



[Handwritten signature]
26/11/2007

LIBRARY
New Delhi

Call No. T-6602

Acc. No. T-6602

Genetical studies on components of variance of
biparental progenies for yield and disease resistance
in *Brassica juncea* (L.) Czern & Coss.

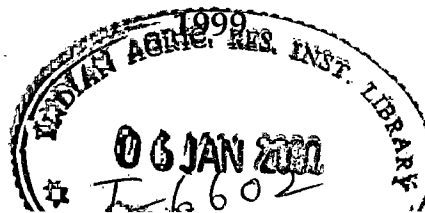
PAVAN KUMAR PREM MEENA

DIVISION OF GENETICS
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI - 110 012

T6602



IARI



GENETICS; PROGENY; YIELDS; DISEASES;

BRASSICA JUNCEA; HERITABILITY;

INFECTION; MATING;

**Genetical studies on components of variance of
biparental progenies for yield and disease resistance
in *Brassica juncea* (L.) Czern & Coss.**

By

PAVAN KUMAR PREM MEENA

A Thesis

submitted to the faculty of Post-Graduate School,
Indian Agricultural Research Institute, New Delhi
in partial fulfilment of the requirements
for the degree of

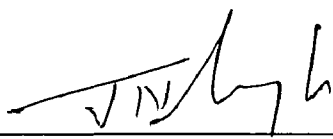
DOCTOR OF PHILOSOPHY

IN

GENETICS

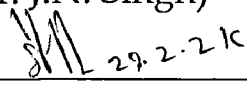
Approved by :

Advisory Committee : Chairman :

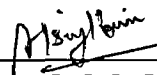


(Dr. J.N. Singh)

Members :



(Dr. V.P. Singh)



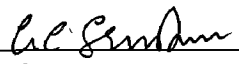
(Dr. S. M. S. Tomar)



(Dr. R. S. Malik)



(Dr. S.K. Mishra)



(Dr. G. C. Srivastava)



Dr. J.N. Singh
Senior Scientist

Division of Genetics
Indian Agricultural Research Institute
New Delhi-110012

CERTIFICATE

This is to certify that the thesis entitled "Genetical studies on components of variance of biparental progenies for yield and disease resistance in *Brassica Juncea* (L.) Czern & Coss." submitted in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy in Genetics, to the Faculty of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, embodies the results of *bona fide* research work carried out by Mr. Pavan Kumar Prem Meena, under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma. The assistance and help received during the course of investigation has been duly acknowledged by him.

Place : New Delhi

Date : 11th Sept. , 1999



(J. N. Singh)

Chairman

Advisory Committee

ACKNOWLEDGMENTS

It is my privilege to record profound sense of gratitude and indebtedness to Dr. J. N. Singh, Senior Scientist, Division of Genetics, Indian Agricultural Research Institute, New Delhi, and Chairman of my advisory committee, for his insightful guidance with care, constant encouragement, keen interest and valuable suggestions through out the course of present investigation and preparation this manuscript.

I express my warm regards and sincere thanks to the members of my advisory committee, Dr. R.N. Raut, Dr. S. R. Singh Division of Genetics, who got retired shortly, Dr. V.P. Singh, Dr. S. M. S. Tomar, Dr. R.S. Malik, Dr. S.K. Mishra, Division of Genetics and Dr. G.C. Srivastava, Division of Plant Physiology, for their valuable suggestions during the course of present investigation.

I am immensely thankful to Dr. O.P. Govila, Professor of Genetics, Dr. K.R. Sarkar (former Professor, Division of Genetics) and Dr. Balram Sharma, Head, Division of Genetics for providing necessary facilities.

I owe my thanks to Dr. F.U. Zaman, Senior Scientist of Rice section for providing seed counting facility, and to Dr. P.N. Gambhir, Senior Scientist, NRL for the assistance in the estimation of oil content through NMR.

I am indebted and grateful to Dr. R.B. Mehra, Principal Scientist (Biometrics) for his valuable suggestions during the analysis of data, interpretation of results and preparation of this manuscript. I am sincerely thankful to Mr. S.K. Mahajan, IASRI, for providing me computer package to analyse the data.

I express my sincere thanks to Dr. R.K. Chaudhary, computer centre for providing computer facilities in analysis of data. My sincere thanks are due to Dr. B.K. Makin, Senior Scientist for his continuous encouragement and help during the period of this investigation.

I express my thanks to Dr. Rajendra Singh and Mr. Rahman for their help and assistance in field and laboratory works.

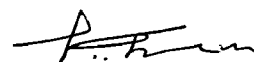
My thanks are due to Mr. Suresh and His son Sushil for typing in manuscript to its present shape.

The words in my knowledge are inadequate to express my deep sense of gratitude and indebtedness to my parents, brother, sisters and Rekha for their blessings, love, sacrifice and continuous inspiration during the course of study.

I express my ever lasting love to Shailesh, Golu, Neema, Sheema, Yogesh and Keshav.

The list of acknowledgment would be incomplete unless I express my thanks to Sh. Faiz Mohamad, Kailash, Sumer, Kamal, Samarth Lal, Ramswaroop and other fellows who were close to me during the study.

Finally, I express my gratitude to the director IARI, Dean, P.G. School for providing me fellowship and facilities for this study.



(Pavan Kumar Prem Meena)

IARI, New Delhi

Date : 11th September, 1999

CONTENTS

Sl. No.	Title	Page No.
1	INTRODUCTION	1-3
2	REVIEW OF LITERATURE	4-17
3	MATERIALS AND METHODS	18-30
4	EXPERIMENTAL RESULTS	31-49
5	DISCUSSION	50-64
6	SUMMARY	65-68
7	BIBLIOGRAPHY	i-viii
	APPENDIX	

LIST OF TABLES

Table No.	Title	After Page No.
1	Origin and cheif charactristics of parents	18
2	Analysis of variance (N.C. II mating design) for twelve characters in biparental progenies of Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	32
3	Analysis of variance for twelve characters in F ₃ progenies of Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	32
4	Analysis of variance (N.C. II mating design) for twelve characters in biparental progenies of Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	32
5	Analysis of variance for twelve characters in F ₃ progenies of Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	33
6	Analysis of variance (N.C. II mating design) for twelve characters in biparental progenies of BJ-38 x Poorbijaya cross of <i>Brassica juncea</i> (L.) Czern & Coss.	33
7	Analysis of variance for twelve characters in F ₃ progenies of BJ-38 x Poorbijaya cross of <i>Brassica juncea</i> (L.) Czern & Coss.	34
8	Estimates of variance, components of genetic variance and average degree of dominance for twelve characters in biparental progenies of Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	34
9	Estimates of variance, components of genetic variance and average degree of dominance for twelve characters in biparental progenies of Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	34
10	Estimates of variance, components of genetic variance and average degree of dominance for twelve characters in biparental progenies of BJ-38 x Poorbijaya cross of <i>Brassica juncea</i> (L.) Czern & Coss.	34
11	Mean, range, variance and genetic parameters for days to anthesis in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	38
12	Mean, range, variance and genetic parameters for plant height in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	38

13	Mean, range, variance and genetic parameters for number of primary branches in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	39
14	Mean, range, variance and genetic parameters for number of secondary branches in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	39
15	Mean, range, variance and genetic parameters for length of main axis in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	40
16	Mean, range, variance and genetic parameters for number of siliquae on main axis in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	40
17	Mean, range, variance and genetic parameters for length of siliqua in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	41
18	Mean, range, variance and genetic parameters for number of seed per siliqua in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	41
19	Mean, range, variance and genetic parameters for 1000-seed weight in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	42
20	Mean, range, variance and genetic parameters for seed yield per plant in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	43
21	Mean, range, variance and genetic parameters for oil content in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	43
22	Mean, range, variance and genetic parameters for WR infection index in F ₃ and biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	44
23	Comparison of BIP(s-1) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	45
24	Comparison of BIP(s-2) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	45
25	Comparison of BIP(s-3) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	45
26	Comparison of BIP(s-4) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x Varuna cross of <i>Brassica juncea</i> (L.) Czern & Coss.	45

27	Comparison of BIP(s-5) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	46
28	Comparison of BIP(s-6) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	46
29	Comparison of BIP(s-7) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	46
30	Comparison of BIP(s-8) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	46
31	Comparison of BIP(s-9) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	46
32	Comparison of BIP(s-10) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	46
33	Comparison of BIP(s-11) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	47
34	Comparison of BIP(s-12) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	47
35	Comparison of BIP(s-13) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in Poorbijaya x RH-30 cross of <i>Brassica juncea</i> (L.) Czern & Coss.	47
36	Comparison of BIP(s-14) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in BJ-38 x Poorbijaya cross of <i>Brassica juncea</i> (L.) Czern & Coss.	47
37	Comparison of BIP(s-15) with corresponding F ₂ parent selfs (F ₃ generation) for twelve characters in BJ-38 x Poorbijaya cross of <i>Brassica juncea</i> (L.) Czern & Coss.	47
38	Analysis of variance for thirteen characters in selected BIP plant progenies of three cross of <i>Brassica juncea</i> (L.). Czern & Coss.	48
39	Comparison of BIP(selections) plant progenies with National check (Varuna) and better basic parent for three characters in <i>Brassica juncea</i> (L.) Czern & Coss.	48
40	Comparison of varaince components, average degree of dominance and heritability (narrow sense) for twelve characters in biparental progenies of three crosses of <i>Brassica juncea</i> (L.) Czern & Coss.	56

INTRODUCTION

Among the oil bearing crops grown in India, oleiferous *Brassicaceae* play a vital role and are being cultivated annually in an area of 7.1 million hectare with the production of 4.7 million tonnes. However, the national average yield level is only 667 Kg/ha (1997-98), which is very low as compared to other developed countries (3000 kg/ha).

Under Indian conditions mustard [*Brassica juncea* (L.) Czern & Coss.] occupies about 80% of area and gives 90% of production. It is cultivated parallel to Himalayas, mostly in U.P., Punjab, Haryana, Assam, Bihar, Madhya Pradesh, Rajasthan, West Bengal and Orissa during winter season, from October to March.

The low yield of mustard could be attributed to its past history of natural selection under moisture stress conditions, that probably exhausted variation for the sake of adaptation as also observed by Stebbins (1950). Hemingway (1976) confirmed that oleiferous *Brassicaceae* evolved from basic chromosome number of six, through autopolyploidization. Monogenomic species are cross pollinated while amphidiploids like *B. juncea*, *B. napus* and *B. carinata* are inbreeders and allow limited out crossing resulting restriction of free flow of genes (Rai, 1980).

Narrow genetic base of Indian mustard is also one of the reason for its wider susceptibility to a number of diseases like white rust, alternaria and powdery mildew.

Empirical breeding in self pollinated crops tend to release genetic

T-6602

variation as a consequence of segregation in F_2 generation, thus carries the maximum segregational variability. However, in the presence of linkages, an-enormously large recombinational potential that is expected on an independent assortment of genes, may not be realised (Clegg *et al.* 1972). On the contrary, under the regime of inbreeding, linkage blocks would be more intensified. The consequent restriction on release of variability will narrow down the range of variation, hence rare recombinants may not be available for selection in F_2 generation. The presence of repulsion phase linkage, and the consequent linkage disequilibrium which tends to mimic overdominance (Gardner, 1963), is likely to cause an over estimate of dominance variance due to pseudo-over dominance effect, and hence of total phenotypic variance. Therefore, even with no change in the magnitude of additive variance, heritability is under estimated, resultingⁱⁿ lack of correspondence between expected and realised responses to selection. Unfavourable genetic associations are likely to limit advance under selection due to correlated response in F_2 generation. Therefore, selection may be delayed till sufficient recombinations has occurred and consequent variability generated. Studies in *Brassica juncea* (L.) have shown that the visual selection on single plant basis for seed yield and oil content is ineffective in the F_2 generation (Chopra, 1981). Thus the breeder normally prefers to delay any selection for yield until F_4 or even later generations. This, however invites the risk of loosing desirable recombinants.

The above situation can be mitigated by subjecting the F_2 generation to biparental mating as suggested by Comstock and Robinson (1948, 1952) and Moll and Robinson (1967). It may be useful in breaking unfavourable character associations, rapid generation of additive type of variability, better

estimates of components of variance, heritability and larger gain under selection.

In view of above scenario the present investigation was undertaken involving two major types i.e., RH-30, widely grown in N.W. India and Varuna which covers more than 60% area in central and eastern India, an advanced breeding line, BJ-38 and a white rust resistant i.e., Poorbijaya, their biparental and F_3 progenies and selected segregants with the following objectives.

1. To study the nature of gene action exhibited by the cross combinations for the yield and component traits.
2. To estimate the average degree of dominance and other genetic parameters.
3. To determine and compare the nature and magnitude of genetic variation in biparental progenies, with that of F_3 s created by selfing in F_2 s.
4. To evaluate the progeny performance of superior segregants selected from biparental progenies

REVIEW OF LITERATURE

The oilseed *Brassicac*s comprised of three basic species & their amphidiploides i.e., *B. juncea*, *B. napus* and *B. carinata*. These crops are grown under varied agroclimatic conditions. Indian mustard [*Brassica juncea* (L.) Czern & Coss.], popularly known as *rai* or *laha*, is the predominant *Brassica* of Indian sub-continent. It is an amphidiploid of *B. campestris* L. and *B. nigra* L. Koch. Due to ecogeographic variation and human selection, a number of morphologically distinct forms are grown. These include oleiferous, semi-oleiferous, repiferous and leafy types. Due to the sympatric range of distribution of the two diploid progenitors, *B. nigra* and *B. campestris*, the allopolyploid *B. juncea* may have originated any where between eastern Europe and China (Hemingway, 1976).

Robbelen (1960) made deep studies and opined that there was a common progenitor species with $X=6$ of the polymorphic forms of Brassicac and is now extinct. Subsequently, due to autosyndetic pairing diploid species with $n=8, 9$ and 10 chromosomes evolved, and amphidiploidization resulted *B. napus* (AACC, $2n=38$); *B. carinata* (BBCC, $2n=34$); and *B. juncea* (AABB, $n=36$).

The Indian mustard [*Brassica juncea* (L.) Czern & Coss] is one of the most important oilseed crop in India. It has more inbuilt capacity for high yield potential. But the momentum of increase in productivity has been rather slow. The breeding technique of individual plant selection in natural population and among recombinants derived from crosses do not seem to be rewarding methodologies for substantial improvement in these crops

(Anand and Sharma, 1993). These conventional methods of plant breeding do not allow growing and testing of large number of plants in F_2 and succeeding generations and also do not permit repeated inter-crossing required for obtaining desired recombinations. Biparental approach appears to be of considerable importance in case of self-pollinated crops. Though, sharply differing views have been advocated on the effectiveness of biparental approach in self-pollinated crops. However, limited information is available on the potential and effectiveness of this approach and there is a need to compare the merits of conventional methods of breeding with that of early generation intermated breeding procedures.

Biparental mating system

The concept of biparental mating was originally developed by Comstock and Robinson in 1948 and 1952. In this technique, plants are randomly selected in F_2 or subsequent generations of a cross between two pure lines having contrasting performance; the selected plants are crossed in a definite fashion. Biparental crosses include full-sib and half-sib progenies in the mating programme.

Biparental crosses provide information on two important genetic parameters i.e. additive (σ^2_A) and dominance (σ^2_D) components of genetic variance. However, this analysis does not provide any information of the epistasis components. Comstock and Robinson (1948, 1952) proposed three mating designs known as North Carolina Design I, II and III. They pointed out that biparental mating causes forced recombinations and break down of the linkages. Comstock and Robinson (1952) made following assumptions while deriving the expectations of mean squares.

1. Random choice of individuals mated for production of experimental progenies.
2. Random distribution of genotypes relative to variation in environment.
3. No non-genetic maternal effects.

Interpretations of the variance components of the design also involve some assumptions (Comstock and Robinson 1952). These are :

1. Regular diploid behaviour of chromosomes at meiosis.
2. Population gene frequencies of one-half at all loci where there is segregation.
3. No multiple allelism.
4. No correlation of genotypes at separate loci. This implies no linkage among genes affecting the character studied, or that if linkage exist, the distribution of genotypes is at equilibrium with respect to coupling and repulsion phases.
5. There is no non-allelic interaction.

To combine a number of desirable genes from more than two parents, Palmer (1953) suggested, sib-pollinated selection scheme, for the gradual improvement of self-pollinated crops. In this procedure high yielding lines isolated from a cross are intercrossed to give sister line crosses. This approach is based on the reasonable expectation that the sister lines will contain different plus genes. The intermating among superior sibs in the early generation (i.e. F_2) as in Palmer's method is apparently the biparental mating.

Kemphorne (1957) proposed a mating design analogous to North Carolina mating design II of Comstock and Robinson (1952), which could

be employed equally efficiently to self-pollinated and cross-pollinated crop species. In this mating design randomly chosen m inbreds (used as males and called as lines) are mated to each of the randomly selected inbreds, used as females (designated as testers). This mating design is known as line \times tester. Kempthorne (1957) expressed the covariance of half-sibs and full-sibs respecting in terms of variances due to general and specific combining ability. Thus

$$\sigma_{gca}^2 = \text{cov. (H.S.)} \quad \text{and}$$

$$\sigma_{sca}^2 = \text{cov (F.S.)} - 2 \text{ cov. (H.S.)}$$

Biparental mating design has been advocated by Hanson (1959) for breaking large linkage blocks in self-pollinated crops in the 4-5 generations of intermating and thereby releasing more variability along with improving the performance of progenies produced after intermating selected F_2 individuals in pairs.

Kearsey (1965) opted large number of paired matings. This involves using n number of plants as parents and crossing them in pairs (taken at random) to yield $n/2$ progeny families. Two statistics only can be obtained from this type of mating-the variances within and between BIP families.

An extension of North Carolina design III of biparental mating was proposed by Kearsey and Jinks in (1968), which is known as Triple Test cross analysis. This technique provides information about the presence or absence of epistasis besides additive and dominance variances. The triple test cross refers to the crossing of randomly selected F_2 plants with both the parents involved in the original cross and with their F_1 hybrids.

Jenson (1970) proposed a diallel selective mating system to use multi-parents input in to a central gene pool through selective mating of individuals in advanced generations. Selection and inter crossing may be continued for several generations to maximise heterozygosity and recombinations. This system provides scope for broadening the genetic base of the population through use of multiple parents and an opportunity of recombination of genes and breaking of linkage through intercrossing of selected types at different stages.

Studies on biparental mating

Biparental mating is a recently developing concept in which only limited investigations have been attempted. This system involves a random mating among two or more individuals belonging to a segregating generation, preferably the F_2 generation. The random nature of mating design, however depends upon the objective. If the objective is to obtain unbiased estimates of variance components and allied genetic parameters, the inter se mating must be as much random as possible to satisfy the conditions of genetic models. And if the objective is to bring about an alteration in the nature of genetic associations, than a non random or selective inter se mating is a better choice.

As biparental mating is related with inter mating and random mating, information on these two aspects and other related works has been reviewed in this chapter on the following headings.

Release of variability

Substantial genetic variability previously not available was released for many traits in biparental progenies. Moll and Robinson (1967) opined that in the system of biparental mating the frequency of desirable recombinants

is improved through forced recombinations, because it is assumed that repulsion linkage can be converted into coupling phase. Thus a greater amount of concealed genetic variability particularly of additive type is released. Such a mating system would break the plateau of limited response to selection even in cross pollinated crops under linkage equilibrium.

Baker (1968) stated that inter-mating enhances the breaking of linkages both in the coupling and repulsion phases. He added that the advantages would be the greatest with the tight linkage and the maximum advantage could be to a tune of 25 percent.

Patnaik (1972) reported in *Brassica campestris* that BIPs released greater amount of concealed genetic variation.

Redden and Jensen (1974) studied the effect of intermating in segregating population in barley and wheat and they opined that intermating was an effective tool for providing more genetic variability in case of natural inbreeding crops.

In bread wheat Behari Lal (1976) used NCD I and NCD III of Comstock and Robinson (1952) and found a considerable genetic variance for plant height, ear length, spikelet number, grain per ear, grain per spikelet and grain weight. He also observed dominant genetic variance for grain yield and tiller number.

Genetic variability in flowering time, plant height, number of tillers/m, number of grains/cm², number of leaves/plant and ear length was released in F₂ progenies derived by North Carolina design I of biparental mating in pearl millet (Sharma *et al.*, 1979).

Yunus and Paroda (1983) compared the effectiveness of biparental mating with conventional selfing in two inter varietal crosses of wheat.

Biparental progenies (BIPs) had better mean performance than the F_3 selfs for seven characters. Although the phenotypic and genotypic variances were of higher magnitude in F_3 s compared to the BIPs, yet attributes like ear length, grain/ear, grain weight/ear, 1000 grain weight and yield/plant showed higher genotypic variance in the BIPs.

Random mating before selection was recommended by Altman and Busch (1984) for the improvement of quantitative traits in self pollinated crops. Since random mating produced sufficient useful recombinations in single cross population, they justified it as a primary breeding procedure prior to selection.

Frederickson and Kronstad (1985) noticed significant losses of genetic variation in selfed population for certain traits like plant height, spikelets per plant in two diverse winter wheat crosses.

Gurudev Singh *et al.* (1986) used North carolina designs I and II and selfing with the cross of WL 711 x HD 2009 in wheat. Means, range, phenotypic and genotypic variance, genotypic coefficient of variability were higher in the biparental progenies than in F_2 or F_3 plants from selfing. But the values for height and resistance to *Puccinia striiformis* were greater in the selfed plants.

Singh and Balyan (1988) compared selfed (F_3) and biparental mated (BIPF1) populations from two F_2 populations in wheat and found that variation was greater in BIP F_1 than in the F_3 for several characters including grain yield. It is suggested that this was due to biparental mating causing breakage of linkage.

Biparental mating with in the F_2 and intermating between individuals of two different populations in wheat significantly elevated population means and variation in yield components. (Srivastava *et. al.*, 1989).

Pant *et. al.* (1992) studied biparental mating (BIP) in two oat crosses along with their parents. The superior means and generally wider range in the BIPs indicated more genetic variability than in F_3 s.

North Carolina design I was attempted by Nematullah and Jha (1993) in common bread wheat and found better mean values of BIPs than those of F_3 progenies for grain yield and most of the characters studied. In general BIPs showed wider range in desired direction than F_3 s.

Robin and Subramaniam (1994) observed more variability in BIPs for most of the traits studied, while comparing biparental and F_3 progenies of two maize crosses.

Kinshlin *et al.* (1996) investigated the performance of F_1 s, F_2 s, F_3 s and F_2 intermated biparental progenies (BIPs) in pigeonpea (*Cajanus cajan* (L.) Mill. sp.) and inferred that maximum variability can be created through the intermating of selected plants.

Kathiria *et al.* (1997) opined that biparental mating approach would be useful for enhancing genetic variability and creation of transgressive segregates in bread wheat.

Shift in nature and magnitude of genetic associations

A significant effect of biparental mating was reflected in a change in the nature and magnitude of genetic associations. The study on nature of variation and change in association for characters in biparental mating and traditional populations of pearl millet made by Singh and Murty (1973),

revealed that magnitude and nature of association among characters in the two populations were more favourable in the former.

Behari lal (1976) also reported in bread wheat that the negative correlation of ear length with grain per ear and grain yield changed to significant positive after intermating in NCD I. The report also showed that there was a reduction of significant negative correlation of spikelet number and the grains per spikelet, and spikelet number and grain yield to non significant in design I and design III.

Yadav and Murty (1979) reported that a positive correlation between plant-height and grain-weight or grain number was broken down for grain number and weakened from $r=.622^{**}$ (in F_2) to $r=.269^{**}$ (in BIPs) for grain size after only one cycle of random mating in F_2 of 15 wheat crosses.

A shift in the magnitude and some times in the directions of associations was observed in biparental mating in wheat by Dwivedi and Singh (1980). Mostly the estimates of favourable associations were higher in the BIPs than the F_3 s.

Subedar Singh and Misra (1981) studied character association among BIPs, BIP selfs and F_3 progenies, for yield per plant and five yield related traits. Intercrossing in early segregating generations affected character associations. It is suggested that biparental matings must result in the accumulation of favourable genes, change in direction and magnitude of character associations and maintenance of genetic variability in subsequent generations for selection to be effective.

Path coefficient analysis indicated that the direct effect of tiller number per plant on grain yield was higher in the BIPs than in the corresponding F_3 self progenies of two wheat crosses (Yunus and Paroda, 1982). Intermating

appeared to influence both direct and indirect effects of the various characters on yield to provide scope for increasing frequency of rare recombinants.

Tyagi (1986) produced BIPs according to North Carolina design I and allowed to self in cotton. Some correlations were significant and negative in the selfed families, but were non-significant and negative or positive in biparental intermated progenies. This reduction or disappearance of negative associations in the biparental progenies is thought to be due to breakage of linkages predominantly in repulsion phase.

The data obtained by Tyagi *et al.* (1988) in cotton indicated that the biparental intermated population was more amenable to improvement through selection than the selfed F_3 .

Pant *et al.* (1992) compared genotypic and phenotypic correlations among characters between the biparental progenies and selfs in forage oat. Several new correlations were indicated in the BIPs as compared to the selfs.

Reduced correlation values among characters were observed in biparental progenies as compared to F_3 s in bread wheat. (Nematullah and Jha, 1993). The direct and indirect dependence of grain yield on component characters also changed in biparental progenies.

Robin and Subramaniam (1995) compared the correlation matrices for BIPs and F_3 s in two maize crosses and changes in the direction and magnitude of correlation coefficients between BIPs and F_3 s were identified for ear length with ear weight, ear weight with 100-grain weight, dry matter production with harvest index, and harvest index with yield.

Response to selection

It was found that selection response was greater in biparental progenies developed by intermating in F_2 individuals than in the F_3 generation. According to Singh and Murty (1973) the biparental mating selections in pearl millet were significantly superior to the selected progenies.

Arunachalam and Amirthadevarathinam (1978) recorded improvement in the yield and major yield components in the biparental progenies of oilseed Brassicas. They suggested that biparental progenies can very well be used to up lift the stagnant yield levels.

Singh and Dwivedi (1979) reported that intermating in early generation coupled with selection will not only effectively accumulate the favourable genes but would also make variability for selection to be effective till later generations for characters of high as well as low heritability.

Biparental mating of the three best F_1 crosses (revealed by combining ability study) yielded three new recombinants, out yielding the best control, T10, by between 14% and 39% in *Brassica campestris* L. var. yellow sarson. (Singh and Murty 1980).

Chaudhari *et. al.* (1984) analysed 8 x 8 incomplete diallel and concluded that biparental mating followed by recurrent selection in segregating generations is suitable for improvement of seasmum.

Frederickson and Kronstad (1985) studied response to two cycles of mass selection for heading data involving selfing or intermating in two diverse winter wheat crosses. The results showed that the response to selection after intermating was superior to that after selfing.

Higher genetic advance for grain yield was recorded by Gurudev Singh *et al.* (1986) in biparental progenies than in F_2 or F_3 (selfs) in WL 711x HD 2009 cross of wheat.

Biparental mating followed by recurrent selection for the improvement of yield in sesamum was recommended by Krishnadoss *et al.* (1987).

Singh and Chauhan (1987) opined that recurrent selection with cyclical intermating of the selections is the best breeding method for improving Indian mustard.

Higher predicted response to selection for grain yield and the correlated response for several characters in the BIP F_1 s than in F_3 was attributed by Singh and Balyan (1988) in wheat. This was due to the concentration of favourable genes in segregants arising from intermating.

Prakash and Prakash (1993) suggested biparental mating followed by recurrent selections to produce superior recombinants with higher oil yields in safflower.

Yadav *et al.* (1994) proposed intermating of selections in early segregating generations to exploit both additive and dominance components of genetic variance in Indian mustard.

Menon and Sharma (1995) suggested that biparental mating and/or recurrent selection by intermating the most desirable segregants; alternately with selection may prove useful in combining important yield component traits for more tangible advancement in bread wheat.

The response to selection was evaluated in sesame by comparing three synthetic populations derived by random mating without selection from the parents and from the first and second cycles of

recurrent selection. (Jaisil *et al.*, 1997) . The response to selection for larger seed size was linear with a gain of 0.145 mg/seed/cycle, indicating the increased frequency of additive alleles of larger seed size.

Chauhan (1998) suggested biparental mating to increase grain weight in rice (*Oriza sativa*). Biparental mating or intermating was also recommended by Singh *et al.*(1998) to combine selection for high yields with high protein contents in peas (*Pisum sativum* L.)

Components of variance, heritability and allied genetic parameters

Due to the presence of repulsion phase linkages in the F_2 or F_3 generations, heritability estimates are underestimated. But in BIPs such linkages are broken hence fairly realistic estimates of h^2 , variance components and allied genetic parameters are obtained. (Kearsey, 1965).

Sharma *et al.* (1979) observed in pearl millet that genetic variance was chiefly due to an additive component in one population (B) but to overdominance in a second related population (A). Higher heritability estimates were obtained for BIPs than those obtained from corresponding selfed generations.

Yunus and Paroda (1983) observed in two wheat crosses that the BIPs exhibited improved heritability estimates for grains/ear, 1000-grain weight and yield per plant in cross I and for tillers per plant and 1000-grain weight in cross II.

Higher heritability estimates were recorded by Gurudev Singh *et. al.* (1986) in biparental progenies than in F_2 or F_3 plants in wheat.

Srivastava and Sharma (1987) studied through biparental mating design in opium poppy that additive variance appeared to exceed dominance and

environmental variances for most of the traits. Narrow sense heritability estimates were generally high in BIPs.

Relative magnitude of genetic variance in wheat revealed importance of additive genetic variance for tiller per plant, spike length, 1000-grain weight and grain yield where as non-additive genetic variance was preponderant for plant height, number of spikelets per spike and number of grains per spike (Nematullah and Jha, 1993).

Sekhawat *et al.*(1993) found that dominance variance (σ^2_D) was very high for number of ear per plot and ear weight per plot, while plant height and ear length indicated the preponderance of additive genetic variance in BIPs of pearl millet.

Higher heritability coupled with higher genetic advance for many traits was established by BIPs in maize (Robin and Subramaniam, 1994).

The components of genetic variation in TTC families of wheat were studied by Katiyar and Ziauddin Ahamad (1996). Both the additive and dominance components of genetic variation were highly significant for all the traits.

Kingshlin *et al.*(1997) investigated NCD I in pigeonpea and noticed low heritability estimates for pods per plant and seed yield per plant and high for 50% flowering, plant height, seeds per pod. They suggested recurrent selection for the characters which exhibited low heritability and low genetic advance.

MATERIALS AND METHODS

The present investigation was undertaken at Division of Genetics, Indian Agricultural Research Institute (IARI), New Delhi, during the period 1993-96. The geographical situation of the experimental site is as under :

Altitude : 228.16 meters above mean sea level

Latitude : 28.40' N

Longitude : 77.10' E

Experimental materials

The experimental materials comprised of three *Brassica juncea* (L.) Czern & Coss., crosses namely.

1. Poorbijaya x Varuna
2. Poorbijaya x RH-30
3. BJ-38 x Poorbijaya

F₂ seeds of these crosses, which were used to develop biparental progenies (BIPs) were obtained from the department of Genetics, IARI, New Delhi. A brief description of the parents used in the experiment is presented in Table 1.

Layout and design of the experiment

Crossing block

F₂ seed of the three crosses were raised adopting a spacing of 45 cm between rows and 15 cm between plants. The material was sown

on 19 October, 1993, with ten rows of five meters length. All the agronomical practices were followed.

Build - up of the material

Biparental crossing was followed according to North Carolina Design II. of Comstock and Robinson (1948,1952). Eight F_2 plants were assigned to a set at random, four being male parents and another four as female parents. All the sixteen possible intercrosses were made among these plants and at the same time each was selfed to give F_3 progenies. Three of these sets were made by the use of different random samples of plants in each F_2 .

Table 1. Origin and chief characteristics of parents.

Parents	Origin	Chief Characteristics	Remarks
Poorbijaya	Pant Nagar	Medium flowering time, medium tall, moderate branching, short siliqua, medium yield, high oil content, resistant to white rust	Collected from eastern U.P. and Bi har
Varuna	Varanasi	Medium flowering time, tall, more branched, Medium length of siliqua, high yield, bold seed size, moderate oil content susceptible to white rust	Selection from the material collected from the bank of river varuna.
RH-30	HAU	Medium flowering time, moderate tall, moderate branching, moderate siliqua length, medium seed size, moderate oil content. susceptible to white rust	Selection from hybridization
BJ-38	IARI	Medium flowering time, tall, more branched, medium siliqua length, moderate seed size, low yielder, high oil content, moderate resistant to white rust.	Selection

Study of F_3 and BIPs

Sixteen BIP progenies and eight F_3 progenies constituted one set, and nine such sets were raised in a randomised block design (RBD) with three

replications, during rabi 1994-95. The sets and progenies within sets were randomised separately. Each plot comprised two rows of 3.0 meter length. The inter and intra-row spacing was maintained at 45 cm and 15 cm, respectively.

Evaluation of selected plant progenies

Selection was exercised among the biparental progenies for more branching, higher yield, greater 1000-seed weight, higher oil content and least white rust infection. Thus, 15 selected superior plants, along with 4 basic parents were evaluated in randomised block design with three replications during rabi 1995-96.

Crop management

Fertilization was done at the rate of 80 kg N₂ + 40 kg P₂O₅ + 40 kg K₂O per hectare. The entire P₂O₅, K₂O and half of nitrogen was applied as a basal dose, and remaining half of nitrogen was applied as top dressing at the time of second and third irrigation. Metacystox 25 EC was sprayed at the rate of 0.01 per cent as a prophylactic measure and also at the appearance of aphids. Thining of the crop was done twice after second and third week of sowing to maintain the intra-row spacing. Crop was maintained properly with timely irrigation and other agronomic practices.

Recording of Observations

Observations for twelve different characters were recorded on single plant basis. Five plants were randomly sampled from each plot (family) in each replication. These plants were tagged and labelled at the time of flowering to record observations. The following characters were examined.

1. Days to anthesis

Days to anthesis were recorded as the number of days from the date of sowing to blooming of the plants.

2. Plant height

Height of the plant was recorded in centimeters, just before harvesting from the base of the plant to the tip of the plant.

3. Number of primary branches

At the time of maturity, primary branches were counted as the number of effective branches arising from the main shoot.

4. Number of secondary branches

Secondary branches were counted as the number of effective branches arising from the primary branches

5. Length of main axis

Length of the main axis was measured in centimeters as the distance between the last node and the tip of the plant.

6. Number of siliquae on main axis

Total number of siliquae were counted on the main axis of each of the sampled plant.

7. Length of siliqua

Length of the siliqua was measured in centimeters excluding the beak, as the average of the five randomly taken siliquae on each plant.

8. Number of seeds per siliqua

Number of seeds were counted in five randomly collected siliquae for

length and average number of seeds per siliqua were recorded.

9. 1000-seed weight

1000-seeds were counted using Electric Seed Counter and weighed by Mettler Electric Balance from each plant sample in grams.

10. Seed yield per plant

Seed yield per plant was recorded in grams on individual sampled plants.

11. Oil content

The oil content was estimated in percentage from the random samples of seeds on each plant through Nuclear Magnetic Resonance Spectrometer (NMR).

12. White rust (WR) infection index

The data for white rust infection on leaves were recorded in percentage on individual plants of every plot in each replication, after two weeks of flowering. Six leaves were taken from each of the plant from lower position. The severity of the disease was recorded by using the scale as per Anonymous (1985) in six grades, viz. 0, 1, 2, 3, 4 and 5 representing 0, 3, 10, 40 and more than 40 per cent leaf area covered by white rust pustules, respectively. Infection index per cent was calculated by the formula outlined by Singh (1984) as under :

$$\text{per cent infection index} = \frac{\text{Sum of all disease ratings}}{\text{Total number of rating} \times \text{Maximum disease grade}} \times 100$$

where, disease rating = Grade x number of leaves in the grade. The infection index in per cent was then subjected to angular transformation as advocated by Fisher and Yates (1957).

Statistical analysis

Analysis of variance For F_3 progenies

The analysis of variance for F_3 progenies was done following the method of statistical analysis given by Snedecor and Cochran (1968). Plants basis model of analysis of variance table in given below :

Source	d.f.	M.S.	F ratio
Sets	(s-1)	MS_s	MS_s/MS_e
Replications in sets	s(r-1)	MS_r	MS_r/MS_e
F_3 progenies in sets	s(p-1)	MS_p	MS_p/MS_e
Plots in progenies	s(p-1)(r-1)	MS_e	MS_e/MS_w
Within plots	spr(k-1)	MS_w	

Where,

- s = number of sets
- r = number of replications
- p = number of parents (males+females)
- k = number of plants sampled in each plot
- MS_s = mean sum of squares due to sets
- MS_r = mean sum of squares due to replications in sets
- MS_p = mean sum of squares due to F_3 progenies
- MS_e = error mean sum of squares among plots
- MS_w = error mean sum of squares within plots

Analysis of variance for biparental progenies

The analysis of variance for North Carolina Design II was done following the method given by Comstock and Robinson (1952). The statistical model for this design would be as follows:

$$y_{ijkln} = \mu + s_i + b_{ij} + m_{ik} + f_{il} + (m \times f)_{ik,l} + e_{ijkln}$$

Where,

μ	=	the general mean,
s_i	=	the effect of i^{th} set,
b_{ij}	=	the effect of j^{th} replication in i^{th} set,
m_{ik}	=	the effect of k^{th} male in i^{th} set,
f_{il}	=	the effect of l^{th} female in i^{th} set,
$(m \times f)_{ik,l}$	=	the male \times female effect in i^{th} set,
e_{ijkln}	=	the error associated with each observation.

Analysis of variance table on plants basis and their expectations are given as bellow:

Source	d.f.	M.S.	Expectation M.S.
Sets	(s-1)		
Replications in sets	s (r-1)		
Males in sets	s (m-1)	M_{21}	$\sigma_e^2 + k\sigma_p^2 + r\sigma_{mf}^2 + rkf\sigma_m^2$
Females in sets	s (f-1)	M_{22}	$\sigma_e^2 + k\sigma_p^2 + rk\sigma_{mf}^2 + rkm\sigma_f^2$
Males \times Females in sets	s (m-1) (f-1)	M_{23}	$\sigma_e^2 + k\sigma_p^2 + rk\sigma_{mf}^2$
Biparental progenies in sets	s (mf-1)	M_{bip}	$\sigma_e^2 + k\sigma_p^2 + rkmf\sigma_{bip}^2$
Plots in progenies	s (mf-1) (r-1)	M_{24}	$\sigma_e^2 + k\sigma_p^2$
Within plots	smfr (k-1)	M_e	σ_e^2

Where,

s	=	number of sets
r	=	number of replications
m	=	number of males

f	=	number of females
k	=	number of plants sampled in each plot
M_{21}	=	mean sum of squares due to males in sets
M_{22}	=	mean sum of squares due to female in sets
M_{23}	=	mean sum of squares due to males x females in sets
M_{24}	=	error mean sum of squares among plots
M_{bip}	=	mean sum of squares due to biparental progenies in sets
M_e	=	error mean sum of squares within plots.
σ_e^2	=	error variance within the same plot
σ_p^2	=	variance of plot effects (error variance among plots).
σ_{bip}^2	=	variance arising among biparental progenies.
σ_m^2	=	progeny variance arising from genetic difference among male parents.
σ_f^2	=	progeny variance arising from genetic difference among female parents.
σ_{mf}^2	=	progeny variance arising from interaction of genotypes of male and female parents.

Test of significance of mean squares

The significance of mean squares was tested by 'F' test

i) To test $\sigma_p^2 = 0$

$$F_{plots} = \frac{M_{24}}{M_e} \text{ at d.f. correspondingly associated with } M_{24} \text{ and } M_e.$$

ii) To test $\sigma_{mf}^2 = 0$

$$F_{(m \times f)} = \frac{M_{23}}{M_{24}} \text{ at d.f. associated with } M_{23} \text{ and } M_{24}, \text{ respectively}$$

iii) To test $\sigma_m^2 = 0$

$$F_{(males)} = \frac{M_{21}}{M_{23}} \text{ at d.f. associated with } M_{21} \text{ and } M_{23}, \text{ respectively}$$

iv) To test $\sigma_f^2 = 0$

$$F_{(females)} = \frac{M_{22}}{M_{23}} \text{ at d.f. associated with } M_{22} \text{ and } M_{23}, \text{ respectively}$$

v) To test $\sigma_{bip}^2 = 0$

$$F_{(bip)} = \frac{M_{bip}}{M_{24}} \text{ at d.f. associated with } M_{bip} \text{ and } M_{24}, \text{ respectively}$$

Estimation of variance components and estimates

$$\sigma_m^2 = (M_{21} - M_{23})/frk$$

$$\sigma_f^2 = (M_{22} - M_{23})/mrk$$

$$\sigma_{mf}^2 = (M_{23} - M_{24})/rk$$

However, since $m = f$ Hence $\sigma_m^2 = \sigma_f^2$

$$\text{Average mean sum of squares, } M_{20} = \frac{M_{21} + M_{22}}{2}$$

and $\sigma_m^2 = \sigma_f^2 = (M_{20} - M_{23})/nrk$ (when both, M_{21} and M_{22} were significant)

Where,

n = number of males = number of females

r = number of replications

k = number of plants sampled in each plot

Since,

$$\sigma_m^2 = \sigma_f^2 = \text{COV (HS)} = 1/4 \sigma_A^2$$

$$\sigma_{mf}^2 = \text{COV (FS)} - 2 \text{COV (HS)} = 1/4 \sigma_D^2$$

Hence,

Additive variance, $\sigma_A^2 = 4 \times \sigma_{mf}^2$ (when both, M_{21} and M_{22} were significant)

$$\text{or } \sigma_A^2 = 4 \times \sigma_m^2 \text{ (when only } M_{21} \text{ was significant)}$$

$$\text{or } \sigma_A^2 = 4 \times \sigma_f^2 \text{ (when only } M_{22} \text{ was significant)}$$

Dominant variance, $\sigma_D^2 = 4 \times \sigma_{mf}^2$

Average degree of dominance, $\bar{a} = [2n (M_{23} - M_{24}) / (M_{20} - M_{23})]^{1/2}$

$$\text{Heritability (narrow sense), } h^2_{ns} (\%) = \frac{\sigma_A^2}{\sigma_m^2 + \sigma_f^2 + \sigma_{mf}^2 + \sigma_p^2 + \sigma_e^2} \times 100$$

where,

$$\sigma_p^2 = \frac{M_{24} - M_e}{k}$$

Standard error of variance components and estimates

$$\text{SE } (\sigma_m^2) = [2/(frk)^2 \left(\frac{M_{24}^2}{df+2} + \frac{M_{23}^2}{df+2} + \frac{M_{21}^2}{df+2} \right)]^{1/2}$$

$$\text{SE } (\sigma_p^2) = [2/(mrk)^2 \left(\frac{M_{24}^2}{df+2} + \frac{M_{23}^2}{df+2} + \frac{M_{22}^2}{df+2} \right)]^{1/2}$$

$$\text{SE } (\sigma_{mf}^2) = [2/(rk)^2 \left(\frac{M_{24}^2}{df+2} + \frac{M_{23}^2}{df+2} \right)]^{1/2}$$

$$SE (\sigma_e^2) = \left[2 \left(\frac{M_{24}^2}{df+2} \right) \right]^{1/2}$$

f = number of females

m = number of males

k = number of plants sampled in each plot

df = the corresponding degrees of freedom

$$SE (\sigma_A^2) = 4 \times SE (\sigma_{m=f}^2)$$

$$SE (\sigma_D^2) = 4 \times SE (\sigma_{mf}^2)$$

Variability studies

Phenotypic and genotypic variances

Phenotypic and genotypic variances were computed according to the method suggested by Panse and Sukhatme (1967). These components were obtained from the following expectations.

Source of variation	Mean square	Parameter estimated
Families	M_1	$\sigma_e^2 + \sigma_g^2$
Error	M_2	σ_e^2

$$\text{Genotypic variance, } \sigma_g^2 = \frac{M_1 - M_2}{r}$$

$$\text{Phenotypic variance, } \sigma_p^2 = \sigma_g^2 + \sigma_e^2$$

Where,

r = number of replications-

σ_e^2 = error variance

Phenotypic and genotypic coefficient of variation

Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were calculated based on the methods adopted by Burton (1952).

$$PCV = \frac{(\sigma_p^2)^{1/2}}{\text{Grand mean}} \times 100$$

$$GCV = \frac{(\sigma_g^2)^{1/2}}{\text{Grand mean}} \times 100$$

Where,

σ_p^2 = phenotypic variance

σ_g^2 = genotypic variance

Heritability estimates

Heritability in broad sense was estimated as per the method described by Lush (1940).

$$h^2_{bs(\%)} = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where,

σ_g^2 = genotypic variance

σ_p^2 = phenotypic variance

Genetic advance

Genetic advance (GA) was estimated by the method of Johnson *et al.* (1955).

$$GA = \frac{\sigma_g^2}{(\sigma_p^2)^{1/2}} \times k$$

σ_g^2 = genotypic variance

σ_p^2 = phenotypic variance

k = selection differential at 5% selection intensity = 2.06
(Falconer, 1967).

$$\text{Genetic advance as per cent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

EXPERIMENTAL RESULTS

The present study was based on the 144 biparental progenies (BIPs) and 72 F_3 progenies (F_3 s) developed from three crosses, i.e., Poorbijaya \times Varuna, Poorbijaya \times RH-30 and BJ-38 \times Poorbijaya of *Brassica juncea* (L.) Czern and Coss. The experiment was conducted to examine the genetical aspects and the extent of variation generated for quantitative, qualitative characters and white rust resistance.

In the pursuit of above the data were recorded for twelve characters viz, days to anthesis, plant height, number of primary branches, number of secondary branches, length of main axis, number of siliquae on main axis, length of siliqua, number of seeds per siliqua, 1000-seed weight, seed yield per plant, oil content and white rust (WR) infection index, in biparental and F_3 progenies of the three crosses. The data were analysed and the results are presented under the following heads.

- i) Analysis of variance for BIPs and F_3 s
- ii) Variability studies between BIPs and F_3 s
- iii) Evaluation of selected BIP plant progenies.

Analysis of variance for BIPs and F_3 s

The analysis of variance (ANOVA) was carried out on plants basis observations separately for each of the three crosses. Biparental progenies developed according to North Carolina mating design II (NCD II) and F_3 s were analysed separately and are given in Tables 2 to 7. Mean data of 48 biparental and 24 F_3 progenies in each of the three crosses have been presented in Appendix-I.

Cross I (Poorbijaya × Varuna)

The (ANOVA) for biparental progenies presented in Table 2 indicated that the differences due to males in sets were highly significant for most of the characters except for number of secondary branches, length of main axis, number of seeds per siliqua, 1000-seed weight, seed yield per plant and oil content. The differences due to females in sets were also significant except for length of main axis, number of seeds per siliqua, 1000-seed weight, seed yield per plant and oil content. The variation due to males × females in sets were non-significant for plant height, number of secondary branches, and number of siliquae on main axis, while remaining were highly significant. However, when biparental progenies in sets were examined, highly significant differences were reflected for all of the characters under investigation. Similarly all the characters except WR infection index exhibited significant variation among plots in progenies.

The variance among F_3 progenies in sets (Table 3) were also highly significant for days to anthesis, plant height, number of secondary branches, length of siliqua and white rust infection index. Number of primary branches, length of main axis, number of seeds per siliqua, 1000-seed weight and oil content were also found to be significant.

Cross II (Poorbijaya × RH-30)

The biparental progenies of the cross Poorbijaya × RH-30 (Table 4) showed highly significant variation for all the characters under study. The contribution of males for this variation was also significant for all the characters but some characters showed highly significant variation such as number of primary branches, number of secondary branches, length of siliqua, seed yield per plant and white rust infection index. Similarly the

Table 2. Analysis of variance (N.C. II mating design) for twelve characters in biparental progenies of Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Sourcev	d.f.	Characters											
		Days to anthesis (cm)	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	WR infection index (%)
Sets	2	193.25	317.00	36.78	363.15	1003.63	181.19	0.22	125.45	0.31	1792.48	2.50	220.50
Replications in sets	6	131.58	463.67	32.87	331.04	453.29	1106.69	2.18	23.51	10.60	1681.72	56.92	63.52
Males in sets	9	175.64**	1171.33**	43.37*	104.72	351.50	472.68**	2.50**	31.00	1.61	344.84	57.86	243.81*
Females in sets	9	193.17**	1621.56**	38.50*	208.83**	482.11	378.58*	5.71**	24.90	3.15	496.01	15.64	242.88*
Males x females sets	27	38.15*	281.93	16.32**	59.77	326.28**	131.67	0.68**	14.64**	1.59**	554.48**	36.15**	88.27**
Biparental progenies in sets	45	96.65**	727.73**	26.16**	98.57**	362.49**	249.26**	2.05**	19.98**	1.91**	500.86**	36.39**	150.30**
Plots in progenies	90	23.23**	176.78*	7.57**	48.37**	149.98**	123.76**	0.30**	7.30**	0.71**	264.66**	15.79**	40.61
With in plots	576	1.10	132.16	3.43	25.46	101.96	66.62	0.15	5.00	0.24	149.36	6.99	136.99

*, **, Significant at 5% and 1% level, respectively

Table 3. Analysis of variance for twelve characters in F₃ progenies of Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Source	d.f.	Characters											
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	WR infection index (%)
Sets	2	7.13	32.00	14.72	306.17	1519.16	939.91	1.96	56.57	1.10	347.71	19.38	136.47
Replications in sets	6	19.67	522.83	47.97	209.47	143.75	810.30	1.68	9.63	2.48	296.63	47.34	94.26
F ₃ progenies in sets	21	94.24**	710.38**	32.37*	83.07**	371.52*	228.44	0.98**	17.68*	1.69*	259.32	27.59*	202.03*
Plots in progenies	42	5.27**	262.57**	14.40**	28.96*	184.16**	129.14**	0.19	8.94**	0.89**	150.00**	15.19**	60.24
With in plots	288	0.94	117.41	8.02	21.44	87.37	76.61	0.15	5.10	0.31	50.30	6.23	60.92

*, **, *** ; Significant at 5% and 1% level, respectively

contribution of the females to this variation in biparental progenies were also significant for all the characters except for length of main axis and number of seeds per siliqua.

Variance due to interactions were non-significant for number of secondary branches, length of main axis number of siliquae on main axis and seed yield per plant, while it was highly significant for most of the remaining characters indicating instability of various pollen and seed parent or may be due environmental interaction. The variance among plots in BIPs were also observed to be highly significant for all the characters except for number of secondary branches, length of main axis, number of seeds per siliqua and WR infection index.

In F_3 progenies from the same cross highly significant variances were observed for days to anthesis, plant height, number of primary branches, number of secondary branches, length of siliqua and WR infection index. However, remaining characters were also found to be significant (Table 5). Variance among plots in F_3 progenies were highly significant for days to anthesis, plant height, number of primary branches, 1000-seed weight and oil content.

Cross III (BJ-38 × Poorbijaya)

Perusal of Table 6 indicated highly significant variation among biparental progenies for all the characters under investigation. It was observed that variance due to both males and females in sets were highly significant for most of the characters except for number of secondary branches in former and number of siliquae on main axis and seed yield per plant in both cases, where only significant differences were observed. Oil content was found to be non-significant in both the cases. Variance due to males×females were

Table 4. Analysis of variance (N.C. II mating design) for twelve characters in biparental progenies of Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Source	d.f.	Characters											
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	WR infection index (%)
Sets	2	85.50	1410.00	45.80	357.88	1945.00	206.88	0.45	17.18	3.97	89.62	40.81	130.66
Replications in sets	6	34.96	2115.00	29.36	279.96	155.00	385.90	1.60	14.21	4.92	468.03	58.81	90.41
Males in sets	9	172.19*	1149.11*	35.95**	222.52**	589.19*	403.39*	2.58**	44.12*	2.99*	537.76**	72.75*	503.98**
Females in sets	9	197.46**	1210.00*	27.78**	105.62*	242.75	497.35*	2.12**	39.51	2.97*	699.73**	90.67**	259.76*
Males x females sets	27	58.36**	417.93**	7.24*	46.22	237.88	172.73	0.45*	18.15**	1.18**	102.55	25.72**	91.21**
Biparental progenies in sets	45	108.95**	722.58**	17.09**	93.36**	309.12**	283.78**	1.21**	27.61**	1.90**	309.03**	48.12**	207.48**
Plots in progenies	90	11.64**	204.96**	3.73*	35.06	150.96	132.39**	0.23**	6.84	0.58**	172.08**	12.10**	36.60
With in plots	576	2.20	144.38	2.93	28.30	129.85	83.11	0.14	5.98	0.20	119.14	6.28	145.68

* , ** ; Significant at 5% and 1% level, respectively

Table 5. Analysis of variance for twelve characters in F₃ progenies of Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Source	d.f.	Characters											WR infection index (%)
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	
Sets.	2	181.78	4759.50	32.10	16.87	902.13	1252.31	2.23	73.64	1.61	37.56	19.75	40.29
Replications in sets	6	25.24	620.83	12.96	40.42	593.65	642.05	0.43	5.23	2.97	82.38	18.68	58.16
F ₃ progenies in sets	21	44.54**	705.71**	19.00**	64.02**	333.65*	205.96*	0.64**	14.68*	1.01*	239.67*	31.19*	167.08**
Plots in progenies	42	4.28**	251.24**	5.46**	26.85*	146.12	97.81*	0.20	6.68	0.49**	115.41*	16.29**	66.94
With in plots	288	0.73	115.50	2.34	17.43	109.35	69.23	0.18	5.65	0.19	85.12	6.84	124.04

*, **; Significant at 5% and 1% level, respectively

Table 6. Analysis of variance (N.C. II mating design) for twelve characters in biparental progenies of BJ-38 x Poorbijaya cross of *Brassica juncea* (L.) Czern & Coss.

Source	d.f.	Characters											WR infection index (%)
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	
Sets	2	143.94	743.00	11.89	15.42	690.88	972.38	0.37	16.88	0.76	43.54	185.63	71.93
Replications in sets	6	43.90	343.33	13.88	113.21	368.29	588.67	0.84	15.09	2.84	724.82	40.36	5.09
Males in sets	9	125.01**	1116.22**	21.27**	57.33*	861.83**	394.10*	1.36**	27.93**	3.57**	460.42*	53.87	110.28**
Females in sets	9	287.00**	1196.89**	14.33**	122.95**	514.75**	452.92*	1.62**	46.96**	2.48**	483.12*	48.46	133.67**
Males x females sets	27	27.07**	241.93	4.24	21.16	121.85	157.53	0.36*	6.79	0.40	181.89	28.69**	19.09
Biparental progenies in sets	45	98.64**	607.78**	9.66**	48.75**	348.43**	263.92**	0.81**	19.05**	1.45**	297.84*	39.68**	60.24**
Plots in progenies	90	10.54**	179.98	3.10	22.03	194.14**	116.29*	0.18*	6.90	0.61**	169.06**	11.35**	13.40
With in plots	576	1.41	148.06	2.78	22.49	119.64	89.60	0.13	7.18	0.22	111.28	5.78	36.80

*, ** ; Significant at 5% and 1% level, respectively

found significant for length of main axis and highly significant for days to anthesis and oil content. Variance among plots in biparental progenies were shown to be non-significant for plant height number of primary and secondary branches, number of seeds per siliquae and WR infection index.

F₃ progenies showed significant differences for all the characters (Table 7). Though some character, i.e., days to anthesis, plant height, number of secondary branches, length of main axis, length of siliqua, oil content and white rust infection index exhibited highly significant differences. The variance among different plots in F₃ progenies were significant for number of primary branches, number of secondary branches and number of seeds per siliquae. While days to anthesis, 1000-seed weight, seed yield per plant and oil content showed highly significant variance.

Estimates of variance components and allied genetic parameters

Estimates of genetic components of variance (σ^2_A and σ^2_D), average degree of dominance (\bar{a}) and heritability in narrow sense (h^2_{ns}) for the crosses Poorbijaya \times Varuna, Poorbijaya \times RH-30 and BJ-38 \times Poorbijaya are presented in Tables 8, 9 and 10, respectively. Characterwise presentation are given as under.

1. Days to anthesis

Among the BIPs the magnitude of additive genetic variance was higher in cross Poorbijaya \times Varuna and BJ-38 \times Poorbijaya, whereas in case of Poorbijaya \times RH-30, dominance variance was of higher magnitude. The degree of dominance (\bar{a}) was greater than unity (1.72) in Poorbijaya \times Varuna cross indicating over dominance, whereas in other two crosses it was in partial dominance range. Heritability estimate was very high (85.56%) in the cross Poorbijaya \times Varuna.

Table 7. Analysis of variance for twelve characters in F₃ progenies of B.J-38 x Poorbijaya cross of *Brassica juncea* (L.) Czern & Coss.

Source	d.f.	Characters											
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	WR infection index (%)
Sets	2	156.41	2010.00	16.68	41.94	495.31	496.44	1.57	11.11	2.30	415.95	7.75	166.00
Replications in sets	6	34.91	919.00	12.02	36.70	921.25	140.28	0.77	13.42	0.89	167.71	23.31	15.24
F ₃ progenies in sets	21	44.35**	474.24**	7.99*	42.74**	304.21**	191.58*	0.61**	18.84*	1.23*	153.96*	33.55**	139.92**
Plots in progenies	42	7.61**	147.71	4.09*	17.22*	127.24	88.93	0.17	9.26*	0.65**	83.11**	14.30**	53.45
With in plots	288	0.99	133.63	2.64	12.04	101.78	74.25	0.16	5.98	0.22	43.70	5.22	45.61

* **, ; Significant at 5% and 1% level, respectively

Table 8. Estimates of variance, components of genetic variance and average degree of dominance for twelve characters in biparental progenies of Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Estimates/ Components	Characters											
	Days to anthesis	Plant height (cm)	Number of primary branches	Length of main axis (cm)	Number of siliqua on main axis	Length of siliqua (cm)	Number of seeds/ siliqua	1000-seed weight (g)	Seed yield/ plant (g)	Oil content (%)	WR infection index (%)	
σ_m^2	2.29** ±1.26	14.82** ±8.43	0.45* ±0.32	0.42 ±2.90	5.68** ±3.42	0.03** ±0.02	0.27 ±0.23	0.00 ±0.01	-3.49 ±3.51	0.36 ±0.44	2.59* ±1.78	
σ_f^2	2.58** ±1.38	22.33** ±11.60	0.37* ±0.28	2.60 ±3.73	4.12* ±2.77	0.08** ±0.04	0.17 ±0.19	0.03 ±0.02	-0.97 ±4.33	-0.34 ±0.20	2.58* ±1.77	
σ_{mf}^2	0.99* ±0.71	7.01 ±5.23	0.58** ±0.30	11.75** ±5.90	0.53 ±2.61	0.03** ±0.01	0.49** ±0.27	0.06** ±0.03	19.32** ±10.05	1.36** ±0.65	3.18** ±1.60	
σ_A^2	9.75 ±5.29	74.30 ±40.05	1.64 ±1.20	6.04 ±13.26	19.60 ±12.38	0.23 ±0.12	0.89 ±0.84	0.05 ±0.07	-8.94 ±15.68	0.04 ±1.28	10.34 ±7.10	
σ_D^2	3.98 ±2.82	28.04 ±20.93	2.33 ±1.18	47.01 ±23.60	2.11 ±10.43	0.10 ±0.05	1.96 ±1.06	0.23 ±0.11	77.29 ±40.20	5.43 ±2.61	12.71 ±6.38	
\bar{a}	0.90	0.87	1.69	3.95	0.46	0.94	2.10	2.98	-	16.51	1.57	
h_{ms}^2 (%)	85.56	40.11	28.97	4.78	22.18	71.41	13.92	12.47	-4.77	0.39	8.20	

*, ** ; Significant at 5% and 1% level, respectively

Table 9. Estimates of variance, components of genetic variance and average degree of dominance for twelve characters in biparental progenies of Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Estimates/ Components	Characters											
	Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliquae on main axis	Length of siliqua (cm)	Number of seeds/ siliqua	1000-seed weight (g)	Seed yield/ plant (g)	Oil content (%)	WR infection index (%)
σ^2_m	1.90* ±1.25	12.19* ±8.38	0.48** ±0.26	2.94** ±1.60	5.86* ±4.33	3.84* ±2.98	0.04** ±0.02	0.43** ±0.32	0.03* ±0.02	7.25** ±3.87	0.78* ±0.53	6.88** ±3.60
σ^2_f	2.32** ±1.43	13.20* ±8.81	0.34** ±0.20	0.99* ±0.78	0.08 ±2.05	5.41* ±3.63	0.03** ±0.02	0.36 ±0.29	0.03* ±0.02	9.95** ±5.01	1.08** ±0.65	2.81* ±1.89
σ^2_{mf}	3.11** ±1.03	12.20** ±7.59	0.23* ±0.13	0.74 ±0.88	5.79 ±4.42	2.69 ±3.29	0.01* ±0.01	0.75** ±0.32	0.04** ±0.02	-4.64 ±2.47	0.91** ±0.47	3.64** ±1.64
σ^2_A	8.43 ±5.35	50.78 ±34.38	1.64 ±0.92	7.86 ±4.76	23.42 ±17.32	18.51 ±13.22	0.13 ±0.07	1.73 ±1.30	0.12 ±0.09	34.41 ±17.76	3.73 ±2.37	19.38 ±10.99
σ^2_D	12.46 ±4.11	56.79 ±30.36	0.94 ±0.53	2.98 ±3.52	23.18 ±17.68	10.76 ±13.17	0.06 ±0.06	3.02 ±1.30	0.16 ±0.09	-18.54 ±9.87	3.63 ±1.86	14.56 ±6.55
\bar{a}	1.72	1.50	1.07	0.87	1.41	1.08	0.97	1.87	1.63	-	1.40	1.23
h^2_{ns} (%)	63.85	25.89	39.63	22.89	16.06	17.64	52.81	22.49	31.72	24.18	36.53	14.12

*, ** ; Significant at 5% and 1% level, respectively

Table 10. Estimates of variance, components of genetic variance and average degree of dominance for twelve characters in biparental progenies of BJ-38 x Poorbijaya cross of *Brassica juncea* (L.) Czern & Coss.

Estimates/ Components	Characters											
	Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliqua on main axis	Length of siliqua (cm)	Number of seeds/ siliqua	1000-seed weight (g)	Seed yield/ plant (g)	Oil content (%)	WR infection index (%)
σ^2_m	1.63** ±0.90	14.57** ±8.02	0.28** ±0.15	0.60* ±0.42	12.33** ±6.17	3.94* ±2.90	0.02** ±0.01	0.35** ±0.20	0.05** ±0.03	4.64* ±3.36	0.42 ±0.40	1.52** ±0.79
σ^2_f	4.33** ±2.04	15.92** ±8.58	0.17** ±0.10	1.70** ±0.88	6.55** ±3.73	4.92* ±3.30	0.02** ±0.01	0.67** ±0.34	0.03** ±0.02	5.02* ±3.55	0.50 ±0.43	1.91** ±0.95
σ^2_{mf}	1.10** ±0.49	4.13 ±4.59	0.08 ±0.88	-0.06 ±0.43	-4.82 ±2.86	2.75 ±2.99	0.01* ±0.01	-0.01 ±0.14	-0.01 ±0.01	0.86 ±3.59	1.16** ±0.51	0.38 ±0.36
σ^2_A	11.93 ±5.88	60.98 ±33.20	0.90 ±0.51	4.60 ±2.60	37.76 ±19.79	17.73 ±12.41	0.08 ±0.04	2.04 ±1.07	0.17 ±0.09	19.33 ±13.88	1.83 ±1.68	6.86 ±3.49
σ^2_D	4.41 ±1.94	16.52 ±18.36	0.30 ±0.32	-0.23 ±1.72	-19.28 ±11.45	11.00 ±11.94	0.05 ±0.03	-0.03 ±0.55	-0.05 ±0.04	3.42 ±14.37	4.62 ±2.06	1.52 ±1.44
\bar{a}	0.86	0.74	0.82	-	-	1.11	1.12	-	-	0.59	2.25	0.67
h^2_{ns} (%)	64.68	32.25	26.79	18.66	25.41	16.64	38.96	25.13	47.56	14.49	20.43	19.09

*, ** ; Significant at 5% and 1% level, respectively

2. Plant height

Additive genetic variance was in higher magnitude in the crosses Poorbijaya × Varuna and BJ-38 × Poorbijaya. Cross Poorbijaya × RH-30 showed higher magnitude of dominance variance than the additive. The estimate ' \bar{a} ' was greater than 1.0 (1.50) in the cross II. Heritability estimates were higher in cross I.

3. Number of primary branches

The magnitude of additive variance was higher in Poorbijaya × RH-30 and BJ-38 × Poorbijaya crosses. However the average degree of dominance was greater than 1.0 in Poorbijaya × Varuna (1.69) and Poorbijaya × RH-30 (1.07). Heritability estimates were higher (39.63%) for Poorbijaya × RH-30 cross.

4. Number of secondary branches

In the crosses Poorbijaya × Varuna and Poorbijaya × RH-30 additive variance was larger than the dominance variance, while in BJ-38 × Poorbiaya cross only additive genetic variance was observed. The estimate of ' \bar{a} ' was in partial dominance range (i.e. less than 1.0) in the former two crosses. Moderate heritability was observed in all three crosses.

5. Length of main axis

The high value of average degree of dominance (\bar{a}) 3.95 for the cross Poorbijaya × Varuna revealed that the dominance variance was predominant.

Additive variance was highly pronounced in BJ-38 × Poorbijaya cross, whereas additive and dominance variance were of equal magnitude in Poorbijaya × RH-30 cross. Low heritability (4.78%) was indicated in the cross I.

6. Number of siliquae on main axis

In the cross Poorbijaya × Varuna dominance variance was very less in magnitude (2.11) as compared to additive type (19.60). However, the magnitude of additive variance was also higher in Poorbiaya × RH-30 and BJ-38 × Poorbijaya crosses but the parameter 'ā' was exceeding 1.0 (i.e. 1.08 1.11, respectively). Medium heritability (22.18%) was observed in Poorbijaya × varuna cross.

7. Length of siliqua

Results indicated that magnitude of additive variance was higher than that of dominance variance in all the three crosses for this character. Average degree of dominance was in over dominance range (1.12) for the cross BJ-38 × Poorbijaya. High heritability estimates were obtained in Poorbijaya × Varuna (71.41 %) and Poorbijaya × RH-30 (52.81 %) crosses.

8. Number of seeds per siliqua

In the crosses Poorbijaya × Varuna and Poorbijaya × RH-30 estimates of 'ā' (2.10 and 1.87) indicated predominance of dominance variance. Whereas additive variance was pronounced in BJ-38 × Poorbijaya cross. Moderate heritability was recorded in the later two crosses.

9. 1000-seed weight

The component of σ^2_D was higher in magnitude for Poorbijaya × Varuna and Poorbijaya × RH-30 cross. While in the cross BJ-38 × Poorbijaya additive type of genetic variance was established.

The magnitude of 'ā' was found higher (2.98) in Poorbijaya × Varuna cross. High heritability of 47.56 per cent was recorded in BJ-38 × Poorbijaya cross for this trait.

10. Seed yield per plant

Dominance variance was observed in Poorbijaya × Varuna cross. Whereas, in the Poorbijaya × RH-30 and BJ-38 × Poorbijaya crosses additive variance was predominant. Moderate estimate of h_{ns}^2 was reflected by later two crosses.

11. Oil content

Preponderance of dominance variance was indicated by very high value for the estimate of 'ā' (16.51) in Poorbijaya × Varuna cross. Similar results were obtained for the cross BJ-38 × Poorbijaya. While σ_A^2 and σ_D^2 were of equal magnitude in Poorbijaya × RH-30 cross.

High heritability estimate (36.53%) was recorded in the cross II, as compared to cross III (20.43%) .

12. WR infection index

Perusal of the results revealed that dominance variance was of higher magnitude in Poorbijaya × Varuna cross and lower in Poorbijaya × RH-30 cross. While additive variance was found predominant in BJ-38 × Poorbijaya cross. Average degree of dominance for the former two crosses was in over dominance range. Heritability estimates were low in all the three crosses.

Variability studies between BIPs and F_3 s

The comparison of mean, range, genotypic and phenotypic variances (σ_g^2 and σ_p^2), genotypic and phenotypic coefficients of variation (GCV and PCV), heritability in broad sense (h_{bs}^2), genetic advance (GA) and genetic advance as per cent of mean for twelve characters between BIPs and corresponding F_3 progenies for cross I, Cross II and Cross III are presented in Tables 11 to 22.

1. Days to anthesis

Cross I

BIPs showed wider range but lower mean values than F_3 for this trait. The lower limit of the range was shortened in desired direction for BIPs as compared to F_3 . Higher PCV (5.72%) was observed in BIPs (Table 11).

Cross II

Wider range and higher mean value was observed in BIPs. BIPs also recorded higher values for all the other parameters except heritability which was better in F_3 (75.82%) (Table 11).

Cross III

Like cross I, BIPs indicated lower mean value but wider range in case of cross III. F_3 exhibited a decline from BIPs for all the other estimates (Table 11).

2. Plant height

Cross I

Except PCV (4.98%) all other parameters such as mean, range, GCV, heritability and genetic advance were reported to be higher in BIPs (Table 12).

Cross II

Higher values of mean (164.37 cm), range (148.33-178.60 cm), GCV (3.57%), heritability (45.71%) and genetic advance as per cent of mean were obtained in BIPs than F_3 , whereas high PCV (5.49%) was observed in the F_3 (Table 12).

Table 11. Mean, range, variance and genetic parameters for days to anthesis in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ_g^2	σ_p^2	GCV	PCV	h_{bs}^2 (%)	GA	GA ₃ % of mean
I	F ₃	54.25 ± 0.85	50.73-80.67	5.93	6.99	4.49	4.87	84.92	4.62	8.52
	BIPs	54.04 ± 0.65	47.87-59.60	4.89	9.54	4.09	5.72	51.31	3.26	6.04
II	F ₃	52.33 ± 0.69	48.27-56.27	2.68	3.54	3.13	3.60	75.82	2.94	5.62
	BIPs	52.81 ± 0.67	47.53-61.93	6.49	8.82	4.82	5.62	73.59	4.50	8.52
III	F ₃	50.97 ± 0.67	47.00-54.87	2.45	3.97	3.07	3.91	61.69	2.53	4.97
	BIPs	50.78 ± 0.65	46.40-58.00	5.87	7.98	4.77	5.56	73.58	4.28	8.43

Table 12. Mean, range, variance and genetic parameters for plant height in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ_g^2	σ_p^2	GCV	PCV	h_{bs}^2 (%)	GA	GA ₃ % of mean
I	F ₃	168.77 ± 2.33	159.07-188.87	29.85	82.37	3.24	5.38	36.24	6.78	4.01
	BIPs	170.33 ± 1.72	124.60-187.53	36.73	72.09	3.56	4.98	50.95	8.91	5.23
II	F ₃	163.45 ± 2.97	146.33-178.13	30.30	80.55	3.37	5.49	37.62	6.95	4.25
	BIPs	164.37 ± 1.77	148.33-178.60	34.51	75.50	3.57	5.29	45.71	8.18	4.98
III	F ₃	159.86 ± 2.25	145.00-172.33	21.77	51.31	2.92	4.48	42.42	6.26	3.92
	BIPs	164.13 ± 1.60	148.60-179.07	28.52	64.52	3.25	4.89	44.21	7.31	4.46

Cross III

A reduction in all the parameters including mean and range was observed in F_3 as compared to their intermated progenies (Table 12).

3. Number of primary branches

Cross I

BIPs showed higher mean value of 7.87, range of 5.93-12.67, heritability of 45.03 per cent and genetic advance as per cent of mean 19.57 per cent. GCV (15.21%) and PCV (28.07%) of higher magnitude were reported in F_3 (Table 13).

Cross II

BIPs showed higher mean value (7.51), range (5.80-10.00) and heritability (54.41%), but GCV and PCV were shown to be reduced from F_3 progenies (Table 13).

Cross III

When F_3 recorded higher PCV value (15.80%), BIPs registered higher values for all the other parameters viz., mean (7.18), range (5.67-8.67), GCV (9.21%), heritability (41.35%) and genetic advance as per cent of mean (12.19%) (Table 13).

Number of secondary branches

Cross I

A reduction in GCV, PCV, heritability and genetic advance as per cent of mean was noticed in BIPs. Though they had higher mean (13.89) and wider range (8.33-20.67) for the trait (Table 14).

Table 13. Mean, range, variance and genetic parameters for number of primary branches in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ^2_g	σ^2_p	GCV	PCV	h^2_{bs} (%)	GA	GA ₂ , % of mean
I	Poorbijaya x Varuna	7.19±0.51	5.07-9.87	1.20	4.08	15.21	28.07	29.36	1.22	16.98
	BIPs	7.87±0.33	5.93-12.67	1.24	2.75	14.15	21.09	45.03	1.54	19.57
II	Poorbijaya x RH-30	6.74±0.41	4.33-9.80	0.90	2.00	14.09	20.94	45.25	1.32	19.52
	BIPs	7.51±0.28	5.80-10.00	0.89	1.64	12.56	17.03	54.41	1.43	19.09
III	BJ-38 x Poorbijaya	6.57±0.27	5.40-7.27	0.26	1.08	7.77	15.80	24.14	0.52	7.86
	BIPs	7.18±0.20	5.67-8.67	0.44	1.06	9.21	14.32	41.35	0.88	12.19

Table 14. Mean, range, variance and genetic parameters for number of secondary branches in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ^2_g	σ^2_p	GCV	PCV	h^2_{bs} (%)	GA	GA ₂ , % of mean
I	Poorbijaya x Varuna	11.38±0.92	6.53-15.73	3.61	9.40	16.69	26.94	38.38	2.42	21.30
	BIPs	13.89±0.68*	8.33-20.67	3.35	13.02	13.17	25.98	25.70	1.91	13.75
II	Poorbijaya x RH-30	11.94±0.71	8.27-15.20	2.48	7.85	13.18	23.45	31.57	1.82	15.26
	BIPs	14.19±0.66*	9.80-20.80	3.89	10.90	13.90	23.27	35.66	2.43	17.09
III	BJ-38 x Poorbijaya	10.52±0.60	7.93-13.47	1.70	5.15	12.40	21.56	33.06	1.54	14.69
	BIPs	12.67±0.44*	9.53-16.93	1.78	6.19	10.54	19.64	28.80	1.48	11.65

*, ** ; Significant at 5% and 1% level, respectively

Cross II

Except for the estimate of PCV (23.45%) in F_3 , all other parameters including mean and range were of higher magnitude in BIPs (Table 14).

Cross III

Although GCV (12.40%), PCV (21.56%), heritability (33.06%) and genetic advance as per cent of mean were higher in the F_3 as compared to BIPs, nevertheless an increase in the mean and range was obtained in BIPs (Table 14).

5. Length of main axis

Cross I

BIPs exhibited improved mean (56.85 cm), range (46.93-68.40), GCV (6.62%), heritability (32.08%) and genetic advance as percent of mean (7.73%) over their self progenies (Table 15).

Cross II

The mean, and range were higher in case of BIPs, other genetic parameter were found to of lower magnitude than that of F_3 (Table 15).

Cross III

With an increase in the lower and upper limits of the range, BIPs indicated greater mean (58.83 cm) and PCV (11.91%) (Table 15).

6. Number of siliquae on main axis

Cross I

F_3 registered higher value of PCV (14.75%) while BIPs exceeded all other parameters like mean (40.98), range (33.47-50.40), GCV (7.06%) heritability (25.26%) and genetic advances as per cent of mean (7.310%)

Table 15. Mean, range, variance and genetic parameters for length of main axis in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ_s^2	σ_p^2	GCV	PCV	h_{bs}^2 (%)	GA	GA, % of mean
I	Poorbijaya x Varuna	53.88±1.98	43.33-61.53	12.49	49.32	6.56	13.04	25.33	3.66	6.80
	F ₃									
II	Poorbijaya x RH-30	54.31±1.79	41.67-64.93	12.50	41.73	6.51	11.89	29.96	3.99	7.34
	F ₃									
III	BJ-38 x Poorbijaya	54.96±1.64	46.20-63.80	11.80	37.25	6.25	11.10	31.68	3.98	7.25
	F ₃									
	BIPs	28.83±1.23	48.33-70.93	10.29	49.11	5.45	11.91	20.94	3.02	5.14

Table 16. Mean, range, variance and genetic parameters for number of siliquae on main axis in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ_g^2	σ_p^2	GCV	PCV	h_{bs}^2 (%)	GA	GA, % of mean
I	Poorbijaya x Varuna	38.61±1.56	30.67-49.27	6.62	32.45	6.66	14.75	20.40	2.39	6.20
	F ₃									
II	Poorbijaya x RH-30	39.31±1.57	30.73-48.07	7.21	26.77	6.83	13.16	26.93	2.87	7.30
	F ₃									
III	BJ-38 x Poorbijaya	41.92±1.35	34.40-48.67	6.84	24.63	6.24	11.84	27.78	2.84	6.78
	F ₃									
	BIPs	43.50±1.11	33.67-51.87	9.84	33.10	7.21	13.23	29.73	3.52	8.10

(Table 16).

Cross II

An increase in all the genetic parameters was noticed in BIPs from F_3 , including lower and upper limits of the range (Table 16).

Cross III

Similar to cross II all the genetic parameters remained higher in BIPs against their F_3 progenies (Table 16).

7. Length of siliqua

Cross I

Including mean (3.69 cm) and range (2.90-4.65 cm), for all the estimates viz., GCV (9.24%), PCV (11.39%), heritability (65.77%) and genetic advances as per cent of mean (15.43%), BIPs recorded higher values than F_3 (Table 17).

Cross II

It is indicated that similar to cross I, F_3 exhibited a decline for all the estimate from their intermated progenies (Table 17).

Cross III

For all the genetic parameters, higher values were shown by BIPs except the upper limit of the range which was slightly higher (3.81 cm) in case of F_3 compared to BIPs (3.79 cm) (Table 17).

8. Number of seeds per siliqua

Cross I

The estimates PCV (10.41%) remained high with F_3 as BIPs recorded

Table 17. Mean, range, variance and genetic parameters for length of siliqua in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ^2_g	σ^2_p	GCV	PCV	h^2_{bs} (%)	GA	GA, % of mean
I	Poorbijaya x Varuna	3.62±0.09	3.19-4.17	0.05	0.09	6.33	8.35	57.47	0.36	9.89
	BIPs	3.69±0.09	2.90-4.65	0.12	0.18	9.24	11.39	65.77	0.57	15.43
II	Poorbijaya x RH-30	3.31±0.08	2.97-3.80	0.03	0.07	5.16	8.01	41.59	0.23	6.86
	BIPs	3.43±0.07	2.63-4.01	0.07	0.11	7.47	9.73	58.93	0.41	11.81
III	BJ-38 x Poorbijaya	3.24±0.08	2.75-3.81	0.03	0.06	5.27	7.73	46.40	0.24	7.39
	BIPs	3.38±0.06	2.75-3.79	0.04	0.08	6.06	8.29	53.47	0.31	9.13

Table 18. Mean, range, variance and genetic parameters for number of seeds per siliqua in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ^2_g	σ^2_p	GCV	PCV	h^2_{bs} (%)	GA	GA, % of mean
I	Poorbijaya x Varuna	14.78±0.42	12.67-17.20	0.58	2.37	5.16	10.41	24.60	0.78	5.28
	BIPs	15.39±0.32	12.67-18.07	0.85	2.31	5.98	9.87	36.67	1.15	7.45
II	Poorbijaya x RH-30	14.26±0.41	12.20-16.87	0.53	1.87	5.12	9.59	28.54	0.80	5.64
	BIPs	14.82±0.34	10.93-17.47	1.38	2.75	7.94	11.19	50.30	1.72	11.60
III	BJ-38 x Poorbijaya	13.94±0.39	11.67-15.93	0.64	2.49	5.73	11.32	25.64	0.83	5.98
	BIPs	14.50±0.28	11.93-17.87	0.81	2.19	6.20	10.20	36.98	1.13	7.77

higher mean (15.39), range (12.67-18.07), GCV (5.98%) heritability (36.67%) and genetic advance as per cent of mean (7.45%) (Table 18).

Cross II

With an increase in the range in both directions, the BIPs in comparison to F_3 , had higher mean (14.82), GCV (7.94%), PCV (11.79%), heritability (50.30%) and genetic advances as per cent of mean (11.60%) (Table 18).

Cross III

An increase in all the genetic parameters was reported in BIPs, except the estimate of PCV, which was higher in F_3 (11.32%) than in BIPs (Table 18).

9. 1000-seed weight

Cross I

BIPs revealed higher value of mean (3.83 g), range (3.00-4.84g), GCV (7.36%), heritability (35.77%) and genetic advances as percent of mean (9.07%), while F_3 exhibited high PCV (13.22%) (Table 19).

Cross II

The upper limit of the range was slightly higher in F_3 (4.18 g) as compared to BIPs (4.17g) . All other parameters were shown to be high in BIPs (Table 19).

Cross III

F_3 registered high mean value (3.35g) in additions to showing wider range for the trait. BIPs had an improvement in GCV (7.15%), PCV (12.67%), heritability (31.81 %) and genetic advance as per cent of mean (8.30%) (Table 19).

Table 19. Mean, range, variance and genetic parameters for 1000-seed weight in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ^2_g	σ^2_p	GCV	PCV	h^2_{bs} (%)	GA	GA, % of mean
I	Poorbijaya x Varuna									
	F ₃	3.64±0.12	2.81-4.24	0.05	0.23	6.37	13.22	23.20	0.23	6.32
II	Poorbijaya x RH-30									
	F ₃	3.83±0.09	3.00-4.84	0.08	0.22	7.36	12.31	35.77	0.35	9.07
III	BJ-38 x Poorbijaya									
	F ₃	3.64±0.09	3.09-4.18	0.03	0.13	5.13	10.00	26.26	0.20	5.41
	Poorbijaya									
	F ₃	3.71±0.09	2.75-4.17	0.09	0.20	7.99	12.17	43.05	0.40	10.80
	BJ-38 x Poorbijaya									
	F ₃	3.35±0.10	2.99-4.02	0.04	0.17	5.84	12.26	22.72	0.19	5.74
	Poorbijaya									
	F ₃	3.32±0.08	2.63-3.99	0.06	0.18	7.15	12.67	31.01	0.28	8.30

Table 20. Mean, range, variance and genetic parameters for seed yield per plant in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ^2_g	σ^2_p	GCV	PCV	h^2_{bs} (%)	GA	GA, % of mean
I	Poorbijaya x Varuna									
	F ₃	14.61±1.49	8.25-22.03	7.29	37.29	18.48	41.81	19.55	2.46	16.83
II	Poorbijaya x RH-30									
	F ₃	20.83±1.52**	11.24-36.18	15.75	68.68	19.05	39.79	22.93	3.91	18.79
III	BJ-38 x Poorbijaya									
	F ₃	14.21±1.36	9.21-23.23	8.28	31.37	20.25	39.40	26.41	3.05	21.44
	Poorbijaya									
	F ₃	18.69±1.12*	11.21-30.43	9.13	43.55	16.16	35.30	20.97	2.85	15.24
	BJ-38 x Poorbijaya									
	F ₃	12.89±1.21	8.34-19.24	4.72	21.35	16.88	35.85	22.13	2.11	16.34
	Poorbijaya									
	F ₃	18.53±1.09**	10.73-26.14	8.59	42.40	15.82	35.15	20.25	2.72	14.66

*, ** ; Significant at 5% and 1% level, respectively

10. Seed yield per plant

Cross I

Except, PCV, all other genetic parameters namely, mean, range, GCV, heritability and genetic advance as per cent of mean were higher in BIPs than F_3 (Table 20).

Cross II

A reduction in GCV, PCV, heritability and genetic advance as per cent of mean was noticed in BIPs from F_3 . Whereas BIPs reported higher mean (18.69 g) and wider range (11.21- 30.43 g) for the characters (Table 20).

Cross III

While BIPs registered higher value for mean (18.53 g), advanced range (10.73 - 26.14 g), the other estimated such as GCV, PCV, heritability and genetic advance as per cent of mean were reported to be higher in F_3 progenies (Table 20).

11. Oil content

Cross I

BIPs depicted higher estimates for all the parameters in comparison of corresponding F_3 progenies (Table 21).

Cross II

All the calculated parameter viz., mean, GCV, PCV, heritability and genetic advance as per cent of mean were reported to be higher in BIPs (Table 21).

Cross III

When F_3 obtained higher mean value (38.53%) for the trait, GCV

Table 21. Mean, range, variance and genetic parameters for oil content in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ_g^2	σ_p^2	GCV	PCV	h_{bs}^2 (%)	GA	GA, % of mean
I	Poorbijaya x Varuna	39.76±0.47	36.25-42.01	0.83	3.87	2.29	4.94	21.37	0.87	2.18
	BIPs	40.11±0.38	36.15-43.11	1.37	4.53	2.92	5.31	30.31	1.33	3.31
II	Poorbijaya x RH-30	38.78±0.50	35.05-41.58	0.99	4.25	2.57	5.32	23.35	0.99	2.56
	BIPs	40.08±0.45	35.81-42.73	2.40	4.82	3.87	5.48	49.80	2.25	5.62
III	BJ-38 x Poorbijaya	38.53±0.51	35.26-40.64	1.28	4.14	2.94	5.28	30.97	1.30	3.37
	BIPs	37.84±0.44	33.75-41.68	1.89	4.16	3.63	5.39	45.42	1.91	5.04

Table 22. Mean, range, variance and genetic parameters for WR infection index in F₃ and biparental progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Crosses	Generations	Mean	Range	σ_g^2	σ_p^2	GCV	PCV	h_{bs}^2 (%)	GA	GA, % of mean
I	Poorbijaya x Varuna	19.30±1.28	13.21-25.43	9.45	21.50	15.93	24.03	43.97	4.20	21.76
	BIPs	18.58±0.80	12.28-25.05	7.31	15.43	14.55	21.14	47.38	3.83	20.63
II	Poorbijaya x RH-30	20.63±1.14	11.99-24.91	6.68	20.06	12.52	21.71	33.27	3.07	14.88
	BIPs	19.85±0.92	9.74-28.10	11.39	18.71	17.01	21.79	60.88	5.43	27.33
III	BJ-38 x Poorbijaya	7.08±1.09	3.85-15.56	5.76	16.45	33.94	57.33	35.03	2.93	41.38
	BIPs	6.59±0.50	3.42-10.76	3.12	5.80	26.81	36.54	53.83	2.87	40.52

(3.63%), PCV (5.39%), heritability (45.42%) and genetic advance as per cent of mean (5.04%) including the upper limit of the range (41.68) were high in BIPs (Table 21).

12. WR infection index

Cross I

BIPs showed a decline in mean value accompanied with reduction in lower and upper limits of the range, GCV, PCV and genetic advance as per cent of mean. However heritability (47.38%) was high for BIPs than F_3 s (43.97%) (Table 22).

Cross II

BIPs exhibited lower mean value (19.85%) than F_3 (20.63%), while other parameters such as GCV, PCV, heritability and genetic advance as per cent of mean found to be high in BIPs (Table 22).

Cross III

Mean value as well as lower and upper limits of range were foreshortened in case of BIPs. GCV (33.94 %), PCV (57.33%) and genetic advance as per cent of mean (41.38%) were reported to be higher in F_3 whereas high heritability (53.83 %) was observed in BIPs (Table 22).

Extent of variability generated through biparental mating

The biparental progenies developed were screened for their superiority over corresponding pollen and seed parent selfs (F_3 generation) which were randomly selected from the F_2 generation of the three cross combinations i.e., Poorbijaya x Varuna, Poorbijaya x RH-30 and BJ-38 x Poorbijaya. Selection was exercised among the biparental plant which were sampled to record observations. Out of 2160 total sampled plants, only 15 best

recombinants for more branching, high seed yield per plant, high oil content and least white rust infection index were selected. The best recovered BIP plants designated as BIP(s-1 to s-15), are presented along with their male and female parent selfs in Tables 23 to 37.

BIP(s-1) was selected based on number of primary and secondary branches. It was observed that number of primary branches (15.00) exceeded the upper limits of range in male (10.00) and female (8.00). Similarly number of secondary branches were also very high in this plant (35.0) as compared to both the parents (Table 23). Seed yield per plant was noticed beyond the range of selfed generation.

BIP(s-2) was selected on the basis of seed yield per plant (99.8 g) and white rust infection index (0.00%) which surpassed the upper limit of the range in both the parents for yield (Table 24). In the selfed generation of parents, none of the plants were found disease free. Length of main axis, length of siliqua and oil content were also observed to be higher than the selfed generation.

BIP(s-3) was selected for zero infection index of white rust, which was not observed in the parent selfs (Table 25). Other characters like, number of primary branches (15.00), seed yield per plant (70.20 gm) and length of siliqua (5.50 cm) were also beyond the upper limits of the male and female parent selfs.

BIP(s-4) presented in Table 26 selected for high seed yield per plant i.e. (74.10 gm) which exceeded entire sampled plant in corresponding F_3 s. Number of primary (14.00) and secondary branches (24.00) were also pre-eminent over F_3 generation.

BIP(s-5) was selected because of highest oil content i.e., 47.40 per cent

Table 23. Comparison of BIP (s-1) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-1)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	54.00	55.20±0.23	54.00-57.00	51.93±0.27	49.00-55.00
Plant height (cm)	167.00	170.67±2.42	158.00-189.00	162.80±3.37	134.00-181.00
<u>No. of primary branches</u>	15.00	7.80 ±0.29	6.00-10.00	6.27±0.35	4.00-8.00
<u>No. of secondary branches</u>	35.00	12.53±1.25	8.00-26.00	14.93±1.29	9.00-29.00
Length of main axis (cm)	64.00	57.67±1.50	47.00-72.00	61.53±2.44	42.00-89.00
No. of siliquae on main axis	27.00	37.47±2.24	21.00-54.00	44.27±2.65	24.00-71.00
Length of siliqua (cm)	4.50	3.55±0.08	2.90-4.00	3.77±0.10	3.00-5.00
No. of seeds/siliqua	15.00	15.40±0.54	11.00-21.00	15.80±0.62	12.00-21.00
1000-seed weight (g)	3.62	3.51±0.15	1.44-4.20	3.66±0.10	3.08-4.56
Seed yield/plant (g)	41.20	9.81±1.13	2.80-21.70	17.60±1.26	9.70-30.50
Oil content (%)	42.10	38.93±0.72	32.90-45.10	39.51±0.41	36.60-41.90
WR infection index (%)	8.72	17.35±2.28	1.83-33.74	18.10±1.53	7.03-28.11

Selection on the basis of underline^d characters

Table 24. Comparison of BIP (s-2) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-2)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	51.00	51.07±0.22	49.00-53.00	55.33±0.27	53.00-58.00
Plant height (cm)	195.00	174.47±3.84	128.00-205.00	167.47±3.43	141.00-200.00
No. of primary branches	16.00	5.53±0.25	4.00-8.00	5.93±0.39	4.00-8.00
No. of secondary branches	21.00	9.27±0.76	6.00-16.00	10.07±1.31	5.00-25.00
Length of main axis (cm)	88.00	56.67±3.33	24.00-85.00	45.27±2.73	25.00-63.00
No. of siliquae on main axis	41.00	39.40±2.71	17.00-56.00	30.67±2.18	18.00-42.00
Length of siliqua (cm)	4.20	3.32±0.08	2.90-4.00	3.19±0.06	2.80-3.50
No. of seeds/siliqua	13.00	15.33±0.63	11.00-20.00	12.87±0.33	10.00-15.00
1000-seed weight (g)	3.60	3.62±0.11	2.40-4.08	3.25±0.09	2.28-3.82
<u>Seed yield/plant (g)</u>	99.80	17.17±1.68	9.00-34.00	11.07±1.16	3.79-19.00
Oil content (%)	44.30	40.86±0.33	38.10-43.90	41.45±0.56	34.00-43.70
<u>WR infection index (%)</u>	0.00	25.43±2.54	6.55-41.78	14.84±2.15	4.44-30.13

Selection on the basis of underlined characters

Table 25. Comparison of BIP (s-3) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-3)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	49.00	51.07±0.22	49.00-53.00	55.33±0.27	53.00-58.00
Plant height (cm)	166.00	174.47±3.84	128.00-205.00	167.47±3.43	141.00-200.00
No. of primary branches	15.00	5.53±0.25	4.00-8.00	5.93±0.39	4.00-8.00
No. of secondary branches	22.00	9.27±0.76	6.00-16.00	10.07±1.31	5.00-25.00
Length of main axis (cm)	65.00	56.67±3.33	24.00-85.00	45.27±2.73	25.00-63.00
No. of siliquae on main axis	42.00	39.40±2.71	17.00-56.00	30.67±2.18	18.00-42.00
Length of siliqua (cm)	5.50	3.32±0.08	2.90-4.00	3.19±0.06	2.80-3.50
No. of seeds/siliqua	13.00	15.33±0.63	11.00-20.00	12.87±0.33	10.00-15.00
1000-seed weight (g)	3.20	3.62±0.11	2.40-4.08	3.25±0.09	2.28-3.82
Seed yield/plant (g)	70.20	17.17±1.68	9.00-34.00	11.07±1.16	3.70-19.00
Oil content (%)	42.00	40.86±0.33	38.10-43.90	41.45±0.56	34.00-43.70
<u>WR infection index (%)</u>	0.00	25.43±2.54	6.55-47.78	17.84±2.15	4.44-30.13

Selection on the basis of underlined character

Table 26. Comparison of BIP (s-4) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x Varuna cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-4)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	56.00	52.33±0.27	50.00-55.00	54.20±0.21	52.00-56.00
Plant height (cm)	194.00	164.40±2.73	148.00-186.00	175.53±3.16	162.00-200.00
No. of primary branches	14.00	5.87±0.50	2.00-8.00	9.87±0.54	6.00-12.00
No. of secondary branches	24.00	9.87±1.26	3.00-20.00	12.47±0.79	8.00-18.00
Length of main axis (cm)	70.00	56.07±2.81	34.00-79.00	43.33±1.84	35.00-53.00
No. of siliquae on main axis	46.00	36.73±2.19	15.00-50.00	33.80±2.56	18.00-50.00
Length of siliqua (cm)	3.60	3.41±0.09	2.90-4.00	3.63±0.06	3.10-4.20
No. of seeds/siliqua	17.00	13.80±0.82	9.00-22.00	13.87±0.48	11.00-18.00
1000-seed weight (g)	3.66	3.77±0.26	1.60-5.50	3.88±0.13	3.00-4.82
<u>Seed yield/plant (g)</u>	74.10	19.62±2.90	4.40-42.80	17.43±1.45	6.00-37.00
Oil content (%)	41.80	37.93±0.66	33.30-41.80	39.19±0.54	32.60-42.40
WR infection index (%)	7.09	24.86±2.32	7.03-40.74	21.83±1.91	11.09-30.13

Selection on the basis of underlined character

(Table 27), while in the parent selfs 43.20 per cent highest oil content was noticed in one sample. Number of primary branches (11.00) and seed yield per plant (41.40 g) was also exceeding the highest range in F_3 s.

BIP(s-6) was selected for number of primary branches (12.00) and number of secondary branches (42.00) but in the selfed generation of their pollen and seed parents, highest number of primary and secondary branches were observed 11.0 and 22.0 respectively (Table 28). Seed yield per plant (66.80 g) was also found exceeding the highest range in F_3 generation of both the parent .

BIP(s-7) was selected on the basis of seed yield per plant (94.70 g) with more number of primary (12.0) and secondary branches (35.00) (Table 29). In the corresponding male and female parent selfs, plants with highest seed yield of 44.40 g, highest number of primary branches, 11.0 and highest number of secondary branches, 25.00 were observed.

It is revealed from Table 30 that BIP(s-8) recorded 47.00 per cent of oil content, while in the F_3 generation of their male and female parents, plants were found with 41.70 per cent and 42.00 per cent highest oil content, respectively. In this plant, length of siliquae was recorded 4.90 cm which was not noticed in any sample from the parental generation.

The criteria for the selection of BIP(s-9) was more primary and secondary branches (15.00 and 40.00 respectively) (Table 31) which exceeded all the sampled plants in the selfed generation of its pollen and seed parent. Length of siliqua (5.01 cm) was also found higher while compared with the above selfs.

High oil content of 47.30 per cent was the criteria for selection of BIP(s-10) plant (Table 32). When the parental selfs of this plant were studied, 43.30

Table 27. Comparison of BIP (s-5) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-5)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	51.00	53.73±0.29	51.00-56.00	52.20±0.17	51.00-54.00
Plant height (cm)	164.00	152.07±2.41	140.00-171.00	146.33±1.30	137.00-155.00
No. of primary branches	11.00	6.73±0.35	5.00-10.00	6.07±0.34	4.00-9.00
No. of secondary branches	20.00	14.20±1.16	8.00-24.00	8.27±0.60	5.00-12.00
Length of main axis (cm)	54.00	41.67±0.93	30.00-50.00	51.47±2.42	26.00-67.00
No. of siliquae on main axis	42.00	37.80±1.74	21.00-55.00	35.87±2.03	20.00-48.00
Length of siliqua (cm)	3.30	3.54±0.13	2.60-5.00	3.10±0.08	2.50-3.60
No. of seeds/siliqua	16.00	12.33±0.47	9.00-15.00	13.84±0.33	12.00-17.00
1000-seed weight (g)	4.38	3.78±0.17	2.80-5.20	3.09±0.11	1.60-4.08
Seed yield/plant (g)	41.40	14.88±1.94	3.50-35.70	10.27±1.76	2.90-36.50
<u>Oil content</u> (%)	47.40	38.15±0.76	32.00-43.20	39.51±0.67	32.50-42.90
WR infection index (%)	8.53	22.59±3.04	4.44-36.99	22.74±3.01	8.13-42.19

Selection on the basis of oil content character

Table 28. Comparison of BIP (s-6) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-6)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	51.00	49.80±0.17	47.00-53.00	53.20±0.25	51.00-55.00
Plant height (cm)	190.00	156.87±2.61	144.00-181.00	176.47±2.35	164.00-198.00
<u>No. of primary branches</u>	12.00	7.20±0.27	5.00-9.00	9.07±0.39	7.00-11.00
<u>No. of secondary branches</u>	42.00	12.07±0.99	8.00-22.00	13.80±1.04	7.00-20.00
Length of main axis (cm)	67.00	50.40±2.20	32.00-63.00	52.93±2.63	34.00-71.00
No. of siliquae on main axis	61.00	41.27±2.41	27.00-65.00	40.13±2.21	22.00-53.00
Length of siliqua (cm)	4.20	3.37±0.11	2.70-4.20	3.35±0.15	2.30-4.10
No. of seeds/siliqua	19.00	14.93±0.60	11.00-20.00	14.60±0.75	10.00-19.00
1000-seed weight (g)	3.98	4.04±0.10	3.44-4.96	3.50±0.16	2.32-4.18
Seed yield/plant (g)	66.80	11.07±1.59	4.10-25.40	13.42±2.20	4.00-35.50
Oil content (%)	41.20	40.46±0.27	38.00-43.20	39.87±0.85	32.30-44.40
<u>WR infection index (%)</u>	0.00	24.00±3.25	4.05-37.70	19.95±2.96	3.14-35.97

Selection on the basis of underlined characters

Table 29. Comparison of BIP (s-7) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-7)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	56.00	52.67±0.24	51.00-56.00	53.60±0.22	52.00-55.00
Plant height (cm)	175.00	167.13±2.20	147.00-185.00	166.53±3.41	139.00-189.00
<u>No. of primary branches</u>	12.00	6.27±0.51	4.00-11.00	5.93±0.39	3.00--9.00
<u>No. of secondary branches</u>	35.00	11.07±1.69	3.00-25.00	10.13±1.07	5.00-19.00
Length of main axis (cm)	61.00	56.60±2.92	38.00-79.00	53.60±2.94	31.00-76.00
No. of siliquae on main axis	46.00	43.87±2.53	23.00-65.00	38.20±1.89	22.00-49.00
Length of siliqua (cm)	3.60	3.35±0.06	2.80-3.80	3.43±0.09	2.80-4.00
No. of seeds/siliqua	18.00	15.47±0.63	11.00-19.00	14.33±0.65	10.00-18.00
1000-seed weight (g)	2.74	3.45±0.10	2.32-4.28	3.34±0.08	2.66-4.20
<u>Seed yield/plant (g)</u>	94.70	14.17±1.67	3.00-32.70	11.57±2.91	3.60-46.50
Oil content (%)	41.90	39.98±0.35	36.20-42.50	39.85±0.48	35.70-44.40
WR infection index (%)	3.81	11.99±2.27	2.56-27.52	22.23±3.19	5.74-42.25

Selection on the basis of underline characters

Table 30. Comparison of BIP (s-8) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-8)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	55.00	49.67±0.18	48.00-51.00	50.33±0.21	49.00-52.00
Plant height (cm)	169.00	162.67±3.42	134.00-180.00	170.67±2.42	157.00-187.00
No. of primary branches	6.00	6.67±0.34	3.00-10.00	6.07±0.42	3.00-9.00
No. of secondary branches	11.00	9.60±0.48	4.00-17.00	10.40±0.76	4.00-15.00
Length of main axis (cm)	67.00	55.33±3.56	25.00-87.00	59.40±2.21	41.00-78.00
No. of siliquae on main axis	45.00	34.47±2.71	17.00-51.00	40.47±1.61	28.00-52.00
Length of siliqua (cm)	4.90	3.33±0.13	2.40-4.50	3.80±0.11	3.20-4.50
No. of seeds/siliqua	16.00	14.07±0.52	11.00-18.00	16.13±0.40	13.00-19.00
1000-seed weight (g)	3.36	3.57±0.12	2.92-4.88	3.64±0.10	2.60-4.18
Seed yield/plant (g)	12.60	11.07±1.99	2.30-30.40	22.23±3.29	10.30-58.60
<u>Oil content</u> (%)	47.00	38.09±0.51	34.90-41.70	39.29±0.58	33.90-42.00
WR infection index (%)	36.09	18.69±2.98	4.44-37.64	23.61±2.87	0.00-37.46

Selection on the basis of oil content character

Table 31. Comparison of BIP (s-9) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-9)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	58.00	49.67±0.18	48.00-51.00	50.80±0.24	49.00-53.00
Plant height (cm)	184.00	162.67±3.42	134.00-180.00	168.07±2.61	151.00-188.00
<u>No. of primary branches</u>	15.00	6.67±0.34	3.00-10.00	4.60±0.26	3.00-7.00
<u>No. of secondary branches</u>	40.00	9.60±0.48	4.00-17.00	9.60±1.03	4.00-17.00
Length of main axis (cm)	49.00	55.33±3.56	25.00-87.00	59.93±2.47	35.00-82.00
No. of siliquae on main axis	33.00	34.47±2.71	17.00-51.00	46.93±2.26	22.00-66.00
Length of siliqua (cm)	5.01	3.33±0.13	2.40-4.50	3.49±0.13	2.70-4.70
No. of seeds/siliqua	14.00	14.07±0.52	11.00-18.00	16.87±0.46	13.00-21.00
1000-seed weight (g)	2.92	3.57±0.12	2.92-4.88	3.81±0.09	2.92-4.60
Seed yield /plant (g)	48.60	11.07±1.99	2.30-30.40	15.43±2.06	4.90-36.60
Oil content (%)	38.40	38.09±0.51	34.90-41.70	39.45±0.79	32.50-42.90
WR infection index (%)	11.09	18.69±2.98	4.44-37.64	23.64±3.56	5.74-42.94

Selection on the basis of underlined characters

Table 32. Comparison of BIP (s-10) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-10)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	50.00	55.53±0.21	54.00-57.00	52.60±0.19	50.00±55.00
Plant height (cm)	148.00	165.40±2.93	148.00-189.00	171.33±2.82	158.00-193.00
No. of primary branches	8.00	4.33±0.29	3.00-7.00	7.20±0.46	5.00-11.00
No. of secondary branches	13.00	12.47±1.32	7.00-25.00	14.33±1.12	6.00-25.00
Length of main axis (cm)	52.00	56.67±2.96	42.00-84.00	57.80±3.06	38.00-90.00
No. of siliquae on main axis	39.00	38.93±2.00	28.00-58.00	48.07±1.64	35.00-63.00
Length of siliqua (cm)	3.90	3.53±0.13	2.80-5.10	3.14±0.11	2.40-3.60
No. of seeds/siliqua	21.00	13.87±0.47	10.00-17.00	14.67±0.63	11.00-18.00
1000-seed weight (g)	3.12	3.96±0.10	3.12-5.08	3.77±0.07	3.28-4.60
Seed yield/plant (g)	10.90	13.07±2.07	2.90-35.50	12.72±1.22	5.90-22.80
<u>Oil content</u> (%)	47.30	38.84±0.44	32.60-43.30	39.18±0.44	35.10-42.20
WR infection index (%)	7.52	20.40±3.06	0.00-39.99	21.62±3.27	4.05-42.82

Selection on the basis of character

per cent highest oil content was noticed.

BIP(s-11) was selected on the basis of high oil content (47.20%). Whereas, in the F_3 generation of male and female parents of this plant, 44.20 per cent was the highest oil content (Table 33). Length of main axis and number of siliquae on main axis were also observed to surpass upper range of F_3 generation.

BIP(s-12) was a good recombinant for high yield (78.00g) and white rust resistances accompanied with more primary and secondary branches (12.00 and 26.00, respectively), which were not observed in any sample from the corresponding parent selfs (Table 34).

Selection, BIP(s-13) was made for high oil content (47.00%) which exceeded all the sampled plants in its male and female parent selfs (Table 35).

Description in Table 36 reveals that BIP(s-14) was a selection based on number of primary and secondary branches (14.00 and 32.00, respectively) and white rust resistance. In the corresponding F_2 selfs, highest number of primary and secondary branches were observed as 10.00 and 18.0 respectively. Seed yield of this plant (58.20 g) also surpassed the parental selfs.

BIP(s-15) was selected on the basis of seed yield per plant (71.50 g). Whereas in the male and female parent selfs, highest yield was recorded 45.50 g (Table 37). Number of secondary branches were higher (18.0) than all the sampled selfs.

Evaluation of selected BIP plant progenies

The 15 best recombinants selected from the BIP generation of the three

Table 33. Comparison of BIP (s-11) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-11)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	54.0	50.67±0.21	49.00-53.00	53.40±0.19	51.00-56.00
Plant height (cm)	174.00	173.53±2.58	150.00-188.00	168.93±2.44	152.00-195.00
No. of primary branches	4.00	7.73±0.37	5.00-11.00	6.47±0.34	4.00-9.00
No. of secondary branches	11.00	14.67±1.49	6.00-26.00	13.80±0.55	10.00-18.00
Length of main axis (cm)	96.00	54.33±2.41	44.00-78.00	53.93±1.88	40.00-66.00
No. of siliquae on main axis	59.00	40.53±1.87	28.00-53.00	45.53±1.89	34.00-55.00
Length of siliqua (cm)	3.70	3.45±0.13	2.90-4.40	3.29±0.07	2.90-4.00
No. of seeds/siliqua	14.00	16.07±0.71	12.00-21.00	13.67±0.42	10.00-16.00
1000-seed weight (g)	4.08	3.61±0.14	2.22-4.52	3.67±0.08	2.76-4.08
Seed yield/plant (g)	26.60	14.25 ±1.75	3.60-31.60	12.39±1.28	6.00-22.10
<u>Oil content</u> (%)	47.20	38.91±1.07	28.40-44.20	38.70±0.81	29.20-43.10
WR infection index (%)	17.35	21.79±2.83	2.56-34.33	19.77±2.93	0.00-37.52

Selection on the basis of underlined character

Table 34. Comparison of BIP (s-12) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss:

Characters	BIP (s-12)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	57.00	50.47±0.20	49.00-52.00	53.40±0.19	51.00-56.00
Plant height (cm)	166.00	178.13±3.20	161.00-195.00	168.93±2.44	152.00-195.00
No. of primary branches	12.00	6.47±0.36	4.00-9.00	6.47±0.34	4.00-9.00
No. of secondary branches	26.00	11.20±0.77	6.00-17.00	13.80±0.55	10.00-18.00
Length of main axis (cm)	61.00	60.40±4.89	18.00-88.00	53.93±1.88	40.00-66.00
No. of siliquae on main axis	55.00	43.87±1.90	28.00-55.00	45.53±1.89	34.00-55.00
Length of siliqua (cm)	3.10	3.29±0.08	2.70-3.90	3.29±0.07	2.90-4.00
No. of seeds/siliqua	17.00	13.27±0.65	9.00-17.00	13.67±0.42	10.00-16.00
1000-seed weight (g)	3.44	3.78±0.10	3.12-4.52	3.67±0.08	2.76-4.08
<u>Seed yield/plant (g)</u>	78.00	12.31±2.25	2.20-36.40	12.39±1.28	6.00-22.10
Oil content (%)	43.10	37.65±0.72	32.10-40.80	38.70±0.81	29.20-43.10
<u>WR infection index (%)</u>	0.00	20.74±2.23	5.13-31.50	19.77±2.93	0.00-37.52

Selection on the basis of underlined characters

Table 35. Comparison of BIP (s-13) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in Poorbijaya x RH-30 cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-13)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	51.00	49.67±0.18	48.00-51.00	53.41±0.19	51.00-56.00
Plant height (cm)	137.00	162.67±3.42	134.00-180.00	168.93±2.44	152.00-195.00
No. of primary branches	8.00	6.67±0.34	3.00-10.00	6.47±0.34	4.00-9.00
No. of secondary branches	11.00	9.60±0.48	4.00-17.00	13.80±0.55	10.00-18.00
Length of main axis (cm)	55.00	55.33±3.56	25.00-87.00	53.93±1.88	40.00-66.00
No. of siliquae on main axis	28.00	34.47±2.71	17.00-51.00	45.53±1.89	34.00-55.00
Length of siliqua (cm)	3.20	3.33±0.13	2.40-4.50	3.29±0.07	2.90-4.00
No. of seeds/siliqua	17.00	14.07±0.52	11.00-18.00	13.67±0.42	10.00-16.00
1000-seed weight (g)	3.64	3.57±0.12	2.92-4.88	3.67±0.08	2.76-4.08
Seed yield/plant (g)	14.60	11.07±1.99	2.30-30.40	12.39±1.28	6.00-22.10
<u>Oil content</u> (%)	47.00	38.09±0.51	34.90-41.70	38.70±0.81	29.20-43.10
WR infection index (%)	9.70	18.69±2.98	4.44-37.64	19.77±2.93	0.00-37.52

Selection on the basis of underlined character

Table 36. Comparison of BIP (s-14) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in BJ-38 x Poorbijaya cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-14)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	50.00	49.67±0.29	48.00-52.00	51.07±0.24	49.00-53.00
Plant height (cm)	161.00	159.27±3.72	134.00-177.00	159.27±2.45	145.00-186.00
<u>No. of primary branches</u>	14.00	7.80±0.41	5.00-10.00	7.33±0.49	4.00-10.00
<u>No. of secondary branches</u>	32.00	12.60±0.64	8.00-17.00	13.07±0.72	7.00-18.00
Length of main axis (cm)	60.00	53.47±1.51	42.00-64.00	46.80±2.24	22.00-67.00
No. of siliquae on main axis	46.00	46.00±1.72	34.00-56.00	44.07±2.12	32.00-59.00
Length of siliqua (cm)	3.80	3.39±0.08	2.90-3.90	3.18±0.10	2.50-3.70
No. of seeds/siliqua	13.00	14.80±0.64	11.00-21.00	14.27±0.51	11.00-17.00
1000-seed weight (g)	3.12	3.26±0.19	2.10-4.40	3.10±0.06	2.76-3.42
Seed yield/plant (g)	58.20	10.51±1.16	4.50-23.60	19.24±2.58	8.30-48.40
Oil content (%)	35.90	37.83±0.58	34.70-42.90	37.07±0.34	33.70-39.00
<u>WR infection index (%)</u>	0.00	8.97±1.47	0.00-23.11	4.83±1.11	0.00-13.05

Selection on the basis of underline characters

Table 37. Comparison of BIP (s-15) with corresponding F₂ parent selfs (F₃ generation) for twelve characters in BJ-38 x Poorbijaya cross of *Brassica juncea* (L.) Czern & Coss.

Characters	BIP (s-15)	F ₃ Male		F ₃ Female	
		Mean	Range	Mean	Range
Days to anthesis	48.00	50.33±0.24	48.00-53.00	47.67±0.28	46.00-50.00
Plant height (cm)	166.00	172.33±3.27	154.00-197.00	157.27±3.17	138.00-176.00
No. of primary branches	10.00	6.53±0.24	4.00-8.00	6.40±0.58	4.00-13.00
No. of secondary branches	18.00	8.13±0.51	5.00-12.00	9.40±0.70	5.00-15.00
Length of main axis (cm)	45.00	54.47±2.51	40.00-75.00	55.33±2.79	42.00-80.00
No. of siliquae on main axis	38.00	40.13±2.40	24.00-55.00	41.07±2.37	29.00-59.00
Length of siliqua (cm)	3.50	3.21±0.08	2.50-3.80	3.81±0.15	2.50-4.80
No. of seeds/siliqua	10.00	12.00±0.35	10.00-15.00	14.93±0.51	10.00-19.00
1000-seed weight (g)	4.04	4.02±0.18	2.48-5.36	3.42±0.11	2.64-4.43
<u>Seed yield/plant (g)</u>	71.50	11.18±2.00	3.10-30.00	16.47±2.27	4.30-45.50
Oil content (%)	38.80	37.20±0.55	33.20-44.50	40.60±0.79	34.30-44.00
WR infection index (%)	3.81	4.75±1.14	0.00-12.85	6.15±1.19	5.20-22.22

Selection on the basis of underline character

cross i.e., 4 from Poorbijaya x Varuna, 9 from Poorbijaya x RH-30 and 2 from BJ-38 x Poorbijaya, were evaluated along with 4 basic parents involved in the study, which also included National check, Varuna, to compare the yielding performance in replicated trials.

The mean data of random samples of five plants per plot and plot yield converted to yield per hectare were subjected to analysis of variance. Mean over replications were taken to compare the plant progenies with National check Varuna and better basic parent in the cross using corresponding critical difference (CD) values.

Analysis of variance

Analysis of variance (ANOVA) of the trial for thirteen characters is presented in Table 38, which revealed that the treatments were highly significant for most of the characters under study except for number of secondary branches and length of main axis.

Test of performance

Since the ANOVA indicated the significant differences among treatments table of means (Table 39) for three important characters is presented comparing individual plant progenies with National check Varuna and better basic parent for the character.

1. Oil content

The oil content in the parental population varied between 41.57 to 43.63 per cent. However, the plant progeny of BIP(s-9) from the cross Poorbijaya x RH-30, showed significant and highest oil content (45.60%) followed by BIP (s-6) as compared to the parents. All the selected plants from the BIP generation except two indicated superior oil content as compared to the

Table 38. Analysis of variance for thirteen characters in selected BIP plant progenies of three crosses of *Brassica juncea* (L.) Czern & Coss.

Source	d.f.	Characters												
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliqua on main axis	Length of siliqua (cm)	Number of seeds/siliqua	1000-seed weight (g)	Seed yield/plant (g)	Oil content (%)	WR.infection index (%)	Yield/ hectare (kg)
Replication	2	60.05	317.81	0.97	11.62	295.49	189.46	0.19	0.83	0.29	30.99	0.63	2.58	633412.00
Treatments	18	26.05*	134.94**	0.74**	6.06	47.43	120.16*	0.40**	2.86*	0.40**	15.61*	6.42**	146.05**	151680.00**
Error	36	13.31	31.70	0.29	3.59	47.74	53.67	0.04	1.25	0.13	7.76	1.00	2.83	45151.11

* , ** ; Significant at 5% and 1% level, respectively

Table 39. Comparison of BIP (selections) plant progenies with National check (Varuna) and better basic parent for three characters in *Brassica juncea* (L.) Czern & Coss.

Crosses	Characters			
	BIP(selections)/ basic parents	Oil content (%)	WR infection index (%)	Yield/hectare (kg)
Poorbijaya x Varuna	s-1	44.65 ** (**)	3.84**	1623.5**(*)
	s-2	44.57** (**)	1.86**	1876.5**(**)
	s-3	44.29* (*)	14.68**	1419.8*
	s-4	44.47**(**)	16.10**	1543.2**
Poorbijaya x RH-30	s-5	44.17*	1.64**	1682.1**(*)
	s-6	45.48**(*)	9.40**	1277.8
	s-7	44.35*	5.59**	1598.8**
	s-8	44.67**	1.46**	1296.3
	s-9	45.60**(*)	5.33**	1237.0*
	s-10	44.99**	11.19**	1561.7**
	s-11	44.21*	3.43**	1425.9*
	s-12	43.62	10.18**	1339.5
	s-13	44.47**	6.31**	1296.3
BJ - 38 x Poorbijaya	s-14	39.69	1.85**	1256.2
	s-15	44.16*(*)	2.07**	1790.1**(**)
	Poorbijaya	41.57	2.03	1271.6
	Varuna	42.15	24.43	1067.9
	RH - 30	43.63	20.88	1234.6
	BJ - 38	42.24	13.52	1086.4
	CD at 5%	1.66	2.79	351.8
	CD at 1%	2.23	3.74	471.9

*,** ; significant at 5% and 1% level, respectively,

Significant marked in the parentheses are comparison with better basic parent

best parent, i.e., RH-30, which showed 43.63 per cent oil content. There was one case where BIP (s-15) was low yielder for oil content as compared to the check Varuna.

2. WR infection index

The WR infection index indicated that among the 4 basic parents, Poorbijaya was resistant, BJ-38 was moderately resistant, whereas Varuna and RH-30 were susceptible to white rust. The selection made from biparental progenies involving these parents, have demonstrated that selected plant progenies were showing significantly less infection of white rust as compared to susceptible parents.

BIP (s-2), BIP (s-5) and BIP (s-8) were superior to resistant parent. Both the selected plants from BJ-38 x Poorbijaya were superior and equal to the resistant parent.

3. Yield per hectare

The impact of selection after intermating may be clearly observed from the expression of yield which was very interesting. BIP(s-1), BIP (s-2), BIP (s-5), and BIP (s-15) were significantly higher yielder as compared to the best parent, i.e., Poorbijaya. However, when National check Varuna was considered, 10 selections were found significantly superior. It has amply demonstrated that there is a shift in yield level in desired direction due to biparental mating. For characters like yield, which has less response to empirical methods particularly in this crop.

DISCUSSION

Brassica juncea (L.) Czern & Coss., is the major oil yielding crop among oleiferous *Brassicaceae* in India. The autogamous nature might have restricted the free flow of genes limiting recombinations and the release of genetic variability for various economic traits. Narrow variability for economic traits and white rust susceptibility are the major limiting factors for improvement of this crop. Correlated response of agronomically desirable with undesirable traits reduces the impact of selection, and close linkages delay the realization of full recombination potential (Murty, 1971; Clegg *et al.*, 1972).

Selection for quantitative characters is generally taken up in early segregating generations. For the characters like yield, selection is to be continued till the material becomes homozygous. Such characters are controlled by more number of genes which needs large population to make selection effective. Since the theoretically required size of the population could never be grown by most of the breeders, thus the recombination is restricted. It is also observed that many of the variable genes may be practically lost in the process of advancing the material by continued selfing. Andrus (1963) suggested crossing of selected sibs in early generation for reassembling the genes capable for functioning in a balanced polygenic system.

Among the methods of improving the frequency of desirable recombinants, biparental mating, was recommended under the assumption that it can convert repulsion phase linkages into coupling phase due to

forced recombinations and thereby release a greater amount of concealed genetic variation particularly of additive type. Such a mating system may also break the plateau of limited response to selection even in cross pollinated crops under linkage equilibrium (Moll and Robinson, 1967). Moreover, BIPs could also be to great use of isolate desirable recombinants quite in early generations by recombining desirable characters (Miller and Rawlings, 1967; Sharma *et al.*, 1979; Nematullah and Jha, 1993; Yadav *et al.*, 1994).

The results obtained in this study on the pattern of genetic variation for yield and its components has permitted direct comparison of the efficiency of the two systems of mating (biparental and selfing) for the magnitude of variation. Moll and Robinson (1967) and Miller and Rawlings (1967) considered that the estimates of additive genetic components from advanced generations would be more reliable than those from corresponding F_2 generation. They suggested that the estimates from the F_2 generation might be biased in the presence of repulsion phase linkages which over-estimates non-additive variance and therefore, conceal the additive variation. These effects would be dissipated in biparental matings. If this proposition holds true, superior recombinants must be expected in the biparental progenies as compared to F_3 progenies.

Analysis of variance

Analysis of variance (Table 2) of the BIPs from the cross Poorbijaya x Varuna have revealed that variances due to males in sets were significant for days to anthesis, plant height, number of primary branches, number of siliquae on main axis, length of siliqua and WR infection index. Similarly variances due to females in sets were also found significant for most of the characters except for length of main axis, number of seeds per siliqua,

1000-seed weight, seed yield per plant and oil content. Significance of mean squares due to interactions of males x females were observed for most of the characters except plant height, number of secondary branches and number of siliquae on main axis.

A comparison of variances between biparental and F_3 progenies (Table 2 and 3) indicated that intermating in F_2 generation generated highly significant variation for number of siliquae on main axis, length of siliqua and seed yield per plant which were non-significant in F_3 progenies. Number of primary branches, length of main axis, number of seeds per siliqua, 1000-seed weight and oil content also exhibited greater variation than F_3 progenies. The variation among the plots in biparental progenies were higher for number of secondary branches and length of siliqua.

Persual of Table 4 for Poorbijaya x RH-30 cross indicated significant differences among the males and females in sets for all the characters except for length of main axis in later, which indicates presence of additive variance and equal contribution of males as well as females to the total variation present among biparental progenies for these characters. Non-significant mean square due to males x females in sets were observed for number of secondary branches, length of main axis, number of siliquae on main axis and seed yield per plant.

However, when biparental progenies were considered with F_3 progenies, greater variances were generated for the character like, length of main axis, number of siliquae on main axis, number of seeds per siliqua, 1000-seed weight, seed yield per plant and oil content in biparental progenies as compared to F_3 progenies (Table 5), where the characters showed less variation. Significantly higher variances were noticed for anthesis and seed

yield per plant. Intermating also released greater variation between different plots in biparental progenies for number of siliquae on main axis, length of siliqua and oil content.

In the cross BJ-38 x Poorbijaya (Table 6) mean square due to males and females in sets were significant for all the characters except for oil content in both. Males x females mean squares were significant for days to anthesis, length of siliqua and oil content.

A comparison of variances between biparental and F_3 progenies (Table 6 and 7) indicated release of sizable variation in biparentals for all the characters except WR infection index. Significantly higher variances were observed in BIPs for days to anthesis and seed yield per plant. The inter plot variances family variances were higher in biparental progenies for days to anthesis, plant height, number of secondary branches, length of main axis, number of siliquae on main axis and length of siliqua and seed yield per plant.

Significant of mean squares due to males in sets implies that those were significant differences among the half-sib progenies of males because of the genetic differences among the plants chosen as pollen parents. When mean squares due to females in sets were significant, it is inferred that there were significant genetic differences among the plants employed as seed parents. Significance of mean squares for males x females indicated that the behaviour of different males was not consistent over different females and vice-versa. It suggested that the variation arose due to interaction of genotypes of different male and female parents.

It could be seen that random intermating has created greater genetic variability as compared to selfing. Thus it may be confirmed that substantial

genetic variability previously not available, was released for many traits in biparental progenies developed from F_2 population. Greater variation in BIPs as compared to F_3 s were also reported by Patnaik (1972) in Brassica, Gurudev Singh *et al.*, (1986), Srivastava *et al.* (1989) in wheat and Robin and Subramaniam (1994) in maize. Such a release of latent variability attributed to the breakdown of undesirable linkages. The magnitude of variation is reflected mainly in σ_w^2 (variation within BIPs), which is larger than σ_f^2 (variation between BIPs), thus showing frequent recombinations having been occurred and substantial concealed variation released (Hanson, 1959).

Nature of gene action, degree of dominance and heritability (h^2_{ns})

The information regarding nature of genetic variation that exists in the breeding population is of prime importance in deciding which particular procedure may be followed. The breeder should not only know what proportion of the total variation among segregates is the direct result of genetic difference, but also the nature (that is fixable or non fixable) of the genetic variation that exists. There are several methods which are at the disposal of a plant breeder for determining the genetic architecture of quantitative traits. In the present study the components of genetic variance were estimated according to Comstock and Robinson (1952).

Results of the three crosses demonstrated that the variance components of the current investigation were negative in some cases. Robinson *et al.* (1955) and Miller *et al.* (1958) pointed out that the true values of negative estimates were either zero or small positive value, and that the negative result from sampling error. Consequently the negative estimates of variance components obtained either for σ_A^2 or for σ_D^2 appeared to have resulted due to sampling error.

Heritability in narrow sense (h^2_{ns}) were categorised as approximately classified by Robinson (1965) for different traits averaged over various corps, procedures of estimation, environment and cultivars.

Estimates of variance components derived form Poorbijaya x Varuna. Cross (Table 8) showed that additive variance was predominant for days to anthesis, plant height, number of secondary branches, number of siliquae on main axis and length of siliqua. The degree of dominance, for number of primary branches, length of main axis, number of seeds per siliqua, 1000-seed weight, seed yield per plant, oil content and WR infection index, indicated preponderance of the dominance variance for the expression of these characters.

High heritability estimates were observed for days to anthesis, plant height, and length of siliqua due to higher magnitude of σ^2_A . While number of primary and secondary branches, number of siliquae on main axis, number of seeds per siliqua and 1000-seed weight depicted medium heritability. Length of main axis, oil content and WR infection index indicated low heritability. Heritability was in negative direction for seed yield per plant as σ^2_A was not existing for this character.

It will be seen from Table 9 that in the cross Poorbijaya x RH - 30, additive variance was higher for number of primary and secondary branches, number of siliquae on main axis, length of siliqua, seed yield per plant, oil content and WR infection index. However, the magnitude of 'ã' was in over dominance range indicated importance of dominance variance for days to anthesis, plant height, length of main axis, number of seed siliqua, 1000-seed weight, oil content and WR infection index. High heritability was observed for days to anthesis number of primary branches, length of

siliqua, 1000-seed weight and oil content. Rest of the characters recorded moderate heritability.

In the cross BJ-38 x Poorbijaya (Table 10) additive genetic variance was appeared to be predominant for all the character except for oil content, where dominance variance was predominated. The σ^2_D component also played significant role for the expression of siliqua on main axis and length of siliqua. Only σ^2_A component existant for number of secondary branches, length of main axis, number of seed per siliqua, 1000-seed weight, as σ^2_D was in negative direction.

As explained earlier negative value obtained could be considered due to sampling error or they may be equated to zero.

High heritability estimates were obtained for days to anthesis, plant height, length of siliqua and oil content, whereas rest of the chracters showed moderate heritability.

The estimates of genetic components of variance in the present study, summarised in Table 40, revealed that most of the characters exhibited higher magnitude of additive component than dominance component in Poorbijaya x RH-30 and BJ-38 x Poorbijaya. Whereas in case of Poorbijaya x Varuna, higher magnitudes of dominance variance were observed for seven characters. Additive component of genetic variances was found to be of higher magnitude for number of secondary branches, number of silquae on main axis and length of siliqua in all the three crosses. The differences generated due to basic male parents i.e., varuna and RH-30 vary significantly. The BIPs developed form the cross Poorbijaya x Varuna were distinctly reflected higher additive variances for mostly developmental characters, whereas, BIPs from Poorbijaya x RH-30 showed superiority

Table 40 Comparison of variance components, average degree of dominance and heritability (narrow sense) for twelve characters in biparental progenies of three crosses of *Brassica juncea* (L.) Czern. & Coss.

Cross	Estimates/ Components	Characters											
		Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of siliqueae on main axis	Length of siliqua (cm)	Number of seeds/ siliqua	1000-seed weight (g)	Seed yield/ plant (g)	Oil content (%)	WR infecta index (%)
Pooorbijaya x Varuna	σ^2_A	9.75**	74.30**	1.64*	9.94**	6.04	19.60**	0.23**	0.89	0.05	-8.94	0.04	10.34*
	σ^2_D	3.98*	28.04	2.33**	3.04	47.01**	2.11	0.10**	1.96**	0.23**	77.29**	5.43**	12.71**
	\bar{a}	0.90	0.87	1.69	0.61	3.95	0.46	0.94	2.10	2.98	-	16.51	1.57
	h^2_{ns} (%)	85.56	40.11	28.97	23.93	4.78	22.18	71.41	13.92	12.47	-4.77	0.39	8.20
Pooorbijaya x RH-30	σ^2_A	8.43**	50.78*	1.64**	7.86**	23.42*	18.51*	0.13**	1.73*	0.12*	34.41**	3.73**	19.38**
	σ^2_D	12.46**	56.79**	0.94*	2.98	23.18	10.76	0.06*	3.02**	0.16**	-18.54	3.63**	14.56**
	\bar{a}	1.72	1.50	1.07	0.87	1.41	1.08	0.97	1.87	1.63	-	1.40	1.23
	h^2_{ns} (%)	63.85	25.89	39.63	22.89	16.06	17.64	52.81	22.49	31.72	24.18	36.53	14.12
BJ-38 x Pooorbijaya	σ^2_A	11.93**	60.98**	0.90**	4.60**	37.76**	17.73*	0.08**	2.04**	0.17**	19.33*	1.83	6.86**
	σ^2_D	4.41**	16.52	0.30	-0.23	-19.28	11.00	0.05*	-0.03	-0.05	3.42	4.62**	1.52
	\bar{a}	0.86	0.74	0.82	-	-	1.11	1.12	-	-	0.59	2.25	0.67
	h^2_{ns} (%)	64.68	32.25	26.79	18.66	25.41	16.64	38.96	25.13	47.56	14.49	20.43	19.09

*, ** ; Significant at 5% and 1% level, respectively

for seed yield per plant, oil content and WR infection index, where heritability estimates were also higher for many traits including yield and oil content. A separate trend was observed where BJ-38 was used as female and Poorbijaya as male.

Comstock and Robinson (1952) have pointed out that estimates of dominance as well as average degree of dominance are likely to be biased due to genic interaction.

Linkage disequilibrium is always a source of upward bias in the estimates of σ^2_D . Consequently, the level of dominance would be over estimated due to the presence of linkage. Comstock and Robinson (1952) indicated that overdominance would result from genes showing partial to complete dominance but interlocked in the repulsion phase. However, as pointed out by Gardner *et al.* (1953), overdominance at least at some loci, could not be ruled out. The effect of repulsion phase linkage of favourable dominant genes tend to mimic the overdominance effect, i.e. pseudo-overdominance which is indistinguishable from true overdominance in the absence of crossing over.

Heritability estimates are also under estimated due to the presence of repulsion phase linkages. But in BIPs such linkages are broken, hence fairly realistic estimates of heritability, variance components and allied genetic parameters are obtained (Kearsey, 1965). Murty and Ahmad (1974) in pearl millet, reported that the estimates of additive variance and heritability (narrow sense) were by and large, greater in the BIPs than the corresponding estimates in F_2 and F_3 diallels. Srivastava and Sharma (1987) in opium poppy also reported higher heritability in BIPs.

Mean and range

According to Finkner *et al.* (1973) progenies with highest mean was relatively effective in identifying the superior segregants and thus, mean values were considered the first criterion for evaluating the biparental progenies. Based on the theoretical considerations, the means of F_3 and biparental progenies should be the same in the absence of linkage (Mather and Jinks, 1971).

The comparison of mean and range values (Table 11 to 22) between F_3 and BIPs indicated that the mean performance of BIPs were in general higher than that of F_3 s for almost all the characters. However, it was significantly so, only for number of secondary branches and seed yield per plant in all the three crosses. Mean performance for WR infection index was lower in BIPs compared to F_3 's. BIPs of cross BJ-38 x Poorbijaya also showed lower mean values for 1000-seed weight and oil content. For days to anthesis BIPs recorded lower mean value corresponding their F_3 progenies in Poorbijaya x Varuna and BJ-38 x Poorbijaya cross.

It was of interest to find that the mean performance improved considerably for seed yield per plant and oil content in Poorbijaya x Varuna and Poorbijaya x RH-30, and for seed yield in BJ-38 x Poorbijaya. In addition, high mean seed yield was also accompanied by early anthesis.

The ranges of biparental progenies were wider for almost all the characters in Poorbijaya x Varuna and Poorbijaya x RH-30 crosses, except for plant height in the later. Although the difference were less in some cases.

The lower limits of the ranges were shortened for all the characters except for days to anthesis and WR infection index. At the same time the upper limits of range increased in desired direction.

For days to anthesis and WR infection index the lower limits were also increased which is desirable for these characters. In the cross BJ-38 x Poorbijaya, F_3 indicated wider range for length of siliqua, 1000-seed weight and oil content, where the mean of BIPs were also found lower for these characters. Similar trend were observed for other characters in this cross.

The higher mean and wider range in BIPs for most of the characters appeared to be due to creation of greater genetic variability by breakage of undesirable linkages which otherwise conceal the genetic variation in the small size of F_2 generation (Gill *et al.*, 1973). Similar results were also observed in wheat by Singh and Paroda (1983), Singh *et al.* (1986), Nematullah and Jha (1993).

Higher means and wider ranges in the BIPs were also reported by Joshi (1979), in cotton and by Mishra *et al.* (1983) and Pant *et al.* (1992), in Oats.

The comparison of means of BIPs and F_3 progenies for different character in the present study revealed that linkage were present in F_3 material amongst genes controlling yield and yield components.

Superior mean performance of BIPs over F_2 selfs (F_3 generation) would generally be expected when major portion of the total genetic variance is additive and additive x additive type. In addition even dominance

and epistasis components could play some role towards increase in the mean of BIPs, compared to F_3 (Singh and Dwivedi, 1978).

Increase in mean value was reported in wheat by Verma *et al.* (1979), Yunus and Paroda (1983) and in Cotton by Joshi (1979).

Variability

The potential of a cross or population is measured not only by mean, but also on the extent of variability (Allard, 1960) as variability indicates the extent of recombination for initiating effective selection. Selection for improvement of quantitative characters can be effective only when segregating generation possesses the potential variability. Variability in a population is measured by the estimates like genotypic and phenotypic coefficients of variation.

As for as variability in terms of genotypic coefficient of variation in concerned, BIPs were more variable than F_3 progenies for all the characters except days to anthesis, number of primary branches, number of secondary branches, and WR infection index in cross I, for all the chracters except, number of primary branches, length of main axis and seed yield per plant in cross II and for all the characters except secondary branches, length of main axis, seed yield per plant and WR infection index in cross III (Tables 11 to 22).

The estimates of phenotypic coefficient of variation was higher following biparental mating than F_3 generation for days to anthesis, length of siliqua and oil content in cross I. Though it was higher in F_3 s for plant height, primary and secondary branches, length of main axis and seed yield per plant in cross II and for number of primary

and secondary branches, number of seeds per siliqua, seed yield per plant and WR infection index in cross III.

Increase in the genetic variances through biparental mating was also reported by Khadr and Frey (1965) in oats. On the other hand, William *et al.*, (1971) found that the genotypic variances of the same magnitude were present in both, the selfs and BIPs in cotton. Whereas Singh and Dwivedi (1978), reported higher genotypic variances in F_3 compared to BIPs for most of the characters in wheat. Higher genotypic and phenotypic variances and genotypic coefficient of variation were also observed in biparental progenies than F_3 in wheat by Gurudev Singh *et al.*, (1986).

Heritability and genetic advance

Heritability in broad sense (h^2_{bs}) indicates whether there is sufficient genetic variation present or not, which implies that whether a population will respond to selection pressure or, in other words, whether a selection can be operative. Heritability estimates should be considered in term of selection concept (Hanson, 1959). Genetic advance being the product of heritability and selection differential, indicates the potentiality of selection intensity. Moreover, genetic advance considered alongwith heritability gives a reliable assesment of the resultant effect of selection in breeding populations. The estimates of high heritability does not always signify an increased genetic advance (Johnson *et al.*, 1955).

In the present investigation, comparison between the BIPs and the F_3 s (Tables 11 to 22), revealed that heritability estimates were improved coupled with higher genetic advance in BIPs of cross I, for all the characters except days to anthesis and secondary branches; in BIPs of cross II, for all the characters except length of main axis and seed yield per plant and

in BIPs cross III, for all the characters except secondary branches, length of main axis and seed yield per plant. This suggested that variation in the environment played relatively limited role in influencing the inheritance of these characters and these characters have a higher selection value and variation in it can be attributed to high degree of additive genetic effects (Panse, 1957; Rathnaswamy *et al.*, 1978). Though, BIPs from all the three crosses had higher heritability estimates, for WR infection index, genetic advance got reduced in cross I and III. This indicated favourable influence of environment rather than genotypes and selection for such traits may not be rewarding. Similar trend was also observed by Gill *et al.* (1973) and Yunus and Paroda (1983) when they reported high heritability in biparental progenies of wheat. High heritability estimates coupled with higher genetic advance were also established by BIPs in wheat (Gurudev Singh *et al.*, 1986) and in maize (Robin and Subramaniam, 1994).

Pattern of variability

The superiority of BIPs as compared to F_3 would be of practical importance to locate desirable recombinants generated through biparental mating. In the present study, 15 best selected plants from biparentals, were evaluated to examine the performance and pattern of associations in the next generation, that is corresponding to F_4 generation, where family characters start appearing.

It may be seen that BIP(s-2), where selection was exercised for seed yield per plant have shown increased plant height, more number of primary branches, elongated length of main axis and high oil content with zero WR infection index, not observed in either of the parent selfs. It has been observed by number of workers that higher yield, high oil content with

more number of primary and secondary branches and elongated length of main axis are normally more prone to white rust susceptibility. But the pattern of above characters with WR resistant have rarely been reported. Such type of appearance of rare recombinants are the real advantage accrued through biparental mating.

Similar situation was observed for BIP(s-3) which showed more number of primary branches and length of siliqua, also superior for seed yield per plant, with zero per cent of WR infection. The other selections which were higher yielder have also shown less WR infection index. Selection, BIP(s-4), BIP(s-7), BIP(s-12), BIP(s-14) and BIP(s-15) were reflected similar pattern.

When the pattern of other characters with high oil content was considered, it was noticed that BIP(s-5), BIP(s-8), BIP(s-10), BIP(s-11) and BIP(s-13), which were selected for high oil content and it was observed that number of primary and secondary branches, 1000-seed weight and seed yield per plant were considerably reduced and WR infection index also increased showing susceptibility to white rust.

The pattern of association in characters showed that in future, selection for oil content alone may not fulfil for increasing yield level. Therefore balanced is to be maintained. There was clear indication of different associations for different characters selected for ancillary characters.

It would be of interest to judge the efficacy of selection from biparental progenies and to examine yield potential, oil content and WR infection index. The multi row replicated trial data have confirmed the superiority of BIP(s-2), selection from BIPs of Poorbijaya x Varuna cross have significantly out yielded the National check Varuna and best parent,

Poorbijaya. There were 9 other selections which were significantly higher yielder than the check Varuna, among them 4 significantly exceeded the best parent.

Singh and Murty (1980) were also able to isolate three new recombinants, out yielding the best control, T10 by between 14 and 39 per cent in *Brassica campestris*.

This indicated that in the present study selection have created a new pattern of association which was not available in the mustard crop. It may revolutionize the *Brassica* breeding and may give a new yield level and low WR infection index.

Arunachalam and Amirthadevarathinam (1978) also suggested biparental mating to up lift the stagnant yield levels in this crop.

As is expected on genetic principles, the usefulness of intermating, as is the case of BIPs, is largely dependent of aspects like genetic architecture and the nature of linkages amongst genes controlling specific traits. Utility of BIPs, would, therefore, be more pronounced if the additive or additive x additive type of genetic variances are predominant coupled with repulsion phase linkage between genes. Nevertheless, this approach will help in creating new populations with high frequencies of rare recombinants which can not otherwise be realized in small segregating populations normally being raised through the conventional method of breeding specially when desired genes are unfavourably linked. In addition, it will also help in maintaining a greater variability for selection to be effective for longer period and will thus avoid the early fixation of genes in homozygous state. However, the procedure can not be considered a replacement of conventional method of breeding but is expected to supplement them.

SUMMARY

A study was made to evaluate the biparental progenies in three crosses of *brassica juncea* (L.) Czern & Coss., viz., Poorbijaya x Varuna, Poorbijaya x RH-30 and BJ-38 x Poorbijaya. Biparental progenies were developed according to NCD II of Comstock and Robinson (1948, 52). Twelve traits viz., days to anthesis, plant height, number of primary branches, number of secondary branches, length of main axis, number of siliquae on main axis, length of siliqua, number of seeds per siliqua, 1000-seed weight, seed yield per plant, oil content and WR infection index, were considered for analysis of variance, nature of gene action, average degree of dominance, estimates of mean, range, variance and other genetic parameters like, heritability and genetic advance for biparental progenies (F_2 intermated) and F_3 generation (F_2 selfed) in each cross separately. In addition 15 best recombinants were selected from the biparentals to examine the efficacy of selection and evaluated with their basic parents in replicated trial. The salient findings of this investigation are summarized as under :

1. Analysis of variance for Biparental progenies of Poorbijaya x Varuna cross revealed significant differences among males and females for all the character except for number of secondary branches, length of main axis, number of seeds per siliqua 1000-seed weight, seed yield per plant and oil content, among males x females for all the characters except for plant height, number of secondary branches and number of siliquae on main axis. Biparental progenies indicated highly significant variance for all the characters as compared to F_3 progenies which showed significant variances for most of the characters.

2. In the cross Poorbijaya×RH-30, ANOVA indicated significant differences among males and females for all the characters except for length of main axis and seed yield per plant in later. Males and females were non-significant only for number of secondary branches, number of siliquae on main axis and seed yield per plant. Biparental progenies were significant for all the character and showed release of significantly greater variation as compared to F_3 progenies for days to anthesis and seed yield per plant.
3. In the cross, BJ-38×Poorbijaya, significant variation among males and females were present for most of the characters for oil content in both, while males×females were significant only for days to anthesis, length of siliqua and oil content. Biparental progenies showed significant differences for all the characters under study and significantly greater variation for days to anthesis and seed yield per plant, as compared to corresponding F_3 progenies which also indicated significant variation for all the characters.
4. Additive genetic variance was higher for days to anthesis, plant height, number of secondary branches, number of siliquae on main axis and length of siliqua in the cross Poorbijaya×Varuna and for number of primary branches, number of secondary branches, number of siliquae on main axis, length of siliqua, seed yield per plant and WR infection index in Poorbijaya×RH-30 cross. In the cross BJ-38×Poorbijaya, dominance variance was higher only for oil content and additive genetic variance was reflected for number of secondary branches, length of main axis, number of seeds per siliqua and 1000-seed weight.

5. Average degree of dominance, was in overdominance range that indicated importance of dominance variance in cross Poorbijaya×Varuna for number of primary branches, length of main axis, number of seeds per siliqua, 1000-seed weight, oil content and WR infection index in cross Poorbijaya×RH-30, for all the characters except for number of secondary branches, length of siliqua and seed yield per plant. In cross BJ-38×Poorbijaya, over dominance was indicated for number of siliqua on main axis, length of siliqua and oil content.
6. Heritability estimates in narrow sense were higher for days to anthesis, plant height and length of siliqua, in cross Poorbijaya×Varuna , for days to anthesis, number of siliqua, in cross Poorbijaya×Varuna , for days to anthesis, number of primary branches, length of siliqua and oil content in cross Poorbijaya×RH-30 and for days to anthesis, plant height, length of siliqua and 1000-seed weight in cross BJ-38 x Poorbijaya.
7. Biparental progenies indicated higher mean value as compared to the respective F_3 progenies for all the characters except for days to anthesis and WR infection index in cross Poorbijaya×Varuna, for all the characters except WR infection index in cross Poorbijaya×RH-30 and for all the characters except days to anthesis, 1000-seed weight, oil content and WR infection index in cross BJ-38×Poorbijaya. Significantly higher mean values were observed for number of secondary branches and seed yield per plant in all the three crosses.
8. More variability in biparental progenies was recorded for all the characters, except days to anthesis, number of primary branches,

number of secondary branches and WR infection index in cross Poorbijaya x Varuna, for all the characters, except number of primary branches, length of main axis and seed yield per plant in cross Poorbijaya×Rh-30 and for all the characters, except length of main axis, seed yield per plant and WR infection index in cross BJ-38×Poorbijaya. This showed the release of additive genetic variability through breakage of repulsion phase linkage and formation of new recombinants.

9. High heritability (broad sense) coupled with high genetic advance was exhibited by biparental progenies for all the characters except days to anthesis and secondary branches in cross Poorbijaya×Varuna, for all the characters except length of main axis and seed yield per plant in Poorbijaya×RH-30, and for all the characters except secondary branches, length of main axis and seed yield per plant in cross BJ-38×Poorbijaya. This confirms the more suitability of the biparental progenies for advancing the generation to have effective selection on these traits.
10. The best 15 plants, which were selected from BIPs, have indicated the significant superiority of 4 selections over check Varuna and best parent, Poorbijaya)
11. A new pattern of character expression like number of branches, oil content, seed yield and negligible WR infection index, which has not been reported earlier in this crop, was observed. It also demonstrated the advantage of biparental mating over empirical methods of breeding.

T-6602

BIBLIOGRAPHY

- Allard, R.W. (1960). Principles of Plant Breeding. John Wiley & Sons New York.
- Altman, D.W. and Busch, R.H. (1984). Random intermating before selection in spring wheat. *Crop Sci.* **24** : 1085-1089.
- Anand, I.J., and Sharma, N.K. (1993). Genetic enhancement of oilseed crops: repeseed mustard : National seminar on oilseeds research and development in India : status and strategies : extended summaries. *Indian Soc. Oilseed Res.*, Hyderabad, pp. 11-12.
- *Andrus, C.F. (1963). Plant Breeding systems. *Euphitica* **12** : 205-228.
- Anonymous (1985). The proceedings of Annual Oilseeds Workshop of Rapeseed and Mustard (ICAR), 1985.
- Arunachalam, V. and Amirthadevarathinam, A. (1978). Cross-compatibility among three varietal forms and its impact on the components of yield in oil *Brassica*. *Indian J. Genet. & Plant Breed.* **38** : 207-215.
- Baker, R.J. (1968). Extent of intermating in self-pollinated species necessary to counteract the effects of genetic drift. *Crop Sci.*, **8** : 547-550.
- Behari Lal (1976). Effect of selection for certain grain characters on yield in bread wheat (*Triticum aestivum* L.). Ph.D. Thesis submitted to the Post Graduate School, IARI, New Delhi.
- Burton, G.W. (1952). Quantitative inheritance in grasses. *Proc. 6th Int. Grassland Cong.*, **1** : 277-283.
- Chaudhari, F.P., Shah, R.M. and Patel, I.D. (1984). Heterosis and combining ability in sesamum. *Indian J. Agric. Sci.*, **54** : 962-966.
- Chauhan, J.S. (1998). Inheritance of grain weight, size and shape in rainfed rice (*Oriza sativa*). *Indian J. Agric. Sci.*, **68** : 9-12.
- Chopara, S. (1981). Early generation selection for high oil content and seed yield in Indian mustard (*Brassica juncea* (L.) Czern & Coss.). M.Sc. Thesis Punjab Agril. Univ. Ludhiana, India.

- Clegg, M.T., Allard, R.W. and Kahler, A.L. (1972). Is the gene unit of selection ? . Evidence from two experimental plant populations. *Proc. Nat. Acad. Sci. (USA)*. **69** : 2474-2478.
- Comstock, R.E. and Robinson, H.F. (1948). The components of genetic variation in populations of biparental progenies and their use in estimating average degree of dominance. *Biometrics*, **4** : 254-266.
- Comstock, R.E. and Robinson, H.F. (1952). Estimation of average dominance of genes. **In** : Heterosis, pp. 494-515. Iowa State College Press, Ames.
- Dwivedi, S.L. and Singh, R.B. (1980). Effects of intermating in early segregating generations on character associations in wheat. *Indian J. Agric. Sci.*, **50** : 103-127.
- Falconer, D.S. (1967). Introduction to quantitative Genetics, Oliver & Boyd. Edinburgh.
- Finkner, V.C., Porelirt, C.G. and Devis, D.L. (1973). Heritability of rachis node number of *Avena sativa* L. *Crop Sci.*, **13** (1) : 186-188.
- Fisher, R.A. and Yates, F. (1957). Statistical tables for biological, agricultural and medical research (5thed.). Hofner, New York.
- Frederickson, L.J. and Kronstand, W.E. (1985). A comparison of intermating and selfing following selection for heading date in two diverse winter wheat crosses. *Crop Sci.*, **25** : 555-560.
- *Gardner, C.O. (1963). Estimates of genetics parameters in cross fertilizing plants and their implications in plant breeding. **In**: Statistical Genetics and Plant Breeding. NAS-NRC, 982-242-252.
- Gardner, C.O., Harvey, P.H., Comstock, R.E. and Robinson, H.F. (1953). Dominance of gene controlling quantitative characters in maize. *Agron. J.*, **45** : 186-191.
- Gills, K.S., Bains, S.S., Singh, G. and Bains, K.S. (1973). Partial diallel test crossing for yield and its components in *Triticum aestivum* L. *Proc. 4th Int. Wheat Genet. Symp.* Missouri, Columbia, 29-32.

- Gurudev Singh, Bhullar, G.S. and Gill, K.S. (1986). Comparison of variability generated following biparental mating and selfing in wheat. *Crop Improv.* **13** : 24-48.
- Hanson, W.D. (1959). The break up of initial linkage blocks under selected mating system, *Genetics*, **44** : 857-868.
- Hemingway, J.S. (1976). Mustards : *Brassica* spp. and *sinapis alba* (cruciferae). In: Evolution of crop plants (Ed.), Longman, London, pp. 56-59.
- Jaisail, P., Sanitchon, J., Jogloy, S. and Fukuoka, H. (1997). Recurrent selection for increase seed size in sesame (*Sesamum indicum* L.) *SABRAO J.*, **29** (1) : 47-52.
- Jenson, F. (1970). A diallel selective mating system for cereal breeding. *Crop Sci.*, **10** : 629-633
- Johanson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimates of genetic and environmental variability in soyabean. *Agron. j.*, **47**: 314-318.
- Joshi, A.B. (1979). Breeding methodology for autogamous crops. *Indian J. Genet.*, **39** : 567-578.
- Kathiria, K.B., Parmaer, L.D. and Poshiya, V.K. (1997). Genetic architecture of heading and maturity in bread wheat under early and timely sown conditions. *Gujarat Agric. Univ. Res. J.*, **22** : 7-12.
- Katiyar, P.K. and Ziauddin Ahmad (1997). Detection of epistasis component of variation for yield contributing traits over two environments in Bread Wheat. *Indian J. Genet.*, **42** (3) : 389-392.
- Kearsey, M.J. (1965). Biometrical analysis of a random mating population : Comparison of five experimental designs. *Heredity*, **20** : 205-235.
- Kearsey, M.J. and Jinks, J.L. (1968). A general method of detecting additive, dominance and epistasis variation for metrical traits. I. Theory. *Heredity*, **23** : 403-409.
- Kempthorne, O. (1957). An Introduction to Genetic Statistics, John Wiley & Sons, New York.

- Khadr, F.H. and Frey, K.J. (1965). Effectiveness of recurrent selection in oat breeding (*A. sativa* L.), *Crop Sci.*, **5** : 349-354.
- Kingshlin, M., Subbaraman, N. and Vanniarajan, C. (1997). Estimates of heritability and genetic advance in the full sib progenies of pigeonpea (*Cajanus cajan* (L.) Mill sp.). *Crop. Res.*, **14**(2) : 303-306.
- Kingshlin, M., Subbaraman, N. and Vanniarajan, C. (1996). Performance of different generations for various characters in pigeonpea (*Cajanus cajan* (L.) Mill. Sp.). *Legume Res.*, **19** (2) : 127-130.
- Krishnadoss, D. and Kadambavanasundaram, M., Ramalingam, R.S. and Raja Sekaran, S. (1987). Combining ability in sesamum. *Indian J. Agric. Sci.*, **57** (2) : 85-88.
- Lush, J.L. (1940). Intra-sire correlation and regression of offspring on dams as a method of estimating heritability of characters. *Proc. Amer. Soc. Animal Production.*, **32**: 293-301.
- Mather, K. and Jinks, J.L. (1971). Biometrical Genetics : The study of continuous variation (2nd ed.). Chapman & Hall, London.
- Menon, U. and Sharma, S.N. (1995). Inheritance studies for yield and yield component traits in bread wheat over the environments. *Wheat-Information Service*, No. **80**: 1-5.
- Miller, P.A. and Rawling, J.O. (1967). Break up of initial linkage blocks through inter-mating in a cotton population. *Crop. Sci.*, **7** : 199-204.
- Miller, P.A., Williams, J.C. (Jr.), Robinson, H.F. and Comstock, R.E. (1958). Estimates of genotypic and environmental variances and co-variances in upland cotton and their implications in selection. *Agron. J.*, **50** : 126-131.
- Mishra, S.N., Verma, J.S., Prasad, R. and Rastogi, R. (1983). Performance of BIPs, DII and direct descent progenies in oats. *Oat Newslett.*, **33** : 38-39.
- Moll, R.H. and Robinson, H.F. (1967). Quantitative genetic investigations of yield of maize. *Der Dichter*, **37** : 192-199.
- Murty, B.R. (1971). Developmental traits in breeding for disease resistance in some cereals. In : Mutation breeding for disease resistance. IAEA (Vienna), 93-105.

- Murty, B.R. and Ahmad, Z. (1974). Components of genetic variation in biparental progenies of a diallel set in dwarf pennisetums. *Crop Improv.*, **1** : 82-91.
- Nematullah and Jha, P.B. (1993). Effect of biparental mating in wheat. *Crop Improv.*, **20** (2): 173-178.
- Palmer, T.P. (1953). Progressive improvement in self-fertilized crops. *Heredity*, **7** : 127-129.
- Panse, V.G. (1957). Genetics of quantitative characters in selection to plant breeding. *Indian J. Genet.*, **17** : 318-328.
- Panse, V.G. and Sukhatme, P.V. (1967). Statistical methods for agricultural workers. ICAR, New Delhi, 381 p.
- Pant, D., Mishra, S. N. and Verma, J.S. (1992). Effects of biparental mating in forage oats. *Indian J. Genet.*, **52** (3) : 270-274.
- Patnaik, M.C. (1972). Nature of gene action and effects of selection for developmental traits and productivity in *Brassica campestris* L. var. 'brown sarson'. Ph.D. Thesis, IARI, New Delhi.
- Prakash, K.S. and Prakash, B.G. (1993). Yield structure of oil yield in safflower (*Carthamus tinctorius* L.) *Oleagineux-Paris*, **48** (2) : 83-89.
- Radden, R.J. and Jensen, N.P. (1974). Mass selection and mating systems in cereals. *Crop Sci.*, **15** : 407-409.
- Rai, B. (1980). Self-incompatibility and its scope for the exploitation of heterosis in *Brassica* species. In : Breeding Oilseed Crops, PAV, Ludhiana, pp. 284-295.
- Rathnaswamy, R., Krishnaswamy, S., Iyemperumal, S. and Marappan, P.V. (1978). Estimates of variability correlation coefficients and path coefficient analysis in early maturing green gram (*Vigna radiata* L. wilezek). *Madras Agric. J.*, **65** (3) : 180-190.
- Robbelen, G. (1960). Beitrage Zur Analyse des Brassica-Genoms. *Chromasoma*, **11** : 205-228.
- Robin, S. and Subramaniam, M. (1994). Genetic variability study in biparental progenies in maize (*Zea mays* L.) *Crop Res.*, **7** (1) : 79-83.

- Robin, S. and Subramaniam, M. (1995). Studies on the shift in the association of characters in biparental progenies in maize (*Zea mays* L.). *Crop Res.*, **6** (2) : 243-246.
- Robinson, H.F. (1965). Quantitative genetics in relation to breeding on the centennial of Mendelism. In : Ramanujam (1965) : 171-187.
- Robinson, H.F., Comstock, R.E. and Harvey, P.H. (1955). Genetic variances in open pollinated varieties of Corn. *Genetics*, **40**: 45-60.
- Sharma, J.R., Yadav, S.P. and Singh, J.N. (1979). The components of genetic variation in biparental progenies and their use in breeding of pearl millet (*Pennisetum typhoides*) Burn. S. & H. *Z. Pflanzenzuchtg.* , **82** (3) : 250-257.
- Shekhwat, S.S., Dashora, S.L. , Sastry, E.V.D. and Sharma, R.K. (1993). Components of genetic variance and response of selection in pearl millet (*Pennisetum typhoides*). *Indian J. Genet.* , **53** (2) : 109-114.
- Singh, B.B. and Murty, B.R. (1973). A comparative analysis for biparental mating and selfing in pearl millet (*Pennisetum typhoides* S. & H.). *Theor. Appl. Genet.*, **43** : 18-22.
- Singh, G., Bhuller, G.S. and Gill, K.S. (1986). Comparison of variability generated following biparental mating and selfing in wheat. *Crop Improv.*, **13** : 24-28.
- Singh, J.N. and Murty, B.R. (1980). Combining ability and maternal effects in *Brassica campestris* L. var 'yellow sarson'. *Theor. Appl. Genet.*, **56** : 265-272.
- Singh, O.N. and Chauhan, Y.S. (1987). Triple test cross analysis for seed and oil yield and its components in Indian mustard (*Brassica juncea* L. Czern & Coss.). In: *Proc. 7th Int. Repeseed Cong.*, Poland, pp. 111.
- Singh, R.B. and Dwivedi, S.L. (1979). Population improvement in wheat. *Proc. 5th Int. Wheat Genet. Symp.* New Delhi, India, **2** : 671-679.
- Singh, S.K., Srivastava, S.B.L. and Singh, P. (1998). Association of various metric traits in tall and dwarf genotypes of peas (*Pisum sativum* L.). *Crop Improv.*, **25** (1) : 139-140.

- Singh, Subedar and Misra, G.C. (1981). Effect of intermating in early generation on character association in bread wheat. *J. Indian Soc. Agric. Stat.*, **33** : 112.
- Singh, T., and Balyan H.S. (1988). The usefulness of biparental mating in early segregating generation in wheat (*Triticum aestivum* L.). *Genetica-Agraria*, **42** : 283-297.
- Snedecor, G.W. and Cochran, W.G. (1968). Statistical methods. Oxford and IBA Publishing Co., New Delhi.
- Srivastava, R.B., Paroda, R.S., Sharma, S.C. and Yunus, M. (1989). Impact of different mating approaches in generating variability in wheat (*T. aestivum* L. em Thell). *Indian J. Genet.*, **49** : 331-336.
- Srivastava, R.K. and Sharma, J.R. (1987). Estimation of genetic variance and allied parameters through biparental mating in opium poppy (*Palaver somniferum* L.). *Australian J. agric. Res.*, **38** : 1047-1052.
- Stebbins, G.L. (1950). Variation and evolution in higher plants (Ed. I). Columbia Univ. Press, New York.
- Tyagi, A.P. (1986). Association analysis for yield components in upland cotton (*Gossypium hirsutum* L.). *East African Agric. Forest. J.*, **52** (1) : 37-40..
- Tyagi, A.P. (1986). Variability and heritability for yield and its components in upland cotton (*Gossypium hirsutum* L.). *East African Agric. Forest J.*, **52** (1) : 41-46.
- Tyagi, A.P., Mor, B.R. and Singh, D.P. (1988). Path analysis in upland cotton (*Gossypium hirsutum* L.). *Indian J. Agric. Res.*, **23** (3) : 137-142.
- Verma, M.M., Kochhar, S. and Kapoor, W.R. (1979). The assessment of biparental approach in a wheat cross. *Z. pflanzenzuchtg.*, **82** : 174-181.
- William, Meredith, W.R. (Jr.) and Bridge, R.P. (1971). Breaking of linkage blocks in cotton (*Gossypium hirsutum* L.). *Crop Sci.*, **11** (5) : 695-698.
- Yadav, O.P., Yadava, T.P., Kumar, P. and Gupta, S.K. (1994). Inheritance of reducing sugars in relation to white rust resistance in Indian mustard. *Indian Phytopatho.*, **47** : 56-59.

- Yadav, S.P. and Murty, B.R. (1979). Association of characters and utility of biparental progenies in bread wheat. *Z. pflanzenzuchtg.*, **83** : 218-229.
- Yunus, M. and Paroda, R.S. (1982). Impact of biparental mating on correlation coefficients in bread wheat. *Theor. Appl. Genet.*, **62** : 337-343.
- Yunus, M. and Paroda, R.S. (1983). Extent of genetic variability created through biparental mating in wheat. *Indian. J. Genet.*, **43** : 76-81.

* Original not seen

Appendix I. Mean performance of F₃ and biparental progenies for twelve characters in three crosses of *Brassica juncea* (L.) Czern & Coss.

Sets	Selfs/ crosses	Days to anthesis	Plant height (cm)	Number of primary branches	Number of secondary branches	Length of main axis (cm)	Number of silique on main axis	Length of silique (cm)	Number of seeds/ silique	1000-seed weight (g)	Seed yield/ plant (g)	Oil content (%)	WR infection index (%)
Characters													
Cross-1 (Poorbijaya x Varuna) F₃ progenies													
1	m ₁	53.93	164.27	8.07	14.07	58.93	42.27	3.29	14.67	3.48	20.55	40.36	14.56
	m ₂	54.07	159.40	5.60	8.00	59.73	39.13	3.38	14.60	3.62	8.49	36.26	18.48
	m ₃	52.40	171.00	7.53	14.87	59.93	42.13	3.55	17.20	2.81	11.64	39.32	20.17
	m ₄	55.20	170.67	7.80	12.53	57.67	37.47	3.55	15.40	3.51	9.81	38.93	17.35
	f ₁	52.67	166.20	8.07	12.87	47.20	49.27	4.05	14.67	3.63	18.40	39.13	15.78
	f ₂	60.67	188.67	8.60	15.73	61.27	41.60	3.86	16.07	3.68	22.03	40.37	17.71
	f ₃	51.93	162.80	6.27	14.93	61.53	44.27	3.77	15.80	3.66	17.60	39.51	18.10
	f ₄	55.33	163.20	6.13	12.47	56.93	38.07	3.21	14.33	3.87	18.97	40.52	22.48
2	m ₁	51.07	174.47	5.53	9.27	56.67	39.40	3.32	15.33	3.62	17.17	40.86	25.43
	m ₂	51.93	160.80	5.07	9.20	57.73	41.67	3.52	16.27	4.24	12.95	39.07	13.21
	m ₃	54.33	170.47	5.40	7.33	58.47	41.20	3.73	15.40	3.85	11.71	39.97	21.94
	m ₄	52.33	164.40	5.87	9.87	56.07	36.73	3.41	13.80	3.77	19.62	37.93	24.86
	f ₁	56.07	168.20	8.13	9.20	56.40	37.60	3.61	15.87	3.93	11.59	39.39	19.04
	f ₂	57.93	173.13	8.73	13.73	46.80	39.60	3.69	16.53	3.25	19.99	42.01	19.30
	f ₃	55.33	167.47	5.93	10.07	45.27	30.67	3.19	12.87	3.25	11.07	41.45	14.84
	f ₄	54.20	175.53	9.87	12.47	43.33	33.80	3.63	13.87	3.88	17.43	39.19	21.83
3	m ₁	55.80	172.67	5.93	12.87	49.60	42.67	3.68	15.13	3.77	17.45	41.36	16.26
	m ₂	53.73	159.07	7.47	12.73	48.80	31.40	4.07	13.47	2.94	9.16	38.09	21.71
	m ₃	50.73	165.93	6.27	6.53	49.33	34.20	3.65	14.20	3.85	10.67	40.49	15.30
	m ₄	51.47	164.33	8.87	8.47	49.87	35.13	3.60	13.40	3.99	12.96	38.17	23.14
	f ₁	54.20	171.67	7.60	10.20	57.73	38.67	4.17	14.60	3.49	16.82	41.60	21.67
	f ₂	53.27	166.40	5.80	9.33	56.13	41.60	3.39	13.47	3.83	13.39	39.84	22.40
	f ₃	58.33	175.73	9.27	12.60	47.63	32.67	3.57	12.67	3.43	12.79	40.78	13.96
	f ₄	55.00	174.13	8.87	13.80	50.00	35.40	3.95	15.20	3.93	8.25	39.73	23.59
	SEm±	0.85	2.33	0.51	0.92	1.98	1.56	0.09	0.42	0.12	1.49	0.47	1.28
	SEd±	0.84	5.92	1.39	1.97	4.96	4.15	0.16	1.09	0.34	4.47	1.42	2.83

Table contd.

	1	2	3	4	5	6	7	8	9	10	11	12	
Biparental progenies													
1	$m_1 \times f_1$	52.40	168.33	10.20	15.93	62.33	46.20	3.78	16.33	3.58	30.57	39.33	17.81
	$x f_2$	50.87	179.67	8.53	19.47	49.73	44.60	3.00	15.33	3.48	16.56	40.33	17.07
	$x f_3$	55.33	162.40	12.67	14.73	55.80	43.67	3.57	15.13	3.88	19.54	40.41	15.70
	$x f_4$	52.60	163.47	7.00	12.33	57.60	44.13	3.05	16.47	4.05	26.59	40.97	18.22
	$m_2 \times f_1$	54.13	156.73	9.80	11.73	56.00	40.93	3.77	16.40	3.00	11.94	39.12	20.69
	$x f_2$	51.00	175.53	6.87	13.07	63.47	41.67	3.56	17.33	4.27	18.59	41.18	20.03
	$x f_3$	56.80	154.60	10.67	20.67	58.73	33.47	3.83	15.13	4.12	17.77	41.53	19.58
	$x f_4$	58.33	167.07	8.07	14.47	52.67	42.73	3.84	16.33	3.99	26.64	40.03	19.19
	$m_3 \times f_1$	50.73	168.93	8.47	11.40	56.93	43.67	4.03	17.53	3.80	16.38	40.65	20.83
	$x f_2$	50.73	179.73	6.27	10.40	58.07	38.93	3.61	15.27	3.55	14.73	40.53	19.32
	$x f_3$	54.07	171.20	7.53	14.40	62.13	40.93	3.68	16.53	3.77	24.84	39.63	16.34
	$x f_4$	54.00	172.27	7.33	10.73	57.93	43.13	3.61	15.93	3.75	31.21	40.29	21.60
	$m_4 \times f_1$	49.47	173.47	6.80	11.20	58.00	44.53	4.65	16.33	3.64	16.46	40.26	12.39
	$x f_2$	51.80	180.20	7.67	14.47	58.67	39.73	3.77	16.13	3.54	26.15	38.99	14.40
	$x f_3$	52.67	165.07	7.47	18.20	67.67	40.00	4.32	15.67	3.77	11.69	38.23	13.46
	$x f_4$	53.13	168.73	5.93	13.87	68.40	43.13	3.37	14.60	4.84	24.01	39.95	15.09
2	$m_1 \times f_1$	53.60	162.67	7.40	17.13	54.87	36.40	3.67	13.93	3.82	18.45	41.31	18.84
	$x f_2$	52.67	158.00	7.87	16.33	49.20	38.00	3.82	16.33	3.55	14.77	39.97	21.81
	$x f_3$	50.60	173.13	10.27	13.93	60.73	38.53	4.26	13.13	3.74	36.18	43.11	21.76
	$x f_4$	54.00	169.67	8.53	15.13	61.40	44.80	3.39	14.93	3.98	26.21	42.46	18.16
	$m_2 \times f_1$	53.93	165.73	8.00	17.27	61.93	43.67	3.48	15.00	4.04	24.13	37.93	20.65
	$x f_2$	56.27	173.73	8.07	18.47	49.93	41.33	3.74	17.00	3.29	27.79	41.96	22.54
	$x f_3$	48.60	162.20	8.07	14.33	51.00	38.07	3.67	15.80	3.77	21.99	37.51	18.85
	$x f_4$	52.93	171.13	8.27	15.13	56.40	40.67	3.73	18.07	4.16	23.93	36.15	19.71

Table Contd.

	1	2	3	4	5	6	7	8	9	10	11	12
$m_3 \times f_1$	57.47	176.87	7.13	14.27	67.33	49.20	3.33	15.20	3.86	23.92	43.01	21.05
$x f_2$	57.00	173.67	8.07	14.80	53.27	39.73	3.77	17.60	4.01	21.39	40.72	20.09
$x f_3$	54.67	176.93	6.00	12.33	52.87	39.67	3.74	17.20	3.80	22.14	40.86	20.18
$x f_4$	57.00	187.53	8.60	17.40	65.00	50.40	3.55	15.87	3.94	26.46	37.93	22.35
$m_4 \times f_1$	54.93	166.80	8.60	16.20	55.93	42.73	3.49	13.87	3.91	28.91	38.97	12.67
$x f_2$	59.60	172.33	7.47	12.93	51.27	35.33	3.57	13.47	4.00	30.11	40.97	17.77
$x f_3$	54.53	172.07	7.13	9.47	55.60	35.13	3.61	16.07	3.60	12.25	37.62	22.68
$x f_4$	54.93	181.67	7.87	13.93	58.80	37.60	3.75	15.00	4.41	18.15	39.97	13.26
3												
$m_1 \times f_1$	53.33	173.47	8.13	12.93	56.07	41.60	4.61	14.67	3.92	17.93	40.42	22.59
$x f_2$	57.60	167.93	7.07	11.73	50.00	37.73	3.78	15.47	3.20	27.82	41.68	18.90
$x f_3$	57.60	180.47	10.80	16.07	57.07	44.73	3.70	15.33	3.22	24.99	40.33	19.44
$x f_4$	55.27	174.60	7.07	11.80	46.93	37.33	3.51	12.67	3.57	19.64	41.18	16.83
$m_2 \times f_1$	55.20	171.87	6.27	8.33	57.87	40.73	4.51	14.07	4.10	16.05	42.57	17.15
$x f_2$	54.40	165.33	6.80	9.93	53.53	33.60	3.76	17.33	3.75	16.58	40.55	20.85
$x f_3$	54.40	171.07	7.13	14.13	53.13	35.07	3.63	15.60	3.48	11.81	40.86	21.15
$x f_4$	53.40	169.87	6.33	14.40	52.27	39.93	3.54	14.27	3.68	14.04	38.97	15.40
$m_3 \times f_1$	54.73	162.87	7.07	11.60	56.67	50.20	3.88	14.53	4.71	21.49	40.85	25.05
$x f_2$	54.33	168.13	7.00	9.13	51.93	37.33	3.63	14.80	3.85	16.39	37.53	19.97
$x f_3$	55.40	174.40	8.07	14.60	58.27	48.73	3.71	14.47	3.57	15.90	40.44	13.31
$x f_4$	47.87	165.07	7.53	14.00	55.87	42.80	3.01	14.27	4.10	11.24	40.95	12.28
$m_4 \times f_1$	52.93	162.87	7.73	12.20	56.40	38.47	4.09	15.00	3.68	17.37	37.40	20.46
$x f_2$	55.73	169.40	8.00	11.47	62.13	39.13	3.54	14.33	3.96	26.55	39.06	22.63
$x f_3$	58.60	181.13	7.53	12.27	48.87	38.60	3.54	13.20	4.30	13.02	41.05	18.19
$x f_4$	55.33	165.93	6.47	16.00	62.07	38.53	2.90	13.67	3.70	18.53	39.73	13.70
SEm±	0.65	1.72	0.33	0.68	1.27	1.01	0.09	0.32	0.09	1.52	0.38	0.80
SEd±	1.76	4.85	1.00	2.54	4.47	4.06	0.20	0.99	0.31	4.94	1.45	2.33

Table Contd.

	1	2	3	4	5	6	7	8	9	10	11	12	
Cross-II (Poorbijaya x RH-30) F₃ progenies													
1	m ₁	53.07	155.00	9.80	15.20	46.87	31.93	2.96	14.07	3.25	9.21	36.37	21.87
	m ₂	53.40	169.53	8.00	10.67	64.93	36.60	3.38	13.87	3.86	17.91	37.83	23.30
	m ₃	53.73	152.07	6.73	14.20	41.67	37.80	3.54	12.33	3.78	14.80	38.15	22.59
	m ₄	53.27	150.33	6.73	11.40	46.93	39.80	2.87	12.20	3.31	14.47	41.05	24.91
	f ₁	52.20	146.33	6.07	8.27	51.47	35.87	3.10	13.87	3.09	10.27	39.51	22.74
	f ₂	53.60	156.67	6.53	9.93	55.07	30.73	3.09	13.27	3.42	12.40	41.58	16.38
	f ₃	54.47	158.13	6.67	14.33	49.00	33.40	3.18	13.47	3.52	9.49	35.05	14.82
	f ₄	56.27	169.93	7.20	14.27	58.33	41.20	3.11	13.87	3.84	20.73	37.56	14.79
2	m ₁	49.80	156.87	7.20	12.07	50.40	41.27	3.37	14.93	4.04	11.07	40.46	24.00
	m ₂	50.73	161.33	6.33	10.00	54.93	35.53	3.29	14.80	4.18	16.03	38.13	21.92
	m ₃	52.67	167.13	6.27	11.07	56.60	43.87	3.35	15.47	3.45	14.17	39.98	11.99
	m ₄	52.78	155.53	7.00	11.07	51.13	40.40	2.95	12.87	3.90	23.23	38.86	22.23
	f ₁	53.20	176.47	9.07	13.80	52.93	40.13	3.35	14.60	3.50	13.42	39.87	19.95
	f ₂	51.33	162.20	6.20	10.93	55.73	40.33	3.41	14.73	3.40	10.57	38.31	20.37
	f ₃	48.27	160.07	6.60	13.27	56.00	37.47	3.69	15.00	3.68	18.25	38.16	20.80
	f ₄	53.60	166.53	5.93	10.13	53.60	38.20	3.43	14.33	3.34	11.57	39.85	
3	m ₁	55.53	165.40	4.33	12.47	56.67	38.93	3.53	13.87	3.96	13.07	38.84	20.40
	m ₂	50.67	173.53	7.73	14.67	54.33	40.53	3.45	16.07	3.61	14.25	38.91	21.79
	m ₃	50.47	178.13	6.47	11.20	60.40	43.87	3.29	13.27	3.78	12.31	37.65	20.74
	m ₄	49.67	162.67	6.67	9.60	55.33	34.47	3.33	14.07	3.57	11.07	38.09	18.69
	f ₁	50.33	170.67	6.07	10.40	59.40	40.47	3.80	16.13	3.64	22.23	39.29	23.61
	f ₂	50.80	168.07	4.60	9.60	59.93	46.93	3.49	16.87	3.81	15.43	39.45	23.64
	f ₃	52.60	171.33	7.20	14.33	57.80	48.07	3.14	14.67	3.77	12.72	39.18	21.62
	f ₄	53.40	168.93	6.47	13.80	53.93	45.53	3.29	13.67	3.67	12.39	38.70	19.77
	SEm±	0.69	2.97	0.41	0.71	1.79	1.57	0.08	0.41	0.09	1.36	0.50	1.14
	SEd±	0.76	5.79	0.85	1.89	4.41	3.61	0.17	0.94	0.26	3.92	1.47	2.99

Table Contd.

	1	2	3	4	5	6	7	8	9	10	11	12	
	Biparental progenies												
1	$m_1 \times f_1$	48.80	159.47	6.53	13.87	64.53	40.40	3.13	14.93	3.95	16.15	42.56	17.81
	$x f_2$	49.73	159.27	8.53	20.33	63.53	36.40	3.71	15.07	4.27	11.50	39.51	20.75
	$x f_3$	50.00	151.53	8.47	20.80	55.47	31.20	3.41	14.33	3.63	12.62	36.81	20.99
	$x f_4$	50.67	165.93	8.67	18.27	56.87	44.13	3.38	14.67	3.71	18.65	37.28	18.79
	$m_2 \times f_1$	51.80	156.67	7.27	11.60	60.27	45.80	3.26	14.80	3.53	28.04	41.31	17.58
	$x f_2$	49.40	166.27	6.93	11.00	61.80	45.40	3.14	13.80	4.13	15.22	36.42	19.89
	$x f_3$	51.93	176.27	8.80	16.47	63.40	41.27	3.37	14.33	4.02	14.64	35.81	20.66
	$x f_4$	56.20	174.20	7.87	13.33	55.13	47.67	3.75	15.27	3.90	26.51	38.70	18.53
	$m_3 \times f_1$	51.93	166.07	7.93	15.73	62.67	47.87	3.36	15.07	3.84	30.43	42.73	9.74
	$x f_2$	51.20	163.00	7.60	19.53	50.67	33.40	3.17	12.73	4.43	19.15	40.17	19.58
	$x f_3$	54.33	156.60	8.67	18.27	52.27	33.47	3.34	15.33	4.37	19.71	38.29	17.00
	$x f_4$	52.47	163.80	7.60	18.80	53.13	43.67	3.55	14.60	3.89	21.73	39.27	10.46
	$m_4 \times f_1$	55.00	154.00	8.07	11.00	58.80	50.40	3.08	14.73	2.75	24.27	42.56	19.82
	$x f_2$	53.00	158.80	7.80	13.73	45.93	40.47	3.61	15.00	3.61	12.51	42.11	25.70
	$x f_3$	56.60	165.47	8.07	14.87	58.00	44.13	3.43	15.33	3.55	12.67	39.43	26.94
	$x f_4$	56.60	162.80	7.80	13.73	58.60	44.27	3.62	16.07	3.60	15.59	40.84	19.71
2	$m_1 \times f_1$	50.67	159.07	6.93	13.87	52.60	40.40	3.99	17.47	3.89	19.88	39.79	11.29
	$x f_2$	52.67	173.50	9.27	15.40	59.47	49.93	3.51	17.00	3.86	24.03	40.54	13.39
	$x f_3$	50.93	157.40	7.47	14.40	52.60	39.73	3.99	16.73	3.96	21.02	37.09	21.05
	$x f_4$	54.73	166.00	7.13	14.53	55.20	46.60	3.45	13.40	3.84	20.19	39.86	17.74
	$m_4 \times f_1$	48.60	166.40	5.87	11.93	52.20	39.87	3.41	13.80	3.73	19.81	40.43	21.61
	$x f_2$	49.13	165.47	7.87	15.13	50.67	41.13	3.11	13.53	4.29	18.85	39.96	22.54
	$x f_3$	50.20	148.33	6.00	11.20	48.40	36.57	3.39	10.93	4.47	16.94	38.11	19.09
	$x f_4$	53.87	153.27	5.93	10.27	50.20	40.60	2.87	13.80	3.14	14.13	40.05	19.70

Table Contd.

	1	2	3	4	5	6	7	8	9	10	11	12
$m_1 \times f_1$	51.80	172.87	7.80	15.40	57.60	35.07	3.77	16.67	3.93	17.45	41.84	21.39
$x f_2$	53.20	167.07	7.93	14.73	57.33	36.13	3.51	12.67	3.98	16.46	40.33	19.25
$x f_3$	57.33	164.20	5.80	10.40	56.50	44.13	3.73	12.13	3.78	16.53	42.66	27.34
$x f_4$	56.60	173.56	7.33	14.07	60.40	41.93	3.74	15.33	2.99	18.93	40.99	28.10
$m_2 \times f_1$	50.73	165.67	6.60	12.93	62.80	47.07	3.25	16.60	3.70	14.20	42.68	18.16
$x f_2$	51.27	163.13	6.87	12.33	54.33	40.53	2.63	14.87	3.58	15.49	40.74	19.51
$x f_3$	52.93	154.60	6.60	11.60	55.80	41.40	3.38	14.67	3.26	13.33	40.45	22.56
$x f_4$	54.60	165.73	7.33	14.87	53.93	41.67	2.99	14.00	3.32	21.96	40.20	20.92
$m_3 \times f_1$	52.00	174.60	6.00	14.33	58.40	41.47	3.46	15.60	3.79	19.07	37.76	22.73
$x f_2$	53.93	175.80	7.53	13.00	69.87	47.07	3.55	14.63	3.86	19.20	40.97	16.87
$x f_3$	53.07	162.80	6.80	12.27	57.13	40.27	3.31	16.67	3.29	13.45	41.58	25.05
$x f_4$	52.53	161.93	5.93	9.80	57.93	39.33	3.63	16.47	3.66	11.21	41.15	20.46
$m_4 \times f_1$	47.53	174.27	6.07	12.87	66.47	45.60	3.66	15.87	3.22	23.11	37.47	19.43
$x f_2$	54.27	178.60	6.60	12.27	62.33	44.00	3.39	14.40	3.88	22.67	40.41	20.99
$x f_3$	61.93	163.93	7.33	13.53	61.67	40.00	3.31	14.27	3.65	16.67	41.47	19.97
$x f_4$	54.20	168.53	6.07	15.67	66.40	44.33	3.49	14.27	3.27	18.71	40.52	21.73
3 $m_1 \times f_1$	52.13	170.93	9.33	14.33	64.60	44.80	3.48	14.80	3.85	25.16	40.84	19.44
$x f_2$	56.47	164.80	9.40	15.87	60.07	47.13	3.27	14.33	3.62	26.33	39.46	20.49
$x f_3$	52.40	170.33	9.13	15.33	60.40	43.13	3.12	14.87	3.49	16.01	37.49	18.86
$x f_4$	52.13	163.33	7.73	12.53	59.13	48.60	3.53	15.07	3.49	21.27	39.88	18.19
$m_4 \times f_1$	51.67	162.40	6.67	12.27	60.40	41.33	4.01	16.93	3.44	20.15	42.42	21.50
$x f_2$	55.13	169.80	10.00	17.67	55.20	42.60	3.23	12.33	3.40	21.13	40.15	20.07
$x f_3$	53.60	157.13	9.73	14.93	56.73	43.07	3.43	15.13	3.89	19.63	42.03	16.95
$x f_4$	53.00	154.60	6.87	11.93	54.53	39.20	3.79	16.00	3.33	15.01	40.92	22.37
SE $m \pm$	0.67	1.77	0.28	0.66	1.26	1.08	0.07	0.34	0.09	1.12	0.45	0.92
SE $d \pm$	1.25	5.23	0.71	2.16	4.49	4.20	0.17	0.96	0.28	4.79	1.27	2.21

Table contd.

	1	2	3	4	5	6	7	8	9	10	11	12	
	Cross III (BJ-38 x Poorbijaya) F₃ progenies												
1	m ₁	50.87	145.00	7.60	13.40	59.07	43.93	3.25	14.20	3.46	9.97	40.53	3.85
	m ₂	52.80	158.40	6.07	13.47	59.40	41.93	3.41	14.53	3.37	15.49	37.06	7.28
	m ₃	52.33	153.13	7.80	12.33	52.47	34.40	3.25	14.00	3.28	8.34	40.23	5.88
	m ₄	51.80	164.73	6.07	7.93	56.47	42.33	2.75	13.20	3.14	9.71	35.26	5.89
	f ₁	50.27	154.80	7.67	10.73	54.73	41.00	3.26	14.27	3.05	10.22	40.64	5.69
	f ₂	53.80	158.80	6.00	9.73	53.27	35.87	3.11	14.27	3.35	10.67	40.37	7.11
	f ₃	49.27	146.87	7.87	11.13	46.60	36.33	3.14	14.40	3.07	10.50	36.14	9.33
	f ₄	52.40	159.63	5.53	10.87	51.33	41.80	2.93	11.67	3.01	12.59	37.72	4.55
2	m ₁	49.33	159.27	6.60	8.20	60.93	46.13	3.39	15.93	3.14	13.51	38.81	5.64
	m ₂	50.33	172.33	6.53	8.13	54.47	40.13	3.21	12.00	4.02	11.18	37.20	4.75
	m ₃	49.67	159.27	7.80	12.60	53.47	46.00	3.39	14.80	3.26	10.51	37.83	8.97
	m ₄	47.00	156.20	6.60	9.40	46.20	36.07	3.09	13.40	3.41	11.84	38.97	4.65
	f ₁	51.07	159.27	7.33	13.07	46.80	44.07	3.18	14.27	3.10	19.24	37.07	4.83
	f ₂	50.47	162.53	6.20	8.40	53.93	42.53	3.38	13.60	3.36	8.84	37.31	6.16
	f ₃	47.67	157.27	6.40	9.40	55.33	41.07	3.81	14.93	3.42	16.47	40.60	6.15
	f ₄	51.73	165.53	6.47	11.87	56.40	43.00	3.46	15.40	3.10	13.07	38.58	11.77
3	m ₁	52.67	161.93	6.60	9.13	51.13	37.33	3.29	15.47	3.98	16.61	39.28	13.78
	m ₂	49.60	162.73	6.13	9.67	60.80	45.40	3.07	15.13	3.14	15.44	39.59	8.21
	m ₃	50.13	156.67	6.00	9.27	52.13	41.80	3.15	13.73	3.46	17.89	38.80	6.59
	m ₄	50.60	171.20	7.07	10.60	63.80	48.67	3.36	13.60	3.25	10.14	39.71	4.82
	f ₁	53.80	162.07	5.40	10.67	59.67	48.07	3.17	13.67	3.50	18.27	38.47	4.61
	f ₂	49.47	158.20	5.60	9.67	58.20	44.20	3.47	13.47	3.89	10.00	37.93	4.42
	f ₃	51.47	167.80	5.73	11.20	54.53	40.53	3.29	12.47	3.73	10.37	38.36	15.86
	f ₄	54.87	162.80	6.60	11.60	57.87	43.53	2.95	12.27	2.99	18.43	38.23	9.02
	SEm±	0.67	2.25	0.27	0.60	1.64	1.35	0.08	0.39	0.10	1.21	0.51	1.09
	SEd±	1.01	4.44	0.74	1.52	4.12	3.44	0.15	1.11	0.30	3.33	1.38	2.67

Table Contd.

	1	2	3	4	5	6	7	8	9	10	11	12	
Biparental progenies													
1	$m_1 \times f_1$	50.13	151.47	8.47	15.47	57.93	38.93	3.24	17.87	3.40	12.70	35.50	5.11
	$x f_2$	49.07	161.87	6.80	13.40	64.67	36.73	3.34	15.73	3.67	20.71	36.67	6.78
	$x f_3$	48.53	156.73	7.07	10.73	61.27	37.60	3.79	14.73	3.99	18.24	38.59	6.58
	$x f_4$	50.73	166.93	8.40	16.93	65.07	43.53	3.37	12.53	3.86	22.29	38.83	9.02
	$m_2 \times f_1$	50.20	159.53	7.07	15.27	54.67	43.47	3.35	15.27	2.66	20.27	37.86	5.63
	$x f_2$	50.53	164.40	5.67	11.00	57.27	43.47	3.44	15.07	3.07	14.43	34.83	6.15
	$x f_3$	47.33	148.60	5.93	9.93	50.60	44.60	3.69	13.73	2.93	19.47	37.71	5.87
	$x f_4$	53.40	179.07	7.40	14.33	57.67	47.20	3.23	13.33	2.63	24.61	36.14	9.07
	$m_3 \times f_1$	49.00	155.73	7.00	12.00	58.20	45.53	3.19	16.60	3.20	16.81	38.87	5.94
	$x f_2$	51.73	159.00	5.93	9.53	57.80	42.47	3.29	16.07	3.05	13.71	36.62	5.24
	$x f_3$	49.00	152.47	5.73	11.67	57.13	45.13	3.61	14.87	3.41	16.01	39.46	10.00
	$x f_4$	51.40	165.93	6.93	12.60	57.93	45.93	3.09	13.73	3.24	22.71	39.40	7.21
	$m_4 \times f_1$	49.60	171.07	8.20	16.73	60.93	51.87	3.08	15.13	3.10	24.44	38.49	5.48
	$x f_2$	53.73	174.00	7.73	10.80	65.27	44.40	2.97	14.80	3.11	16.91	33.75	5.09
	$x f_3$	48.53	161.00	6.67	11.73	59.53	37.93	3.64	14.13	3.53	15.18	38.73	8.43
	$x f_4$	52.67	175.80	8.00	15.20	66.80	50.13	3.27	11.93	3.31	19.51	36.19	6.94
2	$m_1 \times f_1$	53.93	168.40	8.00	12.73	54.80	44.27	3.59	15.00	3.93	19.71	36.18	3.56
	$x f_2$	54.47	171.60	7.00	10.60	58.13	45.33	3.47	14.00	3.29	11.49	40.12	3.67
	$x f_3$	51.47	166.60	7.27	11.53	59.27	46.13	3.77	15.13	3.31	23.99	39.04	4.28
	$x f_4$	56.20	160.60	6.53	10.40	59.60	48.00	3.58	14.47	3.71	16.17	37.41	4.40
	$m_4 \times f_1$	51.00	161.60	7.53	15.07	55.33	40.07	3.52	14.40	3.34	19.09	34.67	7.92
	$x f_2$	50.60	170.07	7.47	12.33	63.47	46.27	3.55	14.60	3.53	17.61	37.21	9.69
	$x f_3$	47.07	165.67	8.67	13.60	55.07	45.53	3.65	13.60	3.71	22.91	37.39	10.35
	$x f_4$	58.00	166.53	8.00	15.40	58.93	48.60	3.34	14.00	3.89	22.13	37.59	10.46

Table Contd.

	1	2	3	4	5	6	7	8	9	10	11	12
$m_3 \times f_1$	50.33	154.73	7.93	14.60	52.93	40.33	3.55	14.07	2.83	19.68	37.02	5.38
$\times f_2$	50.93	157.80	6.87	11.40	56.60	50.53	3.31	13.80	3.42	14.33	38.01	5.11
$\times f_3$	46.10	156.87	6.40	9.60	53.33	50.60	3.25	14.13	3.28	10.73	35.67	7.81
$\times f_4$	56.13	160.00	7.87	12.93	58.40	48.67	2.97	14.20	3.53	14.94	37.91	10.76
$m_4 \times f_1$	50.13	165.47	8.20	14.60	56.53	38.40	2.75	13.13	3.11	17.15	36.14	4.96
$\times f_2$	50.13	162.80	7.53	11.87	58.00	46.73	3.57	15.47	3.55	16.32	38.53	5.99
$\times f_3$	46.40	166.73	7.20	13.07	56.67	46.00	3.19	13.33	3.05	25.28	38.26	7.31
$\times f_4$	53.60	161.53	6.60	10.93	53.20	41.07	2.93	14.00	3.42	19.39	36.05	10.60
$m_1 \times f_1$	50.07	157.07	5.87	11.00	58.73	33.87	3.58	14.67	3.18	12.31	38.01	3.56
$\times f_2$	50.27	163.20	6.13	12.27	60.93	41.93	3.67	15.80	3.27	19.45	40.26	6.01
$\times f_3$	50.47	169.20	6.13	12.47	53.13	44.07	3.41	15.93	3.76	26.14	41.68	8.09
$\times f_4$	54.47	168.13	6.07	13.27	48.33	38.00	3.42	14.60	3.44	25.73	38.33	6.16
$m_2 \times f_1$	50.60	167.67	7.20	13.20	66.47	41.60	3.67	15.13	3.49	24.55	39.45	3.74
$\times f_2$	50.47	169.27	6.80	12.27	68.20	49.53	3.39	14.73	3.30	20.88	40.23	6.57
$\times f_3$	50.33	170.93	7.53	12.27	63.13	48.80	3.55	16.93	3.55	25.49	39.89	6.86
$\times f_4$	53.80	167.47	7.47	11.87	61.40	40.07	3.25	15.33	3.35	22.45	40.18	5.36
$m_3 \times f_1$	47.53	162.93	7.47	11.47	54.47	33.67	3.49	14.53	3.30	10.93	38.92	3.89
$\times f_2$	47.73	167.33	8.40	12.93	63.20	44.27	3.28	13.87	3.08	13.72	37.79	7.06
$\times f_3$	47.93	159.53	6.67	13.47	49.73	37.53	3.32	13.67	3.91	15.61	39.11	6.66
$\times f_4$	47.73	163.80	6.67	11.67	56.20	42.27	3.18	12.87	3.12	21.29	39.00	5.98
$m_4 \times f_1$	51.60	168.73	7.27	12.60	70.93	43.00	3.64	14.27	3.28	12.73	39.65	3.42
$\times f_2$	52.20	163.27	8.67	12.40	64.87	44.53	3.33	13.07	2.92	14.23	34.79	6.83
$\times f_3$	50.47	166.33	7.07	12.13	56.00	38.20	3.33	14.40	3.26	15.23	35.35	7.11
$\times f_4$	49.40	172.80	7.40	14.73	65.07	45.00	3.31	13.53	3.27	21.55	38.97	8.26
SEm±	0.65	1.60	0.20	0.44	1.23	1.11	0.06	0.28	0.08	1.09	0.44	0.50
SEd±	1.19	4.90	0.64	1.71	5.09	3.94	0.16	0.90	0.28	4.75	1.23	1.34