145.33	1.22	43.63	-1.89**	9.07	2.12**	18.23	1.04	52.00	-5.90**
Jawahar-1 x Vardan	42.00	-2.18*	135.00	2.86**	144.00	1.68	41.87	-3.00**	8.07	-0.66**	20.40	3.05	50.00	-3.25**
Vaibhav x Kranti	39.23	-0.58	132.33	1.04	129.67	6.98**	37.90	-5.72**	7.13	1.56**	17.00	4.54	46.00	2.32**
Vaibhav x Rohini	46.00	-2.55**	132.67	1.69*	148.00	9.95**	41.50	-5.20**	8.03	1.02**	16.93	1.91	57.33	1.49**
Vaibhav x Varuna	43.00	1.90*	134.33	-0.18	130.00	-8.28**	54.87	6.10**	4.07	-1.91**	13.60	-2.52	48.33	-2.90**
Vaibhav x Vardan	44.233	1.23	126.33	-2.56**	128.33	-8.15**	52.93	4.82**	7.10	-0.66**	12.33	-3.94	45.67	-0.91
Pusa Bold x Kranti	41.33	-1.75*	128.33	-4.62**	115.67	-22.52**	48.90	2.09**	5.23	0.36**	8.33	-3.89	40.00	-5.93**
Pusa Bold x Rohini	51.00	-0.72	127.67	-4.97**	136.33	-16.72**	52.97	3.09**	5.10	-1.22**	11.07	-3.72	48.00	-4.10**
Pusa Bold x Varuna	46.00	1.73*	140.67	4.49**	153.00	19.72**	49.83	-2.12**	6.17	0.89**	19.17	3.28	60.33	6.85**
Pusa Bold x Vardan	47.00	0.73	135.67	5.11**	141.00	19.52**	48.23	-3.06**	7.03	-0.02	20.37	4.33	52.00	3.17**

RK-2001 x Kranti	47.00	3.92**	136.33	1.38	153.00	6.90**	48.80	2.42**	6.07	-0.81**	11.07	-3.87	58.33	4.40**
RK-2001 x Rohini	54.00	2.28**	135.67	1.05	140.67	9.37**	53.50	4.05**	8.17	-0.15	16.23	-1.07	61.67	1.57*
RK-2001 x Varuna	41.00	-3.27**	136.00	-2.17**	154.00	-7.53**	48.13	-3.39**	7.17	-0.11	22.30	3.90		5.83
RK-2001 x Vardan	43.33	-2.93	132.33	-0.22	151.00	-8.73**	47.80	-3.07**	10.13	1.08	19.40	0.85	52.00	-4.83**
RK-2002 x Kranti	41.67	-2.67**	131.33	-2.96**	137.00	-9.52**	41.77	1.35**	7.17	0.68**	14.67	-1.00	57.33	6.40**
RK-2002 x Rohini	52.33	-0.63	131.00	-2.97**	160.00	-1.38	43.90	0.41**	8.17	0.24**	18.30	0.07	56.33	-0.74**
RK-2002 x Varuna	46.33	0.82	140.00	2.49**	160.00	4.38**	44.53	-1.02**	6.30	-0.59**	19.43	0.11	55.00	-3.48**
RK-2002 x Vardan	50.00	2.48**	135.33	3.44**	146.33	6.52**	44.17	-0.74**	8.33	-0.33**	20.30	0.82	51.67	-2.16**
RK-2003 x Kranti	47.00	3.08**	134.33	7.62**	151.33	11.65**	40.93	-1.97**	7.13	0.46**	18.23	3.87	45.33	1.82**
RK-2003 x Rohini	53.33	0.78	133.67	7.28**	160.67	16.12**	42.43	-3.54**	7.17	-0.94**	19.17	2.24	56.00	6.32**
RK-2003 x Varuna	43.32	-1.77**	136.33	6.41**	140.33	-14.45**	49.77	1.73**	7.23	0.16**	15.03	-2.99	48.33	-2.73**
RK-2003 x Vardan	45.00	-2.10*	103.00	-21.31	139.67	-13.32**	51.17	3.78**	9.17	0.32**	15.07	-3.11	41.00	-5.41**
RK-9803 x Kranti	41.33	-0.33	132.00	-3.96**	124.33	-7.18**	46.83	1.21**	7.57	2.11	10.07	0.19	39.33	-8.43**
RK-9803 x Rohini	42.00	-8.30*	133.33	-2.31**	142.00	-4.38**	48.73	0.04	7.07	0.18**	12.10	-0.34	45.67	-8.26**
RK-9803 x Varuna	45.67	2.82*	142.00	2.83**	151.00	4.38**	50.17	-0.60**	5.10	-0.76**	12.30	-1.23	81.67	6.35**
RK-9803 x Vardan	50.67	3.44*	137.00	3.44**	152.00	7.18**	49.47	-0.64**	8.10	-1.53**	15.07	1.38	81.00	10.3**
RK-9804 x Kranti	47.33	1.25	173.33	1.21	138.00	-7.85**	-43.47	-3.97**	5.07	-0.24**	9.07	-1.52	61.33	2.40**
RK-9804 x Rohini	53.33	-1.38	133.67	-2.14**	156.00	-4.72**	47.77	-2.75**	8.10	1.35**	11.07	-2.08	64.67	-0.43**
RK-9804 x Varuna	47.33	0.07	140.67	1.33	165.67	4.72**	55.17	2.58**	5.07	-0.65**	17.17	2.92	64.67	-1.81**
RK-9804 x Vardan	49.33	0.07	133.33	-0.39	161.00	7.85**	56.07	4.14**	7.03	-0.46**	15.07	0.67	61.67	-0.16

CROSS COMBINATION	Number of seeds/ siliqua		Biomass (g)		Harvest Index (%)		1000-seed weight (g)		Seed yield/plant		Oil content		Protein content	
	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca	Mean	Sca
Sanjukta x Kranti	17.27	3.23**	97.00	1.50	23.22	-1.64**	4.14	0.14*	22.51	-1.14**	36.40	-0.89**	26.34	-1.45*
Sanjukta x Rohini	14.00	-0.29**	92.00	-6.10**	23.33	1.48**	4.97	1.07**	21.46	0.04	35.37	-1.79**	24.82	-2.82*
Sanjukta x Varuna	14.60	-0.83**	95.00	-1.36	23.5	0.87*	3.06	-0.87**	22.41	0.23**	36.50	-0.63**	29.90	2.00**
Sanjukta x Vardan	12.30	-2.11**	101.33	5.97**	23.08	-0.66	3.75	-0.34**	23.37	0.86**	40.90	3.32**	30.20	2.26**
Pusa Basant x Kranti	12.53	-1.39**	76.67	-7.00**	26.72	1.41**	4.09	0.12*	20.47	-0.70**	40.20	-0.19	30.33	-0.09
Pusa Basant x Rohini	14.00	-0.15	86.67	0.40	23.57	1.27**	2.83	-1.05**	20.41	1.48**	38.90	-1.36**	30.50	0.22**
Pusa Basant x Varuna	11.60	0.28**	89.67	5.12**	21.24	-1.98**	3.87	-0.04	19.00	-0.70**	41.63	1.40**	30.72	0.18
Pusa Basant x Vardan	14.57	1.26**	85.00	1.47	23.50	-0.70*	5.03	0.97**	19.94	-0.08	40.83	0.15	30.26	-0.32*
Pusa Jaikisan x Kranti	15.00	1.16**	91.00	-5.16**	27.09	3.51**	4.75	0.07	24.62	2.17**	39.43	0.92 **	30.31	2.54**
Pusa Jaikisan x Rohini	14.33	0.24**	100.67	1.90	16.45	-4.12**	4.82	0.23**	16.54	-3.68**	40.13	1.75**	30.31	2.75**
Pusa Jaikisan x Varuna	13.80	-1.43**	101.00	3.95**	24.09	2.60**	4.09	-0.52**	24.33	3.55**	36.63	-1.73**	27.12	-0.77*
Pusa Jaikisan xVardan	14.23	0.02	95.33	-0.70	20.46	-2.00**	5.06	0.23**	19.48	-1.83**	37.87	-0.94**	23.40	-4.52*
Pusa Bahar x Kranti	15.30	1.19**	82.33	-4.33**	30.62	0.99**	4.84	0.44**	25.20	-0.54**	36.70	-0.39	24.24	-2.98*
Pusa Bahar x Rohini	14.90	0.54**	91.67	2.40**	27.42	0.80	5.32	1.01**	25.12	1.61**	37.23	0.27	27.00	-0.08*
Pusa Bahar x Varuna	14.37	-1.13**	92.00	-9.45**	27.70	0.16	3.24	-1.10**	25.48	1.21**	37.90	0.97**	30.54	3.20**
Pusa Bahar x Vardan	13.80	-0.59**	84.00	-2.53**	26.58	-1.94**	4.14	-0.35**	22.32	-2.28**	36.53	-0.85**	27.24	-0.13
Krishna x Kranti	10.13	4.14**	83.00	-6.66**	16.76	-9.54**	3.15	-0.37**	13.92	-9.86**	37.50	0.39	29.83	1.70**
Krishna x Rohini	14.40	-1.85**	92.33	0.07	28.76	5.46**	4.70	1.28**	26.55	5.00**	36.20	-0.78**	28.87	0.88**
Krishna x Varuna	13.47	-1.92**	96.00	5.45**	25.41	1.20**	4.16	0.70**	24.39	2.08**	38.20	1.25**	25.13	-3.12*
Krishna x Vardan	14.00	-0.37**	90.67	1.14	28.06	2.88**	2.00	-1.61**	25.42	2.78**	36.53	-0.87**	28.83	0.54**

Urvashi x Kranti	15.30	1.51**	97.00	7.59**	25.64	-1.30**	4.10	0.10	24.87	0.96**	40.60	0.69*	30.45	0.41**
Urvashi x Rohini	5.07	-0.97**	96.00	3.99**	18.27	-5.65**	4.21	0.31**	17.54	-4.14**	39.40	-0.38	27.75	-2.15**
Urvashi x Varuna	14.20	-0.98**	81.00	-9.30**	28.87	4.02**	4.70	0.76**	23.38	0.94**	39.67	-0.08	30.69	0.54**
Urvashi x Vardan	14.60	0.44**	87.00	-2.28*	28.75	2.93**	2.93	-1.16**	25.01	2.24**	39.97	-0.23	31.40	1.21**
Sita x Kranti	10.97	-1.40**	67.67	-2.75**	20.81	-2.15**	1.79	-1.50**	14.07	-2.36**	40.90	0.66*	29.65	-1.15**
Sita x Rohini	14.67	1.04**	72.00	-1.01	20.13	0.19	4.14	0.95**	14.49	0.28	39.00	-1.11**	28.82	-1.84**
Sita x Varuna	14.63	0.87**	75.67	4.37**	20.90	0.03	4.36	1.13**	15.79	0.82	40.27	0.18	34.15	3.24**
Sita x Vardan	12.23	-0.51**	69.67	-0.61	23.78	1.93**	2.80	-0.58**	16.55	1.26	40.80	0.27	30.70	-0.26**
RK-9901 x Kranti	13.30	0.11	86.67	-1.50	28.76	1.77**	1.85	-1.69**	24.39	1.08	39.87	-0.32	30.54	0.15
RK-9901 x Rohini	11.70	-0.74**	93.33	2.57*	25.55	2.16*	3.59	0.15**	23.68	2.60	41.60	1.54**	30.61	0.36**
RK-9901 x Varuna	9.73	1.16**	86.00	-3.05**	19.15	-5.16**	4.19	0.72**	16.47	-5.37	35.60	-0.43	30.07	-0.44**
RK-9901 x Vardan	13.03	-0.53**	90.00	1.97	26.51	1.23**	4.45	0.82**	23.86	1.69	39.70	-0.78*	30.49	-0.06**
RK-9902 x Kranti	12.47	-0.89**	91.00	5.42**	29.27	0.62	3.96	-0.49**	26.65	2.13	39.17	-1.00**	30.16	-0.20
RK-9902 x Rohini	12.90	1.29**	81.67	-6.51**	32.32	6.68	4.15	-0.21**	26.39	4.10	33.90	-0.13	30.86	0.64**
RK-9902 x Varuna	5.20	0.45**	89.00	2.54*	17.25	-9.31**	4.43	0.04	15.36	-7.68	41.23	1.22**	30.05	-0.43**
RK-9902 x Vardan	12.90	-0.84**	84.00	-1.45	29.55	2.01**	5.21	0.66**	24.82	1.45	40.37	-0.09	30.51	-0.01**
RK-2007 x Kranti	11.97	-0.14	86.00	-2.16**	32.00	4.16**	3.80	0.11	27.52	3.04	39.30	-0.07	30.16	-0.56**
RK-2007 x Rohini	14.30	-0.06	91.00	0.24	28.48	3.64**	3.10	-0.50**	25.59	3.34	37.93	-1.60**	29.03	0.45**
RK-2007 x Varuna	14.30	0.80**	87.00	-2.05	22.48	-3.28**	5.36	1.73**	19.56	-3.46	30.90	-0.31	31.61	-0.23**
RK-2007 x Vardan	11.90	-0.59**	92.00	3.97**	22.21	-4.52**	2.46	-1.33**	20.43	-2.92	31.63	1.08**	29.22	0.34**

RK-9807 x Kranti	10.17	-2.53**	95.33	8.09**	25.55	-2.91**	5.06	0.99**	24.27	-0.50*	40.67	1.04**	27.61	-1.90**
RK-9807 x Rohini	14.23	-0.71**	88.00	-6.85**	31.31	5.86**	2.94	-1.03**	25.77	3.23**	41.17	1.67**	30.00	0.55**
RK-9807 x Varuna	12.17	2.08**	86.00	-2.13*	25.28	-1.09**	2.72	-1.28**	21.76	-1.54**	37.90	-1.57**	30.44	0.73**
RK-9807 x Vardan	14.23	1.16**	88.00	0.89	25.94	-1.85**	5.19	1.32**	22.44	-1.19**	38.77	-1.15**	30.45	0.70**
Basanti x Kranti	14.53	0.27**	83.00	-3.16**	31.60	6.79**	4.92	0.18**	26.33	4.33**	39.33	-0.67*	30.57	0.11
Basanti x Rohini	12.70	1.19**	83.00	-5.76**	16.41	-5.39**	4.72	0.08	13.62	-6.04**	40.47	0.59*	30.43	0.12
Basanti x Varuna	15.37	-0.28**	92.00	4.95**	27.35	4.64**	4.40	-0.27**	27.01	6.58**	38.90	-0.95**	30.14	-0.40**
Basanti x Vardan	13.47	-1.17**	90.00	3.97**	17.65	-6.04**	4.83	0.01	15.89	-4.87**	41.33	1.03**	30.80	0.19
Jawahar-1 x Kranti	11.43	-1.94**	89.67	-0.00	26.90	-1.62**	3.76	-0.52**	24.06	-1.50**	41.37	1.08**	30.89	1.36**
Jawahar-1 x Rohini	13.90	0.28**	97.67	5.40**	24.93	-0.58	5.20	1.02**	24.09	0.76**	39.00	-1.15**	31.07	1.69**
Jawahar-1 x Varuna	11.30	0.54**	93.67	3.12**	27.09	0.66	3.96	-0.26**	25.82	1.73**	41.17	1.04**	28.75	-0.89**
Jawahar-1 x Vardan	14.87	1.12**	81.00	-8.53**	28.94	1.54**	4.13	-0.24**	23.44	-0.98**	39.60	-0.97**	27.52	-2.16**
Vaibhav x Kranti	13.77	-0.07	72.67	-4.91**	29.71	0.78*	4.56	0.91**	21.57	-1.04**	40.73	1.30**	30.49	0.92**
Vaibhav x Rohini	7.80	1.71**	82.33	215*	25.81	-0.11	3.77	0.21**	21.24	0.86**	36.70	2.40**	26.57	-2.86**
Vaibhav x Varuna	14.90	-0.33**	81.33	2.87**	26.23	-0.61	2.08	-1.51**	21.34	0.20	38.90	-0.38	30.05	0.37**
Vaibhav x Vardan	12.90	-1.31**	77.33	-0.11	27.75	-0.07	4.14	0.39**	21.45	-0.02	36.40	-3.32**	31.30	1.57**
Pusa Bold x Kranti	11.50	-0.49**	93.00	-0.50	24.19	2.20**	3.75	-0.41**	22.49	2.22**	37.90	-1.03**	29.29	-0.31**
Pusa Bold x Rohini	13.37	-0.87**	99.00	2.90**	14.65	-4.33**	3.67	-0.40**	14.51	-3.53**	39.09	-1.27**	30.37	0.91**
Pusa Bold x Varuna	13.53	0.16*	89.00	-5.38**	28.45	8.55**	5.36	1.27**	25.32	6.53**	41.27	0.26	28.68	-1.03**
Pusa Bold x Vardan	13.57	1.20**	96.33	2.97**	14.45	-6.42**	3.79	-0.46**	13.91	-5.21**	39.60	2.04**	30.19	0.43**

RK-2001 x Kranti	12.80	1.06**	86.00	-1.91	26.25	0.51	5.18	0.68**	22.57	-0.03	41.53	-1.17**	30.15	0.32**
RK-2001 x Rohini	15.03	1.04**	92.00	1.49	20.82	-1.92**	4.17	-0.24**	19.15	-1.21**	35.70	0.89**	30.11	0.42**
RK-2001 x Varuna	12.57	-0.57**	88.00	-0.80	24.59	0.93*	2.96	-1.48**	21.49	0.36	40.27	1.08**	29.37	-0.58**
RK-2001 x Vardan	10.60	-1.52**	89.00	1.22	25.10	0.47**	5.14	1.04**	22.34	0.88**	39.90	-0.80**	29.84	-0.15
RK-2002 x Kranti	9.27	-8.00**	92.00	6.17**	28.55	2.91*	4.26	0.54**	26.27	4.19**	40.17	-0.11	31.09	1.13**
RK-2002 x Rohini	13.30	-1.22**	89.00	0.57	15.14	-7.49*	2.82	-0.81**	13.48	-6.37**	39.10	0.29	29.38	-0.44**
RK-2002 x Varuna	14.90	1.24**	85.67	-1.05	28.36	4.81**	3.50	-0.17**	24.30	3.68**	40.87	-0.75*	28.65	-1.13*
RK-2002 x Vardan	15.63	2.99**	80.00	-5.70**	24.30	-0.22**	4.26	0.44**	19.44	-1.50**	39.80	0.57*	30.86	0.74**
RK-2003 x Kranti	13.30	-0.48**	86.00	2.84**	28.33	2.74	5.06	1.26**	24.37	3.42**	38.70	0.55*	30.14	1.02**
RK-2003 x Rohini	7.77	1.74**	89.00	3.24**	12.65	-9.94**	4.23	0.53**	11.26	-7.45**	38.87	-0.42	30.52	1.54**
RK-2003 x Varuna	14.90	-0.27**	82.00	-2.05	23.89	0.38	3.10	-0.64**	19.59	0.11	39.67	-0.26	27.64	-1.60*
RK-2003 x Vardan	13.17	-0.99**	79.00	-4.03**	31.30	6.82**	2.75	-1.15**	23.73	3.92**	39.67	0.13	28.32	-0.96*
RK-9803 x Kranti	13.20	-0.04	95.67	5.42**	20.98	-4.07**	3.28	-0.69**	19.96	-1.79**	38.90	-0.61*	28.97	-0.75*
RK-9803 x Rohini	15.20	-0.30**	87.67	-5.18**	31.64	9.61**	2.10	-1.78**	25.08	5.55**	38.87	-0.51*	29.25	-0.33*
RK-9803 x Varuna	14.57	-0.07	92.00	0.87	11.48	-11.48**	4.15	0.24**	10.56	-9.72	39.77	0.42	30.53	0.70**
RK-9803 x Vardan	14.03	0.41**	89.00	-1.11	29.87	5.94**	3.29	2.23**	26.58	5.96**	40.50	0.70*	30.25	0.38**
RK-9804 x Kranti	12.63	-0.29**	97.67	3.00**	22.13	-5.11**	3.45	26.3**	22.21	-4.06**	39.60	-0.18	30.26	-0.18
RK-9804 x Rohini	13.30	-1.88**	101.33	4.07**	27.25	2.36**	3.32	-0.81**	27.61	3.57**	35.73	1.08**	30.28	0.02
RK-9804 x Varuna	14.53	0.22**	85.00	-10.55**	29.92	4.11**	5.10	1.54**	25.43	0.64**	38.90	0.73*	30.56	0.00
RK-9804 x Vardan	15.27	1.96**	98.00	3.47**	25.48	-1.30**	3.45	-0.87**	24.97	-0.15	39.90	-0.17	30.78	0.19

Table – 12 : Estimates of heterosis over commercial cultivar for 14 characters in *Brassica juncea* (L.) Czern. & Coss.

Coss combination	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sanjukta x Kranti	-12.24**	8.52**	-14.11**	17.66**	2.25	6.57**	-41.53**	20.25**	4.65**	12.01**	6.35*	16.70**	-2.28**	0.20
Sanjukta x Rohini	-8.83**	6.20**	-14.35**	15.45**	39.04**	25.70**	-36.92**	24.50**	6.77**	21.20**	-12.95**	29.26**	0.15	1.15
Sanjukta x Varuna	-9.53**	4.39**	-12.5**	6.47**	-1.72**	-16.37**	-38.46**	23.22**	2.11**	24.19**	3.91	26.85**	1.91**	0.67
Sanjukta x Vardan	8.16**	4.13**	-14.58**	12.25**	2.25	26.29**	-27.69**	12.94**	8.04**	17.09**	12.04**	26.55**	0.90	1.04
Pusa Basant x Kranti	2.71	2.58**	14.81**	11.46**	-7.43**	9.64**	1.53	21.54**	9.31**	7.21**	30.12**	17.93**	-0.52	3.01**
Pusa Basant x Rohini	0.61**	3.62**	11.80**	11.97**	19.52**	5.04**	-6.15	22.52**	24.15**	-5.48**	87.04**	17.32**	-3.54	2.46**
Pusa Basant x Varuna	4.75**	0.00	19.21**	10.34	-0.39	-3.82**	-7.69	1.77**	20.33**	-16.37**	53.31**	0.61	-0.93**	2.74**
Pusa Basant x Vardan	0.67	0.51	13.19**	9.62**	20.84**	12.47**	5.12	24.22**	-11.02**	-8.95**	69.27**	4.15	-1.35	4.70**
Pusa Jaikisan x Kranti	10.87**	6.97**	17.82**	20.80**	11.55**	7.88**	-2.56	-4.15**	28.38**	5.84	42.77**	36.08**	-1.86*	3.45**
Pusa Jaikisan x Rohini	15.65**	2.06**	10.41**	25.65**	2.25	11.93**	-12.30**	1.08**	5.50**	25.44**	22.59**	32.34**	-0.93	2.16**
Pusa Jaikisan x Varuna	8.83**	5.42**	27.08**	14.32**	-15.00**	-4.13	-12.81**	-2.47**	8.04**	27.05**	22.59**	37.26**	-0.78	-0.33
Pusa Jaikisan xVardan	2.04	4.65**	12.03**	19.37**	-15.00**	-3.59	4.61	15.31**	10.58**	20.64**	10.54**	33.47**	0.32	0.50
Pusa Bahar x Kranti	10.20**	6.99**	14.35**	6.54**	10.22**	16.52**	-12.81**	18.87**	17.36**	0.84	5.72	18.34**	0.65	-4.60
Pusa Bahar x Rohini	8.83**	4.65**	10.64**	5.25**	8.89**	33.12**	-16.92**	16.60**	31.77**	-11.16**	15.36**	17.06**	0.32	-4.43**
Pusa Bahar x Varuna	10.20**	2.06**	-6.25**	-5.28**	-19.92**	-13.00**	-23.07**	15.61**	32.61**	-11.04**	51.80**	17.99**	1.73**	3.11**

Pusa Bahar x Vardan	9.53**	0.77	-9.02**	-1.92**	-16.33**	-1.83	10.76	6.71**	24.57**	-5.44	35.54**	17.83**	-100.0**	-4.16**
Krishna x Kranti	14.28**	5.42**	-6.02**	1.56**	-25.63**	-0.76	-17.95**	-8.79**	25.84**	-4.35**	25.60**	20.34**	0.83	0.74**
Krishna x Rohini	8.16**	0.77	-8.33**	-4.27**	0.92	-6.12**	23.07**	-7.80**	30.92**	-10.80**	5.42	16.81**	-0.78	-3.07
Krishna x Varuna	3.40*	0.00	-11.80**	-12.55**	2.65	-0.76	-29.23**	20.25**	27.53**	-9.79**	31.32**	14.50**	0.40	-3.58**
Krishna x Vardan	6.79**	0.00	-5.55**	-3.14	5.71	2.52	-16.92**	-4.84**	21.60**	-4.51	36.74**	15.63**	-1.10**	-0.47
Urvashi x Kranti	10.20**	5.42**	-7.40**	-3.29	-3.05	2.75	-21.53**	15.31**	5.50**	15.52**	33.12**	21.88**	-3.62**	-5.24**
Urvashi x Rohini	4.08**	1.55**	11.11**	-5.06**	-25.23**	-7.42**	-27.69**	-3.45**	11.85**	-5.44**	32.22**	39.10**	-0.93	0.16
Urvashi x Varuna	4.75**	10.85**	21.99**	-17.19**	-17.26**	-3.06	-30.26**	32.11**	-1.27**	29.35**	60.84**	27.72**	-2.94**	-0.71
Urvashi x Vardan	2.04	7.75**	10.41**	-9.62**	-11.02**	22.41**	-19.49**	26.48**	-7.62**	39.87**	75.30**	30.13**	-0.78	-5.48**
Sita x Kranti	-18.36**	1.55**	-22.45**	-3.20	-32.27**	-18.13	-24.49**	7.70**	8.04**	-11.29**	15.06**	-4.15**	-8.15**	1.82**
Sita x Rohini	-12.24**	3.10**	-22.91**	-3.84**	20.84**	-0.53	-34.35**	15.61**	1.69*	5.52**	11.14**	3.94**	1.48	1.82**
Sita x Varuna	-2.04	0.77	-23.38**	-13.68**	-36.25*	-31.14**	-44.10**	9.68**	-2.12*	5.12**	52.10**	2.87**	0.40	-3.34**
Sita x Vardan	-2.04	2.84**	-22.68**	-8.48**	7.56**	-1.53	-29.33**	14.62**	-7.20**	16.41**	-9.03**	8.04**	-7.72**	3.21**
RK-9901 x Kranti	2.04	0.77	15.04**	21.29**	-16.33**	9.41**	-20.00**	-4.84*	0.41**	29.23**	2.71	26.34**	1.08	-7.44**
RK-9901 x Rohini	4.08**	0.67	10.41**	21.87**	-12.35**	9.94**	-23.07**	31.42**	4.23**	24.63**	16.86**	29.88**	-0.42	1.99**
RK-9901 x Varuna	6.12**	3.10**	18.28**	9.62**	-30.94**	6.35	-29.33**	1.77	20.75**	17.01**	21.38**	41.05**	-1.53	-4.63**
RK-9901 x Vardan	10.20**	3.10**	20.60**	19.58**	-19.92**	21.11**	-13.33**	-1.48	16.94**	10.20**	44.57**	28.80**	2.49**	2.09**

RK-9902 x Kranti	11.57**	7.75**	15.04**	15.52**	-30.54**	9.18**	-1.53	32.11**	22.88**	-4.15	29.51**	17.78**	0.07	1.75**
RK-9902 x Rohini	12.24**	8.78**	13.88**	11.97**	15.93**	21.65**	-4.61	24.50**	8.04**	10.16**	65.96**	19.06**	-0.10	2.80**
RK-9902 x Varuna	7.48**	6.97**	11.80**	0.70	-17.26**	-9.71**	-10.26**	26.18**	10.58**	20.84**	17.77**	33.67**	-0.52	3.17**
RK-9902 x Vardan	5.44**	5.42**	13.65**	5.40**	-16.33**	2.52	3.58	23.81**	25.84**	-5.32	31.92**	19.16**	5.43**	3.31**
RK-2007 x Kranti	-4.08**	-6.97**	-17.36**	8.25**	19.12**	21.88**	-5.64	19.26**	6.77**	4.11	-11.74**	11.17**	-0.85	2.06**
RK-2007 x Rohini	2.04	-5.17**	-17.36**	6.26**	50.46**	25.24**	-13.33**	25.49**	8.04**	0.08	45.18**	8.14**	-1.28	2.63**
RK-2007 x Varuna	-3.40*	-6.97**	-17.59**	-4.63**	20.84**	20.65**	-16.92**	34.38**	5.50**	7.37**	14.45**	13.27**	-0.42	2.16**
RK-2007 x Vardan	0.67	-6.97**	-15.97**	5.55**	32.80**	18.36**	-7.18	27.47**	1.69**	-1.00	51.80**	-0.10	-0.10	2.40**
RK-9807 x Kranti	-12.24**	-8.27**	-7.63**	9.40**	27.88**	19.58**	-6.15	24.50**	11.85**	3.26	46.38**	15.53**	-1.35	2.70**
RK-9807 x Rohini	-16.32**	-9.82**	-9.72**	4.06**	45.15**	33.89**	-10.76**	26.48**	15.67**	-10.32**	35.24**	3.74**	2.16**	2.87**
RK-9807 x Varuna	-8.16**	-6.45**	-8.33**	-3.14**	20.84**	5.35	-18.46**	24.48**	19.06**	-11.08**	51.20**	5.79**	4.25	2.40**
RK-9807 x Vardan	-4.08**	-8.27**	-9.72**	1.19	34.13**	13.00**	-6.15	22.52**	20.75**	-9.56**	65.15**	9.17**	-1.10	3.21**
Basanti x Kranti	1.36	7.49**	21.29**	12.25**	-1.72	16.29	-23.07**	16.60**	10.58**	4.19*	74.39**	15.22**	0.07	2.36**
Basanti x Rohini	6.12**	7.75**	20.6**	11.97**	36.78**	16.52**	-27.69**	23.81**	8.04**	18.87**	46.68**	28.44**	0.22	14.00**
Basanti x Varuna	-4.08**	10.33**	24.30**	1.98*	16.46**	-12.01**	-3.07	21.83**	5.50**	17.90**	54.51**	24.39**	1.73	5.48**
Basanti x Vardan	4.08**	8.52**	20.60**	6.41**	37.18**	23.18**	-17.43**	23.81**	11.00**	22.29**	-18.97**	35.77**	-2.18**	4.19**
Jawahar-1 x Kranti	5.44**	7.75	11.34**	8.55**	6.24**	-12.01**	-9.23	-1.18	20.75**	1.85	-5.12	18.55**	-0.42	3.51**

Jawahar-1 x Rohini	-2.04	-2.32**	3.47**	3.84**	-18.99**	-8.41**	-16.41**	2.07	8.04**	7.62**	-15.96**	16.29**	-1.18	1.82**
Jawahar-1 x Varuna	4.08**	0.77	13.19**	-2.00**	-6.64*	-3.59**	-16.92**	20.53**	13.13**	8.42**	43.67**	22.55**	3.17	3.45**
Jawahar-1 x Vardan	8.16**	-2.84**	9.72**	3.84**	8.89**	-9.48	-7.69	23.51**	10.16**	10.96**	69.57**	22.24**	1.23	3.28*
Vaibhav x Kranti	4.08	-1.03*	5.09**	-6.56**	12.88**	57.61**	-32.30**	27.47**	-2.12*	4.67*	12.65**	2.46*	-0.02	-1.89**
Vaibhav x Rohini	-4.08**	1.80**	21.75**	-11.20**	19.12**	42.08**	-27.69**	26.77**	20.33**	-2.41	-7.83**	16.55**	1.23	2.57
Vaibhav x Varuna	2.04**	0.00	20.36**	-16.18**	-3.45	28.00**	-13.84**	22.52**	25.84**	-10.92**	-32.53**	11.63**	2.16**	-0.30
Vaibhav x Vardan	4.08**	1.55**	18.28**	-13.40**	-3.05	41.31**	-12.30**	20.55**	2.11**	18.34**	-45.48**	20.86**	5.18**	1.01**
Pusa Bold x Kranti	2.04**	-3.10**	20.60**	52.23**	0.92	19.35**	-25.64**	21.54**	1.69**	27.21**	-22.59**	29.21**	2.59**	-0.50**
Pusa Bold x Rohini	4.08**	-4.13**	20.88**	50.67**	23.50**	47.66**	-29.23**	24.80**	1.27**	30.44**	-26.20**	32.08**	2.23**	-2.70**
Pusa Bold x Varuna	-10.20**	-6.97**	23.38**	49.09**	22.57**	13.77**	-16.92**	25.49**	11.44**	24.27**	-4.51	38.59**	4.75**	4.12**
Pusa Bold x Vardan	-4.08**	-3.87**	12.5**	28.92**	16.46**	28.00**	-23.07**	32.41**	16.94**	19.15**	39.15**	39.36**	1.48	3.38
RK-2001 x Kranti	-15.67**	11.62**	-15.27**	22.68**	11.55**	33.12**	-7.69	17.58**	9.31**	11.61**	4.81	22.03**	-8.65**	-0.27**
RK-2001 x Rohini	-15.65**	13.95**	-15.27**	22.94**	32.80**	37.49**	-16.92**	14.32**	1.69**	16.37**	54.51**	18.34**	-3.44**	-12.85**
RK-2001 x Varuna	-14.28**	9.04**	-14.35**	15.52**	-5.71*	6.57	-16.41**	25.79**	1.69**	16.08**	84.93**	18.04**	-3.19**	-17.01**
RK-2001 x Vardan	-12.24**	11.62**	-5.55**	20.37**	11.15**	25.24**	-7.69	17.58**	1.69**	21.04**	11.14**	23.11**	1.23	-10.04**
RK-2002 x Kranti	-12.91**	13.69**	-3.93**	12.61**	19.92**	42.08**	-12.30**	19.58**	8.04**	58.95**	-23.49**	28.19**	-7.14**	-8.89**
RK-2002 x Rohini	-8.16**	11.88**	-6.94**	16.80**	33.73**	54.55**	-21.53**	27.76**	8.04**	20.40**	4.51	26.65**	0.15	-5.68**

RK-2002 x Varuna	-14.28**	13.95**	-3.00**	5.62**	46.48**	43.22**	-25.12**	25.79**	11.44**	9.19**	19.87**	21.68**	-6.21**	-13.70**
RK-2002 x Vardan	-4.08**	27.38**	-9.49**	11.82**	39.04**	24.48**	-14.87**	26.18**	8.46**	21.17**	47.59**	21.68**	-7.47**	-4.43**
RK-2003 x Kranti	-20.40**	-1.55**	-10.41**	9.62**	15.93**	31.82**	-11.8**	18.28**	15.67**	4.11	41.56**	20.45**	-6.31**	-3.38**
RK-2003 x Rohini	-15.65**	-0.51	23.38**	5.40**	44.35**	32.36**	-15.38**	27.76**	18.21**	0.48	36.44**	27.42**	-6.56**	-8.96**
RK-2003 x Varuna	-17.69**	0.00	-9.72**	-6.84**	39.04**	24.71**	-23.07**	22.52**	10.58**	6.04**	53.31**	17.27**	-1.28	-14.78
RK-2003 x Vardan	-20.40**	-2.32**	-3.47**	1.98*	42.09**	27.23**	-11.8**	17.58**	13.13**	9.07**	-12.95**	23.42**	-2.69**	-10.41**
RK-9803x Kranti	-11.57**	-7.23**	-0.69**	1.56*	21.24**	22.18**	-16.9**	20.84**	11.00**	19.47**	53.01**	32.64**	3.17	4.56**
RK-9803x Rohini	-13.61**	-6.45**	-3.47**	0.42	43.82**	38.25**	-23.07**	23.51**	-1.27**	34.07**	15.66**	32.64**	6.26**	4.49**
RK-9803x Varuna	-19.73**	-9.55**	3.47**	-10.19**	42.09**	31.82**	-26.15**	26.48**	14.40**	20.00**	34.93**	37.31**	1.15	1.75**
RK-9803x Vardan	-19.04**	-7.75**	10.88**	-7.05**	43.55**	29.83**	-13.84**	15.61**	16.94**	14.31**	49.09**	33.67**	-22.24	5.00**
RK-9804x Kranti	3.40*	-10.07**	10.88**	-100**	-5.71**	16.06**	-6.15	9.38**	5.50*	15.60**	11.47**	33.02**	6.11**	-100.0**
RK-9804x Rohini	4.75*	-11.10**	15.50**	10.54**	34.52**	28.69**	-9.23**	10.96**	4.23**	17.82**	58.13**	22.80**	2.23**	4.05**
RK-9804x Varuna	-5.44**	-8.52**	6.71**	1.83*	20.45**	0.99	-14.87**	20.84**	11.00**	14.95**	73.49**	27.62**	0.65	3.11**
RK-9804x Vardan	-2.04	-11.62**	11.80**	13.81**	11.95**	16.06**	-3.07	17.58**	9.73**	16.33**	52.10**	25.01**	3.49**	4.29**

1. Days to flower; 2. Days to Maturity; 3. Plant height; 4. Length of main raceme
5. Number of Primary branches; 6. Number of secondary branches; 7. Number of siliquae on main raceme; 8. Number of seeds per siliqua
9. Biomass; 10. Harvest index; 11. 1000- seed weight; 12. Yield per plant
13. Oil content; 14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table 13 : Estimates of inbreeding depression for 14 characters in *Brassica juncea* (L.) Czern.Coss.

Cross combination	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Sanjuktax Kranti	3.88**	7.85	-3.76**	21.55	4.80	9.76	-37.71**	-41.90*	-17.81**	16.41**	-17.28*	1.14	6.25**	11.07**
SanjuktaxRohini	-15.67**	7.29	21.62**	13.27**	-7.25**	-3.65	-45.53**	-11.11	-9.52**	22.35**	-71.97**	14.90**	11.13**	16.99**
SanjuktaxVaruna	11.27**	-0.74**	15.61**	7.51**	-40.18**	-50.68**	-37.50**	-17.08	-18.26**	23.70**	11.30**	9.45**	9.87**	-0.47
Sanjuktax Vardan	4.44**	1.48*	-22.21**	17.00**	56.75**	51.89	-9.21**	-7.61	19.21**	20.52**	31.69**	5.34**	-1.99	-1.10
Pusa Basant x Kranti	25.82**	-1.26*	20.76**	21.15	-20.51**	15.07*	25.25**	-1.86	10.84**	-0.48	5.32	11.03**	-1.69	0.39
Pusa Basant x Rohini	0.69	13.46**	-6.22**	20.88**	23.00**	-17.26*	9.83**	-12.90	11.26**	-0.55	54.42**	10.83**	-1.48	-0.69
Pusa Basant x Varuna	12.33**	-3.62**	15.34**	-20.25**	-6.26**	28.63**	25.0**	-12.62	5.28**	-2.41	23.96**	3.02	-5.74**	-1.15
Pusa Basant x Vardan	6.08**	-2.31**	-11.24**	1.63**	-2.08**	-4.76	10.72**	-15.92	-21.46**	-4.07	10.49**	1.87	-4.15**	2..22**
Pusajaikisan x Kranti	22.08**	2.41**	23.38**	16.40**	24.64**	6.17	9.47**	-54.63	9.90**	-03.2	-0.21	7.26**	-1.10	0.88
Pusajaikisan x Rohini	4.71**	-3.53**	-7.54**	14.58**	-19.87**	1.77	-14.6**1	-40.07	-21.28**	47.12**	-18.42**	35.94**	-1.93	-0.36
Pusajaikisan x Varuna	15.61**	-4.90**	21.49**	-5.34**	-42.18**	17.55*	-6.45**	-39.81	-18.82**	23.54**	19.32**	9.14**	7.10**	7.94**
Pusajaikisan x Vardan	6.00	-2.96**	21.69**	-0.89**	-6.93**	28.33**	14.70**	-21.93	-9.57**	31.61**	-37.87**	25.19**	5.01**	21.23**
Pusa Bahar x Kranti	18.51**	-0.23**	23.28**	-2.20**	0.84**	14.18*	6.47**	-27.18	10.83**	22.43**	-43.13**	-9.13**	8.25**	14.04**
Pusa Bahar x Rohini	-0.63**	-3.45**	8.15	-8.67**	-11.34**	18.56**	-12.96**	-26.27	11.57**	24.46**	-38.90**	-9.98**	6.62**	4.42**
Pusa Bahar x Varuna	14.81*	-7.08**	-10.61**	16.32**	-83.58**	-41.86**	-9.34**	-22.82**	11.81**	-25.56**	35.71**	-10.68**	6.25**	-0.19
Pusa Bahar x Vardan	10.56	-6.15**	-8.64	-12.86**	-92.53**	-41.62**	6.32**	-27.77**	14.28**	-13.34**	8.0**	-2.91	6.51**	3.84**
Krishna x Kranti	16.07	-3.18**	2..95**	3.55**	-53.57**	-18.19**	10.61**	-9.75	16.16**	29.34**	24.46**	40.71**	6.41**	0.16
Krishna x Rohini	1.88**	-3.33**	16.15**	-11.68**	-34.60**	-38.79**	-14.0**	-54.34	10.35**	-30.01**	-59.68**	-16.49**	8.19**	-0.16
Krishna x Varuna	17.76**	-2.33**	11.02	-13.44**	-25.10**	-31.39**	-23.91**	-10.68	4.31**	-13.59**	4.58	-9.17**	4.26**	11.82**
Krishna x Vardan	14.63**	-1.03*	3.43**	-8.10**	-41.26**	-28.58**	-13.57**	-45.37	5.22**	-18.49**	55.94**	-12.67**	7.07**	2.00**

Urvashi x Kranti	14.20*	-1.47	-9.25**	6.03**	-10.54**	-5.51	-3.92*	-31.10	-14.86**	10.50**	7.23**	-4.58**	-6.00**	-8.71**
Urvashi x Rohini	-5.23**	-1.27**	-4.37**	-2.63**	-45.11**	-26.19**	-30.48**	48.10	-9.09**	64.06**	4.10*	35.37**	-0.07	6.28**
Urvashi x Varuna	9.07*	6.76**	19.73**	-8.44**	9.63	-18.94*	-30.88**	-6.20	-4.28*	10.00**	11.98**	6.17**	-2.85**	-4.56**
Urvashi x Vardan	8.00*	6.74**	11.52*	5.13**	-21.94**	12.31	7.64**	-14.06	-19.71**	17.12**	49.65**	1.49	-1.37	-12.38**
Sita x Kranti	-5.00**	2.03	-13.43**	16.34**	-41.76**	-31.12	6.46**	-0.64	20.38**	5.40**	53.14**	24.75**	-12.05**	1.49*
Sita x Rohini	-24.02**	2.25	-31.82**	9.05**	10.21	22.53**	-16.52**	-25.38	10.0**	23.07*	-12.19**	28.55**	3.29**	4.25**
Sita x Varuna	4.85**	-9.23	-29.91**	-48.20**	-56.87**	-35.88**	-72.50**	-31.80	1.72**	19.83	13.66**	21.32**	-0.92	-19.53**
Sita x Vardan	2.08	-4.01**	-17.66**	-38.48**	-2.46	-57.18**	-21.73**	-5.43	4.56**	17.63*	7.28**	21.48**	-11.26**	-0.62
RK-9901x Kranti	14.66**	-9.23**	20.52**	2.69**	2.06	-69.02**	-1.92	-38.11	-9.70**	10.26**	45.74**	1.05	0.74	-11.62**
RK-9901x Rohini	-4.56**	-5.42**	4.40**	-0.35	-43.48**	-47.32*	-20.66**	12.03**	-13.81**	17.34**	7.47*	6.55**	-5.13**	-1.52*
RK-9901x Varuna	4.48	-5.06**	16.23	7.15**	-57.11**	-16.67*	-39.13**	5.53**	9.47**	34.01**	-3.97**	40.15**	9.02**	-6.66**
RK-9901x Vardan	5.55	-1.50**	19.19*	13.69**	-83.58**	-2.52	-5.92	-30.69	2.17	3.00	7.29**	5.05**	2.52*	-.1.02
RK-9902xKranti	15.85*	3.59**	23.54**	18.69**	-76.48**	1.40	15.62**	6.73**	5.86**	-23.13**	7.90**	-15.97**	1.50	-0.26
RK-9902x Rohini	-1.81**	5.92**	8.73**	11.15**	-16.49**	-0.16	1.61**	-2.38	3.91*	-18.30**	24.68**	-13.60**	14.60**	-1.54*
RK-9902x Varuna	-8.84	-1.93*	1.86	-6.09**	-47.67**	-20.33*	2.84**	59.27	-2.29	42.44**	-13.29**	41.10**	-4.30**	1.47*
RK-9902x Vardan	-3.21**	-1.71**	3.46**	10.15**	-58.73**	-13.20	30.19**	-2.95	15.15**	-25.85**	-18.95**	-6.75**	3.65**	0.09
RK-2007x Kranti	0.70	-15.0**	19.05**	12.75**	17.83**	17.95**	24.99**	0.82	-2.38	-23.93**	-29.69**	-26.87**	0.25	0.03
RK-2007x Rohini	-0.66	-11.99**	-36.69**	5.49**	19.94**	6.84	8.27**	-12.59**	-7.05**	-14.74**	35.68**	-21.28**	3.31**	4.31**
RK-2007x Varuna	3.50**	-13.33**	-37.52**	-9.12**	20.10**	-15.85*	-15.42**	-5.12	-4.81**	15.58**	-41.05**	11.49**	21.91**	-4.66**
RK-2007x Vardan-	-1.35	-13.89**	-32.50**	5.95**	-3.00	-3.82	6.63**	7.75	-15.0**	9.53**	51.19**	-4.82	20.32*	3.46**
RK-9807x Kranti	-4.65**	-11.27*	-18.04**	70.82**	30.42**	14.45*	18.03**	19.28	-8.33**	0.23	-4.11	-7.67**	-3.75**	9.05**
RK-9807x Rohini	-30.90**	-16.62**	-21.28**	-3.08**	33.85**	-2.85	3.44**	-11.17	3.29	-4.078**	34.52**	-27.32**	-1.40	1.34
RK-9807x Varuna	-1.48**	-16.29**	-14.14**	-7.66**	32.96**	9.22	-22.04**	5.65	8.18**	-14.64**	45.81**	-5.42**	8.52**	-0.56

RK-9807x Vardan	0.70	-12.97**	-23.33**	0.90	18.51**	2.30	-3.81*	-14.75**	7.36**	-15.7**	4.77**	-5.35**	1.34	0.19
Basanti x Kranti	6.03	0.48**	16.05**	19.18**	15.27**	39.67**	-20.00**	-23.13**	4.59**	-22.29**	15.02**	-17.12**	1.10	-1.02
Basanti x Rohini	-3.21**	1.43**	15.35**	10.44**	10.44**	9.19	-33.34**	-1.35	2.35	44.33**	3.08	45.65**	-1.60	2.40**
Basanti x Varuna	12.76**	6.32**	20.48**	-6.10**	-6.10**	-31.91**	33.33**	-24.65	-10.84**	6.46**	14.23**	11.29**	3.78**	2.14**
Basanti x Vardan	15.68**	6.42	18.42**	4.36**	4.36**	-2.48	-8.06**	-7.50	-3.05	41.80**	-79.55**	40.01**	-6.32**	-0.65
Jawahar-1 x Kranti	19.35**	4.79*	20.78**	15.63**	15.63**	5.84	6.22**	-14.30	5.61**	-10.51**	-19.36**	-4.02	-4.54**	-2.62**
Jawahar-1 x Rohini	-6.25	-4.79*	4.02**	5.49**	5.49**	13.25*	-11.66**	-34.55	-14.90**	+6.59**	-86.38**	-5.17**	0.68	-1.60*
Jawahar-1 x Varuna	-2.60**	-7.17**	10.84**	4.80**	4.80**	-54.09**	3.70*	7.37	-5.24	-0.74	16.98**	-7.98*	-0.41	5.83**
Jawahar-1 x Vardan	20.75. **	-7.71**	8.86**	13.79	13.79**	0.97**	16.66*	-18.96	6.54*	-5.16*	26.64**	1.71	+1.56	5.10**
Vaibhav x Kranti	23.07**	-3.65**	14.31**	13.27**	13.27**	8.45**	4.54**	-6.74	5.62**	-14.44**	-21.92**	-7.90**	-2.51	-0.56
Vaibhav x Rohini	2..12*	-1.02**	15.58**	0.07**	0.07**	-1.19	-21.97**	39.20	13.03**	-6.65**	-20.91**	6.59**	8.77**	9.84**
Vaibhav x Varuna	14.00**	-4.13**	24.99**	-39.13**	-39.13**	26.36**	13.69*	-20.16	17.84**	-18.74**	7.14	2.82	4.18**	-0.63
Vaibhav x Vardan	13.27**	3.56*	24.65**	-30.69**	-30.69**	20.96**	19.87**	-5.73	37.34	5.54**	-128.7**	9.03**	12.91**	-6.42**
Pusa Bold x Kranti	17.34**	-2.66	33.39**	31.32**	31.32**	56.83**	17.23**	6.50	-16.25**	23.32**	-45.91**	16.78**	7.03**	-1.84*
Pusa Bold x Rohini	0.03	-3.23*	21.64**	24.83**	24.83**	42.64**	-4.34*	-5.85	-24.26**	54.71**	-49.79**	43.69**	3.79**	1.33
Pusa Bold x Varuna	-4.54**	-17.22**	13.88**	28.76**	28.76**	-28.51**	-11.72**	-6.53	-1.57**	7.68**	-69.08**	6.29**	0.86	6.15**
Pusa Bold x Vardan	0.13	-9.41**	12.96**	20.01**	20.01**	-21.75**	-4.0	-1.26	4.70**	51.09**	17.96**	48.84**	1.81	-2.40**
RK- 2001 x Kranti	-13.74	5.32**	-25.40**	14.95**	14.95**	36.37**	27.83	-7.56	0.08	5.16**	-48.85**	5.20*	-14.40**	-17.04**
RK- 2001 x Rohini	-30.65**	7.70**	-15.30**	6.95**	6.95**	9.68	-14.20**	-29.90	-15.0**	27.85**	18.71*	17.06**	6.95**	-22.74**
RK- 2001 x Varuna	2.38**	3.31**	-24.86**	10.91**	10.91**	-60.08**	-**	1.25	-10.0**	14.58**	51.79**	6.68**	-4.674**	-10.45**
RK- 2001 x Vardan	0.76**	8.10**	-11.02**	15.09**	15.09**	-18.00**	1.33**	10.92	-11.25**	16.38**	-39.29**	6.99**	0.82	-10.80**

RK- 2002x Kranti	2.34**	10.45	0.96**	20.69**	20.69**	21.00**	-0.57	23.38**	-8.23**	27.57**	-67.71**	-5.03**	-8.864**	-11.51**
RK- 2002x Rohini	-16.28**	9.23	-19.40**	21.28**	21.28**	9.40	-10.45**	-2.86**	-4.70**	-49.29**	18.73**	45.44**	1.75	-15.17**
RK- 2002x Varuna	-10.30**	4.76**	-14.55**	9.85**	9.85**	3.79	-13.00**	-17.04**	2.28	-4.72	12.00**	-2.35	-9.65**	1.42
RK- 2002x Vardan	-6.38**	17.64**	-12.27**	15.54**	20.43**	24.76**	6.61**	-22.39**	6.24**	12.65**	13.06**	18.11**	-8.24**	-8.05**
RK- 2003x Kranti	-20.51**	-5.77**	-17.31**	21.22**	18.32**	-5.80	20.93**	-11.11	5.49**	-9.72**	-7.66**	-3.70**	-3.94**	-16.32**
RK- 2003x Rohini	-29.30**	-4.16**	9.52**	13.93**	34.03**	-10.80	-1.81	39.90	4.30**	49.23**	6.62**	54.70**	-4.68**	-13.41**
RK- 2003x Varuna	-7.41**	-5.68**	-7.94**	-14.22**	30.94**	7.79	3.34	20.16**	5.74**	9.16**	39.09**	14.37**	-1.12**	-9.72**
RK- 2003x Vardan	-15.38**	18.25**	-0.48**	-8.36**	14.29**	9.38	28.48**	-10.67	11.23**	-15.71**	4.84	1.45	-2.58**	-6.94**
RK- 9803x Kranti	4.61**	-10.30**	13.05**	1.41**	17.08**	36.94**	27.16**	-7.93	-9.55**	29.19**	35.4**	22.87**	5.12**	6.27**
RK- 9803x Rohini	0.77**	-10.49**	-2.15	-3.74**	34.71**	33.03**	8.66**	-21.60**	-12.87**	4.84**	45.31**	2.86	7.95**	5.30**
RK- 9803x Varuna	-16.12**	-21.71**	-1.34	-19.45**	52.33**	32.09**	-70.14**	-13.82**	-2.22	61.42**	7.36**	61.58**	1.06**	-1.64**
RK- 9803x Vardan	27.72**	-15.12**	4.80**	-13.80**	25.06**	11.19	-44.64**	-19.91**	3.26	-5.36**	33.53**	-1.91	-31.06**	2.54**
RK- 9804x Kranti	6.59	-49.42**	13.59**	21.22**	28.59**	40.21**	-0.54	-14.09**	-17.67**	22.81**	7.05**	6.71**	6.09**	6.27**
RK- 9804x Rohini	-3.89**	-16.56**	6.21**	7.60**	20.03**	34.18**	-9.61**	-18.43**	-23.57**	6.74**	36.67**	-15.23**	12.06**	1.56**
RK- 9804x Varuna	-2.15	-19.21**	-7.80**	-15.83**	44.10**	30.07**	-16.68**	-18.80**	2.66	-4.94	11.45**	2.12**	2.75**	-0.26**
RK- 9804x Vardan	-2.77	-16.95**	0.00**	5.33**	16.60	0.65	2.11	-28.31	-13.51**	11.68**	31.68**	-2.33**	2.99**	0.16**

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of Primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table-14: Mean, heritability, genetic advance in percent over mean in 14 characters in parents of *Brassica juncea* (L.) Czern. & Coss.

CHARACTERS	Mean	Heritability (%)	Genetic Advance	Genetic Advance in percent over mean
Days to flower	49.30	9.12	6.80	13.80
Days to maturity	128.3	.963	10.5	8.10
Plant height (cm)	145.5	.995	44.40	30.50
Length of raceme (cm)	48.00	.996	23.60	49.00
Number of primary branches /Plant	6.80	.772	1.80	26.50
Number of secondary branches/Plant	12.67	.867	2.80	22.10
Number of siliquae on main raceme	49.30	.995	26.10	52.90
Number of seeds per siliqua	11.00	.760	2.30	20.90
Biomass (g)	80.50	.968	16.80	20.80
Harvest index (%)	26.7	.940	5.40	20.10
1000-seed weight (g)	3.80	.867	0.75	17.20
Yield per plant (g)	21.50	.972	6.70	31.40
Oil content (%)	38.10	.399	0.90	2.40
Protein Content (%)	28.70	.894	2.54	8.20

Table-15: Mean, heritability, genetic advance in percent over mean in 14 characters in F_1sof *Brassica juncea* (L.) Czern. & Coss.

CHARACTERS	Grand Mean	Heritability (%)	Genetic Advance	Genetic Advance in percent over mean
Days to flower	48.31	96.20	9.30	19.20
Days to maturity	130.91	98.40	17.40	13.30
Plant height	148.01	99.50	44.20	29.90
Length of saceme	50.51	99.70	16.30	32.20
Number of primary branches	8.31	99.00	3.90	46.20
Number of sec. branches	15.06	97.90	4.71	31.11
Number of siliqua on main raceme	53.81	98.20	13.70	25.50
Number of seeds per siliqua	12.91	99.00	4.00	30.70
Biomass	87.61	97.20	22.50	25.70
Harvest index	27.21	97.80	4.31	15.70
1000-seed weight	4.21	97.90	2.10	50.00
Yield per plant	23.71	99.40	7.30	30.80
Oil content (%)	39.61	95.60	2.50	6.30
Protein Content (%)	29.48	96.4	3.10	10.60

Table-16:Mean, heritability, genetic advance in pesernt over mean in 14 character in F_2s of *Brassica juncea* (L.) Czern. & Coss.]

CHARACTERS	Grand Mean	Heritability (%)	Genetic Advance	Genetic Advance in percent over mean
Days to flower	47.0	84.20	8.90	17.80
Days to maturity	134.9	89.40	10.60	7.90
Plant height	145.8	98.10	34.50	23.70
Length of saceme	48.20	99.70	12.70	26.40
Number of primary branches	8.00	99.00	3.60	45.30
Number of sec. branches	15.70	99.30	7.70	49.00
Number of siliqua on main raceme	55.30	94.90	12.70	22.90
Number of seeds per siliqua	14.20	98.80	3.60	25.00
Biomass	88.30	96.90	25.90	29.40
Harvest index	24.70	99.00	6.90	28.11
1000-seed weight	4.00	98.20	2.00	49.01
Yield per plant	21.70	98.20	10.00	46.00
Oil content (%)	39.40	82.80	2.80	7.10
Protein Content (%)	29.60	97.70	3.50	11.90

Table–17 : Environmental correlation coefficient for 14 characters among parents (20 females and 4 testers) in *B. juncea* (L.) Czern. & Coss.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	0.013	0.177	0.256	-0.046	0.115	0.089	-0.052	0.232	-0.091	-0.135	-0.076	0.031	0.007
2		X	0.95	-0.107	0.158	-0.217**	0.324**	0.033	-0.022	0.010	0.075	-0.049	-0.216**	0.0074
3			X	0.040	-0.064	-0.165	0.093	.011	0.020	-0.152	-0.160	-0.205	-0.075	-0.114
4				X	0.002	-0.091	0.136*	-0.139*	0.126*	-0.027	-0.091	0.104*	0.267**	0.105
5					X	0.131	0.102*	0.194*	0.094	-0.041	0.075	0.010	-0.024	0.129
6						X	0.067	-0.156*	-0.141*	0.123	-0.018	0.100	0.138	0.029
7							X	-0.107	0.095	-0.080	-0.117*	-0.117*	-0.031	-0.113
8								X	0.016	0.055	-0.006	-0.053	-.397**	-0.127
9									X	-0.474**	-0.075	-0.309*	-0.160	-0.191
10										X	0.030	0.818***	0.089	0.143
11											X	0.027	-0.133*	0.339*
12												X	0.181*	-0.124
13													X	-0.039

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table–18 : Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficient for 14 characters among parents 20 females and 4 testers in *B. juncea* (L.) Czern. & Coss.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	0.417**	0.498***	0.121	-0.047	0.454**	0.308*	-0.061	0.321*	0.142	0.235	0.278	0.456**	0.234
2	0.444**	X	0.325*	0.404**	-0.162	0.218	0.443**	0.117	0.293*	0.009	0.242	0.167	-0.004	-0.009
3	0.518**	0.330*	X	0.283	-0.515***	0.267	0.257	0.219	0.183	0.327*	0.266	0.336*	0.168	0.196
4	0.122	0.414**	0.284	X	-0.291*	0.173	0.447**	0.296*	0.363*	0.034	0.349*	0.228	-0.191	-0.128
5	-0.048	-0.205	-0.585***	-0.332*	X	0.127	-0.065	-0.014	0.133	-0.205	-0.279	-0.001	0.348*	0.311*s
6	0.496***	0.255	0.292*	0.188	0.127	X	0.355*	0.016	0.386*	0.428**	0.245	0.564***	0.171	0.078
7	0.321*	0.448**	0.258	0.449**	-0.078	0.381**	X	-0.075	0.317*	-0.058	0.341*	0.123	0.057	0.271
8	-0.064	0.133	0.252	0.345*	-0.078	0.054	-0.080	X	0.109	0.297*	0.215	0.299*	-0.142	-0.050
9	0.329*	0.304*	0.186	0.368*	0.144	0.432**	0.322*	0.126	X	0.025	0.323*	0.657***	0.179	0.135
10	0.161	0.009	0.341	0.036	-0.235	0.463**	-0.059	0.344*	0.048	X	0.429**	0.754***	-0.020	-0.277
11	0.281	0.259*	0.291	0.377*	-0.357*	0.285	0.371*	0.266	0.357*	0.452**	X	0.505***	-0.001	0.000
12	0.299*	0.174	0.344*	0.231	-0.002	0.607***	0.127	0.352*	0.686***	0.754***	0.548***	X	0.102	-0.105
13	0.744	0.046	0.274*	-0.324*	0.644***	0.224	0.093	0.015	0.323*	-0.060	0.062	0.191	X	0.016
14	0.258	-0.014	0.211*	-0.138	0.339*	0.084	0.290*	-0.036	0.157	-0.314*	-0.045	-0.125	0.775***	X

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table–19 : Environmental correlation coefficient for 14 characters among F_1s in *B. juncea* (L.) Czern. & Coss.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	0.058	-0.034	0.023	0.121	-0.102	-0.037	-0.173*	-0.039	0.029	-0.001	-0.018	0.140	0.010
2		X	0.045	-0.012	-0.059	-0.018	0.145	0.014	-0.047	0.043	-0.045	0.136	-0.113	0.030
3			X	0.000	0.010	0.083	0.030	-0.020	0.154	0.069	-0.097	-0.068	0.156	-0.094
4				X	-0.162*	0.011	0.005	-0.046	-0.097	0.003	-0.098	-0.137	0.015	0.027
5					X	-0.076	0.226**	0.002	-0.033	-0.055	0.062	-0.033	0.099	0.056
6						X	0.031	0.044	0.034	-0.015	-0.036	-0.168*	0.057	-0.158
7							X	-0.055	-0.023	-0.136	-0.046	0.042	-0.142	-0.040
8								X	-0.010	0.009	0.012	-0.115	0.021	-0.003
9									X	0.035	0.055	0.023	0.089	-0.110
10										X	-0.058	-0.072	0.015	-0.132
11											X	-0.209**	-0.160*	0.075
12												X	-0.097	0.117
13													X	0.185*s

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table–20 : Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficient for 14 characters among F_1s in *B. juncea* (L.) Czern. & Coss.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	0.122	0.498**	0.024	-0.558**	-0.372**	0.181*	-0.417**	-0.324**	0.242**	0.048	-0.216**	0.224**	0.350**
2	0.123	X	0.038	0.015	-0.185*	-0.037	-0.159*	-0.113	-0.044	0.225**	-0.103	-0.093	-0.441**	-0.407**
3	0.509**	0.038	X	0.301**	-0.230**	0.016	0.210**	-0.041	-0.040	0.112	0.004	0.000	0.380**	0.297**
4	0.024	0.016	0.302**	X	0.060	0.198*	0.090	0.092	0.266**	-0.116	-0.192*	-0.032	0.081	-0.035
5	-0.574**	-0.187*	-0.231**	0.062	X	0.626**	0.060	0.462**	0.432**	-0.209**	0.052	0.235**	-0.113	-0.115
6	-0.380**	-0.037	0.017	0.201*	0.637**	X	0.069	0.543**	0.175*	-0.211**	-0.234**	-0.080	-0.053	-0.277**
7	0.187*	-0.164*	0.212**	0.091	0.058	0.070	X	0.016	0.087	0.090	0.233**	-0.153	0.037	0.069
8	-0.423**	-0.115	-0.041	0.093	0.467**	0.551**	0.017	X	0.218**	-0.144	0.009	0.069	0.154	-0.037
9	-0.334**	-0.044	-0.042	0.271**	0.441**	0.178*	0.028	223**	X	-0.483**	0.115	0.335**	0.031	-0.086
10	0.248**	0.229**	0.113	-0.118	-0.212**	-0.215**	0.094	-0.146	-0.496**	X	0.085	0.014	0.043	0.018
11	0.050	-0.104	0.005	-0.194*	0.052	-0.239**	0.239**	0.009	0.116	0.088	X	0.127	-0.034	0.082
12	-0.221**	-0.096	0.000	-0.031	0.237**	-0.079	-0.155	0.071	0.341**	0.015	0.131	X	0.147	-0.036
13	0.228**	-0.451**	0.388**	0.083	-0.119	-0.056	0.042	0.158	0.029	0.044	-0.030	0.152	X	0.402**
14	0.363**	-0.418**	0.304**	-0.036	-0.119	-0.280**	0.072	-0.038	-0.085	0.023	0.082	-0.038	0.426**	X

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table – 21 : Environmental correlation coefficient for 14 characters among F_2s in *B. juncea* (L.) Czern. & Coss.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	0.237**	-0.020	-0.098	-0.121	-0.097	0.056	-0.189*	0.134	-0.006	-0.021	0.050	0.048	-0.059
2		X	-0.021	0.000	0.076	0.065	-0.009	-0.153	0.101	0.100	0.102	-0.028	-0.043	-0.014
3			X	0.003	0.136	-0.087	-0.109	0.169*	10.072	0.010	-0.019	0.080	0.040	0.082
4				X	-0.044	0.031	0.071	0.045	0.135	0.098	0.112	-0.109	-0.001	-0.048
5					X	-0.013	-0.010	-0.128	-0.001	0.043	0.137	-0.093	-0.047	0.025
6						X	0.005	0.013	0.115	0.192*	-0.230**	-0.068	-0.092	0.056
7							X	0.027	0.085	0.018	-0.091	0.021	-0.042	0.030
8								X	0.010	0.023	-0.032	0.027	-0.040	0.085
9									X	0.111	0.017	-0.029	0.030	-0.085
10										X	0.020	0.021	-0.023	-0.133
11											X	-0.474**	0.033	-0.018
12												X	0.007	0.018
13													X	0.028
14														X

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.

Table–22 : Phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficient for 14 characters among F_2s in *B. juncea* (L.) Czern. & Coss.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	X	0.119	0.343**	0.131	0.189*	0.079	0.339**	0.320**	-0.018	-0.054	0.156	0.026	0.029	0.102
2	0.102	X	0.181*	0.189*	-0.020	0.207*	0.359**	0.191*	0.107	0.031	0.128	0.174*	0.008	0.086
3	0.379**	0.195*	X	-0.014	-0.052	0.220**	0.316**	0.170*	-0.105	0.032	0.095	0.025	0.326**	0.140
4	0.145	0.200*	-0.014	X	0.001	0.503**	0.262**	0.014	0.000	0.102	-0.066	0.136	-0.054	0.081
5	0.212**	-0.024	-0.055	0.001	X	0.257**	0.017	0.068	0.456**	0.039	0.004	0.277**	-0.140	-0.219**
6	0.090	0.222**	0.224**	0.505**	0.260**	X	0.191*	0.076	0.042	0.326**	-0.058	2.89**	0.216**	0.103
7	0.374**	0.391**	0.332**	0.269**	0.018	0.196*	X	0.289**	0.056	-0.016	0.360**	0.152	0.089	0.125
8	0.360**	0.209**	0.170*	0.013	0.071	0.076	0.298**	X	0.138	-0.017	0.065	0.263**	-0.194*	-0.139
9	-0.030	0.109	-0.106	-0.001	0.466**	0.041	0.055	0.141	X	-0.224**	0.111	0.490**	-0.090	-0.227**
10	-0.059	0.030	0.032	0.102	0.039	0.327**	-0.017	-0.018	-0.230**	X	-0.085	0.421**	0.183*	0.006
11	0.173*	0.132	0.097	-0.066	0.002	-0.056	0.376**	0.066	0.113	-0.086	X	0.161*	-0.028	-0.099
12	0.026	0.187*	0.024	0.138	0.282**	0.293**	0.157	0.266**	0.503**	0.426**	0.172*	X	0.127	-0.093
13	0.026	0.016	0.359**	-0.059	-0.153	0.242**	0.105	-0.213**	-0.102	0.204**	-0.033	0.140	X	0.413**
14	0.116	0.093	0.141	0.082	-0.224**	0.104	0.128	0.142	-0.231**	0.008	-0.101	-0.095	0.457**	X

1. Days to flower
2. Days to maturity
3. Plant height
4. Length of main raceme
5. Number of primary branches
6. Number of secondary branches
7. Number of siliquae on main raceme
8. Number of seeds per siliqua
9. Biomass
10. Harvest index
11. 1000- seed weight
12. Yield per plant
13. Oil content
14. Protein content.

* and ** denote significant of 5% and 1% levels of significance, respectively.