

**NATURE OF VARIATION, ASSOCIATION ANALYSIS AND
MEIOTIC STABILITY IN Brassica campestris X B. nigra
ALLOTETRAPLOIDS.**

THESIS

BY

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Submitted to



**HIMACHAL PRADESH KRISHI VISHWAVIDYALAYA
PALAMPUR-176 062 (H. P.) INDIA**

IN

Partial fulfilment of the requirements for the degree

OF

**MASTER OF SCIENCE IN AGRICULTURE
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*Dedicated
To My
Respected Parents*

Dr. O.P. Sood
Assistant Soybean Breeder

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CERTIFICATE-I

This is to certify that the thesis entitled "Nature of variation, association analysis and meiotic stability in *Brassica campestris* x *B.nigra* allotetraploids" submitted for the Degree of MASTER OF SCIENCE (AGRICULTURE) in the subject of Plant Breeding of Himachal Pradesh Krishi Vishvavidyalaya, Palampur, is a record of bonafide research work carried out by Miss Neelam Bhardwaj, daughter of Dr.K.K.R.Bhardwaj under my guidance and supervision and no part of this thesis has been submitted for any other degree.

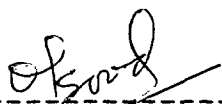
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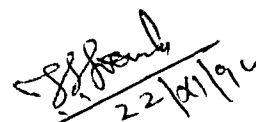

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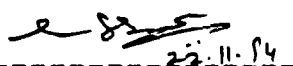
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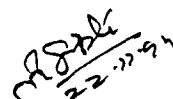
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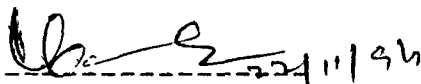
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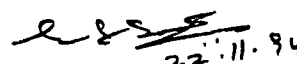
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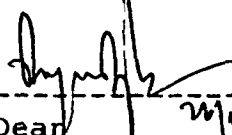
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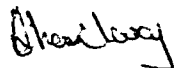
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Neelam Bhardwaj

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1. INTRODUCTION

Oilseeds, the raw material for vegetable oils, constitute the second major group of crops in India after food grains, in terms of area and production (Anonymous, 1992). These vegetable oils and fats are rich source of energy. Of the different oilseed crops, oleiferous Brassicas provide about 13.2% of the world's edible oil supplies. Major producing regions include China, the Indian subcontinent, Canada and Northern Europe. Due to their ability to thrive well under diverse agro-climatic conditions, the oilseed Brassicas are one of the few edible oil crops that can be cultivated in the cooler agricultural regions and at higher elevations, as well as winter crop in the temperate zones.

The oilseed Brassicas mainly comprise four species, namely *Brassica campestris* L., *Brassica juncea* (L.), Czern & Coss., *B.napus* L. and *B.carinata* A.Braun, which occupy over 6,305 thousand hectare area with annual production of 4,872 thousand million tonnes in India (FAO, 1993). Of these, *B.juncea* ($2n=4x=36$, AABB), commonly known as Indian mustard (Raya) constitutes about 70 per cent of the total area under oilseed Brassicas. It is a self-pollinated crop, which gives comparatively better quality oil due to the absence of

rancid smell and comparatively low erucic acid content (Anand, 1975). It possesses higher production potential than other oleiferous Brassicas. This early maturing Brassica species is resistant to shattering but susceptible to certain biotic and abiotic stresses.

For an effective crop improvement programme, availability of wide genetic variability in a particular crop species is the basic requirement. The improvement of *B.juncea* has mostly been confined to the exploitation of naturally occurring genetic variation. The existing narrow genetic base of the crop can be broadened by its artificial synthesis (Prakash, 1973). If such synthesis involves locally adapted *B.campestris* and *B.nigra* genotypes, a wider spectrum of variability is expected to be generated, which could be utilized in crop breeding programmes. It is also desirable to understand the nature and magnitude of genetic variability present in a particular material and to exploit this using appropriate breeding techniques. Burton (1951) emphasized that estimates of correlation between various characters in a crop, specially when partitioned into genotypic and environmental components, are of great value in planning breeding programmes. However, simple correlation coefficients sometime fail to convey relative importance of yield components towards yield. Path coefficient analysis provides an effective mean of finding direct and indirect causes of association, and gives a more comprehensive picture of the type of character association(s).

One of the limitations of commercial exploitation of *B.juncea* like any other synthetic allopolyploid is disturbed meiosis. The meiosis is more irregular if the genomes of the parents involved in the synthesis of allopolyploid have undergone considerable changes. Different meiotic anomalies ultimately lead to the reduction in yield, thereby putting the synthetic allopolyploid to agronomic disadvantages in comparison to the natural allopolyploid.

The present study was undertaken on 23 synthetic Junceas keeping in view the following objectives:

- i) To study the nature of variation for seed yield and other traits,
- ii) to know the inter associations among seed yield and other traits, and
- iii) to determine the meiotic stability of the allotetraploids under study.



REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Among the commercially grown oilseed crops of the world, oleiferous Brassicas are widely distributed in both temperate and subtemperate regions due to their polymorphic nature and wider adaptation. The Brassica group of crops occupy second largest position both in area and production after groundnut among the oilseed crops grown in India (Anonymous, 1992). Indian mustard (*Brassica juncea* L. Czern & Coss.) is one of the important oleiferous Brassicas grown in India.

The presence of heritable variation, the prerequisite for the improvement of any crop species. In the allotetraploid *B. juncea* this variation can be generated by developing synthetic allotetraploids by hybridizing the parental species. Besides, different parameters of variation, like phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance; association of different traits and partitioning of components of yield into its direct and indirect effects is essential. Since the *B. juncea* genotypes under investigation are newly synthesized allotetraploids, it is pertinent to study the meiotic stability.

The literature pertaining to different aspects of the present study in the synthetic allotetraploids is meagre. However, the relevant literature in *B.juncea* is reviewed here under:

2.1 VARIABILITY STUDIES

Superior cultivars with desired characters can be developed if sufficient genetic variability is present among the genotypes for traits of interest. Vavilov (1951) was the first to realize that chances of selecting a desired type are better if a wider range of variability is present in the crop. According to Fisher (1918) the continuous variation exhibited by quantitative characters, which are of main interest to a breeder, includes the heritable and non-heritable components. The heritable components are consequence of the genotype and the non-heritable part is due to environmental factors.

Yadava (1973) observed high heritability and genetic advance for plant height and maturity in Indian mustard.

Singh et al.(1975) found a wide range of variation for plant height, yield, number of secondary branches and main shoot length in a study on 50 strains of Indian mustard. They observed high heritability for oil content, days to flowering, plant height and number of secondary branches per plant.

Katiyar et al.(1976) observed high estimates of genetic coefficient of variation, heritability and genetic advance for seed yield per plant, plant height and days to first

flowering. Paul et al.(1976) found that genotypic variances formed the major part of the total variances and represented high genetic advance for seed yield, number of seeds per siliqua, number of siliquae per plant and number of primary branches per plant.

Yadav and Yadav (1977) reported high heritability for number of days to first flowering, days to maturity, 1000-seed weight and plant height.

Paul (1978) reported moderate to high estimates of broad sense heritability.

Lodhi et al.(1979) found high estimates of narrow sense heritability for number of secondary branches per plant and number of siliquae on the main shoot.

Labana et al.(1980) observed high estimates for secondary branches per plant, seed yield per plant, main shoot length and seed number per siliqua.

Yadav et al.(1981) observed high narrow sense heritability for number of days to maturity, length of main shoot and 1000-seed weight.

Chaudhary and Sharma (1982) observed that the estimates of heritability ranged from 51.08% for seed number to 91.39% for number of primary branches per plant. Genetic advance was the highest for siliqua length (41.14%).

Singh et al.(1987) observed low to medium heritability for number of primary branches per plant and seeds per siliqua. The estimates of heritability in the study were high for the 16 characters.

Chaudhary and Goswami (1991) found the highest genotypic and phenotypic variations for seed yield, followed by number of siliquae per plant. They observed that siliquae per plant alongwith plant height exhibited the highest heritability.

2.2 CORRELATION STUDIES

The idea of correlation was elaborated by Fisher (1918) and Wright (1921). Correlation coefficient is used as a measure of the degree of association between two characters worked at the same time (Hays et al., 1955).

Yadav (1973) observed that in Indian mustard seed yield was positively correlated with number of seeds per siliqua. Srivastava and Das (1973) observed significant and positive correlation between 1000-seed weight and yield. They also reported that genotypic correlations for yield and other characters were greater than the corresponding phenotypic correlations.

Anand (1975) suggested that while breeding for high yield in *Juncea*, emphasis should be laid on such primary characters as number of primary and secondary fruit bearing branches together with medium height and flowering as these were directly associated with yield per se. Singh et al. (1975) observed positive association between siliquae on main shoot and seed yield, while the other yield components showed low association with seed yield.

Katiyar et al. (1976) reported that seed yield per plant was correlated with days to flowering, number of primary and secondary branches per plant and height. Paul et

al.(1976) found that yield per plant was correlated with the number of fruits per plant and seeds per fruit. Ram et al. (1976) observed that seed yield was positively correlated with number of primary branches and 1000-seed weight.

Rawat and Anand (1977) reported that at the phenotypic level, both seed yield and oil content were correlated with number of primary branches, plant height, number of seeds per siliqua and number of days to 50% flowering; only seed yield was correlated with number of secondary branches and 1000-seed weight; and only oil content was correlated with seed yield per plant.

Paul et al.(1978) found that seed yield per plant was significantly correlated with siliqua number per plant and primary and secondary branches per plant. Yadav et al.(1978) reported negative correlation of days to first flowering with shoot length. They further observed a high positive correlation of days to first flowering with days to 50% flowering, maturity and 1000-seed weight. High positive correlation between days to maturity and 1000-seed weight was also observed. However, oil content was not correlated with any of the characters studied.

Labana et al.(1980) reported that seed yield was positively correlated with the primary branch number, secondary branch number, siliquae on main shoot and negatively with plant height. Ahmed (1980), from a study of 12 varieties of *B.juncea*, reported that seed yield per plant was positively correlated with pod length, number of pods

per plant, number of seeds per pod and seed weight per pod. Days to maturity was negatively correlated with number of pods per plant, and per cent oil in seed was positively correlated with seed weight but negatively with number of seeds per pod.

Yadav (1983) reported that seed yield was correlated with number of primary branches and siliquae per plant, number of inflorescences, 1000-seed weight and plant height. Yadava et al.(1983) studied 6 quality and yield traits in 9 parents and 36 F₁'s, and found that only 1000-seed weight and oil content were positively correlated with seed yield.

Kumar (1984) found positive and significant correlation of seed yield with days to maturity, plant height, primary branches per plant, secondary branches per plant and 1000-seed weight. Total number of siliqua had the strongest positive effect on yield, followed by 1000-seed weight. Singh et al.(1985) reported that total siliqua number per plant and 1000-seed weight were positively correlated with yield and total siliqua number per plant. Pathak et al. (1986) concluded that 1000-seed weight, days to flowering, length of main branch, seeds per siliqua, siliquae per plant, number of primary branches and height are the most important yield components.

Singh et al.(1987) reported that number of siliqua per plant was positively associated with seed yield per plant under both irrigated and unirrigated conditions.

Kumar et al.(1988) found positive correlation of seed yield with number of primary branches, secondary branches and siliquae per plant.

Badwal and Labana (1989) reported positive correlation between seed yield and plant height, primary branches, secondary branches and siliqua length.

Yadav et al.(1990) found positive and significant correlation between harvest index and biomass production.

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

2.3 PATH ANALYSIS

The studies on correlation coefficient merely indicate the nature of association and do not provide an exact insight of the relative importance of direct and indirect influences of each of the component characters, towards independent variable. Path coefficient analysis suggested by Wright (1921,1923,1934,1960) furnishes a mean of untangling direct and indirect contributions of various factors involved in building-up a complex correlation. The utility of path coefficient analysis in plant breeding was demonstrated by Dewey and Lu (1959) in 81 crested wheat grass progenies.

Chauhan and Singh (1975) reported in Indian mustard that plant height, seeds per siliqua and number of branches were main yield contributing characters, whereas days to

flowering had negligible direct effect on seed yield and affected yield only through plant height.

Labana et al.(1977) observed in Indian mustard that the number of secondary branches had the maximum direct effect on seed yield, followed by length of main shoot, siliquae per main shoot, primary branches and days to maturity. Seeds per pod showed a high indirect negative effect through siliqua length and days to flowering; 1000-seed weight showed a high negative indirect effect through days to flowering, but positive indirect effect via days to maturity. Shivahare et al.(1977) reported in Indian mustard that number of primary and secondary branches per plant, number of seeds per siliqua and 1000-seed weight had large direct influence on yield per plant. They further observed that plant height and days to flowering influenced seed yield through the number of secondary branches.

Singh et al.(1978a) observed that the number of siliqua on the main shoot and the number of secondary branches were the main yield components in Indian mustard.

Paul et al.(1978) reported that in Indian mustard the siliqua number per plant, primary and secondary branch number had positive direct effect on seed yield per plant. Singh et al.(1978b) found that number of secondary branches and plant height are the most important yield components.

Srivastava et al.(1983) analysed data on 8 yield components and quality characters, and found that days to maturity and primary branch number were the most important

characters contributing to yield. Singh and Choudhary (1983) analysed data on 8 traits from 37 cultivars and found that number of secondary branches, plant height, seed weight, and to some extent seeds per pod should be considered in breeding for increased yield.

Kumar (1984) reported that seed yield was positively and significantly correlated with days to maturity, plant height, primary branches per plant, secondary branches per plant and 1000-seed weight. They noticed that the strongest positive effect on seed yield was of total number of siliqua, followed by 1000-seed weight. Singh et al. (1985) found that total siliquae per plant, harvest index and 1000-seed weight had the greatest direct effect on seed yield.

Pathak et al. (1986) concluded that 1000-seed weight, days to flowering, length of main branch, seeds per siliqua, siliquae per plant, number of primary branches and plant height are the most important yield components.

Kumar et al. (1988) analysed data on seed yield per plant and 7 related characters from 16 genotypes and identified siliqua number and flowering time as the possible indirect selection criteria.

2.4 MEIOTIC STUDIES

B. juncea allopolyploid comprises diploid sets of A and B genomes. Chromosome abnormalities viz., univalents, laggards and anaphasic bridges may occur in the newly synthesized allotetraploid.

U et al.(1937) reported (0-3)II and (18-12)I in *B.campestris* x *B.nigra* having 18 chromosome number.

Ramanujam and Srinivasachar (1943) made cytological investigations on *B.campestris* and *B.nigra* amphidiploids. They noticed 18(II) at Metaphase I. In most of the cases they noticed chromatin bridges at anaphase I. The anaphase separation was regular at metaphase II, with 18 + 18 grouping of chromosomes resulting in normal tetrad. Frandsen (1943) also noticed mostly 18 II after A₄ to A₆ generation.

Ramanujam and Deshmukh (1945) confirmed previously recorded chromosome number for this *B.juncea* allopolyploid (2n=36). They reported 18(II) at diakinesis and a distribution of 18+18 chromosomes at Metaphase II.

Olsson (1960) reported that fertility in the synthesised hybrid was very low and the hybrid was very highly irregular meiotically with (0-5)II + (18-8)I at diakinesis and metaphase I. In the first generation artificial *B.juncea*, meiotic disturbances were very common but by the fourth and fifth generations meiosis got stabilised.

Srinivasachar (1965) reported (0-6)II and (18-6)I in the hybrid of *B.campestris* x *B.nigra* having somatic chromosome number 18. Parkash (1973) reported 1 to 2 quadrivalents in the *B.juncea* hybrid suggesting that allosyndetic recombination has occurred in the 18 chromosome hybrid.

Herberd and Mcarthur (1981) studied the meiotic behaviour of some species and genus hybrids in the *Brassica* and reported that diploid hybrid averaged 2.9 bivalents, triploid 6.2 and tetraploid 10.2, with a wide range of variations with the ploidy levels. Khanna and Choudhary (1981) reported meiotic disturbances in 23.6% meiocytes *B. juncea*.

**MATERIALS
AND
METHODS**

3.MATERIALS AND METHODS

The present investigation entitled "Nature of variation, association analysis and meiotic stability in *Brassica campestris* x *B. nigra* allotetraploids" was carried out at two locations namely, Oilseed Research Station, Kangra (700m amsl) and Department of Plant Breeding & Genetics, Himachal Pradesh Krishi Vishvavidyalaya, Palampur (1300m asml). The 23 synthetic *B.juncea* allotetraploids alongwith diploid parents and locally adapted *B.juncea* cv. Varuna were used as a basic material for the present study. The parentage of these synthetic Junceas are given in Table 1.

Table 1. Parentage of twenty three synthetic Junceas used in the study

Parentages	Synthetic Junceas
<i>Brassica campestris</i> var. Brown sarson cv. Candle X <i>B.nigra</i> Landrace	JSP1,JSP2, JSP3,JSP4 JSP5,JSP6, JSP7
<i>B.campestris</i> var.Yellow sarson cv.YS1 X <i>B.nigra</i> Landrace	JSP8,JSP9,JSP10,JSP11 JSP12,JSP13,JSP14 JSP15,JSP16,JSP17 JSP18,JSP19,JSP20 JSP21,JSP22,JSP23

These were raised in a Randomized Complete Block Design with 3 replications during rabi 1993-94 at Palampur and Kangra. Each entry was raised in a 3 row plot, each 3-m long

with row-to-row and plant-to-plant spacings of 30cm and 10cm, respectively. Recommended cultural practices and plant protection measures were used.

3.1 RECORDING OF OBSERVATIONS

The data were recorded for the following traits on 10 randomly taken plants in each replication.

1. Seed yield per plant (g): The seed produce of 10 randomly taken plants was recorded.
2. 1000-seed weight (g): A random sample of 1000 seeds was taken from the produce of each entry and weighed.
3. Seeds per siliqua: Number of seeds of 10 randomly taken siliquae from each of the 10 plants was counted.
4. Siliqua length (cm): Ten mature siliquae were randomly taken from each selected plant and their length upto tip was measured.
5. Siliquae per plant: Total number of siliqua were counted in each randomly tagged plant.
6. Siliquae per primary branch: Number of siliqua on each of the primary branch of the 10 randomly taken plants was counted.
7. Primary branches per plant: All the branches which arose from the main stem were counted at the time of maturity.
8. Secondary branches per plant: All the branches that arose from the primary branches were counted at the time of maturity.

9 Plant height (cm): Height of the plant, from the base to the tip of the main shoot was measured at the time of maturity.

10. Days to flowering: The number of days from sowing to 50% flowering of the plants was recorded on plot basis.

11. Days to maturity: The number of days from sowing to maturity was recorded on plot basis.

12. Oil content (%): The oil content of the genotypes was estimated from the pooled sample derived from ten plants in each replication. Oil in a weighed quantity of seeds was determined through Nuclear Magnetic Resonance Spectrometry as described by Tiwari et al.(1974).

13. Harvest index (%): Harvest index was calculated as below:

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

3.2 STATISTICAL ANALYSIS

Mean values in each replication for different genotypes were calculated for all the 13 characters studied. The following statistical analyses were performed:

3.2.1 Analysis of variance for experimental design

The analysis of variance for each trait was based on the following linear model of Panse and Sukhatme (1984).

$$P_{ij} = u + g_i + b_j + e_{ij}$$

where,

P_{ij} = phenotypic effect of the i^{th} genotype in the j^{th} replication,

μ = general population mean,

g_i = effect of i^{th} genotype,

b_j = effect of j^{th} replication, and

e_{ij} = random error associated with the i^{th} genotype in the j^{th} replication

On the basis of this model the analysis of variance is as follows:

Source of variation	df	ms	Expected ms
Replications	$(r-1)$	M_r	$\sigma_e^2 + g \sigma_r^2$
Genotypes	$(g-1)$	M_g	$\sigma_e^2 + r \sigma_g^2$
Error	$(g-1)(r-1)$	M_e	σ_e^2

$$\text{Genotypic variance (} \sigma_g^2 \text{)} = \frac{M_g - M_e}{r}$$

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

r = Number of replications

g = Number of genotypes

Critical Difference (CD): For calculating critical difference following steps were followed:

(i) Standard error of mean $SE_{\bar{x}} = (M_e/r)^{1/2}$

(ii) Standard error of difference between the means of 2 genotypes

$$SE_{\bar{x}} = (2M_e/r)^{1/2}$$

(iii) CD at 5% = $SE_{\bar{x}} \times 't'$ at 5% at error 'df'

3.2.2 Components of variation: Phenotypic and genotypic coefficients of variation were estimated as suggested by Burton and Devane (1953).

$$(i) \text{ Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{p}}{\bar{X}} \times 100$$

$$(ii) \text{ Genotypic coefficient of variation (GCV)} = \frac{\sqrt{g}}{\bar{X}} \times 100$$

Where,

$\sqrt{p}$ = phenotypic standard deviation

$\sqrt{g}$ = genotypic standard deviation and

$\bar{X}$ = grand mean

3.2.3 Genetic parameters: Heritability in broad sense was calculated by the following formula suggested by Burton and Devane (1953)

$$\text{Heritability (h}_{bs}^2) = \frac{\sqrt{g}^2}{\sqrt{g}^2 + \sqrt{e}^2} \times 100$$

The expected genetic advance resulting from selection of five per cent individuals was calculated as suggested by Burton and Devane (1953).

$$\text{Expected genetic advance (GA)} = k \times \sqrt{p} \times h_{bs}^2$$

where,

$\sqrt{p}$ = phenotypic standard deviation

k = selection differential in standard units which indicate the value for 5% selection intensity,

h_{bs}^2 = heritability in broad sense

$$\text{Genetic advance as percentage of mean} = \frac{\text{Expected GA}}{\bar{X}} \times 100$$

For categorising the magnitude of different parameters, the following limits were used:

PCV and GCV: >20% - high; 10-20% - moderate; <10% low

Heritability: >80% - high; 50-80% - moderate; <50% low

Genetic advance: >30% - high; 20-30% - moderate; <20% low

3.3 CORRELATION COEFFICIENTS

For computing phenotypic, genotypic and environmental coefficients of correlation, analysis of covariance was performed in all possible paired combinations of thirteen traits studied.

Covariance table

Source of variation	df	Mean sum of products	Expected ms of products
Replications	(r-1)	$\frac{r}{xy}$	$\frac{\sqrt{e}}{xy} + g \frac{\sqrt{r}}{xy}$
Genotypes	(g-1)	$\frac{g}{xy}$	$\frac{\sqrt{e}}{xy} + r \frac{\sqrt{g}}{xy}$
Error	(r-1)(g-1)	$\frac{e}{xy}$	$\frac{\sqrt{e}}{xy}$
Total	(rg-1)		

$$\text{Genotypic covariance } \left(\frac{\sqrt{g}}{xy} \right) = \left(\frac{g}{xy} - \frac{e}{xy} \right) / r$$

$$\text{Phenotypic covariance } \left(\frac{\sqrt{p}}{xy} \right) = \frac{\sqrt{g}}{xy} + \frac{\sqrt{e}}{xy}$$

The phenotypic and genotypic coefficients of correlation were computed by the formula suggested by Al-Jibouri et al.(1958).

3.3.1 Phenotypic coefficient of correlation

$$r_{P_{xy}} = \frac{\overline{P_{xy}}}{\sqrt{\frac{2}{\overline{P}_x} \cdot \frac{2}{\overline{P}_y}}}$$

Where,

$\overline{P}_{xy}$ = phenotypic covariance between two characters, x and y,

$\overline{P}_x^2$ = phenotypic variance of character x, and

$\overline{P}_y^2$ = phenotypic variance of character y

3.3.2 Genotypic coefficient of correlation

$$r_{g_{xy}} = \frac{\overline{g_{xy}}}{\sqrt{\frac{2}{\overline{g}_x} \cdot \frac{2}{\overline{g}_y}}}$$

Where,

$\overline{g}_{xy}$ = genotypic covariance between two characters, x and y,

$\overline{g}_x^2$ = genotypic variance of character x, and

$\overline{g}_y^2$ = genotypic variance of character y

The significance of phenotypic correlation coefficients was tested against table value of 'r' at n-2 degrees of freedom as given by Fisher and Yates (1963).

3.4 PATH COEFFICIENT ANALYSIS

Path coefficient analysis of various morphological characters and oil content was done, following Dewey and Lu (1959) as under:

$$P_{Y1} + P_{Y2} r_{12} + P_{Y3} r_{13} + \dots + P_{Yn} r_{1n} = r_{Y1}$$

$$P_{Y1} r_{12} + P_{Y2} + P_{Y3} r_{23} + \dots + P_{Yn} r_{2n} = r_{Y2}$$

$$P_{Y1} r_{1n} + P_{Y2} r_{2n} + P_{Y3} r_{3n} + \dots + P_{Yn} = r_{Yn}$$

where,

$P_{Y1}, P_{Y2}, P_{Y3}, \dots, P_{Yn}$ are the direct path effects of 1, 2, 3, ... n variable on the dependent variable Y;

$r_{12}, r_{13}, \dots, r_{1n}, r_{23}, \dots, r_{2n}, \dots, r_{(n-1)n}$ are the possible coefficients

of correlation between various independent variables and $r_{Y1}, r_{Y2}, \dots, r_{Yn}$ are the coefficients of correlation of independent variables with the dependent variable Y

The residual factor (i.e. the variation in yield unaccounted for those associations) was calculated from the following formula:

$$\text{Residual factor (x)} = 1 - R^2$$

$$R^2 = P_{Y1}^2 r_{Y1}^2 + P_{Y2}^2 r_{Y2}^2 + \dots + P_{Yn}^2 r_{Yn}^2$$

where,

R^2 is the squared multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the yield component character.

3.5 MEIOTIC ANALYSIS

Allotetraploids (synthetic Junceas) of *Brassica campestris* x *B.nigra* and the parents and check 'Varuna' were meiotically analysed. Young flower buds were fixed in 1:3 aceto-alcohol. The anthers were squashed in 1% acetocarmine and the following observations were recorded:

1. Diakinesis and Metaphase: Number of bivalents and univalents
2. Anaphase and Telophase: Number of lagging chromosomes
3. Quartets : Number of micronuclei

Besides, other meiotic anomalies were also recorded.

EXPERIMENTAL RESULTS

4. EXPERIMENTAL. RESULTS

The present investigation was carried out during rabi 1993-94 at the Research Farm of the Department of Plant Breeding & Genetics, Himachal Pradesh Krishi Vishvavidyalaya, Palampur (E₁) and the Oilseed Research Station, Kangra (E₂). The results obtained on different aspects of the investigation are briefly described below:

4.1 ANALYSIS OF VARIANCE

Analysis of variance for the characters studied (Table 2) revealed that the mean squares due to genotypes were significant at both the environments for all the characters, except plant height and harvest index in the E₁.

4.2 MEAN PERFORMANCE

Mean performance of different genotypes for the characters studied, presented in Table 3, is described below:

4.2.1 Seed yield per plant (g): In the E₁, none of the synthetic *B. juncea* genotypes could out yield the check, Varuna significantly. However, 13 genotypes were at par with the check. Of these, JSP22 gave the highest mean yield of 7.59g, followed by JSP6 and JSP16 (7.18g), JSP12 (6.41g) and JSP1 (6.35g) as compared to the check, Varuna (6.86g).

Table 2. Analysis of variance for different plant characters in the two environments

Characters	Environment	Mean squares in E ₁			Mean squares in E ₂		
		Repli- cations	Genotypes	Error	Repli- cations	Genotypes	Error
	Source						
	df	2	23	46	2	23	46
Seed yield/plant		0.38	2.28*	0.74	2.65	10.28*	1.83
1000-seed weight		0.16	1.17*	0.23	0.005	0.63*	0.04
Seeds/silique		6.70	10.92*	5.41	0.19	7.11*	1.91
Silique length		0.10	0.37*	0.05	0.95	3.10*	0.57
Silique/plant		217.75	5119.42*	538.90	632.20	6471.17*	347.04
Silique/primary branch		0.95	62.88*	1.41	2.67	273.81*	6.06
Primary branches/ plant		0.11	4.54*	0.69	0.27	4.87*	0.30
Secondary branches/ plant		0.88	35.52*	2.16	0.32	8.75*	0.57
Plant height		79.38	89.71	60.30	237.18	399.47*	148.17
Days to flowering		34.67	25.47*	7.67	10.78	23.97*	2.46
Days to maturity		1.44	1.22*	0.70	6.75	50.89*	3.15
Oil content		0.02	4.54*	0.06	0.09	1.64*	0.11
Harvest index		294.84	75.65	73.97	19.57	92.90*	27.31
E ₁ = Palampur		E ₂ = Kangra		Significant at P<0.05			

Table 3 Mean performance for various characters in two environments

Genotypes	Seed Yield/ plant (g)		1000-seed weight (g)		Seeds/silique		Silique length (cm)		Silique/plant	
	E1	E2	E1	E2	E1	E2	E1	E2	E1	E2
JSP 1	6.35	6.81	4.07	2.79	11.54	13.43	3.83	3.50	184.03	137.67
JSP 2	6.12	7.17	4.00	2.96	11.89	13.90	4.22	3.80	126.40	178.50
JSP 3	5.26	5.69	3.31	2.47	13.00	16.07	4.06	4.07	265.03	160.23
JSP 4	5.42	6.81	2.70	3.75	9.70	13.80	4.14	2.73	230.37	222.10
JSP 5	5.88	6.95	3.24	2.47	10.71	17.63	3.93	3.67	184.33	189.17
JSP 6	7.18	6.37	3.71	2.56	10.92	14.80	3.90	4.03	214.93	196.73
JSP 7	5.82	9.61	2.66	3.33	10.65	14.20	4.08	3.43	236.87	163.03
JSP 8	4.59	12.04	3.12	2.56	13.82	15.37	3.67	3.77	162.00	271.57
JSP 9	6.25	8.02	3.14	2.77	11.56	16.73	4.30	3.93	219.10	192.63
JSP 10	4.27	9.27	2.87	3.17	16.00	16.20	3.60	3.67	168.67	162.70
JSP 11	5.11	6.09	4.61	2.86	16.72	15.67	3.88	4.13	159.00	188.27
JSP 12	6.41	5.81	3.96	2.58	10.96	16.43	4.19	3.53	213.73	136.53
JSP 13	5.45	10.81	2.88	4.10	13.54	12.27	3.14	3.53	158.03	211.83
JSP 14	5.38	8.60	3.00	2.50	12.88	13.73	3.75	3.60	192.97	261.10
JSP 15	5.55	5.14	2.90	2.72	10.57	13.00	3.55	3.63	167.17	115.87
JSP 16	7.18	7.95	2.68	3.31	11.15	13.07	4.48	3.63	202.40	136.77
JSP 17	6.17	5.80	3.99	3.40	10.04	14.73	3.95	3.73	173.17	172.37
JSP 18	5.19	7.95	3.07	2.55	11.94	15.13	3.97	3.87	225.97	145.10
JSP 19	6.25	7.58	3.00	2.43	13.15	17.97	4.36	3.83	251.46	302.63
JSP 20	6.30	8.13	3.66	2.73	10.58	16.13	4.28	3.60	167.97	216.03
JSP 21	4.67	8.77	3.39	3.26	10.84	13.00	3.77	3.13	172.73	142.83
JSP 22	7.59	10.51	3.90	2.73	14.98	16.03	3.96	3.83	123.23	175.00
JSP 23	5.19	6.52	3.22	2.45	13.20	16.73	4.07	4.03	256.47	147.97
Varuna (Check)	6.86	9.96	3.77	3.50	13.41	15.53	4.19	4.20	267.60	215.30
SE(d) ±	0.70	1.10	0.39	0.16	1.90	1.13	0.19	0.62	18.95	15.21
CD 5%	1.40	2.21	0.78	0.32	3.81	2.27	0.38	1.24	38.08	30.57

E₁ = Palampur E₂ = Kangra

Contd.

Genotypes	Siliquae/primary branch		Primary branches/ plant		Secondary branches/ plant		Plant height (cm)	
	E1	E2	E1	E2	E1	E2	E1	E2
JSP 1	22.10	34.80	3.87	3.50	13.33	2.47	109.27	152.00
JSP 2	23.69	31.32	2.60	4.47	8.67	7.03	117.87	166.00
JSP 3	18.40	20.10	3.57	6.90	20.60	6.63	105.97	146.13
JSP 4	14.58	45.33	5.13	3.90	19.03	4.13	107.30	162.43
JSP 5	26.77	26.56	3.80	7.00	10.13	7.03	108.00	176.30
JSP 6	16.44	28.99	3.83	5.00	17.30	6.63	95.87	153.47
JSP 7	20.70	25.01	4.13	3.70	14.47	6.37	114.17	142.37
JSP 8	16.09	46.64	4.27	4.57	12.83	9.97	104.76	184.20
JSP 9	21.89	42.06	4.33	4.27	13.00	6.20	110.27	169.50
JSP 10	15.60	28.47	3.77	4.77	12.53	7.23	114.37	153.97
JSP 11	21.24	34.14	3.37	4.07	13.87	7.07	102.13	156.97
JSP 12	26.77	37.96	3.60	3.50	10.67	5.97	108.30	159.07
JSP 13	13.45	23.47	4.50	7.33	9.27	7.97	108.87	157.03
JSP 14	21.07	48.32	3.73	4.47	9.67	8.47	107.63	153.03
JSP 15	15.60	15.23	3.87	5.77	12.93	4.13	107.90	142.57
JSP 16	21.22	30.06	3.73	3.73	9.07	5.63	103.07	150.07
JSP 17	7.43	31.28	3.93	4.10	14.00	6.83	107.23	155.93
JSP 18	23.87	22.98	4.20	5.53	20.33	5.33	114.47	166.63
JSP 19	12.32	48.00	4.27	4.63	11.23	9.63	117.23	152.63
JSP 20	16.32	30.95	4.73	4.67	12.73	8.77	111.33	174.60
JSP 21	14.32	24.05	4.13	4.87	12.90	5.20	109.90	165.87
JSP 22	16.94	34.41	9.60	4.77	16.67	8.53	112.67	180.33
JSP 23	17.82	15.23	4.47	8.47	16.50	8.63	98.80	162.13
Varuna (Check)	18.97	36.48	3.90	4.67	10.67	6.40	109.50	173.50
SE(d) ±	0.96	2.00	0.68	0.44	1.20	0.62	6.34	9.94
CD 5%	1.92	4.02	1.37	0.88	2.41	1.24	12.74	19.77
E ₁ = Palampur		E ₂ = Kangra		Contd.				

Genotypes	Days to flowering		Days to maturity		Oil content (%)		Harvest Index (%)	
	E1	E2	E1	E2	E1	E2	E1	E2
JSP 1	86.00	83.33	165.33	147.67	41.50	42.20	49.75	43.43
JSP 2	84.67	91.00	165.00	157.67	39.40	42.60	46.16	40.20
JSP 3	80.67	87.67	166.33	151.67	41.33	40.73	55.63	40.07
JSP 4	84.33	91.00	165.33	149.00	41.27	42.10	43.61	43.52
JSP 5	91.00	90.33	165.33	150.33	40.57	42.27	37.37	32.48
JSP 6	77.00	87.33	166.00	150.00	40.33	41.67	51.76	29.05
JSP 7	84.00	86.00	165.33	149.33	42.07	41.40	35.70	40.27
JSP 8	84.30	88.33	166.00	152.67	42.27	41.93	35.52	39.33
JSP 9	84.67	87.67	165.00	154.67	40.23	41.03	43.67	44.27
JSP 10	85.00	90.00	165.33	156.67	39.33	41.33	40.41	51.82
JSP 11	83.30	93.33	164.67	156.00	39.93	41.60	42.87	41.10
JSP 12	84.00	92.33	166.33	157.00	42.30	41.30	44.33	54.05
JSP 13	80.00	89.67	164.00	155.00	42.07	42.20	44.04	44.90
JSP 14	84.00	87.33	164.33	155.67	42.53	41.43	36.53	41.37
JSP 15	80.67	90.00	166.33	147.33	42.77	42.47	43.32	43.51
JSP 16	78.33	93.67	166.00	150.67	40.87	42.00	40.15	49.74
JSP 17	81.33	84.33	165.00	142.67	40.70	42.60	38.02	42.97
JSP 18	85.00	87.33	165.67	150.67	41.90	39.50	40.21	46.41
JSP 19	82.67	90.00	165.00	147.67	42.47	42.43	47.92	39.82
JSP 20	81.33	94.67	165.00	154.67	41.17	41.30	43.66	46.22
JSP 21	86.67	80.33	165.67	145.33	42.03	41.87	39.88	42.03
JSP 22	82.67	92.67	165.33	155.67	41.77	41.67	43.12	35.26
JSP 23	82.67	92.33	166.33	149.67	42.23	42.58	46.39	45.09
Varuna (Check)	80.67	89.67	165.33	157.67	42.23	41.03	36.28	39.72
SE(d.f.)	2.26	1.28	0.68	1.45	0.20	0.27	7.02	4.26
CD 5%	4.54	2.57	1.36	2.91	0.40	0.54	14.11	8.56
E ₁ = Palampur		E ₂ = Kangra						

In the E_2 also, none of the synthetic Junceas was found to be significantly superior to the check, Varuna (9.96g). But 11 genotypes were at par with the check, and of these JSP8 gave the highest mean seed yield per plant of 12.04g, followed by JSP13, JSP22 and JSP7 with yield of 10.81, 10.51, 9.96 and 9.61g, respectively.

4.2.2 1000-seed weight (g): In the E_1 , the genotype, JSP11 was the boldest with a mean value of 4.61g, and was significantly superior to the check, Varuna (3.77g). All the genotypes, except JSP15, JSP13, JSP10, JSP4, JSP6 and JSP7, were at par with the check, Varuna.

In the E_2 , the genotype, JSP13 was the boldest (4.10g) and was significantly superior to the check, Varuna (3.50g). Five genotypes, viz., JSP4, JSP17, JSP7, JSP16 and JSP21 were at par with the check.

4.2.3 Seeds per siliqua: In the E_1 , all the genotypes were at par with the check. The genotype, JSP11 recorded the highest seeds per siliqua (16.72), followed by JSP10 (16.00), JSP22 (14.98), JSP8 (13.82) and JSP13 (13.54), whereas Varuna had 13.41 seeds per siliqua.

In the E_2 , the genotype, JSP19 gave the highest seeds per siliqua (17.97) and was significantly superior to the check, Varuna (15.53). As-many-as 18 genotypes were at par with the check, Varuna.

4.2.4 Siliqua length (cm): For this trait, none of the genotypes was found to be superior to the check, Varuna in the E_1 . However, as-many-as 17 genotypes were at par with

the check, and of these JSP16 had the longest siliqua (4.48cm), followed by JSP19 (4.36cm), JSP9 (4.30cm), JSP20 (4.28cm) JSP2 (4.22cm) and JSP12 (4.19cm) as compared to the check, Varuna (4.19cm).

In the E_2 , all the genotypes were at par with the check, Varuna, except JSP4, which was significantly inferior.

4.2.5 Siliqua per plant: In the E_1 , none of the genotypes could significantly surpass the check, Varuna, but 5 genotypes, viz., JSP3 (265.03), JSP23 (256.47), JSP19 (251.46), JSP7 (236.87) and JSP4 (230.37) were at par with the check, Varuna (267.60).

In the E_2 , JSP19 had the highest siliquae per plant (302.63), followed by JSP8 (271.57), and JSP14 (261.10). These genotypes were significantly superior to the check, Varuna (215.30), whereas 7 genotypes JSP4, JSP5, JSP6, JSP9, JSP11, JSP13 and JSP20 were at par with the check.

4.2.6 Siliquae per primary branch: In the E_1 , as-many-as 9 genotypes, viz., JSP5, JSP12, JSP18, JSP2, JSP1, JSP9, JSP11, JSP16 and JSP14 by bearing 26.77, 26.77, 23.87, 23.69, 22.10, 21.89, 21.24, 21.22 and 21.07 siliquae per primary branch, respectively, were significantly superior to the check, Varuna which bore 18.97 siliquae. Three genotypes, JSP3, JSP7 and JSP23 were at par with the check.

In the E_2 , JSP14 (48.32) had the highest siliquae, followed by JSP19 (48.00), JSP8 (46.64), JSP4 (45.33) and JSP9 (42.06), and were significantly superior to the check,

Varuna which bore 36.48 siliquae per primary branch. Four genotypes, JSP1, JSP11, JSP12 and JSP22 were at par with the check for this trait.

4.2.7 Primary branches per plant: In the E_1 , JSP22 (9.60) was significantly superior to the check, Varuna which bore 3.90 primary branches per plant. All the remaining genotypes were at par with the check.

In the E_2 , JSP23, JSP13, JSP5, JSP3 and JSP15 bearing 8.47, 7.33, 7.00, 6.90, and 5.77 primary branches per plant, respectively, were significantly superior to check, Varuna which bore 4.67 primary branches per plant. As-many-as, 14 genotypes were found to be at par with the check.

4.2.8 Secondary branches per plant: In the E_1 , 10 genotypes had significantly higher secondary branches per plant as compared to the check, Varuna (10.67). Of these, JSP3 had the highest number of secondary branches per plant (20.60). All other genotypes were at par with the check.

In the E_2 , 7 genotypes, viz., JSP8, JSP19, JSP20, JSP23, JSP22, JSP14, and JSP13 by bearing 9.93, 9.63, 8.77, 8.63, 8.53, 8.47 and 7.97 secondary branches per plant, respectively, were significantly superior to the check, Varuna which bore 6.40 secondary branches. The remaining genotypes were at par with the check except, JSP1, JSP4 and JSP15.

4.2.9 Plant height (cm): In the E_1 , the genotype, JSP6 (95.87cm) was significantly shorter in plant height as

compared to the check, Varuna (109.50cm). The remaining genotypes were at par with the check.

In the E_2 , the genotypes, JSP7 (142.37cm), JSP15 (142.57cm), JSP3 (146.13cm), JSP16 (150.07cm), JSP1 (152.00cm), JSP19 (152.63cm), and JSP6 (153.47cm) were significantly shorter as compared to the check, Varuna (173.50cm). Rest of the genotypes were at par with the check.

4.2.10 Days to flowering: For days to flowering in the E_1 , none of the genotypes was significantly earlier in flowering than the check, Varuna. However, 3 genotypes, JSP5 (91.00), JSP21 (86.67), and JSP1 (86.00) were significantly later in flowering than the check, Varuna (80.67).

In the E_2 , 4 genotypes, JSP21 (80.33), JSP1 (83.33), JSP17, (84.33) and JSP7 (86.00), were earlier in flowering than the check, Varuna (89.67). Five genotypes, JSP20, JSP16, JSP11, JSP22 and JSP23 were significantly later in flowering than the check.

4.2.11 Days to maturity: In the E_1 , none of the genotypes was earlier or later in maturity than the check, Varuna.

In the E_2 , all the genotypes, except JSP11, JSP10, JSP12, and JSP22, were earlier in maturity than the check, Varuna (157.67). Of these, JSP17 (142.67) was earliest in maturity, followed by JSP21 (145.33), JSP15 (147.33) and JSP1 (147.67).

4.2.12 Oil content (%): In the E_1 , for oil content, JSP15 (42.77%) gave significantly superior performance to the

check, Varuna (42.23%). Nine genotypes, viz., JSP7, JSP8, JSP12, JSP13, JSP14, JSP18, JSP19, JSP21 and JSP23 were at par with the check.

In the E_2 , as-many-as 15 genotypes had significantly higher oil content than the check, Varuna (41.03%). Of these, JSP2 and JSP17 had the highest oil content (42.60%), followed by JSP23 (42.58%), JSP15 (42.47%) and JSP19 (42.43%). Seven genotypes, viz., JSP3, JSP7, JSP9, JSP10, JSP12, JSP14, and JSP20 were at par with the check, and one genotype, JSP18 was significantly inferior to the check.

4.2.13 Harvest index (%): In the E_1 , JSP3 (55.63%) and JSP6 (51.76%) had significantly higher harvest index than the check, Varuna (36.28%).

In the E_2 also, 2 genotypes, JSP12 (54.05%) and JSP10 (51.82%) were significantly superior to the check, Varuna (39.70%). All the remaining genotypes were at par with the check, except JSP6 which was significantly inferior.

4.3 ESTIMATES OF PARAMETERS OF VARIABILITY

Results with respect to estimates of different variability parameters are presented in Table 4.

4.3. Seed yield per plant (g): The mean seed yield per plant (7.81g) was the highest in the E_2 with a range of 5.69-12.04g as compared to 5.90g at E_1 with a range of 4.59-7.59g.

The estimates of phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were higher in the E_2 environment with the corresponding values

Table 4. Range, mean and variability parameters for different characters in two environments

Characters	Environment	Range	Mean $\pm$ SE	Phenotypic variance	Genotypic variance	PCV (%)	GCV (%)	h^2 (bs) (%)	GA (% of mean)
Seed yield/plant (g)	E ₁	4.59- 7.59	5.90 $\pm$ 0.49	1.25	0.51	19.00	12.12	40.70	15.89
	E ₂	5.69- 12.24	7.81 $\pm$ 0.78	4.64	2.81	27.59	21.48	60.60	34.43
1000-seed weight (g)	E ₁	2.66- 4.61	3.33 $\pm$ 0.28	0.54	0.31	22.10	16.81	57.80	26.27
	E ₂	2.43- 4.10	2.91 $\pm$ 0.11	0.23	0.20	16.69	15.21	83.10	28.21
Seeds/silique	E ₁	9.70- 16.72	12.27 $\pm$ 1.80	7.25	1.83	21.94	11.05	25.30	11.43
	E ₂	12.27- 17.97	15.04 $\pm$ 0.63	3.64	1.73	12.69	8.76	47.60	12.44
Silique length (cm)	E ₁	3.14- 4.48	4.00 $\pm$ 0.13	0.16	0.10	10.02	7.97	62.40	12.85
	E ₂	2.73- 4.13	3.70 $\pm$ 0.43	1.41	0.84	32.09	22.77	59.43	39.29
Siliquae/plant	E ₁	123.23-265.03	197.12 $\pm$ 13.40	2065.74	1526.84	23.06	19.82	73.40	34.86
	E ₂	115.87-302.63	185.04 $\pm$ 10.74	2388.42	2041.38	26.41	24.42	85.50	46.51
Siliquae/primary branch	E ₁	7.43- 26.77	16.47 $\pm$ 0.68	21.90	20.49	25.34	24.50	93.50	48.80
	E ₂	15.23- 48.32	31.76 $\pm$ 1.42	95.31	89.25	30.74	29.74	93.60	59.26
Primary branches/plant	E ₁	2.60- 9.60	4.29 $\pm$ 0.48	1.97	1.28	32.70	26.37	65.00	43.80
	E ₂	3.50- 8.47	5.00 $\pm$ 0.32	1.82	1.52	26.99	24.67	83.60	46.46
Secondary branches/plant	E ₁	8.67- 20.60	13.44 $\pm$ 0.72	13.28	10.12	27.12	24.81	83.70	46.48
	E ₂	2.47- 9.97	6.74 $\pm$ 0.43	3.30	2.72	26.92	24.46	82.60	45.86
Plant height (cm)	E ₁	95.87-117.87	108.74 $\pm$ 4.48	70.10	9.80	7.70	2.88	14.00	2.22
	E ₂	142.37-184.20	161.16 $\pm$ 7.02	231.94	83.76	9.45	5.68	39.10	6.74
Days to flowering	E ₁	77.00- 91.00	83.12 $\pm$ 1.59	13.60	5.93	4.44	2.93	43.60	3.98
	E ₂	83.33- 94.67	89.50 $\pm$ 0.90	9.63	7.17	3.47	2.99	74.50	5.32
Days to maturity	E ₁	164.00-166.33	165.40 $\pm$ 0.48	0.87	0.17	0.57	0.25	19.50	0.23
	E ₂	142.67-157.67	152.39 $\pm$ 1.02	19.06	15.91	2.87	2.62	83.40	4.92
Oil content (%)	E ₁	39.40- 42.77	40.30 $\pm$ 0.14	1.55	1.49	3.02	2.96	96.10	5.56
	E ₂	39.50- 42.60	41.72 $\pm$ 0.19	0.61	0.51	1.89	1.71	83.50	3.22
Harvest index (%)	E ₁	35.52- 55.63	42.44 $\pm$ 4.96	74.53	0.56	20.34	1.76	0.80	0.03
	E ₂	29.05- 54.05	42.56 $\pm$ 3.02	49.17	21.86	16.48	10.99	45.50	15.10

E₁ = PalampurE₂ = Kangra

of 21.59% and 21.48%, as compared to 19.00% and 12.12% in the E_1 environment. Heritability in broad sense was higher (60.60%) in the E_2 as compared to the E_1 environment (40.70%). Expected genetic advance as per cent of mean was higher in the E_2 (34.43%) as compared to the E_1 (15.89%) environment.

4.3.2 1000-seed weight (g): In the E_1 , 1000-seed weight varied from 2.66-4.61g with a mean value of 3.33g. In the E_2 , it varied from 2.43-4.10g with a mean value of 2.91g.

This character exhibited PCV values of 22.10% and 16.69% in the E_1 and E_2 environments, respectively. GCV values were 16.81% and 15.21%, in the E_1 and the E_2 environments, respectively. Heritability for this character was higher in the E_2 (83.10%) as compared to the E_1 (57.80%). The expected genetic advance was 26.27% and 28.21% in the E_1 and E_2 environments, respectively.

4.3.3 Seeds per siliqua: The seeds per siliqua ranged from 12.27-17.97 in the E_2 and 9.70-16.72 in the E_1 with the mean values of 15.04 and 12.27, respectively.

The PCV was 21.94% in the E_1 and 12.69% in the E_2 environment with a corresponding GCV values of 11.05% and 8.76%. In the E_1 and E_2 environments the heritability estimates were 47.60% and 25.30% with expected genetic advance of 12.44% and 11.43%, respectively.

4.3.4 Siliqua length (cm): In the E_1 , siliqua length ranged from 3.14-4.48cm with a mean value of 4.00cm, and from 2.73-4.13cm with a mean value of 3.70cm in the E_2 .

The PCV in the E_1 and E_2 environments were 10.02% and 32.09%, respectively, with the corresponding GCV values of 1.97% and 24.77%. Heritability was 62.40% in the E_1 , whereas it was 59.43% in the E_2 with the corresponding genetic advance of 12.85% and 39.29%.

4.3.5 Siliquae per plant: Siliquae per plant varied from 123.23-265.03 with a mean value of 197.12 in the E_1 and from 115.87-302.63 with a mean value of 185.04 in the E_2 .

In the E_2 , PCV was 26.41% and for E_1 it was 23.06% with the corresponding GCV values of 24.42% and 19.82%. Heritability was 85.50% in the E_2 and 73.40% in the E_1 with the corresponding genetic advance values of 46.51% and 34.86%.

4.3.6 Siliquae per primary branch: Siliquae per primary branch ranged from 15.23-48.32 with a mean value of 31.76 in the E_2 and 7.43-26.77 with a mean value of 18.47 in the E_1 .

PCV values of 30.74% and 25.34% were recorded in the E_2 and E_1 , respectively, whereas the corresponding GCV values for these environments were 29.74% and 24.50%. Heritability value of 93.60% was recorded in the E_2 and 93.50% in the E_1 with the corresponding expected genetic advance values of 59.26% and 48.80%.

4.3.7 Primary branches per plant: Primary branches per plant ranged from 3.50-8.47 in the E_2 and 2.60-9.60 in the E_1 with the mean of 5.00 and 4.29, respectively.

PCV were 32.70% and 26.99% in the E_1 and E_2 with GCV values of 26.37% and 24.67%, respectively. The heritability

was higher in the E_2 (83.60%) as against 65.00% in the E_1 . Expected genetic advance values were 46.46% and 43.80% in the E_2 and E_1 , respectively.

4.3.8 Secondary branches per plant: The secondary branches per plant varied from 8.67-20.60 with a mean value of 13.44 in the E_1 and from 2.47-9.97 with a mean value of 6.74 in the E_2 .

PCV for secondary branches per plant in the E_1 and E_2 were 27.12% and 26.92%, respectively, whereas corresponding GCV values were 24.81% and 24.46%. In the former environment heritability was 83.70%, whereas in the latter it was 82.60% with the corresponding genetic advance values of 46.48% and 45.86%.

4.3.9 Plant height (cm): Plant height ranged from 142.37-184.20cm and 95.87-117.87cm with an average height of 161.16cm and 108.74cm in the E_2 and E_1 , respectively. The trait exhibited PCV values of 9.45% and 7.70% in the E_2 and E_1 , respectively, with the corresponding GCV values of 5.68% and 2.88%. The character showed heritability values of 36.10% and 14.00% in the E_2 and E_1 environments, respectively, with the corresponding genetic advance of 6.74% and 2.22%.

4.3.10 Days to flowering: The range of variation for this character was 77.00-91.00 and 83.33-94.67 days with the mean values of 83.12 and 89.50 days in the E_1 and E_2 , respectively.

The PCV was 4.44% and 3.47% in the E_1 and E_2 , respectively, and the corresponding GCV values were 2.93% and 2.99%. Heritability values of 74.50% and 43.60% were recorded in the E_2 and E_1 , respectively, with the corresponding expected genetic advance values of 5.32% and 3.98%.

4.3.11 Days to maturity: The genotypes under test took 142.67-157.67 and 164.00-166.33 days with the mean values of 152.39 and 165.40 days to mature in the E_2 and E_1 , respectively.

This character exhibited PCV values of 2.87% and 0.57% in the E_2 and E_1 , respectively, with the corresponding GCV values of 2.62% and 0.25%. Heritability was 83.40% in the E_2 while 19.50% in the E_1 with the expected genetic advance values of 4.92% and 0.23%, respectively.

4.3.12 Oil content (%): The oil content, in the E_2 ranged from 39.50-42.60% with a mean value of 41.72%, whereas in the E_1 , it ranged from 39.90-42.77% with a mean value of 40.30%.

The PCV values of 3.02% and 1.89% were recorded in the E_1 and E_2 , respectively, whereas the corresponding GCV values for these environments were 2.96% and 1.76%. The heritability was 96.10% in the E_1 and 83.50% in the E_2 . The genetic advance was 5.56% for the former and 3.22% for the latter environment.

4.3.13 Harvest index (%): In the E_1 , the estimates of harvest index ranged from 35.52-55.63% with a mean value of

42.44%, whereas in the E_2 , the range and mean values for this trait were 29.05-54.05% and 42.56%, respectively.

The PCV values of 20.34% and 16.48% were recorded in the E_1 and E_2 , respectively, whereas the corresponding GCV values for these environments were 1.76% and 10.99%. The heritability was 45.50% and 0.80% in the E_2 and E_1 , respectively. The genetic advance was 15.10% and 0.03% for the E_2 and E_1 environments, respectively.

4.4 CORRELATION STUDIES

The phenotypic and genotypic correlation coefficients among different plant characters in the E_1 and E_2 environments are presented in Table 5 and Table 6.

4.4.1 Phenotypic correlations: In general, values of phenotypic correlations were very low. In the E_1 , none of the characters showed significant correlation among themselves.

In the E_2 , seed yield per plant had significant positive correlation with siliquae per plant. Siliquae per plant in turn had significant positive correlation with siliquae per primary branch and secondary branches per plant, whereas secondary branches per plant showed significant positive correlation with seeds per siliqua. On the contrary, primary branches per plant with siliquae per primary branch and seeds per siliqua with 1000-seed weight showed significant negative correlations.

Table 5 Phenotypic correlation coefficients among different characters in two environments

Character	Environ- ment	1000- seed weight	Seeds/ siliqua	Siliqua length	Siliquae/ Plant	Siliquae/ primary branch	Primary branches/ plant	Secondary branches/ plant	Plant height	Days to flowering	Days to maturity	Oil content	Harvest index
Seed yield/plant	E ₁	0.21	-0.16	0.33	-0.002	0.17	0.27	-0.18	0.17	-0.27	0.21	0.00	0.06
	E ₂	0.28	-0.06	0.15	0.42*	0.24	-0.13	0.32	0.26	0.05	0.38	-0.02	0.13
1000-seed weight	E ₁		0.18	0.10	-0.31	0.08	0.12	-0.03	0.00	0.04	0.01	-0.28	-0.20
	E ₂		-0.49*	-0.13	-0.04	-0.05	-0.08	-0.27	-0.12	-0.14	-0.09	0.13	0.16
Seeds/siliqua	E ₁			-0.21	-0.02	0.02	0.05	-0.12	0.12	-0.16	0.13	-0.07	-0.06
	E ₂			0.19	0.21	0.21	0.11	0.40*	0.21	0.21	0.29	-0.11	-0.08
Siliqua length	E ₁				0.35	0.35	-0.14	-0.03	-0.03	-0.01	0.26	-0.08	0.14
	E ₂				0.11	-0.09	0.15	0.16	0.02	0.06	0.20	-0.11	-0.09
Siliquae/plant	E ₁					0.10	-0.24	0.31	-0.15	-0.10	0.25	0.33	0.15
	E ₂					0.67*	-0.08	0.57*	0.15	0.21	0.38	0.13	-0.28
Siliquae/primary branch	E ₁						-0.25	-0.19	0.03	0.28	0.08	-0.21	-0.00
	E ₂						-0.63*	0.26	0.22	0.09	0.38	0.06	0.00
Primary branches/ plant	E ₁							0.29	0.11	-0.08	-0.11	0.27	0.01
	E ₂							0.22	0.04	0.02	0.25	-0.03	-0.18
Secondary branches/ plant	E ₁								-0.14	-0.03	0.16	0.11	0.13
	E ₂								0.25	0.44*	0.47*	0.09	-0.21
Plant height	E ₁									0.26	0.04	-0.05	-0.04
	E ₂									0.02	0.25	-0.03	-0.18
Days to flowering	E ₁										-0.02	-0.10	-0.17
	E ₂										0.45*	0.01	0.05
Days to maturity	E ₁											0.12	0.15
	E ₂											-0.17	-0.01
Oil content	E ₁												-0.06
	E ₂												-0.12

*: Significant at $P \leq 0.05$. E₁ = Palampur E₂ = Kangra

Table 6 Genotypic correlation coefficients among different characters in two environments

Character	Environ- ments	1000- seed weight	Seeds/ siliqua	Siliqua length	Siliquae/ Plant	Siliquae/ primary branch	Primary branches/ plant	Secondary branches/ plant	Plant height	Days to flowering	Days to maturity	Oil content	Harvest index
Seed yield/plant	E ₁	0.27	-0.54	0.59	-0.002	0.14	0.39	-0.17	-0.29	-0.66	-0.20	0.02	0.46
	E ₂	0.38	-0.14	-2.10	0.44	0.34	-0.04	0.55	0.61	0.07	0.57	-0.05	-0.11
1000-seed weight	E ₁		0.38	0.18	-0.38	0.10	-0.02	-0.05	-0.41	-0.07	-0.17	-0.37	3.36
	E ₂		-0.64	-5.38	-0.06	-0.05	-0.12	-0.30	-0.61	-0.13	-0.12	0.18	0.15
Seeds/siliqua	E ₁			-0.46	-0.32	-0.07	0.44	0.03	-0.06	0.13	-0.91	-0.12	0.06
	E ₂			4.99	0.37	0.24	0.13	0.57	0.57	0.31	0.43	-0.24	-0.14
Siliqua length	E ₁				0.44	0.45	-0.07	-0.01	0.20	0.67	-1.64	-0.21	-2.94
	E ₂				-0.57	-1.14	2.06	3.82	1.71	2.98	2.09	-2.23	-2.78
Siliquae/plant	E ₁					0.07	-0.18	0.37	-0.39	-0.20	0.38	0.42	1.55
	E ₂					0.76	-0.11	0.72	0.46	0.23	0.52	0.16	-0.41
Siliquae/primary branch	E ₁						-0.29	-0.19	0.05	0.52	0.10	-0.21	-0.002
	E ₂						-0.68	0.27	0.34	0.11	0.45	0.07	0.06
Primary branches/ plant	E ₁							0.38	0.34	-0.12	0.06	0.32	-0.22
	E ₂							0.30	-0.03	0.05	-0.07	0.05	-0.41
Secondary branches/ plant	E ₁								-0.32	-0.17	0.50	0.15	3.54
	E ₂								0.48	0.55	0.54	0.13	-0.30
Plant height	E ₁									0.67	-1.64	-0.21	-2.94
	E ₂									0.14	0.29	-0.16	-0.38
Days to flowering	E ₁										-0.38	-0.14	-2.49
	E ₂										0.62	0.02	0.12
Days to maturity	E ₁											0.24	3.16
	E ₂											-0.26	-0.03
Oil content	E ₁												1.71
	E ₂												-0.12

E₁ = PalampurE₂ = Kangra

Days to flowering and maturity, and secondary branches per plant showed significant positive correlations among themselves.

4.4.2 Genotypic correlations: in general, the values of genotypic correlations were higher than the corresponding values of phenotypic correlations in majority of the combinations.

In the E_1 , seed yield per plant showed high positive correlation with siliqua length and high negative correlation with seeds per siliqua and days to flowering. Days to maturity showed high negative correlation with seeds per siliqua and high positive correlation with secondary branches per plant. Days to flowering had positive correlation with siliqua length, siliquae per primary branch and plant height.

In the E_2 , seed yield per plant had high positive correlation with secondary branches per plant, plant height and days to maturity. Days to maturity had high positive correlation with days to flowering. Days to flowering had high positive correlation with secondary branches per plant. Seeds per siliqua showed high positive correlation with secondary branches per plant and plant height, and high negative correlation with 1000-seed weight. Siliquae per plant showed high positive correlation with siliquae per primary branch, secondary branches per plant, and days to maturity while high negative correlation with siliqua

length. Plant height had positive correlation with seeds per siliqua, and negative correlation with 1000-seed weight.

Primary branches per plant showed negative correlation with siliquae per primary branch. Secondary branches showed positive correlation with days to flowering and maturity

4.5 ESTIMATES OF DIRECT AND INDIRECT EFFECTS

In order to understand the causal factors of the correlation among the characters studied, the estimates of direct and indirect effects were computed through path analysis. These estimates of direct and indirect effects at the phenotypic and genotypic levels were worked out with respect to different plant traits both in the E_1 and E_2 environments (Table 7 and Table 8). The results of these effects are presented below:

4.5.1 Estimates of effects at phenotypic level: In the E_1 , primary branches per plant had the highest positive direct effect on seed yield per plant, followed by siliqua length, 1000-seed weight, siliquae per primary branch, days to maturity and plant height. Secondary branches per plant, days to flowering, seeds per siliqua and oil content had negative direct effect on seed yield. Although 1000-seed weight had high positive direct effect, yet exhibited substantial negative indirect effects via seeds per siliqua and siliquae per plant. Similarly, siliqua length had high positive direct effect, but exhibited negative indirect effects via primary branches per plant and plant height.

Table 7 Estimates of direct and indirect effects at phenotypic level in two environments

Character	Environ- ment	1000- seed weight	Seeds/ siliqua length	Siliqua length	Siliquae/ primary branch	Primary branches/ plant	Secondary Plant height	Days to flower- ing	Days to maturity	Oil content	Harvest Correla tion with yield			
1000-seed weight	E ₁	<u>0.42</u>	-0.13	0.02	-0.17	0.002	0.04	0.01	0.000	-0.01	0.002	0.02	0.001	0.21
	E ₂	<u>0.32</u>	0.02	-0.01	-0.02	0.03	0.02	-0.16	0.03	0.03	0.03	-0.01	0.003	0.28
Seeds/siliqua	E ₁	0.03	<u>-0.25</u>	-0.04	-0.06	-0.001	0.02	0.07	0.01	0.03	0.02	0.01	0.002	-0.16
	E ₂	-0.05	<u>-0.24</u>	-0.01	0.09	-0.02	-0.03	0.09	0.04	-0.04	0.09	0.01	0.001	-0.06
Siliqua length	E ₁	0.01	0.02	<u>0.49</u>	0.02	0.01	-0.17	0.08	-0.17	0.02	0.02	0.01	-0.004	0.33
	E ₂	-0.12	0.05	<u>0.35</u>	0.11	-0.21	-0.01	0.09	0.02	0.10	-0.15	0.02	-0.10	0.15
Siliquae/plant	E ₁	-0.06	0.005	0.17	<u>-0.23</u>	0.003	-0.01	-0.03	-0.01	0.12	0.09	-0.05	-0.001	-0.002
	E ₂	-0.01	-0.03	0.01	<u>0.54</u>	-0.24	0.02	0.03	0.03	-0.04	0.12	-0.01	0.005	<u>0.42*</u>
Siliquae/primary branch	E ₁	0.01	-0.14	0.06	0.02	<u>0.33</u>	-0.07	0.08	0.002	-0.16	0.01	0.03	0.000	0.17
	E ₂	-0.09	-0.03	0.003	-0.29	<u>0.26</u>	0.14	0.16	0.04	-0.06	0.12	-0.005	0.000	0.24
Primary branches/ plant	E ₁	0.02	-0.16	0.08	-0.05	-0.10	<u>0.60</u>	-0.09	0.01	0.02	-0.02	-0.04	0.00	0.27
	E ₂	-0.01	-0.02	-0.002	-0.02	0.13	<u>-0.42</u>	0.15	0.06	0.004	-0.02	0.00	0.03	-0.13
Secondary branches/ plant	E ₁	-0.005	0.02	-0.01	0.17	-0.005	0.10	<u>-0.46</u>	-0.01	0.02	0.03	-0.01	-0.003	-0.18
	E ₂	-0.08	-0.04	-0.006	0.15	-0.09	-0.05	<u>0.43</u>	-0.05	-0.08	0.14	-0.01	0.004	0.32
Plant height	E ₁	0.00	-0.07	-0.06	-0.05	0.001	0.03	0.03	<u>0.32</u>	-0.05	0.01	0.01	0.001	0.17
	E ₂	-0.04	-0.02	-0.004	0.07	-0.08	-0.01	0.06	<u>0.26</u>	-0.003	0.02	0.002	0.003	0.26
Days to flowering	E ₁	0.01	0.08	-0.002	-0.08	0.01	-0.02	0.01	0.06	<u>-0.32</u>	-0.03	0.01	0.004	-0.27
	E ₂	-0.04	-0.02	0.01	0.13	-0.02	0.005	0.10	<u>0.003</u>	<u>-0.09</u>	-0.001	-0.001	-0.001	0.05
Days to maturity	E ₁	0.002	-0.03	0.07	0.08	0.002	-0.10	-0.12	0.002	0.002	<u>0.33</u>	-0.02	-0.004	0.21
	E ₂	-0.03	-0.03	0.001	0.07	-0.14	0.02	0.11	0.05	-0.09	<u>0.40</u>	0.02	0.000	0.38
Oil content	E ₁	-0.05	0.01	-0.01	0.07	-0.01	0.13	-0.04	-0.002	0.02	0.02	-0.14	0.002	0.00
	E ₂	0.06	0.02	0.005	0.03	-0.02	0.001	0.02	-0.01	-0.001	-0.02	-0.10	0.002	-0.02
Harvest index	E ₁	-0.004	-0.06	-0.08	0.03	0.00	0.03	-0.05	-0.002	0.03	0.02	0.02	<u>0.13</u>	0.06
	E ₂	0.05	-0.01	-0.005	-0.02	0.002	0.09	-0.05	-0.04	-0.02	-0.003	0.02	<u>0.12</u>	0.13

Residual effect at E₁ (Palampur) = 0.43Residual effect at E₂ (Kangra) = 0.36

Table 8 Estimates of direct and indirect effects at genotypic level in two environments

Character	Environment	1000-seed weight	Seeds/silique length	Silique/Silique/primary branch	Primary branches/plant	Secondary Plant height	Days to flowering	Days to maturity	Oil content	Harvest index	Correlation with yield			
1000-seed weight	E ₁	1.83	-0.95	0.63	0.23	-0.87	0.04	-0.08	0.03	0.14	-0.09	-0.55	-0.09	0.27
	E ₂	-0.52	1.01	0.002	-0.58	0.09	0.05	-0.10	-0.24	0.14	-0.17	0.54	0.16	0.38
Seeds/silique	E ₁	-0.69	2.51	-1.67	1.02	0.05	-0.99	0.03	0.005	-0.11	-0.52	-0.18	0.002	-0.57
	E ₂	0.33	-1.57	-0.004	0.48	-0.44	-0.06	0.21	0.83	-0.33	0.61	-0.07	-0.15	-0.17
Silique length	E ₁	-0.32	-1.17	3.59	-1.44	-0.32	0.16	-0.01	-0.02	0.06	0.24	-0.14	-0.04	0.5
	E ₂	-1.82	0.72	1.54	0.10	-2.72	-2.02	0.90	0.83	0.19	0.82	-0.74	0.10	-2.1
Silique/plant	E ₁	0.69	-0.79	1.60	-3.23	-0.05	0.41	0.37	0.03	0.16	0.21	0.63	-0.04	-0.0
	E ₂	0.03	-0.58	-0.003	1.60	-1.58	0.05	0.21	0.63	0.24	0.73	0.05	-0.45	0.4
Silique/primary branch	E ₁	-0.18	-0.47	1.03	-0.33	0.70	0.66	-0.29	-0.002	-0.71	0.06	-0.32	0.00	0.1
	E ₂	0.02	-0.37	0.001	0.99	-1.82	0.30	0.10	0.50	-0.11	0.64	0.02	0.07	0.3
Primary branches/plant	E ₁	0.04	0.10	-0.25	0.59	0.21	-1.25	0.37	-0.03	0.10	0.03	0.48	0.01	0.5
	E ₂	0.06	-0.20	-0.45	-0.14	1.24	-0.54	0.11	-0.03	-0.05	-0.09	0.09	-0.04	-0.6
Secondary branches/plant	E ₁	0.10	0.08	-0.04	-1.20	0.54	-0.82	0.29	0.33	0.14	0.28	0.22	-0.09	-0.1
	E ₂	0.15	-0.90	-0.04	0.99	-0.50	-0.13	0.36	0.71	-0.57	0.77	0.04	-0.33	0.5
Plant height	E ₁	0.76	-0.15	0.73	1.26	-0.03	-0.77	-0.32	-0.08	-0.52	-0.91	-0.32	0.08	-0.7
	E ₂	0.08	-0.89	0.01	0.59	-0.63	0.02	0.18	1.47	-0.18	0.43	-0.05	-0.42	0.1
Days to flowering	E ₁	0.13	0.34	-0.09	0.64	-0.17	0.28	-0.17	-0.06	-0.80	0.21	-0.21	0.06	-0.1
	E ₂	0.07	-0.48	0.003	0.49	-0.19	-0.22	0.20	0.21	-1.03	0.88	0.007	0.13	0.1
Days to maturity	E ₁	0.30	-2.29	1.45	-1.24	-0.07	-0.13	0.51	0.13	0.30	0.57	0.35	-0.08	-0.
	E ₂	0.06	-0.67	0.002	0.67	-0.82	0.03	0.20	0.43	-0.64	1.42	-0.08	-0.03	0.
Oil content	E ₁	0.68	-0.31	-0.33	-1.37	0.15	-0.73	0.15	0.02	0.12	1.12	0.48	0.04	0.
	E ₂	-0.09	0.38	0.001	0.21	-0.12	-0.02	0.05	-0.23	-0.03	-0.37	0.30	-0.13	-0.
Harvest index	E ₁	-0.14	0.15	5.97	-4.99	0.001	0.49	3.54	0.24	1.99	1.76	-1.52	-1.03	0.
	E ₂	-0.08	0.22	-0.01	-0.54	-0.10	0.18	-0.11	-0.56	-0.12	-0.04	-0.04	1.09	-0.
Residual effect at E ₁ (Palampur) = ± 0.46 Residual effect at E ₂ (Kangra) = ± 0.54														

Primary branches per plant had high positive direct effect but exhibited negative indirect effects via seeds per siliqua, siliquae per primary branch and secondary branches per plant. Similarly, days to maturity had high positive direct effect but negative indirect effects via secondary branches per plant and primary branches per plant.

Secondary branches per plant had high negative direct effect on yield, and indirect positive effects via siliquae per plant and primary branches per plant. Oil content showed negative direct effect on seed yield, and positive indirect effect via primary branches per plant.

In the E_2 , the highest direct positive effect on seed yield per plant was exhibited by siliquae per plant, followed by secondary branches per plant, days to maturity, siliqua length and 1000-seed weight. On the other hand primary branches per plant, seeds per siliqua, oil content and days to flowering had negative direct effects on seed yield. Although days to maturity had high positive direct effect yet it revealed negative indirect effect via siliquae per primary branch on seed yield. Siliquae per plant had high positive direct effect on seed yield.

4.5.2 Estimates of effects at genotypic level: In the E_1 , siliqua length showed the highest positive direct effect on seed yield per plant, followed by seeds per siliqua, 1000-seed weight, and siliquae per primary branch.

Siliquae per plant, though had high negative direct effect on seed yield per plant, yet showed high positive

indirect effects via siliqua length, 1000-seed weight, oil content, primary branches per plant and secondary branches per plant. Similarly, primary branches per plant also had high negative direct effect on seed yield but revealed high positive indirect effects via siliquae per plant, oil content and secondary branches per plant. Harvest index had high positive indirect effects via siliqua length, secondary branches per plant and, days to flowering and days to maturity. Secondary branches per plant showed high positive indirect effects via siliquae per primary branch, plant height and days to maturity. Plant height had indirect positive effect on seed yield via siliquae per plant, 1000-seed weight and siliqua length. Days to flowering had positive indirect effect via siliquae per plant. Days to maturity via siliqua length and secondary branches per plant; and oil content via days to maturity showed indirect positive effects on seed yield. Seeds per siliqua also had high positive indirect effect via siliquae per plant; 1000-seed weight via siliqua length; and siliquae per primary branch via siliqua length.

In the E_2 , siliquae per plant showed the highest positive direct effect on seed yield, followed by siliqua length, plant height, days to maturity and harvest index. Siliquae per plant also had high positive indirect effects via days to maturity and plant height. Siliqua length via secondary branches per plant, plant height, days to maturity and seeds per siliqua; and plant height via siliquae per

plant and days to maturity had high positive indirect effects on seed yield. Days to maturity in turn had high positive indirect effects via siliquae per plant and plant height.

Whereas siliquae per primary branch showed high negative direct effect on seed yield per plant, but its indirect effect via siliquae per plant, days to maturity and plant height was high. Similarly, seeds per siliqua, which showed high negative direct effect, had high positive indirect effects via siliquae per plant, plant height and days to maturity. Days to flowering also had high negative direct effect, but positive indirect effect via days to maturity and siliquae per plant. Besides, 1000-seed weight via seeds per siliqua; primary branches per plant via siliquae per primary branch, and secondary branches per plant via siliquae per plant, days to maturity and plant height showed positive indirect effects. Oil content contributed mainly via seeds per siliqua for seed yield.

4.6 RESIDUAL EFFECTS

Residual effects at the genotypic level were ± 0.46 and ± 0.54 for the E_1 and E_2 environments, respectively. The corresponding values at phenotypic level were ± 0.43 and ± 0.36 .

4.7 MEIOTIC STUDIES

Meiotic studies were carried out in the 23 synthetic Junceas, 3 parents and the check, Varuna. The meiocytes at different stages were analysed for number of bivalents,

univalents and meiotic anomalies. The data obtained from the meiotic analysis are presented in Table 9.

A perusal of the data revealed that all the synthetic allotetraploids, except JSP3, JSP15, JSP7, JSP4, JSP20 and JSP11, had normal course of meiosis with 18II at diakinesis and metaphase I, and normal disjunction of chromosomes at anaphase I. The quartets in all the lines were devoid of any observable micronucleus. The allotetraploid, JSP3 had 17-18 II and 2 I in some meiocytes at diakinesis with the respective means of 17.81 II and 0.40 I, respectively. However, no laggards at anaphase I, telophase I and no micronuclei at quartet stage was observed in these lines. The allotetraploid, JSP5 had normal meiotic stages, except Metaphase I, where one I was observed in some meiocytes with the mean of 0.20. The allotetraploid, JSP7 had 16-18 II with the mean of 17.27 and 4 I with the mean of 0.36. In the allotetraploid JSP20, 16-18 II were observed with the mean of 17.50 and either 0 or 4 I with a mean of 1. In the allotetraploid JSP11 diakinesis stage with good spread was not available, while at metaphase I, it had 2 I with a mean of 0.28. In all the 3 parents (Candle, YS 1, *B.nigra* Landrace), the meiosis was normal but in the parent, *B.nigra* diakinesis could not be studied because of non-availability of cells with good spreads. In the check, Varuna meiosis was normal.

Table 9 Meiotic analysis of synthetic Junceas, their parents and check 'Varuna'

Genotypes	Diakinesis		Metaphase I (Univalents)	Anaphase I (Laggards)	Telophase I (Laggards)	Quartet (Micronuclei)
	Bivalents	Univalents				
<u>Synthetic Junceas</u>						
JSP 1	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 2	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 3	17.81 $\pm$ 0.40 (17-18)	0.40 $\pm$ 0.80 (0 or 2)	-	0.0	0.0	0.0
JSP 4	17.66 $\pm$ 0.47 (16-18)	0.66 $\pm$ 0.94 (0 or 4)	-	0.0	0.0	0.0
JSP 5	18.00 $\pm$ 0.00	0.0	0.2 $\pm$ 0.04 (0 or 1)	0.0	0.0	0.0
JSP 6	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 7	17.27 $\pm$ 0.96 (16-18)	0.36 $\pm$ 0.43 (0 or 4)	-	0.0	0.0	0.0
JSP 8	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 9	-	-	0.0	0.0	0.0	0.0
JSP 10	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 11	-	-	0.28 $\pm$ 0.70 (0 or 2)	0.0	0.0	0.0
JSP 12	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 13	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 14	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 15	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 16	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 17	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 18	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 19	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 20	17.50 $\pm$ 0.86 (16-18)	1 + 1.73- (0 or 4)	0.0	0.0	0.0	
JSP 21	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 22	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
JSP 23	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
<u>B. campestris var. Brown sarson</u>						
Landile	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
<u>B. campestris var. Yellow sarson</u>						
YS 1	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0
<u>B. nigra</u>						
Landrace	-	-	0.0	0.0	0.0	0.0
<u>B. juncea</u>						
Varuna (check)	18.00 $\pm$ 0.00	0.0	0.0	0.0	0.0	0.0

Values in parentheses represent range

5. DISCUSSION

Brassica juncea ($2n = 4x = 36$, AABB), commonly known as the Indian mustard, is an important oilseed crop of the Indian subcontinent. The crop is a natural allopolyploid between *Brassica campestris* ($2n = 2x = 20$, AA) and *B. nigra* ($2n = 2x = 18$, BB). The improvement of *B. juncea* has mostly been confined to the exploitation of naturally occurring variation, which is limited. The existing genetic variation can be broadened by artificial synthesis of the crop using the diploid progenitors, *B. campestris* and *B. nigra* genotypes. Such synthesis generates a wider spectrum of variability, which could be utilized in the breeding programmes. In fact, *B. juncea* has been synthesized by a number of workers. Frandsen (1943) reported synthesis of *B. juncea* by crossing *campestris* with *nigra* and vice versa. Nine of the 13 hybrids obtained, had *campestris* as female and the other four had *nigra* as female. Ramanujam and Srinivasachar (1943) also obtained hybrids between diploid *campestris* and *nigra*. Subsequently artificial forms of *B. juncea* were synthesized by Mizushima (1950), Olsson (1960), Srinivasachar (1965) and by Prakash (1973). All these workers reported the generation of a wide range of variations in the synthetic Juncea.

B.juncea genotypes used in the present investigation were synthesized by hybridizing *B.campestris* var. Brown sarson cv. Candle and *B.campestris* var. Yellow sarson cv. YSL with *B.nigra* Landrace, and the amphidiploid were developed by giving colchicine treatment. The synthesized *B.juncea* were evaluated in the field, and the elite ones (used in the present study) were selected in the A_6/A_7 generations to get information on the nature and magnitude of variability for yield and yield components; to understand the relationship among various characters in order to identify the major yield components of seed yield; and to know the meiotic stability of the synthetic allotetraploids. The results obtained on these aspects in the 23 genotypes at two different environments are being discussed here under:

5.1 VARIABILITY PARAMETERS

Selection, which is the basic to every breeding programme, operates only on variation which is of genetic nature. Response to selection depends upon the nature and magnitude of variation for the characters under selection. Results obtained from the analysis of variance in the present material revealed the presence of sufficient genetic variability for seed yield and other traits in both the environments.

The estimates of range of variation for various characters indicated the presence of wide variability for all the characters. The overall means of the genotypes were higher in the E_2 for seed yield per plant, seeds per

siliqua, siliquae per primary branch, primary branches per plant, plant height, days to flowering and oil content. In the E_1 , means were higher for siliqua length, siliquae per plant, secondary branches per plant and days to maturity indicating thereby that E_1 environment is favourable for the expression of these characters.

To exploit the observed wide range of variability for different traits, it might be desirable to look at the individual genotypes for their mean performances. It can be seen that, in general, there was probable presence of genotype $\times$ environment interaction for all the traits studied because of the dissimilarities in the top ranking genotypes in the two environments for all the characters. The genotypes having high mean performance at a particular environment, were exhibiting poor performance in the other environment and vice versa. For seed yield, notable genotypes were JSP22, JSP6, JSP16, JSP12 and JSP1 in the E_1 , and JSP8, JSP13, JSP22 and JSP7 in the E_2 . The genotype JSP22 gave good performance in both the environments. For oil content, the notable genotype in the E_1 was JSP15, while in the E_2 these were JSP2, JSP17, JSP23, JSP15 and JSP19. The genotype, JSP15 gave high oil content at both the locations, thereby showing the less influence of the environments on this trait. For 1000-seed weight, the notable genotype was JSP11 in the E_1 and JSP13 in the E_2 .

Overall, for the different traits studied, the genotypes JSP11 and JSP22 exhibited good performance for

most of the characters in the E_1 , whereas in the E_2 , JSP19 and JSP14 exhibited good performance. For both the environments JSP14 was a promising genotype combining some of the desired characters.

On partitioning the observed variability into genetic and environmental, and then estimating the coefficients of variations at both the environments for the characters studied (Table 4), it was found that the genotypic variances were of higher magnitude than the ~~environmental~~ variances for most of the characters, indicating thereby the presence of high magnitude of genetic variability and less influence of environments on the manifestation of different traits. The phenotypic coefficient of variation was high (>20%) for 1000-seed weight, seeds per siliqua, siliquae per plant, siliquae per primary branch, primary branches per plant, secondary branches per plant and harvest index; moderate (10-20%) for seed yield per plant and siliqua length; and low (<10%) for the remaining characters in the E_1 . In the E_2 , high PCV was high for seed yield per plant, siliqua length, siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant; moderate for siliqua length, seeds per siliqua and harvest index, and low for rest of the characters. Likewise GCV was high for siliquae per primary branch, primary branches per plant and secondary branches per plant; moderate for seed yield per plant, 1000-seed weight, seeds per siliqua and siliquae per plant; and low for rest of the characters in

the E_1 . In the E_2 , high GCV was observed for seed yield per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant; moderate for 1000-seed weight and harvest index; and low for the remaining characters.

High heritability (>80%) was observed for siliquae per primary branch, secondary branches per plant and oil content in the E_1 , and for 1000-seed weight, siliquae per plant, siliquae per primary branch, primary branches per plant, secondary branches per plant, days to maturity and oil content in the E_2 . Moderate heritability (50%-80%) was recorded for 1000-seed weight, siliqua length, siliquae per plant and primary branches per plant in the E_1 and for seed yield per plant, siliqua length and days to flowering in the E_2 . For the remaining characters, heritability was low. High genetic advance (>30%) was observed for siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant in the E_1 and for seed yield per plant, siliqua length, siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant in the E_2 . Moderate genetic advance (20-30%) was observed for 1000-seed weight in the E_1 and E_2 environments. For the remaining characters genetic advance was low.

In general, for both the environments, siliquae per plant, siliquae per primary branch and secondary branches per plant exhibited high GCV, high heritability with high

expected genetic advance showing that selection for these characters would be effective.

As observed in the present material, earlier workers also reported a wide range of variability, high heritability and genetic advance in the natural *B.juncea* (Yadav, 1973; Singh et al., 1975; Katiyar et al., 1976; Yadav and Yadav, 1977; Paul 1978; Labana et al., 1980; Yadav et al., 1981; Yadav, 1983; Singh et al., 1987; Chaudhary et al., 1991). However, Singh et al. (1987) reported low to medium heritability for primary branches per plant, which is high in the present study. Yadav (1983) reported high heritability for days to flowering, which is low to medium in the present study. Some of the contradictions in the results obtained from the present material are mainly because of the allopoloid nature of the genotypes under investigation.

5.2 CORRELATION STUDIES

The profitable use of sub-characters or components of yield in breeding mainly depends upon the association of each of these components with seed yield and also on the nature of relationships among the components themselves. Such information on the inherent association among seed yield and other quantitative traits has always provided strong bases for selection criteria for an ideal plant type.

In the present study, 23 synthetic *Juncea*s were evaluated for seed yield and 12 other traits. Inter associations were worked out for these 13 traits at the

phenotypic and genotypic levels in the two environments for establishing the selection criteria for increased seed yield.

The phenotypic correlations in the E_2 revealed that seed yield per plant had significant positive association with siliquae per plant. Singh et al.(1985), Pathak et al (1986), Kumar et al.(1988), Singh et al.(1987) and Ahmed (1980) have also reported this correlation in the Indian mustard. Among the traits, siliquae per plant had significant positive correlation with siliquae per primary branch and secondary branches per plant, whereas secondary branches per plant showed significant positive correlation with seeds per siliqua. On the contrary, primary branches per plant with siliquae per primary branch and seeds per siliqua with 1000-seed weight showed significant negative correlation. Days to flowering and maturity and secondary branches per plant showed significant positive correlations among themselves. These associations in the Indian mustard have been reported by Kumar et al.(1984) and Kumar et al. (1988). Oil content did not exhibit any association with any of the traits under study, which is in conformity with the findings of Singh et al.(1975).

None of the coefficients of correlation at the phenotypic level were significant in the E_1 environment. The results obtained from this environment are to be reviewed cautiously.

In both the environments, oil content did not exhibit any association with seed yield and other traits. This is useful for breeding *B.juncea* genotypes having high seed yield as well as oil content.

In general, in both the environments correlation coefficient at the genotypic level were higher than the corresponding phenotypic correlation coefficients, indicating thereby the strong inherent associations among various traits studied,. Earlier workers have also reported similar trends in *B.juncea* (Srivastava and Das, 1973; Sharma, 1982).

It is pertinent to mention that the correlation coefficients of harvest index with 1000-seed weight, siliqua length, siliquae per plant, secondary branches per plant, plant height, days to flowering, days to maturity and oil content; days to maturity with siliqua length and plant height at the genotypic level were greater than unity in the E_1 . Likewise, in the E_2 environment correlation coefficients of siliqua length with all other traits were greater than unity. These values are absurd and might have arisen due to the sampling error and are ignored.

5.3 PATH ANALYSIS

The correlation analysis only provides information on the nature of relationship, but does not give any idea regarding the cause of this relationship. Therefore, the information obtained from the correlation coefficients may be misleading with respect to identification of yield

components. Path analysis, on the other hand, provides information on the causes of such associations. Therefore, it would be advisable to look at the results obtained from the path analysis, which has been done both at phenotypic and genotypic levels, for both the locations (Table 7 and 8).

At the genotypic level in the E_1 , primary branches per plant, siliqua length, 1000-seed weight, siliquae per primary branch, plant height, days to maturity and harvest index had high positive direct effect on seed yield, whereas secondary branches per plant, days to flowering, seeds per siliqua, siliquae per plant and oil content exhibited high magnitude of negative direct effects. Although primary branches per plant had high positive direct effect yet it had no association with seed yield, which is due to the cancellation of high positive direct effect by negative indirect effects via siliquae per primary branch, seeds per siliqua and siliqua length. 1000-seed weight, siliquae per primary branch, days to maturity and plant height had no association with seed yield but their direct effects were positive. The characters, 1000-seed weight, siliqua length, siliquae per plant and secondary branches per plant contributed indirectly towards seed yield.

In the E_2 , siliquae per plant, secondary branches per plant, days to maturity, siliqua length, 1000-seed weight, siliquae per primary branch, plant height and harvest index had high positive direct effect while primary branches per plant, seeds per siliqua, oil content and days to flowering

had negative direct effects on seed yield. The significant positive association of siliquae per plant with yield is contributed mainly by its positive direct effect. The high positive direct effect of secondary branches per plant is counterbalanced by negative indirect effects via 1000-seed weight, siliquae per primary branch, days to flowering and siliqua length leading to its non-significant association with seed yield. Similar is the case with 1000-seed weight, siliqua length, primary branches per plant, seeds per siliqua and other characters. Siliquae per plant, secondary branches per plant, plant height and days to maturity contributed indirectly towards seed yield.

Rawat et al.(1977) found primary branches as the trait having maximum contribution towards seed yield in *B.juncea*. Srivastava et al.(1983) considered primary branch number and days to maturity as the important characters contributing towards seed yield. According to Singh et al.(1983) number of secondary branches per plant, plant height, seed weight, and to some extent seeds per siliqua should be considered in breeding for increased yield. Singh et al.(1987) reported that siliquae per plant, harvest index and 1000-seed weight had the greatest direct effect on seed yield. Kumar et al.(1984) concluded that total siliquae had the strongest positive direct effect on yield. Pathak et al.(1986) concluded that 1000-seed weight, days to flowering, length of main shoot, seeds per plant, pods per plant, number of

primary branches and height are the most important yield components.

From the correlation and path analyses, it is evident that siliqua length, secondary branches per plant, and days to maturity are most important yield components. Moreover, it is possible to combine high oil content with high seed yield because these two characters did not exhibit any association.

5.4 MEIOTIC STUDIES

The amphidiploid *B.juncea* ($2n=36, AABB$) comprise diploid sets of both A and B genomes. In the newly synthesized amphidiploids, meiosis is highly disturbed but after fourth or fifth generation this gets stabilized, though not quite attaining the perfect regularity of the natural material. In the present material, the meiosis was studied in 23 allotetraploids, their parents, *B.campestris* var. Brown sarson cv.candle, *B.campestris* var. Yellow sarson cv. YS1 and *B.nigra* Landrace; and the check, Varuna. Meiosis was normal in all the allotetraploids, except JSP3, JSP4, JSP5, JSP7, JSP11 and JSP20. In the allotetraploids, JSP3 and JSP7 the mean values of bivalents were 17.81 and 17.21, respectively at diakinesis. In JSP3 in 25.0 per cent of meiocytes two univalents were observed while in JSP7 four univalents were observed in 36.4 per cent of the meiocytes at diakinesis. In the allotetraploids, JSP5 and JSP11, at metaphase I, one and four univalents were observed, respectively in 20.0 per cent and 28.6 per cent of the

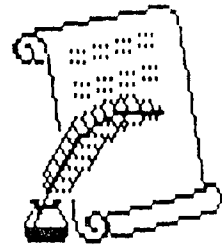
meiocytes. In JSP20, bivalent formation ranged from 16-18 with the mean of 17.50, whereas four univalents were observed in 25 per cent of the meiocytes at diakinesis. In all the allotetraploids studied the latter stages of meiosis, viz., anaphase I, telophase, and quartets were normal.

In the 3 parents of the synthetic Junceas and the check, Varuna, meiosis was normal with regular bivalent formation at diakinesis and metaphase I, normal disjunction of chromosomes at anaphase I and telophase I, and no micronucleus at quartet stage.

Meiosis was normal in the present material, except very few meiotic anomalies at diakinesis and metaphase I. Ramanujam and Srinivasachar (1943) noticed mostly 18 bivalents at metaphase I in the A₂ generation. The anaphase separation was regular at metaphase II, and 18 + 18 grouping of chromosomes was mostly found resulting in normal tetrads. Frandsen (1943) also noticed 18 bivalents at metaphase I and diakinesis after fourth to fifth generation. Ramanujam et al. (1945) also confirmed 18 bivalents at diakinesis and a distribution of 18 + 18 chromosomes at metaphase II. Olsson (1960) noticed stabilised meiosis by the fourth and fifth generation.

Out of the 23 synthetic Junceas, evaluated in the present study all, except JSP3, JSP4, JSP5, JSP7, JSP11 and JSP20 were meiotically stable. Of these, JSP22 was the highest yielder in both the environments. This genotype can

be released as cultivar after multilocation testing, else
can be used in breeding pro



SUMMAR

6. SUMMARY

The objectives of present investigations in synthetic *Brassica juncea* genotypes were to obtain basic information on the nature and magnitude of variation; to understand the inter-associations among seed yield and other traits; to understand the causation of associations; and to know the meiotic stability of the allotetraploids.

Twenty three allotetraploids of *B.campestris* x *B.nigra* (synthetic Junceas) alongwith check, Varuna were grown in a Randomized Complete Block Design (RCBD) with three replications during Rabi 1993 at Palampur (E₁) and Kangra (E₂). Each entry was raised in a 3-row plot, 3-m long with row-to-row and plant-to-plant spacing of 30cm and 10cm, respectively. Ten competitive plants were taken to record data on seed yield per plant (g), 1000-seed weight (g), seeds per siliqua, siliqua length (cm), siliquae per plant, siliquae per primary branch, primary branches per plant, secondary branches per plant, plant height (cm), oil content (%) and harvest index (%). Data on days to flowering and days to maturity were recorded on plot basis.

Components of variability, viz., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense and genetic advance as

per cent of mean; phenotypic and genotypic correlation coefficients; and path analysis for yield with different morphological and quality traits were studied as per methods given by Panse and Sukhatme (1984), Al-jibouri et al.(1958) and Dewey and Lu (1959), respectively over locations.

The analysis of variance revealed a wide range of genetic variability for seed yield, yield components and oil content.

The comparative overall means of different characters at both the locations evinced that means of 1000-seed weight, siliqua length, siliquae per plant, secondary branches per plant and days to maturity were higher in the E_1 as compared to E_2 , where the overall means were higher for the remaining characters.

Among the synthetic *B.juncea* genotypes, JSP22, JSP6, JSP16, JSP12 and JSP1 were at par with the check, Varuna for seed yield in the E_1 . Among these JSP22 and JSP11 combines most of the desired characteristics. In the E_2 , the genotypes, JSP8, JSP13 and JSP22 were at par with the check for seed yield per plant with significantly higher oil content.

The range of variation was higher for 1000-seed weight, siliqua length, siliquae per plant, secondary branches per plant and days to maturity in the E_1 than that of the E_2 . For the remaining traits the variation was higher in the E_2 .

Phenotypic and genotypic coefficients of variability were high for siliquae per primary branch, primary branches

per plant and secondary branches per plant; moderate for seed yield per plant, 1000-seed weight, seeds per siliqua and siliquae per plant; and low for the remaining characters in the E_1 . In the E_2 , both PCV and GCV were high for seed yield per plant, siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant; moderate for 1000-seed weight and harvest index; and low for the remaining characters. In the E_1 , high heritability was observed for siliquae per primary branch, primary branches per plant and oil content, while in the E_2 , the corresponding estimates were higher for 1000-seed weight, siliquae per plant, secondary branches per plant, days to maturity and oil content. High genetic advance was observed for siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant in the E_1 . In the E_2 , high genetic advance was observed for seed yield per plant, siliqua length, siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant. High genetic advance coupled with high heritability was observed for siliquae per primary branch and secondary branches per plant in the E_1 ; and for siliquae per plant, siliquae per primary branch, primary branches per plant and secondary branches per plant in the E_2 .

At the phenotypic level, seed yield per plant showed significant positive association with siliquae per plant in the E_2 . Siliquae per plant had significant positive

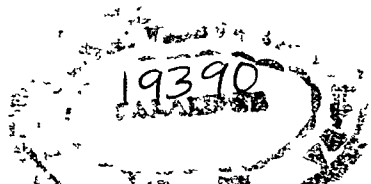
association with siliquae per primary branch and secondary branches per plant, whereas secondary branches per plant showed significant positive correlation with seeds per siliqua. Days to flowering and maturity showed significant positive correlation. Both the traits were positively associated with secondary branches per plant. In the E_1 , none of the characters showed significant correlation among themselves. In general, estimates of genotypic correlation coefficients were of higher magnitude than the corresponding phenotypic ones in both the environments.

At the genotypic level, seed yield per plant had positive association with plant height, days to maturity and secondary branches per plant in the E_2 , while in the E_1 seed yield per plant was positively associated with siliqua length. In the E_1 , days to flowering had positive association with siliqua length and plant height. In the E_2 , siliquae per plant had positive association with siliquae per primary branch and secondary branches per plant; and days to flowering showed positive association with days to maturity.

Path coefficient analysis in the E_1 environment, revealed that siliqua length, seeds per siliqua, 1000-seed weight and siliquae per primary branch had positive direct effects, whereas siliquae per plant, primary branches per plant, harvest index and days to flowering showed negative direct effects on seed yield.

In the E_2 , siliquae per plant, siliqua length, plant height, days to maturity and harvest index had positive direct effect on seed yield, while seeds per siliqua, siliqua per primary branch, days to flowering, primary branches per plant and 1000-seed weight exhibited negative direct effects.

Meiosis in the most of the allotetraploids was normal with 18 II at diakinesis and metaphase I, and normal disjunction of chromosomes at anaphase I and telophase I. The quartets in all the genotypes were devoid of any observable micronucleus. However, meiotic anomalies as univalents at diakinesis and metaphase I were observed in the allotetraploids JSP3, JSP4, JSP5, JSP11 and JSP20. The meiosis was normal in the parents of allotetraploids, viz., *Brassica campestris* var. Brown sarson cv. candle, *B. campestris* var. Yellow sarson cv. YSI and *B. nigra* Landrace, and the check, Varuna.



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