EVALUATION OF HETEROTIC COMBINATIONS FOR SEED YIELD AND QUALITY PARAMETERS UNDER VARIOUS NITROGEN LEVELS IN INDIAN MUSTARD [*Brassica juncea* (L.) Czern. & Coss.]

A Thesis

Submitted in partial fulfillment of the requirements for the

award of the degree of

DOCTOR OF PHILOSOPHY

in

Plant Breeding & Genetics

By

Manoj Kumar

(41600117)

Supervised By

Dr. Harmeet Singh Janeja
Professor & Head
Department of Genetics and Plant Breeding
School of Agriculture
Lovely Professional University, Phagwara, Punjab

LOVELY PROFESSIONAL UNIVERSITY

Transforming Education Transforming India

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

2021

DECLARATION

I hereby declare that the thesis entitled **"Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]"** submitted for Doctor of Philosophy in Plant Breeding & Genetics to the School of Agriculture, Lovely Professional University is entirely original work and all ideas and references are duly acknowledged. The research work has not been formed the basis for the award of any other degree.

Place: LPU, Phagwara
Date : 14.08.2021

(Manoj Kumar)
(Reg No. 41600117)

CERTIFICATE-I

This is to certify that the thesis entitled, **"Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]"** submitted to the Faculty of Technology and Sciences, Lovely Professional University, Phagwara, Punjab in partial fulfilment of the requirement for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Plant Breeding & Genetics** embodies the results of piece of bonafide research carried out by **Mr. Manoj Kumar** under my guidance and supervision. To the best of my knowledge, the present work is the result of original investigation and study. No part of this thesis has ever been submitted for any other degree or diploma or published in any other form. All the assistance and help received during the course of investigation and the sources of literature have been duly acknowledged by him.

Supervisor

(Dr. Harmeet Singh Janeja)
Professor and Head
Deptt. of Genetics & Plant Breeding
School of Agriculture
Lovely Professional University
Phagwara-144 411

CERTIFICATE-II

This is to certify that the thesis entitled **"Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]"** submitted by **Mr. Manoj Kumar (Registration No. 41600117)** to the Lovely Professional University, Phagwara in partial fulfilment of the requirements for the degree of **DOCTOR OF PHILOSOPHY (Ph.D.)** in the discipline of **Plant Breeding & Genetics** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an external examiner.

(Dr. Harmeet Singh Janeja)
Chairperson, Advisory Committee
Professor and Head
Deptt. of Genetics & Plant Breeding
School of Agriculture
Lovely Professional University
Phagwara-144 411

(Dr. Sanjay Chadha)
External Examiner
Principal Scientist
Deptt. of Vegetable Science &
Floriculture, College of Agriculture
CSK Himachal Pradesh Krishi
Vishavidyalaya, Palampur- 176 062

Dean
School of Agriculture
Lovely Professional University
Phagwara- 144 411

SCHOOL OF AGRICULTURE
LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA

Title of Thesis	**:**	Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]
Name of the Student	**:**	Manoj Kumar
Registration Number	**:**	41600117
Year of Admission	**:**	August 2016
Name and Designation of Research Supervisor	**:**	Dr. Harmeet Singh Janeja Professor and Head Department of Genetics and Plant Breeding School of Agriculture Lovely Professional University Phagwara, Punjab- 144 411

ABSTRACT

The research endeavour entitled "Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]" was executed in the Experimental Farms of Department of Genetics and Plant Breeding, School of Agriculture, Lovely Professional University, Phagwara during the year 2017-18 to 2018-19 with an objective to identify hybrids based on the *per se* performance along with study of combining ability including General Combining Ability (*gca*) of parents and Specific Combining ability (*sca*) of crosses under different Nitrogen levels *viz.,* Control (no application of Nitrogenous Fertilisers); 75 Kg and 150 Kg Nitrogen per ha. The research also included the study of nitrogen uptake pattern and its effect on yield and other attributing traits.

The material for present investigation comprised of ten Indian mustard diverse genotypes *viz*. Jumka, RNG-73, Pusa Mustard-28, Gujarat Mustard-3, ZEM-1, DRMR-1, NRCHB-101, RH-30, TM-4 and KBS-3 used as parents along with the standard check Variety Varuna. The aforesaid parental genotypes were sown in *Rabi* 2017-18 and were crossed following diallel mating design without reciprocals

so as to generate 45 F_1's seeds.

The ten parental genotypes along with the standard check- Varuna and 45 F_1's generated through crossing were sown during Rabi *2018-19* in the incomplete block- Alpha Lattice Design with two replications for each of the genotypes. The observations were recorded for seventeen traits *viz*. days to flower initiation, days to fifty percent flowering, days to maturity, plant height (cm), number of primary branches per plant, number of secondary branches per plant, length of main shoot (cm), number of siliquae on main shoot, siliqua length (cm), number of seeds per siliqua, 1000 seed weight (g), seed yield per plant (g), biological yield per plant (g), Harvest Index (%), seed oil content (%), seed nitrogen content (%) and chaff nitrogen content(%). From each treatment in a replication, observations for all traits were recorded on five randomly selected competitive plants from each replication except for days to flower initiation, days to fifty percent flowering, days to maturity and other quality traits *viz.*, seed oil content (%), seed and chaff nitrogen content (%). The readings so obtained from the five plants were averaged replication wise and the mean data was used for statistical analysis. In case of days to flower initiation, days to fifty percent flowering and days to maturity, the number of days from date of sowing to first flower initiation, initiation of flower blooming in fifty percent plants and physiological maturity for each entry in a replication were recorded, respectively. Oil content was estimated on dry seed basis by non-destructive method using Foss-tecator near-infrared reflectance spectroscopy (FT-NIRS) product analyzer. Seed and chaff nitrogen concentration (%) at harvest was determined by modified micro-Kjeldahl method. Nitrogen uptake for seed and stover (g) at harvest was determined by multiplying per cent N content in known weight of plant sample at particular growth stage with respective dry matter accumulation at that particular stage for studying the nitrogen uptake pattern and its effect on yield and its attributing traits.

The statistical analysis included the Analysis of variance under various nitrogen levels for yield and its contributing attributes, estimation of *per se* performance of the parents and their hybrids in comparison to the standard check Varuna, estimation of nitrogen uptake pattern and its effect on yield attributes using student's t test, Pooled analysis of variance based on GGE Biplot and GGE Biplot display, Combining ability analysis including Analysis of variance for the combining ability & estimation of General Combining Ability (*gca*) along with Specific Combining Ability (*sca*) effects, Hayman's Graphical analysis including component analysis and estimation of heterosis comprising of the heterobeltiosis (superiority over better parent) and standard/ economic heterosis (superiority over the standard check).

The significant mean sum of squares differences for the characters studied among parents showed that material used for present study had sufficient variability for different traits. The ANOVA revealed significant differences for all the characters among parents and hybrids under all three conditions.

Based on *per se* performance of parents, two parental genotypes *viz.,* Jumka and ZEM-1 performed best under all three conditions *viz.,* control, 75 Kg N/ha and 150 Kg N/ha for various traits including seed yield. The cross combinations *viz.,* RH-30 × KBS-3; NRCHB-101 × KBS-3; RH-30 × TM-4; RGN-73 × DRMR-1 and RNG-73 × Gujarat Mustard-3 also exhibited superior *per se* performance for all seventeen traits in general under all three nitrogen levels *i.e.* control, 75 Kg and 150 Kg Nitrogen per ha. High *per se* performance for seed yield per plant was exhibited by two cross combinations *viz.,* RNG-73 × DRMR-1 and RH-30 × KBS-3.

The seed and stover nitrogen uptake along with other traits days to flower initiation, days to 50 percent flowering, days to maturity, plant height, number of secondary branches per plant, siliqua length, 1000 seed weight, seed yield per plant, Harvest Index, oil content, seed nitrogen and chaff nitrogen concentration increased with increase in nitrogen levels. However, the variation was non-significant in majority of cases. A decrease in count was observed for number of seeds per siliqua on increase of nitrogen levels. No clear trends were observed for the traits *viz.,* number of primary branches per plant, length of main shoot, number of siliqua on main shoot and biological yield.

The pooled GGE analysis of variance revealed that the mean squares due to genotypes and environment were significant for majority of the characters. The

Genotype × Environment interaction was insignificant for maximum traits. On overall basis, the condition of 75 Kg N/ha was established as the most discriminating environment for majority of the character. A close correlation was found between three environments *viz.*, as evident from their position in same sector.

Significant *gca* and *sca* differences for most of the traits across the nitrogen levels was inferred from the Analysis of Variance for combining ability. Both additive and dominant gene actions were found responsible for the expression of various traits through ANOVA. However, low potence ratio (σ2*gca*/σ2*sca*) indicated pre dominance of dominant gene actions in the inheritance of the traits under study. The parent RNG-73; RH-30 and Gujarat Mustard-3 were established as good general combiners for various traits including seed and oil yield. None of the cross combinations exhibited significant level of desirable *sca* effects for the traits under study. The cross combination RH-30 × KBS-3 appeared most promising for seed and oil yield including some other yield attributing traits. The other cross combinations *viz.,* Jumka × ZEM-1, Pusa Mustard-28 × ZEM-1 and RNG-73 × Gujarat Mustard-3 were also found promising across the nitrogen levels.

The additive dominance model was found adequate for plant height, Harvest Index and chaff nitrogen under all three nitrogen levels. the model was also fitted for number of secondary branches per plant, length of main shoot, number of siliquae on main shoot, number of seeds per siliqua, seed yield per plant, biological yield per plant and oil content but not under all nitrogen levels. Overdominance was predominant for most of the traits. The parents Jumka, RNG-73 and Pusa Mustard-28 possessed more dominant genes.

The cross combinations *viz.,* Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; Jumka × Pusa Mustard-28; RNG-73 × DRMR-1 and RNG-73 × Gujarat Mustard-3 exhibited desirable values of heterobeltiosis for most of the characters including seed yield. The estimates of the standard or economic heterosis indicated the superiority of cross combinations *viz.,* RNG-73 × DRMR-1, RNG-73 × Gujarat Mustard-3, RNG-73 × TM-4, RNG-73 × KBS-3 and Jumka × Pusa Mustard-28 for the various characters including seed yield in comparison to the standard check

Varuna. However, most of the cross combinations were found less responsive for standard heterosis at higher nitrogen dose of 150Kg/ha for all seventeen traits which may be due to nitrogen imbalance.

The perusal of the results of the research endeavour indicated the superiority and desirability of the hybrids RNG-73 × DRMR-1, RNG-73 × Gujarat Mustard-3, RH-30 × KBS-3 and NRCHB-101 × KBS-3. These cross combinations can be utilized further and exploited for obtaining high seed and oil yield cultivars through breeding programmes.

ACKNOWLEDGEMENT

Pride, praise and perfection belong to almighty alone. This treatise, a humble expression of my life's ambition and a scientific dream come true, would have not materialized the way it is, without the benediction from almighty God. With limitless humility, I am Grateful to "God" the merciful, the compassionate, who bestowed me with health, tenacity and courage enough to go through this crucial juncture.

I owe felicitousness overwhelms to express my deepest sense of reverence towards my admired parents. I solemnize to allocate the thesis to them and vis-a-vis offer this as a humble tribute to agriculture science. This account will be incomplete without revealing my loving father ***Sh Bratia Ram*** *and mother* ***Smt. Amro devi*** *for their inspiration, encouragement and sacrifice to fulfil my higher academic achievements.*

The insuperable contribution and peer support rendered by my adorable, debonair, dynamic and revered major advisor, ***Dr. Harmeet Singh Janeja*** *Professor & Head, Department of Genetics and Plant Breeding, LPU, is incomprehensible. He enthused inexhaustible inspiration, volition and constructive criticism for generating vital, valuable and innovative ideas for the execution of the present endeavour. I will remain indebted to him for pruning my personality and giving new dimension in the scientific field through his analytical scientific outlook for bringing revolution in agriculture sector.*

I would also like to thank ***Dr. Ramesh Kumar Sadawarti****, Head School of Agriculture, LPU for continuous inspiration and guidance throughout my Ph.D. programme.*

I express my gratitude to Chancellor and the Dean, School of Agriculture, Lovely Professional University, Phagwara for providing me the necessary facilities to complete this study.

I would be selfish if I do not appreciate and extol the incessant constant inspiration of my sister ***Alpna****, brother,* ***Sanjeev, Sushil*** *and and bhabi* ***Anju*** *who maintained the circle of strength around me. I express my heartiest affection to them.*

My heart feels indebted for the unstinted cooperation, guidance and help rendered by my dear friend ***Ishan Mehta.*** *I also take the opportunity to acknowledge the help and love by my friends specially* ***Sopan, Devender,*** *and* ***Mayur Thalkar.***

Moreover the services rendered by all those who have not mentioned are acknowledged who provided me the best support and service during this period.

Needless to say, all errors and omissions are mine.

Place : LPU, Phagwara
Dated: 14th August, 2021

(Manoj Kumar)

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

Sr.No.	Symbol/ Abbreviated Form	Full Form
1.	%	percentage
2.	&	and
3.	cm	centimeter
4.	*et al.*	*et alia* (and others)
5.	g	grams
6.	*gca*	General Combining Ability
7.	ha	hactare
8.	*i.e.*	id est (that is)
9.	Kg	Kilograms
10.	mha	million hactare
11.	ml	millilitre
12.	mt	million tonnes
13.	no.	number
14.	*per se*	by itself
15.	*sca*	Specific Combining Ability
16.	*vs*	Versus
17.	*viz.*	videlicet (namely)

INTRODUCTION

Mustard is an important crop of the Indian subcontinent and has been grown for centuries as an oilseed crop. The genus *Brassica of cruciferae family is* an important group comprising of various economically important species grown for their different edible parts including buds, flowers, leaves, stems, roots and seed. Rai or Laha are the widely used names for Indian mustard (*Brassica juncea* L. Czern. & Coss).

In India, Indian mustard (*Brassica juncea* L. Czern. & Coss.) occupies the second largest area after groundnut under oilseed crops. It is cultivated in *rabi* season mainly in Northwest India. The seed oil of Indian mustard accounts for almost 27 per cent of the total edible oil production of the country. Rajasthan is the leading mustard growing state in the country followed by the states of Uttar Pradesh, Madhya Pradesh, Haryana, West Bengal, Gujarat, Bihar and Punjab. It is widely used for human and animal consumption directly or in form of oil. Methods have been developed across the world for conversion of its biomass to bio-energy; (Ofori and Becker, 2008). This group of crops plays very important role in the oilseed economy in our country. During the year 2018-19, the rapeseed-mustard group of crops occupied an area of 36.59 million hectares (mha) around the world leading to the production of 72.37 million tonnes (mt) (DRMR 2019). The productivity attained in the year was 1980 Kg/ ha. India accounts for 19.8 % of the total acreage of rapeseed mustard group crops but, its contribution to the world production is only 9.8% of the total acreage and production. In India the Rapeseed-mustard was grown on 6.23 mha during 2018-19 crop season out of which 75-80% area was occupied by Indian mustard. The production and productivity of Rapeseed-mustard crops in India was 9.26 mt and 1511 Kg /ha, respectively in 2018-19 (DAC&FW 2019).

Hybridization plays a crucial role in creation of variability in self-pollinated crops like Indian mustard through carefully selected parents. The exploitation of hybrid vigour depends upon the direction (positive or negative based on desirability) & magnitude of heterosis, biological feasibilities and the type of gene action decides the exploitation of hybrid vigour. The success of efficient breeding program depends upon such clues. However, in highly self-pollinated crops heterosis cannot be commercially exploited, in later generations F_1s can be used separate greater frequency of productive derivatives, also the diversification of genotypes in self-pollinated crops is limited as compared to cross pollinated crops.

The first step in any breeding programme is selection of parents which are to be used as parents and can supply all the desired important character which lack in good standard variety. They must be chosen with a great care taking into account all the objectives of study, so that the chances of selecting desirable genotypes become more. As for as possible the parental lines must be selected from local collections which are supposed to be best suited in existing conditions. Therefore selection of promising parents or lines and incorporates them in crosses with desired mating design is an important step in any breeding programme.

The diallel analysis (Griffing 1956) is one of the simple and efficient methods for preliminary evaluation of genetic studies through hybridization. It gives information about general combining ability of the parents and the specific combining ability of the crosses. Along with this, it simultaneously helps in identification and estimation of various types of gene effects. The type of gene action involved in inheritance of various characteristics and suitable breeding strategies for them can be known by analyzing combining ability effects. Beside the yield potential, oil quality from nutritional point of view is very important. It is necessary to assess the nutritive value of newer varieties at the experimental stage itself, before they are released for mass production because most of the people prefer safest oil for edible purpose. This information may help the plant breeders to bring forth those varieties for future programmes.

Crop production depends upon use of high yielding cultivars along with the application of nutrients based on the crop requirements. The primary and essential plant nutrient- Nitrogen (N) is an important constituent of protoplasm and protein. Besides this, it impacts the growth, productivity and quality of crops because of its involvement in several metabolic and enzymatic processes (Reddy and Reddy 1998, Kumar *et al.* 2000). The rapeseed mustard group of crops falls under the category of soil exhausting crops and therefore has high demand of nutrients including nitrogen which is supplemented through use of fertilizers. The high nitrogen demand can be accounted due to their larger nitrogen content in seeds and plant tissues. The use of Nitrogenous fertilizer in rapeseed-mustard accounts for significant crop production cost (Laine *et al.* 1993, Pasricha and Tandon 1993, Malagoli *et al.* 2005). Applications of nitrogen doses as high as 150 Kg/ha have been reported to cause increase in yield in Indian mustard across various locations (Singh and Rathi 1984, Tomar *et al.* 1997, Deekshitulu *et al.* 1998, Singh and Brar 1999, Singh *et al.* 2010). Brassicas are known to remove higher amount of N until flowering with relatively lower amount taken up during reproductive growth phase (Rathke *et al.* 2006).

Genotypes may differ in their response to applied N. These may differ in their ability to absorb N from soil (uptake efficiency) and/or in their efficiency to utilize absorbed N for dry matter production (utilization efficiency). Nitrogen efficient cultivars may yield better under conditions of limited N supply or require lower amount of N for given yield than N inefficient cultivars. Differences in response, absorption and utilization of N among genotypes have been reported from different countries in maize (Hirel *et al.* 2001, Gallais and Coque 2005, Mi *et al.* 2007), rice (Ladha *et al.* 1998, Koutroubas and Ntanos 2003, Duan *et al.* 2007), wheat (Le Gouis *et al.* 2000, Rahimizadeh *et al.* 2010) and oilseed rape (Yau and Thurling 1987, Hirel and Lemaire 2005, Balint *et al.* 2008) but such information is not available for Indian mustard. Nitrogen uptake and distribution is controlled by genes as evident from differences in nitrogen concentration in various plant parts of rapeseed (*Brassica napus* L.) (Grami and La Croix 1977). The cultivars of spring rapeseed with higher yield at high nitrogen levels responded less than the cultivars having lower yields at lower levels of nitrogen application to the increased dosage of nitrogen (Yau and Thurling 1987). There are very few hybrids available in Indian mustard (*Brassica juncea* L) which are responsive for different fertilizers specially nitrogen. The present investigation will help in evaluation of different possible cross combinations for the better utilization of nitrogen at appropriate quantity of dose.

Keeping in view the above aspects, the present investigation was planned with the following objectives:

1. Identification of hybrids on the basis of *per se* performance.
2. To study nitrogen uptake pattern and its effect on plant growth and yield attributes.
3. To study combining ability and heterosis.
4. To study *gca* effects of parents and *sca* effects of crosses for the traits under study.

The genetic information gathered on potentiality of crosses made between diverse parents and superior heterotic crosses, thereof for yield, its components, oil and oil quality parameters would be of great value in carrying an efficient breeding programme for improvement in Indian mustard.

REVIEW OF LITERATURE

2.1 Combining Ability and Heterosis

Shull (1909), Jones (1917) and East (1936) observed in their classical heterosis studies that certain lines produce more desirable hybrids than others. Clear cut or exact explanation on aspect of combining ability was given by Sprague and Tatum (1942). Ability of a genotype to transmit its superior performance or traits to its crosses is known as combining ability. They defined general combining ability (*gca*) "as the average performance of a line in a series of cross combinations" and specific combining ability (*sca*) " as denoted by the cases in which certain combinations did relatively better or worse than would be expected on the basis of average performance of the lines involved".

Handerson (1952) described general combining ability as "the average value with respect to some character or weighted combination of characters of an infinitely huge number of progenies of a line when crossed with a random sample from some particular populations under a specified environment. He considered specific combining ability as "a deviation of a mean value of a cross from the expected value calculated on the basis of known *gca* of the two parents or lines involved". Griffing (1956) gave the method of *gca* analysis using diallel crossing system. The *gca* estimates includes additive based higher order epistatic variance and the *sca* variance estimates include dominance and other parts of epistatic variance (Matzinger and Kempthorne, 1956). Similar results were also published by Griffing (1956). In the absence of epistasis, diallel cross can be used for estimation of additive and dominance genetic variance.

Combining ability analysis is being widely used for studying the nature and extent of genotypic variability and for facilitation of selection of parents in breeding programmes. The information of gene effects involved in expression of a character is helpful for plant breeders in making accurate decisions in regard of breeding material, procedure for selection and variety kind.

The term heterosis was suggested by George Harrison Shull (1909) in original to the developmental stimulus obtained as a result from gamete union and hybrid vigour to the noticeable effects of heterosis. Heterosis was described as hybrid vigour as a result of which F_1 falls outside the parental range with respect to some trait(s) by Allard (1960). As per Hayes *et al.* (1955), heterosis is superiority of F_1 generation obtained from the cross over the better parent. Fonseca and Patterson (1968) termed the same as heterobeltiosis.

Heterosis is defined as the supremacy or inferiority of F_1 over the parents. It is the phenomenon resulting in increase of the 'Darwinian fitness' of F_1 hybrids over the parental genotypes. The same population tends to have different fitness in diverse environments as it is a result of interaction between the phenotype and the environment to which a population is exposed. Thus the plant breeders make use of both positive and negative heterosis while hybrid varieties development programmes.

Kumar *et al.* (1990) evaluated 13 inbred lines/varieties which were crossed with the varieties RH30, Varuna and Parkash in line × tester fashion; the 16 parents and 39 F_1s were evaluated for 6 traits. Cross combinations which had positive heterosis for the seed yield also showed significantly positive heterosis for seeds per siliqua, primary branches per plant, and secondary branches per plant and siliqua length. Cross combinations *viz.*, RLM-198 × RH-30 followed by RLM-514 × Varuna, RS-64 × Varuna, RLM-514 × Varuna and RL-18 × Varuna observed highest positive heterosis. Highest positive heterobeltiosis was observed by RLM-198 × RH-30.

Gupta *et al.* (1991) generated 48 crosses from 9 × 9 tester cross to study heterosis and combining ability for the same nine traits plus oil yield and content. Based on seed yield and components, the lines were grouped into five clusters, with no correlation between geographical and genetic diversity. However, a relationship did exist between the genetic diversity of parents and *sca* effects and heterosis for the crosses. It was suggested that selection of parents for breeding should be based on diversity estimates coupled with combining ability analysis.

Pradhan *et al.* (1993) evaluated accessions and on the basis of divergence, ten lines were selected and crossing was done in half diallel fashion. Studies revealed that heterosis was contributed by various parameters like number of primary and secondary branches per plant, number of siliqua per plant, siliqua density and Harvest Index.

Chaudhary *et al.* (1997) used ten diverse genotypes using half diallel mating design and concluded that Varuna was the best general combiner for seed yield, oil content and other most of the important traits. The cross combination Yellow Appressed × RL-18 performed better for seed yield and oil content.

Khulbe *et al.* (1998) studied on combining ability for eight *Brassica juncea* genotypes and their F1 crosses by half diallel mating system. The study reveled that all the characters exhibited significant differences for general and specific combining ability. Thirteen crosses out of twenty eight cross combinations exhibited good combining ability for seed yield.

Singh and Verma (1998) derived information on combining ability from 15 lines crossed with 3 testers and their F_1 hybrids for 7 yield components. The cross RH-8814/PR-8801 followed by JMM-1628/DIRA-313 were the best combinations for seed yield while KBJ-15/PR-8801 was best for oil content.

Sheikh and Singh (1998) conducted their studies on *Brassica juncea* and revealed that Pusa Barani was the best general combiner for the seed yield, oil content, 1000-seed weight, and days to flowering, plant height, length of main axis and length of siliqua. RH-30 and Varuna were also good general combiners for seed yield and other attributes. Desirable *gca* results for short height was shown by Glossy mutant and Poorbijaya. Cross combination of Pusa Barani × Glossy also exhibited superior *sca* effects for oil content, seed yield, plant height, primary branches per plant, and lenth of main shoot.

Kumhalkar *et al.* (1999) identified better parents based on combining ability and to isolate superior crosses for study in further generations. On the basis of mean performance and *gca* effects, the parental genotypes *viz.*, ACN-9, PKV-NU-2, Seeta and RW-351 were identified as the best general combiners. The cross RW 351 × PKV NU-2 was identified as a potential cross for seed yield per plant.

Patel *et al.* (1999) obtained results on heterosis from 22 line × 3 tester cross of *Brassica juncea* data on seed yield and oil content and the data was categorized with respect to parental *gca* values (low × low, high × low and high × high).

Verma and Kushwaha (1999) evaluated the parental genotypes as well as the cross combinations obtained from 15 line × 3 tester cross of Indian mustard for various seed quality traits. Analysis of the combining ability revealed that significant differences were present among the lines for all traits except cytoplasmic leakage. *sca* contributed more towards variance than *gca*, signifying the higher proportion of non-additive gene effects in the seed quality traits expression *viz.*, test weight, oil content, seed yield per plant, germinability, vigour and cytoplasmic leakage.

Yadav and Kumar (1999) studied heterosis and combining ability for forty five crosses and their parents. The best general combiner for oil content was RH-781 followed by RH-8311, RH-839, RH-848 and Varuna. Specific combining ability was shown by RH-781 × Varuna.

Katiyar *et al.* (2000) evaluated 96 F1 hybrids for heterosis and combining ability obtained from 6 lines, 16 testers through line × tester mating design for seed yield and its attributing traits. 64 cross combinations exhibited heterobeltiosis while 38 hybrids were found associated with standard or economic heterosis over the Standard check Varuna.

Kumar and Srivastava (2000) established the roles of both additive and non-additive gene effects for various traits. The parents RN-26, RJ-6, Varuna, RIC-8620 and RSM-24 exhibited desirable *gca* effects for number of primary branches per plant, siliqua length and seed yield per plant. The cross combinations *viz.*, RSM-24 × RLC-8620, RN-26 and RN-26 × RLC 8620 were identified as potential candidates for use in breeding programmes.

Sood *et al.* (2000) evaluated 33 hybrids for six quantitative traits obtained from the line × tester mating design along with the parental genotypes. P17 was found good general combiner for number of siliqua per plant. The genotypes - RLM619, CSR83-268, RCC15 and NDR8602 were identified as good general combiners on average for the characters. The significantly positive and highest heterosis for seed yield per plant was exhibited by the cross combination NDR860 × RLM619 (141%).

Tak and Khan (2000) estimated the combining ability, degree of variability and gene effect for various traits of 15 Indian mustard genotypes (lines) crossed with 3 testers. The estimates of genetic variance indicated predominance of non additive gene action for the days to flowering. However, the inheritance of most of the traits was governed both by additive and non-additive gene actions. The genotype KS-216 was found associated with desirable *gca* effects for earliness, whereas the genotypes KS-240 and KS-181 were established as good general combiners for seed yield per plant.

Verma (2000) estimated the *gca* and *sca* variance to assess the additive and non-additive gene action contribution involved in the various trait inheritance. Four parental genotypes exhibited higher *gca* effects for seed yield and other attributing traits.

Sarkar and Singh (2001) evaluated 10 Indian mustard genotypes for thirteen traits for studying combining ability. The results indicated significant variance for *gca* and *sca* for various traits including seed yield per plant and its attributing traits. The effects of reciprocal crosses were also found significantly different for all characters except for early vigour and siliqua length. Significant positive correlation was identified between *per se* performance and *gca* of the parental genotypes for days to fifty percent flowering, plant height, test weight and seed yield.

Ghosh *et al.* (2002) evaluated hybrids in Indian mustard for ten qualitative traits generated from 29 lines crossed with 7 tester parents. Seven parents were identified as good general combiners for seed yield per plant and associated traits.

Both additive and non-additive gene action were of established as important contributing factors for inheritance of majority of the traits.

Rao and Gulati (2002) observed significantly high correlations between general combining ability and specific combining ability effects with the *per se* performance of the F_1 and F_2 generations.

Singh *et al.* (2002) evaluated sixty hybrids obtained from twenty lines crossed with three cultivars in a line × tester mating design. Significant *gca* and *sca* effects were observed for all the characters. The genotypes Basanti and Varuna were identified as good general combiners for seed yield per plant. Three crosses exhibited desirable *sca* effects for seed yield per plant and oil content.

Swarnkar *et al.* (2002) found highly significant variances for both *gca* & *sca* for almost all the characters. Four parents each for number of primary branches per plant & oil content; three parents for test weight; two parents for length of main shoot and one parent each for number of secondary branches, number of siliqua on main shoot and seed yield per plant were identified as good general combiners. Eight cross combinations out of the total thirty six were found associated with desirable *sca* effects for seed yield per plant in both generations.

Acharya and Swain (2004) evaluated 9 × 9 half-diallel set of *Brassica juncea* with respect to nine traits for analysis of combining ability. Pre- dominance of additive gene effects was observed for various traits including number of secondary branches, number of siliqua on main shoot, siliqua length, number of seeds per siliqua, seed yield per plant and test weight. Pusa Bahar was the identified as best general combiner for seed yield and other attributing traits. The cross combinations with parents having high × high or high × low *gca* effects exhibited high *per se* performance. Three cross combinations *viz.,* Pusa Bold × Pusa Bahar, BM 20-12-3 × JC 26 and Pusa Bahar × JC 26 were associated with desirable *sca* effects and high *per se* performance for various characters including seed yield and oil content. However, no close association was found between *per se* performance and specific combining ability in both generations for most traits.

Mahto and Haider (2004) observed highly significant *gca* for various traits in combining ability analysis. Sca was also found highly significant for all characters, except for primary branches per plant. None of the parents exhibited desirable *gca* effects. The genotype RW 873 was identified as good general combiner for seed yield, test weight, Harvest Index, plant height, days to maturity & fifty percent flowering. High heterosis was observed over better parent for most of the characters.

Singh and Lallu (2004) observed significant difference for all the traits in both F1 and F2, except for test weight in F2 on the basis *gca* and *sca* variance analysis. Good general combiners were identified for seed yield and its attributing traits on basis of *gca* effects. The specific combining ability of crosses was identified as suitable parameter to determine the *per se* performance of crosses for exploitation of heterosis. Desirable *sca* effects were found in F1s and F2 generations for eight crosses.

Singh *et al.* (2004) identified good general combiner for test weight, biological & Seed yield, Harvest Index and oil content. The inheritance plant height and biological yield was identified to be governed predominantly by additive gene action. The seed yield and biological yield were found to be positively correlated with days to fifty percent flowering, number of primary and secondary branches, main shoot length and number of siliqua on main shoot. Harvest index was also found to be positively correlated with seed yield per plany, length of main shoot and number of siliqua on the main shoot. The standard heterosis was observed to be significant for most of the traits under evaluation.

Dixit *et al.* (2005) recorded 104.40 per cent heterobeltiosis for seed yield with significantly positive *sca* effects. Desirable heterobeltiosis was observed for oil content in most of the cross combinations.

Goswami and Bahal (2005) found significantly high *gca* and *sca* effects for seed yield per plant and its attributing traits. Three parents were good general combiners for seed yield and other yield contributing characters. Non-additive gene action played important role for inheritance of all the traits. Seven hybrids out of the total of thirty exhibited significant positive *sca* effects along with significantly high *per se* performance for seed yield aper plant and its attributing traits. Non-additive gene actions were found important in the expression of all the traits. Duplicate epistasis was observed for test weight, number of primary branches per plant and siliqua on main shoot.

Katiyar *et al.* (2005) evaluated 88 cross combinations of *Brassica juncea* for heterosis and combining ability. Significant differences for all traits were found among parental genotypes. Five crosses were identified exhibiting desirable heterobeltiosis upto 91.6% and upto 90.5% economic heterosis. Both additive and dominance genetic variance were found involved in governance of inheritance of seed yield per plant.

Monalisa *et al.* (2005) observed a wide range of genetic diversity in the material indicated by highly significant differences for the traits studied estimated by analysis of variance. Tocher's method was used for grouping of the cultivars. Nineteen cultivars were grouped into 6 clusters. Nine genotypes were present in Cluster III. Cluster III was also associated with highest intra cluster distance. The highest inter-cluster distance was observed between cluster V and II. Number of siliqua per followed by number of days to maturity and plant height had the highest contribution towards total genetic divergence. The *gca* and *sca* effects were found highly significant for all the characters studied. The parents with medium genetic divergence combined with low or average *gca* effect resulted in high *sca* effects and exhibited high heterosis for the traits.

Nair *et al.* (2005) identified the good general combiners on the basis of their combining ability under Line × Tester mating design. The lines were found to be contributing towards variance for plant height while variances due to the testers were highly significant for all characters except days to maturity. The genotype- Rohini was identified as good general combiner for number of siliqua per plant. The cross combination Seeta × Rohini was found promising for yield and yield attributing traits.

Rai *et al.* (2005) observed higher values of *sca* estimates as compared to *gca* values for most of the traits including seed yield per plant, plant height, days to fifty percent flowering & maturity, siliqua length, seeds per siliqua, test weight and oil content. The partial dominance was identified based on average degree of dominance for various characters including seed yield per plant. Narrow-sense heritability were found associated with high values for seed yield per plant, length of main shoot, days to fifty percent flowering & maturity, number of secondary branches, plant height and oil content. However siliqua length was associated with low estimates of narrow sense heritability. Seven parents exhibited desirable *gca* effects. 43% of cross combinations were found associated with significantly positive specific combining effects with respect to seed yield per plant.

Singh *et al.* (2005a) studied combining ability and heterosis for seed yield and its attributing traits in Indian mustard cross combinations involving the eight genotypes. Pusa Bold, Pusa Barani, CM 3 and BR 40 were identified as good general combiners for seed yield per plant.

Singh *et al.* (2005b) evaluated 11 distinct types of Indian mustard and their F1 generation and identified best general combiner for seed yield and other attributing characters. The genotype- Prakash was established as best general combiner among various genotypes evaluated for seed & biological yield, Harvest Index and 1000 seed weight. None of the genotypes were found associated with desirable *gca* effects for seed & biological yield and Harvest Index. Additive genetic variance was found predominantly responsible for inheritance for plant height and biological yield. Non additive gene action played important role for other remaining characters.

Shweta *et al.* (2005) found significantly high *gca* and *sca* effects for all the traits studied. The study indicated predominance of non-additive gene action for all the traits along with over dominance. However, in case of the trait- oil content additive gene action along with partial dominance was indicated by the studies. Good general combiners were identified for various triats. Rohini was established as good combiner in general for various traits among the tester. The results favored the development of commercial hybrids in Indian mustard.

Nassimi *et al.* (2006) evaluated eight *Brassica napus* L. genotypes using diallel crosses. Highly significant differences were observed for all the traits on perusal of analysis of variance for genotypes. Components of combining ability analysis exhibited that, *gca* was significantly high for, number of siliqua on main shoot, days to fifty percent flowering and primary branches per plant, while non-significant for plant height and days to maturity. The *sca* and *gca* effects were highly significant for the traits studied. The additive gene effects were found showing important role for expression of the traits studied.

Turi *et al.* (2006) in their studies estimated relative heterosis and heterobeltiosis in Indian mustard genotypes. Significantly negative mid parent heterosis & heterobeltiosis were observed for days to fifty percent emergence, fifty percent flowering & physiological maturity along with plant height. The trait- number of primary branches exhibited significantly positive mid parent heterosis and heterobeltiosis. Among parents, four parents were found associated with significantly positive & desirable *gca* effects for most of the traits studied.

Kumar and Srivastava (2007) in their studies identified 7, 8, 14 and 15 crosses associated with significantly positive and desirable heterosis for seed oil content, siliqua length, number of primary branches per plant and seed yield, respectively. However none of the crosses exhibited economic heterosis for seed yield and oil content when compared with the standard check. The cross combinations- RSM 107 × Krishna, RSM 24 × RLG 8620, RN 26 × RJ 6, and RN 26 × RLC 8620 were found exhibiting heterosis over the better parent for seed yield along with significantly positive and desirable *sca* effects. The additive and non-additive gene actions were established as important factors governing inheritance of different characters studied but the the magnitude of contribution of non-additive gene action was found relatively high.

Nair *et al.* (2007) studied fifteen elite genotypes of mustard crossed with two testers in line × tester mating design. The F1's so generated along with parents were evaluated for heterosis with respect to yield and yield attributing traits. The cross combination *viz.*, vardhan × TM-17, Vardhan × Laxmi and vardhan × RL-1359 were found associated with significantly high heterosis for seed yield per plant.

Singh *et al.* (2007a) analyzed genetic divergence, combining ability and heterosis in nineteen *Brassica juncea* cultivars with respect to seed yield, its attributes and oil content. The data were analysed with Mahalanobis' D2 statistics to determine the genetic divergence. Highly divergent parents were selected and hybridized in a diallel mating design (without reciprocals) to produce 21 F_1 hybrids. The studies showed predominance of non-additive gene action and the possibility of exploiting heterosis. Five parents were identified as superior general combiners for seed yield and its attributing traits. Four crosses exhibited significant and desirable *sca* effects along with desirable heterosis. The parents having medium genetic divergence along with low or average general combining ability effects were found to induce high *sca* effects.

Singh *et al.* (2007b) observed significant differences for *gca* and *sca* effects. The studies indicated that both additive and non-additive gene actions were important for the inheritance of seed yield and other attributing traits. The parents corresponding to low and average combining ability had crosses exhibiting high *sca* effects for seed yield.

Singh and Dixit (2007) found positive association of *gca* effects with respective *per se* performance. The parental genotypes Pusa Bold, RH-30, RL-1359 and T-59 were identified as best general combiners for both seed yield per plant and seed oil content. The *sca* estimates for majority of the crosses were higher in the F1 than in the F2.

Akbar *et al.* (2008) evaluated 5 × 5 diallel cross of *Brassica napus* using combining ability analysis. Mean Squares for all the characters except for test weight were found significantly high for all the traits. RBN 96040 and KS-75 was identified as good general combiner for majority of the characters studied. The cross combination RBN 96040 × RBN 96038 followed by “RBN 96038 × DGL/Shiralee exhibited significant *sca* effects for all traits including seed yield per plant.

Aher *et al.* (2009) evaluated ten lines and four testers of Indian mustard and their crosses following Line × Tester mating design for determining combining ability and gene action. The ratio of variance estimates due to *gca* and *sca* indicated predominant role of non-additive gene action in inheritance of days to fifty percent flowering, number of secondary branches per plant, number of seeds per siliqua, oil content, test weight, siliqua number and seed yield per plant. The additive gene action was identified as predominant factor in inheritance of plant height, number of primary branches and length of main shoot. The parents involved in crosses that were either good × good, good × average, average × good and poor × poor combining parents were found linked with hybrids having high *per se* performance and significant *sca* effects for various traits. The parents with high *gca* effects did not seem compulsorily to exhibit high *per se* performance in respective cross combinations.

Gupta (2009) reported that six crosses involving the genotype EC – 289602 were found associated with high heterosis in six yield attributing traits *viz.*, days to fifty percent flowering, number of primary & secondary branches, number of seeds per siliqua, biological yield and Harvest Index.

Nigam and Richa (2009) used 10 parental genotypes of Indian mustard and crossed them in diallel fashion excluding reciprocals to generate 45 F1s. The cross combinations *viz.*, CSR-1017 × T-6342, RK-8601 × RK-8608, A-11 × B-85, T-6342 × B-85 and CSR-1017 × RK-8608, A11 × B-85, T-6342 × B-85 and CSR-1017 × RK-8901 exhibited significantly high and desirable heterosis for seed yield per plant, days to flowering, number of primary and secondary branches and dry matter per plant.

Chaudhary and Lal (2010) identified high heterotic cross combination along with their relationship in terms on *gca* and *sca* effects in Indian mustard carrying out half diallel analysis of eight parents. The cross combination IC-199715 × IC-199714 was found associated with high heterosis with respect to seed yield per 100 siliqua and days to fifty percent flowering. The cross EC-289602 × Pusa Bahar exhibited significantly high relative heterosis and heterobeltiosis for biological and seed yield per plant. The *gca* and *sca* variances were found significant for all traits studied.

Gupta *et al.* (2010) in their studies on *Brassica juncea* found highest standard heterosis and heterobeltiosis with respect to days to fifty percent flowering, number of primary branches per plant, Harvest Index, length of main shoot, number of siliqua on main shoot, biological yield and seed yield per plant. *gca* and *sca* variances were significant for most of the traits studied. The *gca* effects were more significant in days to fifty percent flowering & maturity and plant height whereas *sca* effects were more pronounced in seed yield and other attributing traits.

Turi *et al.* (2010) used 8 × 8 diallel design in *B. juncea* L. for identification of parents with good combining abilities for quality traits. The studies showed that *gca* was significantly high for oil percentage. Sca effects also exhibited highly significant values for all traits except for oleic acids. The *gca* effects were of greater degree than the *sca* effects for various quality parameters including glucosinolate, erucic acid and protein content. The study established the importance of both additive and non-additive gene action for various traits suggesting the use of integrated breeding strategies.

Turi *et al.* (2011) used diallel mating design to study general and specific combining ability in *Brassica juncea* for seed yield and other traits. ANOVA showed significant differences for all the traits. The mean square due to general combining ability was desirable for seed yield per plant and 1000 seed weight whereas it was no significant for siliquae per plant, siliqua length and seeds per siliqua. ANOVA analysis for specific combining ability (*sca*) was significant for all the traits except seeds per siliqua. Five genotypes *viz.,* MYT-123, MYT-117, MYT-009, MYT-120 and MYT-113 were identified as best general combiners whereas six cross combinations *viz.,* MYT-105 × MYT-103, MYT-113 × MYT-120, MYT-117 × MYT-123, MYT-123 × MYT-113, MYT-124 × MYT-117 and MYT-113 × MYT-009 were observed as best specific combiners for most of the traits.

Verma *et al.* (2011) on their studies on Indian mustard used 12 diverse female and 3 male parents in Line × Tester mating design for evaluation of seven quantitative traits. The inheritance of majority of the traits was established to be controlled by non-additive gene action. Four parents were identified as good general combiners for seed yield per plant. The 5 crosses were found associated with desirable *sca* effects for seed yield and its attributing traits. The cross combinations HUJM-05-1 × Kranti exhibited highest heterosis for seed yield to the extent of 80.97%.

Vaghela *et al.* (2011) studied heterosis and combining ability in Indian mustard using six parents in half diallel fashion. Analysis of variances was significant for all the characters under study. Most desired heterotic combinations were RSK 28 × RH (OE) 0103 and GM 3 × GM 1. ANOVA of *gca* and *sca* was significant for all the traits except oleic acid. Three crosses SKM 532 × GM 3, RSK 28 × RH (OE) 0103 and BPR 380-1 × RSK 28 were best for seed yield.

Azizinia (2012) used eight parental winter rapeseed genotypes in a complete diallel mating design 8 × 8 simple lattice design was used for evaluation of 56 diallel F_1 hybrids (with reciprocals) including their parents. The parental genotypes exhibited significant level of variation for all traits except seeds per siliqua. Significantly high *gca* and *sca* effects were observed for test weight, seed oil content and seed yield per plant. The Reciprocal effects so observed were found significantly different for seed oil content.

Arifullah *et al.* (2012) used 8 × 8 diallel system for crossing of eight diverse and desirable genotypes for combining ability analysis. The results for combining ability analysis indicated significant *gca* for most of the traits except length of siliqua and plant height. Desirable *sca* effects were associated with one cross combination for number of primary branches and siliqua per plant, while two cross combinations exhibited significantly high and desirable *sca* effects for test weight. Both of these cross combinations involved at least one of the promising general combiner parents.

Malviya *et al.* (2012) used 12 Indian mustard varieties and 3 testers in triple test cross analysis for studying heterosis for seed yield & its contributing traits along with seed oil content. Significantly positive and negative standard heterosis was observed for seed yield. Four crosses were identified with significantly high standard heterosis for seed yield per plant along with high mean performance. The study indicated the superiority of single crosses over three way crosses for seed yield per plant and its attributing traits.

Patel *et al.* (2012) conducted a study to estimate combining ability and heterosis using 10 diverse genotypes of Indian mustard and their forty five crosses using half diallel mating design. On the basis of perse performance one parent and one hybrid *viz.,* RK 9501 and RK 9501 × GM 2 found to be most promising for seed yield per plant. Significant differences were observed for general and specific combining abilities for majority of the traits under study. Four parents *viz.,* RK-9501, GM-1, GM-2, GM-3 and SKM-139 were most important general combiners. Six crosses namely, SKM -149 × PM- 67, GM -1 × GM- 3, GM- 1 × RK- 9501, SKM-139x PM -67, RK- 9501 × GM-2 and GM-3 × SKM -139 were found to be promising on the basis of *sca* effects.

Ramesh (2012) evaluated spring rapeseed to study combining ability and heterosis for plant height, seed yield and its contributing characters using six lines and two testers. The study revealed importance of non additive genetic actions for inheritance of number of seeds per siliqua and seed yield. Significant average heterosis was exhibited by the cross combinations for most of the traits except seeds per siliqua. The additive gene actions were established to play primary role for most characters except seeds per siliqua as indicated by high narrow-sense heritability estimates. The crosses involving atleast one parent with negative *gca* effects exhibited negative *sca* effects for plant height.

Gami and Chauhan (2013) investigated combining ability, gene action for four tester and six parental lines and their crosses. Two parents *viz.,* Pusa Bold and showed significantly positive *gca* effects and parental genotype PCR-7 was good general combiner for test weight. Crosses namely PCR-7 × Varuna and SKM-9820 × GM-2 exhibited highest *sca* effects and heterosis over better parent and standard parent.

Kumar *et al.* (2013) carried out diallel mating design excluding reciprocals. They used seven parents to identify the best heterotic combinations and relationship in terms of general combining ability and specific combining ability. Five crosses out of

21 crosses *viz.*, RK03-3 × RK03-4 (43.90%), RK03-2 × RK03-4 (34.55%), Varuna × RK03-4 (31.75%), RH-819 × RH-9801 (25.00%) and RH-819 × RK02-4 (24.22%) showed highest economic heterosis. ANOVA for *gca* and *sca* was significant except secondary branches per plant. On the basis of *gca* Varuna and RK-03-2 were the best parents along with high *per se* performance. Highest *sca* effects were exhibited by Varuna × RK03-4 and Varuna × RK03.

Saeed *et al.* (2013) used six *Brassica juncea* genotypes in 6 × 6 diallel design for studying heterosis and combining ability analysis. Significant differences were found among parental genotypes and the resulting cross combinations for all the traits as evident from the analysis of variance. The parents DP 18-9 and INDIA III were identified as best general combiners for most of the traits. The cross DP 7-91 × INDIA III exhibited significantly high *sca* effects for various traits including seed yield per plant. Both additive and non-additive gene action were established to play important role in the expression or inheritance of the traits under study.

Vaghela *et al.* (2013) did their study on six parents in half diallel fashion in India mustard and evaluated fifteen crosses with parent and standard check. The analysis of variance revealed that significant genetic variation existed for all the crosses and parents for all the traits. The cross RSK 28 × RH (OE) 0103 exhibited significant positive heterosis over the better parent and standard parent. The other best cross combination with respect to all three types of heterosis for days to 50 per cent flowering was RSK 28 × GM 3 and GM 3 × G 1 for days to maturity and SKM 532 × GM 1 for number of branches per plant.

Dholu *et al.* (2014) conducted 8 × 8 half diallel studies for combining ability and heterosis in Indian mustard. The presence of genetic variability among the parents was evident from the analysis of variance for combining ability. On the basis of *per se* performance and estimates of heterosis, the hybrids, IC-491446 × IC-560696, IC-560696 × Vardan and Laxmi × GM-2 were found to be most desirable and excelling for seed yield and other related traits as evaluated based upon the perse performance ans the estimates of the heterosis of hybrids. It was advocated for utilization of these crosses in future breeding programme to obtain desirable segregants for the development of superior genotypes along with further evaluation for exploitation of heterosis. The maximum positive and significantly desirable heterobeltiosis was exhibited by the hybrids IC-491446 × IC-560696 (45.31%), Laxmi × GM-2 (41.93%) and IC-560696 × Vardan (16.37%) for seed yield.

Chaudhari *et al.* (2015) studied combining ability and heterosis studies in nine mustard genotypes, their cross combinations and standard check. General combining results showed that GS 1 and PS 66 were two best combiners for seed yield and other traits. Three hybrids *viz.,* NDYS 53-1 × AA14 ,YSB 2001 × SSK 9203 and SPAN × SSK 9203 showed significantly positive *sca* effects for seed yield and other desired traits. Three cross combinations *viz.*, PS 66 × YSB 2001, GS 1 × YSB 2001 and GS 1 × YSB 4-2005 found to be significantly superior to the standard check.

Adhikari *et al.* (2017) conducted study on ten diverse Indian mustard genotypes using diallel mating excluding reciprocals. Heterosis studies indicated that there was prevalence of all three types of heterosis, most of the traits except plant height and Glucosinolates content. Crosses namely RRN-778xMaya, RRN-778xMaya and RB-57xMaya were desirable for early maturity, MayaxRMM-09- 4, RB-57xPM-25 and PRL-2012-13xDRMR-675-39 for seed yield and PRL-2012-13xRRN- 778, PRL-2012-13xRRN-778 and DRMR-675-39xMaya for oil content were most promising and desirable heterotic combinations.

Barupal *et al.* (2017) studied heterosis for 50 crosses generated from 10 lines and 5 testers revealed that cross combinations *viz.,* GM-3 × RGN-145, RGN-48 × Kranti and Gm-3 × Kranti was most early to flower and also had highest and negatibe heterosis and heterobeltiosis. Out of all fifty crosses most promising cross was RGN-48 × Kranti for various traits like days to 50% flowering, days to maturity, plant height, number of primary branches per plant and biological yield per plant.

Mohan *et al.* (2017) based on combining ability analysis found that Varuna, RK-9109, Pusa Jagannath and Kranti were good general combiners for oil content and other parents namely, RH-819, Pusa Bahar, Rohini and Kranti were good general combiners for seed yield per plant. Three crosses namely, Pusa Jagannath × Pusa

Bahar, Pusa Jagannath × Kranti and RH-819 × Kranti exhibited good specific combining ability effects as well as superiority over the check in terms of economic heterosis.

Tomar and Singh (2017) studied combining ability effects and found that parents *viz.*, Vaibhav, Varuna, Durgamani and Kranti were best general combiners for desired traits. Three crosses namely, Vaibhav × Mathura Rai, Pusa Jai Kisan × Pusa Agrani and KR-5610 × Pusa Agrani exhibited better specific combining ability effects in relation to seed yield. Economic heterosis was exhibited by Rohini × Mathura Rai, Maya × RK-9807, Pusa Bahar × Pusa Agrani, KR-5610 × Pusa Agrani and Pusa Jai Kisan × Pusa Agrani for seed yield per plant.

Chaurasiya *et al.* (2018) studied diallel analysis excluding reciprocals using seven parents. Three crosses *viz.*, NRCDR-2 × Urvashi, Urvashi × Pusa Bold, NRCHB-101 × Pusa M-21 , showed highest economic heterosis. ANOVA study revealed that General combining ability analysis was significant for all the traits and specific combining ability analysis exhibited significance for nine traits except days to maturity, plant height and biological yield per plant. Parents Urvashi and Pusa Bold had highest *per se* performance along with high *gca* depicting thema as the best parents. Six cross combinations namely Maya × NRCDR-2, NRCDR-2 × Urvashi, NRCHB-101 × Pusa M-21 Maya × Urvashi, Maya × Pusa Bold, and Urvashi × Pusa Bold exhibited highest *sca* effects along with high *per se* performance.

Dahiya *et al.* (2018) crossed six local germplasm lines and four released mustard varieties in half diallel fashion. Based upon combining ability data pertaining to *gca* five genotypes *viz.*, PRHC 17-1, RGN73, Maya, Kranti, PRHC13-14 were found to be best general combiners for seed yield. Thirteen crosses namely PWR 15-8 × PRHC 12-14, PWR 15-8 × Kranti, PRHC 17-1 × FS-14-24, PRHC 17-1 × PWR 15-8-1, PRHC 17-1 × RGN73, PRHC 17-1 × PRHC 13-14, FS-14-24 × Maya, PWR 15-8-1 × RGN73, PWR 15-8-1 × PM 25, RGN73 × Maya, RGN73 × Kranti, Maya × PRHC 12-14, PRHC 12-14 × PRHC 13-14 were good specific combiners for seed yield/plant based upon specific combining ability results. In case of better parents heterosis and economic heterosis twenty crosses and twelve crosses showed significantly desirable heterosis, respectively.

Gul *et al.* (2018) studied inheritance studies in *Brassica napus* for combining ability in F_1 Population by 8 × 8 diallel design. Significant differences was observed foe all the traits. Analysis of variance for Specific Combining ability and General Combining ability was highly significant for all the traits under study. Two parental genotypes namely, Punjab Sarson and Abbison were identified as best general combiners. Following hybrids *viz.,* Rustam Canola × Faisal Canola, Punjab Sarsoon × Dunkled and Dunkled × Rainbow showed significantly desirable results for *sca* and mean performance.

Kumar *et al.* (2018) observed combining ability effects in F_1 and F_2 generations of the crosses generated through half diallel mating. Two genotypes namely, Ashirwad and Vardan were best general combiners among the parents for various traits under study. Following crosses *viz.,* MK (L) 13-306 × MK (L) 13- 301, MK (L) 13-310 × MK (L) 13-308, MK (L) 13-307 × MK (L) 13-308, Ashirwad × MK (L) 13-301 and MK (L) 13-304 × MK (L) 13-303, MK (L) 13-306 × MK (L) 13-301 had significant specific combining effects.

Lal *et al.* (2018) conducted their study for combining ability using diallel mating in F_1 and F_2 generations. Analysis of variance for specific combining ability showed significant differences for all the traits which indicated presence of both additive and non-additive genes. Cross combinations namely, Vardan × RH-819 and Krishna × RH-30 showed highest significant *sca* effects for seed yield per plant. For oil content crosses namely, RH-819 × RH-9304 and Rohini × Vaibhav exhibited highest *sca* effects. Crosses *viz.,* Varuna × RH-9801 and Vaibhav × RH-30 and Rohini × RH-9304 showed desirable specific ability effects for earliness in flowering and maturity. RH-9304 × RH-30 and Rohini × RGN-19 exhibited superior specific combining ability effect for length of main raceme and number of siliqua on main raceme.

Singh *et al.* (2018) found significant differences among specific combining ability and general combining ability effects for almost all the traits. Both additive and non-additive interactions were observed due to high magnitude of general combining ability and specific combining ability. Four parents namely, CSR1020, CSR1027, CSR1066 and CSR1118 were found good general combiners for seed yield per plant, similarly twenty one crosses out of forty five crosses showed good specific combining effects.

Chaudhary *et al.* (2019) investigated combining ability in a set of 10 × 10 diallel cross combinations excluding reciprocals and found that analysis of variance for all the traits were significant except lenoleic acid and erucic acid in case of *gca* and *sca* except plant height, lenoleic acid and erucic acid. Parents GM-1 and GM-2 were good general combiners for seed yield and other desirable traits based on general combining ability studies. Similarly parents *viz.,* SKM-9033, RSK-28 and GDM-4 were good combiners for oil content. Desirable *sca* effects were exhibited by Crosses namely, GDM-4 × Dhara, GM-1 × Pusa Mustard-21 and GM-3 × LES-45.

Kaur *et al.* (2019) studied combining ability and heterosis using Line × Tester design. Significant differences were observed for general combining ability and specific combining ability effects. The parent IC-597919 was observed the best general combiner for majority of the traits. The hybrid namely, IC-597879 × IC-571648 showed most desirable results for seed yield/plant. Two cross combinations *viz.,* IC-597919 × IC-335852 and IC-589669 × IC-338586 on the base of *per se* performance and heterosis showed most promising estimates.

Malviya *et al.* (2019) studied heterosis and combining ability using fifteen lines and four testers in Indian mustard. Analysis of variance for *gca* and *sca* was significant for all the characters. Various crosses *viz.,* Pusa Karishma × NDRE-4, RK-08-1 × NDRE-4, PARASMANI-2-10 × NDRE-4 in E1 and RRN-631 × Basanti, TERIWRBJ-32-1 × Basanti, Sahib-36 × Basanti, Pusa Karishma × NDRE-4 showed significant heterosis over better parent and mid parent for seed yield and other desired traits. Five best crosses based on *sca* effects were Pusa Karishma × NDRE -4 (6.88), PRKS-28 × Basanti, BPR-1205-5 × Basanti, TERIWRBJ-32-1 × NDYR–8 & LET-14-1 × Basanti.

Singh *et al.* (2019) investigated combining ability and heterosis studies in Indian mustard. ANOVA revealed significant differences among the characters studied; *gca* effects showed that genotype IC-317528 was best general combiners among the parents. On the basis of mean performance and *sca* effects cross combination IC-589669 × IC-571683 sowed desirable results

Yadav *et al.* (2020) conducted an experiment using 7 × 7 diallel crossing design. Analysis of variance revealed significantly higher differences for all the traits among parents and crosses. Analysis of variance also showed significant differences for both *gca* and *sca* except Harvest Index in *gca* and days to maturity and Harvest Index for *sca*. Specific combining ability had higher values for all the characters than general combining ability except days to maturity and 1000 seed weight which showed that they were influenced by non- additive gene action. Parents namely Kranti, RLM-198, RGN-291 and Vardan were good general combiners for most of the traits. Eight cross combinations *viz.,* Kranti × NRCHB-101, Kranti × Ashirvad, NRCHB-101 × RLM-198, NRCHB-101 × RGN-291, RLM-198 × Ashirvad, RGN-291 × Ashirvad, RH-30 × Ashirvad and Vardan × Ashirvad showed significant and desirable heterosis over the check.

2.2 Nitrogen (N) concentration and uptake

Arora *et al.* (1994) obtained significantly higher seed yield of Indian mustard on N deficient soils of Gwalior, M.P., with each successive increment of N (0, 30, 60 and 90 Kg/ha) up to the highest level. Application of 90 Kg/ha of N (1460 Kg/ha) increased the seed yield by 50.5%, 27.0% and 7.4% over 0, 30 and 60 Kg/ha of N, respectively.

Deekshitulu *et al.* (1998) observed significant increase in seed yield of Indian mustard with successive increases in N doses up to 150 Kg/ha on N deficient soils at Bapatla. Nitrogen application of 150 Kg/ha resulted in 320%, 88.4% and 20.9% higher seed yield than control, 50 and 100 Kg/ha, respectively

Singh and Brar (1999) observed significant response of N application up to 150 Kg/ha in Indian mustard grown on loamy sand, low in available N soil was discerned siliqua per plant, seeds per siliqua and test weight and up to 100 Kg/ha of N for seed yield compared to lower doses Thus application of 100 Kg/ha of N resulted in 107.5% and 21.2% higher seed yield than control and 50 Kg/ha of N, respectively.

Bhari *et al.* (2000) observed significant increase in plant height of Indian mustard with application of N up to 120 Kg/ha on sandy soil testing low in nitrogen.

Garnayak *et al.* (2000) reported slight increase in oil content with N application of 40 Kg/ha (38.3%) over control (38.0%) and decrease with further increase in N doses to 80 (37.7%) and 120 Kg/ha (37.2%). They also observed significant increase in N uptake with N application up to 120 Kg/ha. He also reported that Plant height of Indian mustard and Ethiopian mustard (*Brassica carinata*) significantly increased with increase in N doses from 0 to 120 Kg/ha.

Kandpal (2001) reported increase in plant height and dry matter production of rapeseed-mustard at different growth stages with N application up to 120 Kg/ha.

Meena *et al.* (2001) reported significant increase in N content in seed and total N uptake by crop (74.2 Kg/ha) with 90 Kg/ha of N compared to control (48.7 Kg/ha), 30 (61.3 Kg/ha) and 60 Kg/ha of applied N (70.1 Kg/ha).

Singh *et al.* (2002) conducted study on N deficient soil and reported that number of branches per plant, number of siliquae per plant, seeds per siliqua and seed yield increased up to 120 Kg/ha of N.

Rana and Rana (2003) found an increase in total N uptake by Indian mustard at maturity from 34.2 Kg/ha with control to 52.2, 76.4, 90.2 and 97.3 Kg/ha with N application of 20, 40, 60 and 80 Kg/ha, respectively.

Singh and Meena (2003) reported favourable effect of N fertilization up to 40 Kg/ha on oil content of Indian mustard beyond which there was progressive reduction in oil content.

Singh and Prasad (2003) observed significant improvement in N content and uptake in seed (3.51%, 71.7 Kg/ha), stover (0.59%, 7.4 Kg/ha) and stick (0.59%, 26.2 Kg/ha) of Indian mustard with application of 120 Kg/ha of N over that of 60 Kg/ha.

Dongarkar *et al.* (2005) reported that application of 75 Kg/ha of N resulted in significant increase in the plant height, LAI and dry matter production of Indian mustard over N application of 25 Kg/ha and control but remained at par with 50 Kg/ha of N at Nagpur.

Singh and Singh (2005) also observed significant reduction in oil content with increasing doses of N up to 120 Kg/ha.

Thakur *et al.* (2005) reported that application of 120 Kg/ha of N resulted in significantly higher number of primary and secondary branches and siliquae per plant and seeds per siliqua of Indian mustard over 60 Kg/ha of N, whereas, increase in seed yield with 120 Kg/ha (1592 Kg/ha) over 90 (1416 Kg/ha) and 60 Kg/ha (1187 Kg/ha) of N was significant.

Sah *et al.* (2006) observed significant increase in N uptake by seed and stover of Indian mustard at maturity up to highest dose of 120 Kg/ha of N (42.0 Kg/ha) which resulted in 16.8 and 4.1 Kg/ha higher total N uptake than 40 and 80 Kg/ha of applied N, respectively.

Kumbhare *et al.* (2007) reported that application of 62.5 Kg/ha of N resulted in the significantly higher N uptake (47.8 Kg/ha) compared to its lower doses *viz.,* 25.0, 37.5, and 50.0 Kg/ha.

Yadav *et al.* (2007) reported significantly more number of primary as well as secondary branches and siliquae per plant, and seed yield of Indian mustard with application of N up to 120 Kg/ha. However, seeds per siliqua, 1000-seed weight and Harvest Index were comparable between 90 and 120 Kg/ha of N. Seed yield with application of 120 Kg/ha of N (1700 Kg/ha) was 50.0%, 58.9% and 26.9% higher than that obtained with 30, 60 and 90 Kg/ha of N, respectively.

Kumar and Kumar (2008) observed significant effect of increasing doses of N from 60 to 140 Kg/ha in reducing the number of days required for 50% flowering and 50% pod formation. However, number of days to maturity was not influenced by N application.

Sandhu (2010) in his experiments conducted at 9 locations reported that the Indian mustard hybrid (DMH 1) responded to N application up to 125 Kg/ha. Application of 125 Kg/ha of N resulted in significant improvement in yield attributes and seed yield of Indian mustard than 100 Kg/ha of Nitrogen.

Keivanrad and Zandi. (2014) conducted a field experiment at faculty of Agriculture Takestan Iran under split plot design and found that highest seed yield and oil content was obtained at 200 Kg N/ha. Maximum oil content was observed in nitrogen level 50 Kg N/ha and lowest plant densities.

Raghuvanshi *et al.* (2018) conducted a field experiment on different nitrogen levels in Indian mustard and found that maximum seed yield was obtained at 120Kg per hectare nitrogen in variety NDRI-8501. The increase in seed yield was due to increase in number of siliquae, seeds per siliqua, test weight.

MATERIAL AND METHODS

This chapter contains the detail of materials used and methods adopted in the present study entitled "Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss." are characterized downwards with following headings:

- Experimental material
- Location and description of experimental plot
- Experimental layout
- List of genotypes
- Observations recorded
- Statistical analysis

3.1 Experimental material:

The experimental material for the present investigation consisted of 56 genotypes of Indian mustard including one check for divergence study and 45 F_1 s + 10 parents along with one check for yield and oil quality traits.

3.2 Location and description of experimental plot:

The experimental site was situated at the experimental farm of school of Agriculture Lovely Professional University Jalandhar Phagwara. The experimental plot had sandy loam soil with fairly uniform topography and normal fertility status. The plot is well drained and assured irrigation facility.

3.3 Experimental Layout:

3.3.1 Experiment 1: Ten diverse genotypes were selected and sown to generate 45 F_1s materials through crossing during *Rabi* 2017-18 with half diallel mating design. Three rows of five meter length were prepared for each plot. The distance between row to row was 30 cm and 10 cm was the distance kept between plant to plant. The spacing between plants was maintained at 10 cm by thinning of extra plants only 10 days after emergence. Diallel mating design without reciprocals was adopted for crossing of the parental genotypes.

3.3.2 Experiment 2: 45 F_1s and 10 parents along with one standard check variety were evaluated in alpha lattice design with two replications in Rabi 2018-19 under various nitrogen levels *viz.*, Control, 75Kg/ha and 150 Kg/ha. Each plot consisted of two rows of 1.5 meter length. The row to row and plant to plant distance was kept as 30cm and 10cm, respectively

3.3.3 Date of sowing

a. During *Rabi* 2017-2018 the seeds were line sown on 24th Nov. 2017.

b. During *Rabi* 2018-2019 the seeds were line sown on 26th Nov. 2018.

3.3.4 Layout details

The details of the field layout are given below:-

Season	Gross Area	Net Area
Rabi 2017-18	50 m^2	45 m^2
Rabi 2018-19	320 m^2	305 m^2

3.3.5 Fertilizer Application

a. Recommended fertilizer dose:- P_2O_5: K_2O 40:40 Kg/ha.

b. Nitrogen Doses-: Controlled condition**;** 75Kg/ha and 150Kg/ha

The recommended fertilizer dose of P_2O_5 and K_2O along with respective 50% Nitrogen dose under each condition was applied as basal dose. The remaining Nitrogen quantity was applied 40 days after date of sowing.

3.3.6 Irrigation

Thin film of water was given 2 weeks after sowing. During the latter part of the crop growth, irrigation was then given as and when required up to physiological maturity.

3.3.7 Intercultural operations

Intercultural operations like thinning was done only once for the entire crop life, 3 weeks after sowing. Manual weeding was done regularly as soon as they sprung up.

3.3.8 Pest management

Lipaphis erysimi Kaltenbach, (Aphididae: Homoptera), commonly known as mustard aphid was controlled by spraying with the insecticide Imidacloprid 17.8% SL @ 0.25 ml/litre at 50 and 70 days after sowing.

3.3.9 Harvesting

The entries were harvested at physiological maturity.

3.4 List of genotypes

The ten genotypes which were used for crossing in the research endeavour are enlisted in Table 3.1. The layout of the crossing plan through half diallel mating design without reciprocals is given in Table 3.2. The crosses so generated are presented in Table 3.3. Varuna was used as a standard check. The 45 F_1s so generated along with 10 parental genotypes and standard check were evaluated using alpha lattice design, the layout of which is presented in Table 3.4.

Table 3.1: List of genotypes used for crossing

S.No	Genotype	Source
1.	Jumka	DRMR Bharatpur
2.	RNG-73	DRMR Bharatpur
3.	Pusa Mustard-28	DRMR Bharatpur
4.	Gujarat Mustard-3	DRMR Bharatpur
5.	ZEM-1	DRMR Bharatpur
6.	DRMR-1	DRMR Bharatpur
7.	NRCHB-101	DRMR Bharatpur
8.	RH-30	DRMR Bharatpur
9.	TM-4	DRMR Bharatpur
10.	KBS-3	DRMR Bharatpur

Table 3.2: Layout of half diallel crossing plan without reciprocals (10 × 10)

S.No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	×	1x2	1x3	1x4	1x5	1x6	1x7	1x8	1x9	1x10
2		×	2x3	2x4	2x5	2x6	2x7	2x8	2x9	2x10
3			×	3x4	3x5	3x6	3x7	3x8	3x9	3x10
4				×	4x5	4x6	4x7	4x8	4x9	4x10
5					×	5x6	5x7	5x8	5x9	5x10
6						×	6x7	6x8	6x9	6x10
7							×	7x8	7x9	7x10
8								×	8x9	9x10
9									×	9x10
10										×

Table 3.3: List of crosses used in the experimental studies

S.No	**CROSSES**	**S.No**	**CROSSES**
1.	Jumka × RNG-73	24.	Pusa Mustard-28 × KBS-3
2.	Jumka × Pusa Mustard-28	25.	Gujarat Mustard-3 × ZEM-1
3.	Jumka × Gujarat Mustard-3	26.	Gujarat Mustard-3 × NRCHB-101
4.	Jumka × ZEM-1	27.	Gujarat Mustard-3 × DRMR-1
5.	Jumka × DRMR-1	28.	Gujarat Mustard-3 × RH-30
6.	Jumka × NRCHB-101	29.	Gujarat Mustard-3 × TM-4
7.	Jumka × RH-30	30.	Gujarat Mustard-3 × KBS-3
8.	Jumka × TM-4	31.	ZEM-1 × DRMR-1
9.	Jumka × KBS-3	32.	ZEM-1 × NRCHB-101
10.	RNG-73 × Pusa Mustard-28	33.	ZEM-1 × RH-30
11.	RNG-73 × Gujarat Mustard-3	34.	ZEM-1 × TM-4
12.	RNG- 73 × ZEM-1	35.	ZEM-1 × KBS-3
13.	RNG-73 × DRMR-1	36.	DRMR-1 × NRCHB -101
14.	RNG-73 × NRCHB-101	37.	DRMR-1 × RH-30
15.	RNG-73 × RH-30	38.	DRMR-1 × TM-4
16.	RNG-73 × TM-4	39.	DRMR-1 × KBS-3
17.	RNG-73 × KBS-3	40.	NRCHB-101 × RH-30
18.	Pusa Mustard-28 × Gujarat Mustard-3	41.	NRCHB-101 × TM-4
19.	Pusa Mustard-28 × ZEM-1	42.	NRCHB-101 × KBS-3
20.	Pusa Mustard-28 × DRMR-1	43.	RH-30 × TM-4
21.	PusaMustard-28 × NRCHB-101	44.	RH-30 × KBS-3
22.	Pusa Mustard- 28 × RH-30	45.	TM-4 × KBS-3
23.	Pusa Mustard- 28 × TM-4		

Table 3.4 : Layout plan for Alpha Lattice Design (7 × 8)

Block	Replication ×							
x1	6	20	10	35	13	21	36	33
x2	24	7	22	31	15	16	53	1
x3	14	45	3	55	30	56	2	42
x4	47	32	17	25	38	5	29	23
x5	27	41	50	26	34	19	40	52
x6	51	28	44	43	9	46	18	49
x7	54	12	48	8	11	39	37	4
	Replication Y							
Y1	15	3	37	52	25	12	9	27
Y2	43	4	38	22	6	1	55	36
Y3	42	40	51	5	49	35	7	48
Y4	39	44	45	13	2	34	47	31
Y5	18	21	8	28	32	24	50	56
Y6	41	54	17	53	19	30	23	20
Y7	10	26	46	14	33	29	16	11

3.5 Observations recorded:

From each treatment, observations for all traits were recorded on five randomly marked competitive plants from each replication except for days to flower initiation, days to 50 % flowering, days to maturity and other quality traits *viz.*, seed oil content (%), seed and chaff nitrogen content (%). observations from the five plants were taken & averaged, replication wise and the mean data so obtained was subjected to statistical analysis using Indostat, SAS and .PBtool softwares. The strategy used for taking observations of various characters are described below

3.5.1 Days to Flower Initiation-

The number of days counted from the sowing date of material till the first flower initiation was recorded for each replication of the treatments.

3.5.2 Days to Fifty Percent Flowering

The genotypes were closely observed from the date of sowing to the initiation of flower blooming in 50 % of the plants in each replication of the treatment and the number of days were recorded.

3.5.3 Days to Maturity

The number of days taken from the time of sowing of seed to the time of physiological maturity, for each entry, in each replication were recorded.

3.5.4 Plant Height (cm)

Plant height was measured in centimeters from the ground level to the top of the primary mother axis of plant at the time of maturity.

3.5.5 Number of Primary Branches per Plant

The total number of branches which emerged from the main shoot of the plant was counted and the average of five plants was taken for each replication.

3.5.6 Number of Secondary Branches per Plant

The total number of branches emerging from the primary branch was counted and the average of five plants was taken for each replication..

3.5.7 Length of Main Shoot (cm)

It was measured from the point where last primary branches arises to the top of the primary mother axis of plant at the time of maturity.

3.5.8 Number of Siliquae on Main Shoot

The total number of siliquae emerging from the main shoot was counted and the average was taken.

3.5.9 Siliqua length (cm)

Length of the siliqua was recorded by measuring from the base to tip of the siliquae.

3.5.10 Number of Seeds per Siliqua

The number of seeds per siliquae was counted from five randomly selected siliquae of the five randomly selected plants from each genotype in each replication and averaged.

3.5.11 1000 Seed Weight (g)

1000 seeds from bulk stock of each test entries were taken and weight at 5-6 percent moisture content ‘wet weight’ as according to ISTA rule in triplicate and average 1000 seed weight was worked out in gram.

3.5.12 Seed Yield per Plant (g)

The total seeds obtained by manual threshing from each five randomly selected plants were weighed in gram, and averaged.

3.5.13 Biological Yield per Plant (g)

Biological yield of five randomly selected plants was recorded in gram separately and averaged for each replication before threshing.

3.5.14 Harvest Index (%)

It was recorded as the ratio of economic yield to the biological yield in per cent. Harvest index was calculated by following formula (Donald and Hamblin, 1976).

$$\text{H.I} = \frac{\text{Economic Yield}}{\text{Biological yield}} \times 100$$

Where, Economic yield = Grain yield (g) & Biological yield = Total plant yield (g)

3.5.15 Seed Oil Content (%)

Oil content was estimated on dry seed basis by non-destructive method using Foss-tecator near-infrared reflectance spectroscopy (FT-NIRS) product analyzer at Lovely Professional University, Jalandhar. Over 4g seeds of each intact sample were *sca*nned in a 36 mm inner-diameter ring cup. Such five observations were taken and averaged out.

3.5.16 Nitrogen (N) concentration and uptake

Nitrogen concentration (%) in plant samples taken at periodic intervals at different growth stages and seed and stover at harvest was determined by modified micro-Kjeldahl method proposed by Subbiah and Asija (1956). To determine N content, 0.5 g oven dried sample of from each treatment was subjected to wet digestion using 10 ml concentrated sulphuric acid (H_2SO_4) plus pinch of digestion mixture (potassium sulphate + copper sulphate +

selenium powder). Digested material was taken in 50 ml volumetric flask and volume was made to 50 ml by adding distilled water. In a distillation flask of micro-Kjeldhal assembly, 5 ml of distilled sample was taken and 10 ml of sodium hydroxide (NaOH) was poured into tube. Flask containing 5 ml boric acid was kept under the delivery tube until the appearance of green colour. Then distilled sample was titrated against N/50 sulphuric acid until appearance of purple colour. Volume of N/50 sulphuric acid used was recorded for N content calculation. Nitrogen uptake for seed and stover (g) at harvest was determined by multiplying per cent N content in known weight of plant sample at particular growth stage with respective dry matter accumulation at that particular stage

3.6 Statistical Analysis:

3.6.1 Analysis of variance (ANOVA)-

The analysis of variance was worked out to test the differences among genotypes It was carried out according to the procedure of quasi-factorials or lattice design for each character as per methodology advocated by Yates (1936). ANOVA helps in partitioning the total variance into three component *viz.*, replication, treatment and error.

Source of variance	**Df**	**Sum of Squares**	**Mean sum of squares**	**F**
Replicates	r-1	SSr	MSr	
Blocks (within replicates, ignoring treatments)	rs-r	SSb	MSb	F0
Treatments (adjusted for blocks)	t-1	SSt	MSt	
Error	rt-rs-t+1	SSe	MSe	
Total	n-1	SSc	-	-

The linear model of observations in alpha design is of the form

$$y_{ijk} = m + t_i + r_j + b_{jk} + e_{ijk}$$

where *yijk* denotes the value of the observed trait for i^{th} treatment received in the k^{th} block within j^{th} replicate (superblock), *ti* is the fixed effect of the i^{th} treatment ($i = 1,2,\ldots,t$); r*j* is the effect of the j^{th} replicate (superblock) ($j = 1,2,\ldots,r$); b*jk* is the effect of the k^{th} incomplete block within the j^{th} replicate ($k = 1,2,\ldots s$) and *eijk* is an experimental error associated with the observation of the i^{th} treatment in the k^{th} incomplete block within the j^{th} complete replicate.

3.6.2 Student's T test

To test whether the mean difference between nitrogen treatment for respective traits is significant or not when compared with control, student's t-test was performed as:

$$\text{Student's t-test} = \frac{\overline{X}_d}{SE(X_d)} \quad \text{(at n – 1 d.f.)}$$

Where

$\overline{X}_d$	=	mean-difference between two sets of related samples
SE (x_d)	=	Standard error of mean difference
n	=	Number of related samples

3.6.3 Analysis of variance over the environments

Observations recorded for different characters in two replications were pooled for each environment. Pooled plot means were subjected to pooled analysis of variance in alpha Lattice design.

Source of variation	df	Mean square	F-value
Replication (r)	(r-1)	MS1	
Environment (n)	(n-1)	MS2	MS2/MSe
Genotype (g)	(g-1)	MS3	MS3/MSe
Environment × Genotype (n × g)	(n-1) × (g-1)	MS4	MS4/MSe
Error	n(g-1) (r-1)	MSe	

For F-test each MS was tested against MSe and compared with the table value of F at respective degree of freedom for treatment, environment and environment × treatment. Standard error of mean (SEm±) and coefficient of variation (CV) was calculated as follows:

$$SEm\pm = (MSe/r)^{1/2}$$

$$SEd\pm = (2\ MSe/r)^{1/2}$$

$$CV\ (\%) = \frac{SD}{\bar{x}} \times 100$$

Where,

MSe = Error mean square

r = Number of replications

$\bar{x}$ = Mean of the character

SD = Standard deviation

3.6.4 GGE biplot for environmental group differentiation and environment/genotype evaluation

The GGE biplot methodology (Yan and Hunt 2002; Yan *et al.* 2000) explains the variation due to genotypes main effect and genotype × environment interactions. A PB tool application was used to construct the GGE biplot. The environment-centered Indian mustard trait means for each group and across all group were subjected to singular value decomposition so as to obtain the principal components. The Principal component-1 & 2 were used for the construction of GGE biplot. The GGE biplot so obtained provided information on the cultivars that were suitable for the different environments and identification of the mega-environments.

The GGE biplot Model 1 equation used is as follows:

$$Y_{ij} - \beta_j = \lambda_1\xi_{i1}\eta_{1j} + \lambda_2\xi_{i2}\eta_{2j} + \varepsilon_{ij}$$

Where, Yij = Observed mean of genotype *i* in environment *j*

B_j = Average yield across all genotype in environment *j*

λ_1 and λ_2= Singular values for PC1 and PC2, respectively

ξ_{i1} and ξ_{i2} = PC1 and PC2 scores, respectively for genotype *i*

η_{1i} and η_{2j} = PC1 and PC2 scores, respectively for environment *j*

ε_{ij} = Residual of the model associated with the genotype *i* in environment *j*

Based on above mentioned principles of GGE Biplot, graphs for two way tables for seventeen characters were plotted and interpreted in following way:

1. **Environmental evaluation** :- To study the relationship/correlation between the environments and identify the power of discrimination & representativeness of specific target environment.
2. **Mega-environment analysis** :-To identify specific genotypes that performed desirably in a specific mega-environments (Yan and Tinker 2006).

3.6.4.1 Environmental Evaluation

To know the relationship between different environments within each group and across the groups (three environments), the biplot were constructed by using mean Indian mustard traits for each group (averaged over environments within that group) and across groups, respectively. This function of GGE biplot is approximately equal to the genetic correlation between the environments (Ding *et al.* 2008). The cosine of the angle formed between the vectors of the environment is proportional to the correlation between the respective environments. An angle of zero between the vectors indicates existence of correlation of +1 whereas; the angle of 90 degree or - 90 degree denotes a correlation of zero. On the other hand an angle of 180 degree between the environmental vectors in the GGE biplot depicts a correlation of -1. The ideal environment for testing should have PC1 value and of the same sign and PC2 near zero depicting power of discrimination and close representativeness of the environment mean) (Yan *et al.* 2000).

"Discriminativeness and representativeness" is another tool for evaluation of test environments. The concentric circles on the biplot help to visualize the length of the environment vectors can be measured or visualized with help of concentric circles provided in the GGE biplot. The length of the environmental vector is a measure of discriminating ability of environment as it is directly proportional to the standard deviation of that specific environment. The non-informative test environments have shorter vector length which represents non-discriminativeness and so should not be used for testing as give very less information on the genotypes.

For representativeness of test environments, an average environmental axis (AEA) is drawn from the centre. The average coordinates of the selected environments are represented in the average environment. This axis is the line that passes through the biplot origin and the average environment. The environment whose vector forms smallest angle with the average environmental axis is deemed to be more representative in comparison to the other test environments. For identification and selection of generally adapted genotypes, such environments having good discriminativeness and representativeness are used as test environments. On the other hand, specifically adapted genotypes are selected by use of test environments that discriminating but are non-representative. Such environments can also be used for removal of unstable genotypes if the target environment falls under a single mega environment. The environments with short vector are very less useful due to their non discriminate nature as provide very little differential information about the genotype.

3.6.4.2 Mega-Environment Analysis

For differentiation of three environments into similar environmental groups, the "which-won-where" pattern of GGE biplot was used. The decision as to whether each group of conditions could be considered as representative of an environmental group was based on the similarity of grouping of winning genotypes across environments (Yan *et al.* 2000; Yan *et al.* 2007).

Subsequently, the data on mean Indian mustard yield of three environments were subjected to GGE biplot analysis to get detailed the G × E interactions. A polygon is drawn by connecting the genotypes which are located far from the biplot origin in a way that all other genotypes fall inside the polygon. This is done so as to envision the performance of the genotype in specific environment. Then perpendicular lines are drawn from the biplot origin to the sides of the polygon so formed. These perpendicular lines also called as equality lines divide the biplot graph into different sectors. The genotypes which are located on the ends of polygon (vertex) are the best performing genotypes in one or more environments that are located inside the same sector those genotypes that fall inside the sector perform poor as compared to the genotypes situated in the vertex. Thus based on which genotype won in which environment, the different environmental groups were identified sharing similar group of winning genotype.

3.6.5 Analysis of variance for combining ability (diallel)

Mean value of 55 entries (parents and hybrids) were subjected to combining ability analysis by indostat according to the procedure given by Griffing (1956a) as per Method II (in which parents and a set of F1s without reciprocals are included) and Model I [which assumes that the genotypes and block effects are constant (fixed) but environmental effect is variable].

The combining ability analysis was carried out as per the method suggested by Griffing (1956 a,b) Method- II, Model-1 which assumes that variety and block effects are constant (fixed).

$Yijk = \mu + gi + gj + sij + [1/r]\ \Sigma\ eijk$

Where,

Yijk = Performance of hybrid of ijth cross in kth replication,

i, j = 1, 2, 3, ………..P (Number of parents)

k = 1, 2, 3, ………..b (Number of replications)

μ = General mean,

gi = *gca* effect of i^{th} parent,

gj = *gca* effect of j^{th} parent,

sij = *sca* effect of the cross between i^{th} and j^{th} parents,

eijk = Environmental effect pertaining to ijk^{th} observation.

Based on this model, the analysis of variance for combining ability is done as shown below.

Source	Df	S.S	M.S.S	E.M.S
gca	(p-1)	S_g	Mg	$\sigma^2 e + (p+2) \frac{1}{(P-1)} \sigma_i\, g^2 i$
sca	P(p-1)/2	S_s	Ms	
				$\sigma^2 e + \frac{2}{(p(p-1)} \sigma_I \leq \sigma_j\, S^2_{ij}$
Error	(g-1) (r-1)	S_e	Me	

Where,

p = Number of parents,

G = Number of progenies,

Sg = Sum of squares due to general combining ability,

Ss = Sum of squares due to specific combining ability,

Yi = Array totals of i^{th} parent,

Yii = Mean value of i^{th} parent,

Y… = Grand total, parents and half diallel matrix,

Yij = Mean value of ij^{th} cross,

Me = Error mean square in the analysis of the experimental design

R = Number of replications

Me was used for calculation of variance ratio (F) as a test of *gca* and *sca* mean squares.

Genetic component of variance were estimated as under:

Variance due to *gca* ($g\, i^2$) = (Mg – Me') × (p/p+2)

Variance due to *sca* (sij^2) = (Ms – Me')

3.6.6 Estimates of general and specific combining ability effects

The *gca* and *sca* effects were calculated by applying the following formulae.

gca effect g i = 1/(p+2) [Σ (Yi. + Yii) –2/p Y ..]

sca effect s ij = Yij –1/(p+2) [Yi. + Yii + Y.j + Yjj] + 2/(p+1)(p+2) Y..

Where,

Yi. + Yii = Total of i^{th} array + mean value of parent i

Y.j + Yjj = Total of j^{th} array + mean value of parent j

The estimation of standard errors of general combining ability and specific combining ability effects were obtained as under:

S.E. (gi) (to test individual *gca* effect) = $[(p-1)\ \sigma\ 2\ e/p(p+2)]1/2$

S.E. (sij) (to test individual *sca* effect) = $[p(p-1)\ \sigma\ 2\ e/(p+1)(p+2)]1/2$

S.E. (gi - gj) (to test the difference between two *gca* effects) = $[2\ \sigma\ 2\ e/(p+2)]1/2$

S.E. (sij - sik) (to test the difference between *sca* of the same array or column) = $[2\ \sigma\ 2\ e/(p+2)]1/2$

S.E. (sij - skl) (to test the *sca* of any two crosses) = $[2\ p\ \sigma\ 2\ e/(p+2)]1/2$

Where,

p = Number of parents

σ 2 e = Error mean square (Me)

Each *gca* and *sca* effects were subjected to't' test for testing of significance.

't' test for *gca* = (gi – 0) / S.E. (gi)

't' test for *sca* = (sij – 0) / S.E. (sij)

Since error degree of freedom is greater than 30, the value of calculated 't' is regarded as significant if it exceeds 1.96 and 2.58 at 5 per cent and 1 per cent levels of significance, respectively.

Alternatively *gca* and *sca* effects were compared with critical difference calculated by following formula:

C. D.(gi) = S.E.(gi) × table $t_{0.05}$ and $t_{0.01}$

C. D.(sij) = S.E.(sig) × table $t_{0.05}$ and $t_{0.01}$

3.6.7 Hayman's graphical analysis

The graphical analysis and components of genetic variance was done according to Hayman (1954). The genetic basis of differences in various traits was estimated by use of diallel analysis technique developed by Hayman (1954) and Jinks (1956) (used by Mather and Jinks, 1982) which helps in understanding the basis of the inheritance mechanism (*viz.*, complete dominance, partial dominance and overdominance) for various characteristics. This approach provides the information about the type of gene action which is predominant in inheritance of specific traits. In addition, the analysis also provides information about the proportion of +ve and –ve genes, distribution of dominant and recessive alleles among the parental genotypes, and their ratio. It also tells about the degree of dominance and the presence or absence of gene interactions.

Hayman's additive-dominance model is generally used for estimation of the type of genetic behaviour and determination of the basis of genetic variations. The genetic variance is divided into additive (a), non-additive (b), maternal (c) variance and variance due to non maternal reciprocal effects (d) components. Non-additive component (b) is further partitioned into b1, b2 and b3. All the components were tested against their interaction with the blocks. The smaller components of non-additive component *i.e.* b1, b2 and b3, were tested for homogeneity of their interaction with the blocks. In case the interaction is found homogeneous, all three sub components were tested against (b × blocks) interaction. On the other hand, if the interactions so found were heterogeneous, the sub components of the non additive component were tested against self interactions. The test for homogeneity was also applied upon the interactions of main components with blocks. The main components were added on presence of homogeneous interactions and they were tested with help of the combined error so obtained. The additive and dominant gene actions were indicated by the presence of significant results for the components a (additive) and b (non-additive), respectively. The significant values of b also indicated for use of *Wr*, *Vr* approach (Hayman, 1954) for analysis of data for obtaining dominance ratio. The unidirectional dominance, asymmetrical dominance of genes, specific gene action were evident from significant values of b1, b2 and b3, respectively. The maternal reciprocal effects were indicated by the Significant values of c. The reciprocal effects due to non maternal reasons were depicted by significant values of d.

3.6.7.1 Estimation of genetic parameters

The genetic parameters were determined as described by Hayman (1954) to establish the adequateness of the components with additive dominance model. The environmental variance (E) represents the average shifting of all genotypes due to environmental regions from the point of origin. h2 is the overall dominant effect of heterozygous loci which is estimated as the algebraic sum of heterozygous loci in all the crosses. The mean degree of dominance $\{(H1/D)^{1/2}\}$ tells about the type of dominance. If the value exceeds one, the trait is governed by overdominance whereas if the value is located between zero and one, partial dominance plays predominant role for inheritance of that traits. H2/4H1 represents the proportion of genes in the parents exhibiting positive and negative effects and have maximum value 0.25. A value less than 0.25 signify the unequal distribution of alleles. The perfect value of 0.25 indicates an equal distribution of positive and negative alleles over the loci.

Genetic Parameters	**Symbols**	**Formulae**
Environmental variance	E	{(ESS+RSS)/Edf+Rdf)}/nR
Additive variance	D	VOLO1 – E
Variation due to dominant effect of genes	H1	VOLO1 – 4WOLO1 + 4V1L1- E(3n-2/n)
Variation due to dominant effect of gene correlated with gene distribution	H2	4V1L1-4VOL1-2E
Over all dominant effect of heterozygous loci	h2	4(ML1-MLO)2 – 4(n-1)E/n2
Relative frequency of dominant to recessive alleles	F	2VOLO1 – 4WOLO1 -2(n2)E/n
Mean degree of dominance		(H1 / D) ½
Proportion of genes with positive and negative effect in the parents		H2 / 4H1
Proportion of dominant and recessive genes in the parents	KD/KR	(4DH1) 1/2+ F/(4DH1)1/2 –F
The number of groups of genes which control the character and exhibit dominance		h2/H2
Narrow sense heritability	h2 ns	½ D + ½ H1 -½H2 -½F / ½D +½ H1 –¼ H3 -½F + E1

KD/KR ratio depicts the proportion of dominant and recessive alleles in the parents. If this ratio is greater than one, excess of dominant genes are present in the parents. More recessive alleles are evident from less than unity values for this ratio. h2/H2 is based on the assumptions that positive and negative effects bearing alleles are equally frequent at all the loci with unidirectional dominance.

3.6.7.2 Components of genetic variance and graphical analysis under various Nitrogen levels

The crosses were arranged in arrays and diallel tables were utilized for setting up F*1* values. The diallel table for each trait was used for calculation of variance (*Vr*) of the family means with an array and covariance (*Wr*) of means with no non-recurrent parents.

This can be presented as:

Variance of family means with an array

Var (Vr) = [Σx2 - (Σ ×)2/n] / (n-1)

Covariance of these means with non-recurrent parent

Var (Wr) = [Σ × y - (Σx . Σy)/n] / n – 1

The information about the type of gene actions, diversity among parents by virtue of scattering of arrays, existence of epistasis and knowledge about the distribution of dominant and recessive alleles among the parents can be obtained by plotting of *Wr* with *Vr* for each trait under every condition. The formula Wr2 = *Vr*.Vp was used for construction of limiting parabola by plotting *Vr*.(*Wr* × *Vr*) points. The corresponding values for Wri were calculated for all observed *Vr*i values using the formula.

$$Wri = (Vri \times \text{VOLO})^{1/2}$$

The individual variance and covariance of the traits under various conditions/environment were used as limiting points to fit the different arrays within the parabola limits. The position of array on the graph in comparison to the point of orgin was used for estimation of the presence of dominant/recessive alleles. The genotype/array which were near to the point of origin contained most dominant genes while the array which were located at the far end from the point of origin possessed most recessive genes. However the intermediate position of the array was evident for the presence of both recessive and dominant alleles in the genotypes.

The r mean of variance (*Vr*) and covariance (*Wr*) was used for calculation of regression line. The Wri values were calculated by the formula.

$$Wrei = Wr - bVr + bVri = Wr - Vr \ (b = 1)$$

The point of interception of the regression line with *Wr* ordinate was determined as,

$$A = Wr - bVr$$

The slope of the regression line was fitted to the array points. Complete dominance was indicated by passing of the regression line of unit slope (b=1) through the point of origin. Overdominance and partial dominance were indicated by cutting of the *Wr*-axis below and above the point of origin, respectively.

3.6.8 Estimation of heterosis

The treatment mean value for each character was used for the estimation of heterosis. The magnitude of heterosis was estimated in relation to better parental (BP) and standard check (SC) values by the methods of Turner (1953). Thus heterosis was calculated as the percentage increase or decrease of mean F_1 performance as indicated below:

3.6.8.1 Estimation of heterobeltiosis (Better parent heterosis)

Heterobeltiosis is the heterosis over the better parent. It is expressed as percent difference towards desirable direction which maybe increases or decrease in performance of F_1 over better parents (Fonseca and Patterson, 1968).

Hb (%) = $(\overline{F1} - \overline{BP})/\overline{BP} \times 100$

The critical difference was used for testing the significance

CD (BP) = SE $(\overline{F1} - \overline{BP}) X\ t$ 0.05

Where,

$\overline{BP}$ = mean of the desirable better parent *BP*

$SE\overline{(F1 - \overline{BP})} = \sqrt{(2MSe / r)}$

Where

MSe = mean sum of square due to error

r = number of replications

3.6.8.2 Estimation of standard/Economic heterosis

Economic heterosis was expressed as percentage increase or decrease towards desirable side observed in F_1 performance over standard check **(**Meredith and Bridges, 1972).

Hc (%) = $(\overline{F1} - \overline{SC})/\overline{SC} \times 100$

Critical difference was applied for testing is significance

CD (SH= SE $(\overline{F1} - \overline{SC}) \times t_{0.05}$

Where, SC = mean of high yielding standard check

SE $(\overline{F1} - \overline{SC}) = \sqrt{(2MSe / r)}$

Where,

MSe = mean sum of square due to error

r = Number of replications

RESULTS AND DISCUSSION

The entire experimental results and the information obtained in the present investigation entitled "Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* (L.) Czern. & Coss]." have been presented under the following heads:

- Analysis of variance under various nitrogen levels for yield and its contributing attributes
- *Per se* performance of the parents and their hybrids
- Nitrogen uptake pattern and its effect on yield attributes
- Pooled analysis of variance based on GGE biplot and GGE Biplot display
- Combining Ability Analysis
- Components of genetic variance and graphical analysis under various Nitrogen levels
- Estimation of heterosis

4.1 Analysis of Variance under various nitrogen levels for yield and its contributing attributes

Analysis of variance was performed to test the difference among parents and hybrids for all the seventeen characters and the results are presented in Table 4.1; 4.2; 4.3; 4.4; 4.5 and 4.6. The results revealed that the mean squares due to genotypes were highly significant for all the characters studied under various nitrogen levels *viz.,* 75 Kg N/ha & 150 Kg N/ha and control . The mean squares due to genotypes were further partitioned into parents, hybrids and parents *vs*. hybrids.

The analysis of variance also depicted significant differences for all the characters among parents and hybrids under all three conditions. However, in case of Parents *vs* Hybrids significant differences were observed only for some characters *viz.,* Days to 50% Flowering (Control and 150 Kg Nitrogen per ha); Days to maturity (75 Kg Nitrogen per ha); Number of primary branches per plant (75 Kg and 150 Kg

Nitrogen per ha); Number of secondary branches per plant(75 Kg and 150 Kg Nitrogen per ha); Number of siliqua on main shoot (All three condition); Siliqua Length (150 Kg Nitrogen per ha); Seeds per Siliqua (75 Kg Nitrogen per ha); 1000 Seed Weight (75 Kg Nitrogen per ha); Seed yield per plant (75 Kg and 150 Kg Nitrogen per ha); Biological yield per plant (75 Kg and 150 Kg Nitrogen per ha); Harvest Index (Control) and Chaff Nitrogen (Control and 150 Kg Nitrogen per ha).

The parents under control, 75Kg/ha and 150Kg/ha nitrogen levels differed significantly for all the characters under study except for number of seeds per siliqua under 150 Kg N/ha condition. The hybrids differed significantly for all the characters under control, 75 Kg and 150 Kg N/ha condition except for number of seeds per siliqua under 150 Kg N/ha condition..

The results found were similar to the studies of Akbar *et al.* (2008) who found significant values of mean squares for all the characters with a single exception of 1000 seed weight. Verma and Kushwaha (1999) & Yadav *et al.* (2020) also obtained significant differences among the lines used in their studies for various traits.

4.2 *Per se* Performance of parents and their hybrids

Wide range of variation was found in most of the characters estimated on basis of *per se* performance on comparing with the check variety Varuna. The Mean, Standard Error, Coefficient of Variation, Critical Difference (5% Probability), Range of F_1 and their parents were calculated for all the characters under various Nitrogen levels *viz.*, N- 75 Kg per ha and N- 150 Kg per ha including control (Table 4.7, 4.8, 4.9, 4.10, 4.11 and 4.12) for estimating *per se* performance and making comparison with the Check variety Varuna.

4.2.1 Days to Flower Initiation

Days to flower initiation of 45 crosses varied from 50.99 (ZEM-1 × NRCHB-101) to 60.97 (RNG-73 × Pusa Mustard-28) in case of control. However none of the genotypes were significantly earlier to the check Varuna.

Table 4.1 Analysis of variance for days to flower initiation, days to 50% flowering and days to maturity under various nitrogen levels

Source of Variations	Df	Days to flower initiation			Days to fifty percent Flowering			Days to Maturity		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
Replicates	1	0.2273	2.0455	3.6364	0.9091	4.8091	8.7364*	1.5364	0.7364	4.0091
Treatments	54	14.7350**	19.6902**	15.8047**	81.4115**	71.7350**	69.0253**	33.7475**	50.7003**	49.1003**
Parents	9	18.5333**	26.0222**	15.9111**	107.3333**	71.5333**	69.5333**	40.0500**	40.2278**	40.6056**
Hybrids	44	14.2460**	18.7763**	16.0793**	77.5364**	73.3596**	70.0217**	33.2157**	53.5672**	51.8748**
Parent *Vs*.Hybrids	1	2.0687	2.9172	2.7657	18.6182**	2.0687	20.6081*	0.4248	18.8126*	3.4793
Error	54	1.1902	1.5825	1.0067	0.7609	1.9572	0.9956	1.1475	1.6067	1.3980

*Significance P ≤ 0.05; **Significance P ≤ 0.01

Table 4.2 Analysis of variance for plant height (cm), number of primary and secondary branches per plant under various nitrogen levels

Source of Variations	Df	Plant Height (cm)			Number of Primary Branches /Plant			Number of Secondary Branches/plant		
		Control	**75 Kg N/ha**	150 Kg N/ha	**Control**	75 Kg N/ha	150 Kg N/ha	**Control**	**75 Kg N/ha**	150 Kg N/ha
Replicates	1	8.1818	14.5455*	0.9091	3.7095*	1.8590*	3.3513*	2.5965	0.02045	0.0874
Treatments	54	873.3141**	843.8966**	838.8569**	1.5485**	2.7842**	3.7311**	177.7187**	199.39519**	160.0809**
Parents	9	864.5778**	788.7556**	799.7833**	1.6120*	3.2589**	4.8049**	154.5611**	167.86667**	119.6056**
Hybrids	44	894.8929**	874.3546**	865.8929**	1.5696**	2.5826**	3.5318**	186.4080**	210.17165**	171.6442**
Parent *Vs*.Hybrids	1	2.4748	0.0182	0.9338	0.0526	7.3822**	2.8333*	3.8052	8.98766*	15.5734**
Error	54	4.6448	3.0084	1.5572	0.7356	0.4018	0.5379	3.8842	1.91452	1.9403

*Significance P ≤ 0.05; **Significance P ≤ 0.01

Table 4.3 Analysis of variance for length of main shoot (cm), number of siliquae on main shoot and siliqua length (cm) under various nitrogen levels

Source of Variations	Df	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua Length (cm)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
Replicates	1	0.5818	7.3841	1.1608	2.6273	1.5364	62.6273	0.6415	1.2658*	0
Treatments	54	79.4546**	70.6695**	76.4294**	27.7273**	26.9721**	21.9640**	1.4606**	1.3319**	1.4518*
Parents	9	71.5131**	73.1427**	110.5533**	28.6722**	23.0889**	15.8000*	1.2201*	1.0053*	1.4787*
Hybrids	44	82.8621**	71.4391**	71.1460**	27.4864**	27.5672**	21.7944**	1.5354**	1.4274**	1.4036*
Parent *Vs*.Hybrids	1	0.9956	14.5445	1.7820	29.8227*	35.7354*	84.8990*	0.3336	0.0703	3.3300*
Error	54	2.8610	5.4784	1.0871	3.4236	3.3512	7.1828	0.3520	0.2853	0.5124

*Significance P ≤ 0.05; **Significance P ≤ 0.01

Table 4.4 Analysis of variance for number of seeds per siliqua, 1000 seed weight (g) and seed yield per plant (g) under various nitrogen levels

Source of Variations	Df	Number of Seeds per siliqua			1000 Seed Weight (g)			Seed Yield per Plant (g)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
Replicates	1	1.5364	4.4000	0.9091	0.0015	0.1841	0.2008	0.2273	1.3091	4.0091
Treatments	54	28.3697**	9.5572**	7.3956	0.2863**	0.3180**	0.2792*	132.3680**	147.2273**	124.2381**
Parents	9	30.5833**	10.4500**	7.6722	0.4031*	0.4394*	0.5913**	149.7833**	155.5611**	150.8889**
Hybrids	44	28.4864**	9.5899**	7.2591	0.2688*	0.2642*	0.2217*	131.6727**	147.7869**	120.7232**
Parent *Vs*.Hybrids	1	3.3136	0.0854*	10.9136	0.0034	1.5895*	0.0000	6.2227	47.6005**	39.0323*
Error	54	1.2586	1.3074	5.2980	0.1124	0.0804	0.1203	3.5606	1.8461	4.4535

*Significance P ≤ 0.05; **Significance P ≤ 0.01

Table 4.5 analysis of variance for biological yield per plant (g), Harvest Index (%) and seed oil content (%) under various nitrogen levels

Source of Variations	Df	Biological Yield per Plant (g)			Harvest Index (%)			Seed Oil Content (%)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	75 Kg N/ha	150 Kg N/ha	**Control**	75 Kg N/ha	**150 Kg N/ha**
Replicates	1	163.2364	7.1273	748.8091*	2.0073	0.0029	0.1803	0.0045	3.0445	3.6728
Treatments	54	4852.9721**	5453.5512**	5483.6929**	22.1560**	25.7573**	20.3081**	6.4703**	6.5129**	4.8907*
Parents	9	4610.8056**	4461.7556**	5494.8056**	15.0849**	31.0428**	25.3278**	5.0956**	6.1492**	4.6936*
Hybrids	44	4998.5818**	5755.5591**	5548.5066**	23.9448**	25.2544**	19.7092**	6.8986**	6.7274**	4.9288*
Parent *Vs*.Hybrids	1	625.6409	1091.3636*	2531.8793*	7.0861*	0.3177	1.4850	0.0011	0.3493	4.9901
Error	54	224.9956	269.2569	128.7535	1.5706	1.7843	1.6739	0.7704	0.7876	1.7951

*Significance P ≤ 0.05; **Significance P ≤ 0.01

Table 4.6 Analysis of variance for seed nitrogen content (%) and chaff nitrogen content (%) under various nitrogen levels

Source of Variations	Df	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
Replicates	1	0.00009	0.00013	0	0	0.00004**	0.00001
Treatments	54	0.00332*	0.00277**	0.00249**	0.04335**	0.04536**	0.04466**
Parents	9	0.00277*	0.00255*	0.002*	0.04604**	0.05294**	0.05307**
Hybrids	44	0.00350*	0.00288**	0.00265**	0.04314**	0.04364*	0.04285**
Parent *Vs*.Hybrids	1	0.00004	0.00021	0.00008	0.02818**	0.05275	0.04891**
Error	54	0.00102	0.00051	0.00057	0.00008	0.00002	0.00014

*Significance P ≤ 0.05; **Significance P ≤ 0.01

In case of dose of 75 Kg Nitrogen per ha, the days to flower initiation for crosses varied from 49.34 (ZEM-1 × TM-4) to 62.22 (Gujarat Mustard-3 × NRCHB-101). One genotype *viz.*, ZEM-1 × TM-4 was significantly earlier to the Check Varuna.

The aforesaid character varied from 50.22 (ZEM-1 × TM-4) to 61.53 days (DRMR-1 × TM-4) for crosses in case of dose of 150 Kg Nitrogen per ha. Two Crosses *viz.*, ZEM-1 × TM-4 and ZEM-1 × KBS-3 were found significantly earlier to the Check Varuna in this case.

In case of parents, days to flower initiation varied from 52.41 (KBS-3) to 61.67 (DRMR-1) for control, 52.51 (TM-4) to 62.77 (DRMR-1) for 75 Kg Nitrogen per ha and 53.53 (TM-4) to 60.96 (DRMR-1) for 150 Kg Nitrogen per ha. None of the genotypes were found significantly earlier to the check Varuna.

4.2.2. Days to Fifty Percent Flowering

The Range for crosses varied from 64.63 (ZEM-1 × DRMR-1) to 88.95 days (Gujarat Mustard-3 × TM-4) for fifty percent flowering in case of Control. However none of the crosses exhibited significant superiority for the character under this condition.

The aforesaid character varied from 65.08 (ZEM-1 × TM-4) to 89.12 days (Gujarat Mustard-3 × TM-4) for crosses under the condition- 75 Kg Nitrogen per ha. None of the crosses were significantly earlier to the check Varuna for this character under given condition.

In case of 150 Kg Nitrogen per ha, the days to fifty percent flowering varied from 66.41 (Gujarat Mustard-3 × TM-4) to 90.03 (Pusa Mustard-28 × KBS-3). In this condition, eight crosses were found significantly earlier to the check Varuna *viz.*, Jumka × Pusa Mustard-28; Jumka × RH-30; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; ZEM-1× TM-4 and Gujarat Mustard-3 × KBS-3.

The range of Parents for days to fifty percent flowering varied from 69.5 (KBS-3) to 83.2 (RH-30); 68.26 (Jumka) to 84.19 (RNG-73) and 69.8 (Jumka) to 83.33 (RH-30) for Control, 75 Kg Nitrogen dose per ha and 150 Kg Nitrogen dose per ha, , respectively. However two parents *viz.,* Jumka and TM-4 exhibited superiority for the character over the check Varuna and that too in case of Nitrogen dose of 150 Kg/ha.

4.2.3. Days to Maturity

The range for days to maturity varied from 129.65 (Jumka × Gujarat Mustard-3) to 146.62 (ZEM-1 × KBS-3) for crosses in case of Control. Seven crosses exhibited significant earliness over the check Varuna for days to maturity *viz.*, Jumka × RNG-73; Jumka × RH-30; Jumka × TM-4; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1 and Jumka × DRMR-1.

In case of dose of 75 Kg Nitrogen per ha, the range of crosses for days to maturity varied from 127.66 (Jumka × DRMR-1) to 148.17 (ZEM-1 × RH-30). Here 25 crosses exhibited superiority over the check Varuna *viz.,* Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; RNG- 73 × ZEM-1; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × TM-4; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × DRMR-1; Pusamustard-28 × NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30 and TM-4 × KBS-3.

In the condition of dose of 150 Kg per ha the range for days to maturity was 129.22 to 150.51 for crosses. Thirty six crosses *viz.,* Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; RNG- 73 × ZEM-1; RNG-73 × DRMR-1;

RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × TM-4; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; Pusamustard-28 × NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; DRMR-1 × TM-4; DRMR-1 × KBS-3; NRCHB-101 × KBS-3; RH-30 × KBS-3 and TM-4 × KBS-3 were found significantly earlier to the check Varuna for days to maturity.

The Parents also exhibited superiority for this character over the check Varuna. The range of parents for days to maturity varied from 129.65 (Jumka) to 150.24 (ZEM-1); 128.51 (Jumka) to 152.38 (ZEM-1) and 129.37 (Jumka) to 155.23 (ZEM-1) for Control, condition of 75 Kg Nitrogen per ha and 150 Kg Nitrogen per ha, respectively. In case of control, two parents were found significantly earlier to the check Varuna *viz.,* Jumka and KBS-3. In case of doses of 75 Kg and 150 Kg Nitrogen per ha, same six genotypes exhibited superiority over the check Varuna in both conditions *viz.,* Jumka, Pusa Mustard-28, DRMR-1, RH-30, TM-4 and KBS-3.

4.2.4 Plant Height (cm)

The plant height for crosses varied from 138.22 (Jumka × KBS-3) to 197.6 cm (RNG-73 × ZEM-1); 141.62 (Jumka × KBS-3) to 199.53 cm (RNG-73 × ZEM-1) and 143.01 (Jumka × KBS-3) to 199.91 cm (RNG-73 × ZEM-1) for conditions of Control, 75 Kg Nitrogen per ha and 150 Kg Nitrogen per ha, respectively. Fourteen crosses showed significant superiority for Plant Height in all three conditions (same crosses in all three conditions) *viz.,* Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × TM-4 and ZEM-1 × KBS-3.

Table 4.7 *Per se* performance of genotypes for days to flower initiation, days to fifty percent flowering and days to maturity under various nitrogen levels

	Genotypes	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
1	Jumka	54.7	55.63	58	70.6	68.26	69.8*	129.65*	128.51*	129.37*
2	RNG-73	55.82	58.93	58.8	82.11	84.19	83.22	137.58	137.89	140.3
3	Pusa Mustard-28	56.67	53.55	54.81	77.26	79.26	75.35	133.49	131.17*	132.52*
4	Gujarat Mustard-3	59.73	58.6	57.95	74.39	73.42	75.2	139.55	138.1	141.53
5	ZEM-1	59.54	60.14	60.72	76.45	77.38	79.69	150.24	152.38	155.23
6	DRMR-1	61.67	62.77	60.96	80.3	79.38	79.52	134.26	132.77*	135.78*
7	NRCHB-101	54.9	53.56	55.4	75.79	77.48	78.98	137.6	137.36	139.84
8	RH-30	58.47	56.84	57.66	83.2	82.01	83.33	135.68	132.61*	133.87*
9	TM-4	54.31	52.51	53.53	74.87	76.81	71.02*	132.5	132.22*	136.43*
10	KBS-3	52.41	53.1	53.93	69.5	68.83	74.11	129.73*	130.19*	130.63*
11	Jumka × RNG-73	55.72	53.7	55.73	72.45	74.94	82.09	130.22*	129.56*	129.22*
12	Jumka × Pusa Mustard-28	53.16	54.14	55.26	70.54	71.96	71.48*	129.68*	128.67*	132.82*
13	Jumka × Gujarat Mustard-3	55.57	55.4	55.82	73.35	71.34	75.36	129.6*	130.52*	132.93*
14	Jumka × ZEM-1	55.4	53.18	53.44	71.56	73.49	72.93	131.26*	128.02*	136.08*
15	Jumka × DRMR-1	55.11	55.56	56.6	71.98	71.93	74.6	130.95*	127.66*	130.87*
16	Jumka × NRCHB-101	55.39	57.71	56.85	70.68	69.24	75.4	132.15	129.44*	129.99*
17	Jumka × RH-30	54.97	52.6	53.84	74.69	74.19	71.33*	131.01*	131.99*	129.71*
18	Jumka × TM-4	53.56	51.06	54.47	72.09	73.13	73.77	131.28*	133.36*	133.6*
19	Jumka × KBS-3	54.25	52.91	55.36	70.44	72.51	74.18	132.28	134.63*	136.07*
20	RNG-73 × Pusa Mustard-28	60.97	61.67	57.89	73.93	74.06	74.32	136.96	134.44*	131.9*
21	RNG-73 × Gujarat Mustard-3	55.17	57.06	60.25	72.98	71.29	83.21	135.65	134.33*	131.87*
22	RNG- 73 × ZEM-1	55.38	52.99	54.66	71.94	73.29	78.14	133.03	134.81*	133.99*
23	RNG-73 × DRMR-1	57.04	57.41	58.43	72.84	74.15	83.07	135.05	133.27*	130.92*
24	RNG-73 × NRCHB-101	55.84	57.06	58.7	70.44	70.6	80.23	135.34	133.75*	137.6*
25	RNG-73 × RH-30	56.75	54.68	53.62	70.28	73.03	79.58	136.53	136.34	136.9*
26	RNG-73 × TM-4	57.08	58.12	56.56	74.34	73.22	78.69	132.6	130.34*	132.27*
27	RNG-73 × KBS-3	57.75	56.69	55.63	73.96	73.14	82.07	135.78	133.81*	136.23*
28	Pusa Mustard-28 × Gujarat Mustard-3	57.7	59.07	57.27	80.15	82.46	80.94	132.87	133.88*	135.44*
29	Pusa Mustard-28 × ZEM-1	57.13	59.15	57.37	81.53	82.27	83.99	133.62	136.41	137.31*
30	Pusa Mustard-28 × DRMR-1	58.25	56.41	61.3	77.98	80.44	84.41	134.18	131.32*	133.59*

	Genotypes	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
31	PusaMustard-28 × NRCHB-101	56.84	57.56	59.26	77.4	78.18	82.78	132.93	134.56*	135.08*
32	Pusa Mustard- 28 × RH-30	55.83	52.99	55.53	75.55	76.49	88.44	134.86	131.51*	132.73*
33	Pusa Mustard- 28 × TM-4	57.13	58.15	59.87	79.53	81.77	84.63	135.12	132.91*	139.81
34	Pusa Mustard-28 × KBS-3	57.72	55.7	57.17	76.99	79.37	90.03	132.63	129.75*	135.74*
35	Gujarat Mustard-3 × ZEM-1	60.23	60.29	59.91	86.15	84.53	86.11	136.92	136.96	135.79*
36	Gujarat Mustard-3 × NRCHB-101	59.95	62.22	57.76	83.87	83.6	68.71*	135.92	137.74	136.57*
37	Gujarat Mustard-3 × DRMR-1	60.38	58.79	59.86	82.24	81.41	68.85*	136.18	134.27*	137.95*
38	Gujarat Mustard-3 × RH-30	59.21	57.73	59.01	87.17	88.12	68.14*	134.71	133.46*	135.51*
39	Gujarat Mustard-3 × TM-4	59.23	58.05	58.23	88.95	89.12	66.41*	135.77	137.97	134.1*
40	Gujarat Mustard-3 × KBS-3	60.49	58.23	53.8	85.98	85.67	67.74*	134.37	136.66	134.99*
41	ZEM-1 × DRMR-1	51.47	50.16	52.07	64.63	66.98	81.7	143.79	146.62	149.14
42	ZEM-1 × NRCHB-101	50.99	51.23	52.74	66.02	67.09	83.09	145.27	147.85	150.51
43	ZEM-1 × RH-30	52.17	52.05	53.31	64.76	65.76	83.19	145.49	148.17	148.52
44	ZEM-1 × TM-4	51.97	49.34*	50.22*	66.16	65.08	66.65*	145.78	144.91	145.85
45	ZEM-1 × KBS-3	52.19	51.34	50.43*	64.84	66.53	85.11	146.62	147.21	148.38
46	DRMR-1 × NRCHB -101	59.72	59.77	60.09	80.19	80.69	77.61	134.43	136.07	136.54*
47	DRMR-1 × RH-30	60.67	60.28	61.49	81.96	82.67	77.92	134.65	136.65	137.2*
48	DRMR-1 × TM-4	59.33	59.49	61.53	82.55	82.49	77.32	135.86	137.51	138.73*
49	DRMR-1 × KBS-3	58.32	58.43	59.52	83.31	84.14	82.23	134.97	135.89	135.48*
50	NRCHB-101 × RH-30	55.29	56.55	56.92	75.05	75.29	82.74	137.6	139.13	140.05
51	NRCHB-101 × TM-4	55.23	53.12	54.39	77.61	76.45	83.31	136.21	137.76	138.88
52	NRCHB-101 × KBS-3	54.73	55.06	55.17	75.17	76.16	79.29	134.93	137.64	137.45*
53	RH-30 × TM-4	58.07	59.88	60.38	80.64	80.81	78	135.94	138.36	139.58
54	RH-30 × KBS-3	57.9	58.06	59.33	80.83	82.41	79.65	135.01	135.55	136.36*
55	TM-4 × KBS-3	53.97	55.41	55.07	81.13	82.96	78.37	132.12	131.43*	132.59*
56	Varuna (CHECK)	53.16	52.36	54	60.02	58.84	73.92	134.35	137.99	141.16
	Mean	56.34	55.97	56.59	75.83	76.28	77.02	135.4	135.27	136.5
	SE (d) ±	1.1	1.31	1.01	0.89	1.41	1	1.14	1.21	1.17
	CV (%)	1.95	2.34	1.78	1.18	1.85	1.3	0.84	0.9	0.85
	CD at 5%	2.21	2.65	2.03	1.8	2.84	2.02	2.3	2.45	2.35

*Significance at $P \leq 0.05$

Table 4.8 *Per se* performance of genotypes for plant height (cm), number of primary and secondary branches per plant under various nitrogen levels

	Genotypes	Plant Height (cm)			No. of Primary Branches per Plant			No. of Secondary Branches per Plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1	Jumka	148.35*	151.89*	152.79*	8.51	8.1	9.64	10.33	10.71	12.47
2	RNG-73	196.5	197.09	198.31	8.18	9.78	9.34	35.87*	34.42*	35.22*
3	Pusa Mustard-28	187.52	191.06	193.18	6.42	7.71	8.16	31.81*	34.21*	32.22*
4	Gujarat Mustard-3	189.95	193.14	193.9	7.05	6.45	7.39	31.01*	34.28*	34.39*
5	ZEM-1	146.07*	151.24*	153.36*	6.03	5.88	6.16	20.83	16.71	22.6
6	DRMR-1	178.12	180.89	182.21	7.3	6.4	6.2	33.41*	31.72*	36.07*
7	NRCHB-101	185.23	188.15	189.71	8.81	6.86	8.78	35.88*	38.49*	35.59*
8	RH-30	193.61	194.09	195.15	7.11	6.26	7.14	40.07*	35.02*	37.47*
9	TM-4	176.91	179.45	179.58	7.88	8.09	5.3	29.55*	34.27*	35.74*
10	KBS-3	141.35*	144.84*	145.84*	6.54	4.91	7.67	24.18	26.34	27.69
11	Jumka × RNG-73	141.99*	146.5*	148.09*	8.77	6.83	9.25	16.71	15.14	20.8
12	Jumka × Pusa Mustard-28	141.52*	142.8*	144.15*	8.22	8.53	8.39	13.38	18.49	16.16
13	Jumka × Gujarat Mustard-3	145.72*	147.52*	150.53*	8.11	6.7	6.2	12.05	13.43	17.24
14	Jumka × ZEM-1	149.11*	149.84*	149.74*	8.21	8.66	5.83	11.04	10.82	13.44
15	Jumka × DRMR-1	145.96*	148.9*	151.29*	8.44	8.94	6.57	12.95	11.69	14.72
16	Jumka × NRCHB-101	145*	148.57*	150.21*	8.7	9.18	6.43	10.7	12.68	10.74
17	Jumka × RH-30	138.7*	141.76*	144.72*	7.73	7.41	7.09	14.37	14.36	11.37
18	Jumka × TM-4	143.47*	145.11*	146.04*	8.47	7.03	5.51	10.14	11.25	11.13
19	Jumka × KBS-3	138.22*	141.62*	143.01*	7.83	8.2	8.41	11.18	13.85	11.71
20	RNG-73 × Pusa Mustard-28	187.82	189.5	192.29	8.1	7.02	7.55	40.31*	39.72*	36.81*
21	RNG-73 × Gujarat Mustard-3	194.76	194.3	197.75	8.36	6.88	9.17	39.43*	42.36*	42.11*
22	RNG- 73 × ZEM-1	197.6	199.53	199.91	8.05	7.42	8.01	36.55*	40.86*	38.41*
23	RNG-73 × DRMR-1	192.37	193.53	195.35	7.48	8.28	8.24	39.05*	40.31*	42.07*
24	RNG-73 × NRCHB-101	194.77	195.68	195.87	7.25	8.21	5.48	38.05*	39.48*	41.18*
25	RNG-73 × RH-30	193.13	195.07	196.12	7.78	8.64	7.07	40.03*	40.5*	35.6*
26	RNG-73 × TM-4	192.1	192.15	193.78	7.89	9.25	5.59	39.27*	41.87*	40.33*
27	RNG-73 × KBS-3	186.34	190.99	193.77	8	6.05	8.52	39.51*	42.06*	39.26*
28	Pusa Mustard-28 × Gujarat Mustard-3	186.26	189.23	190.94	7.81	5.81	8.13	32.07*	27.06	31.03*
29	Pusa Mustard-28 × ZEM-1	191.67	193.31	193.46	7.49	5.26	8.02	32.08*	34.97*	34.75*
30	Pusa Mustard-28 × DRMR-1	194.76	195.45	196.43	7.59	9.06	8.72	29.07*	32.48*	34.04*

	Genotypes	Plant Height (cm)			No. of Primary Branches per Plant			No. of Secondary Branches per Plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
31	PusaMustard-28 × NRCHB-101	195.24	198.36	198.95	8.63	8.9	6.26	33.07*	36.1*	36.14*
32	Pusa Mustard- 28 × RH-30	196.6	198.75	198.65	7.32	8.87	7.85	32.09*	34.97*	32.77*
33	Pusa Mustard- 28 × TM-4	191.67	195.31	194.96	7.49	8.11	5.97	25.83*	32.67*	30.65*
34	Pusa Mustard-28 × KBS-3	190.03	192.82	194.51	7.28	8.34	6.82	31.05*	33.32*	34.69*
35	Gujarat Mustard-3 × ZEM-1	189.49	191.85	193.87	6.72	6.08	8.18	31.79*	34.77*	34.93*
36	Gujarat Mustard-3 × NRCHB-101	188.84	191.5	193.58	8.09	5.08	8.91	33.19*	36.91*	35.56*
37	Gujarat Mustard-3 × DRMR-1	193.26	194.57	194.11	8.07	8.63	9.5	31*	34.92*	32.49*
38	Gujarat Mustard-3 × RH-30	185.66	189.28	192.45	6.57	7.26	5.81	33.59*	34.69*	32.08*
39	Gujarat Mustard-3 × TM-4	185.86	187.48	191.56	6.85	8.11	6.44	32.39*	34.89*	32.54*
40	Gujarat Mustard-3 × KBS-3	185.43	187.53	189.36	7.83	7.88	6.86	29.12*	32.49*	30.99*
41	ZEM-1 × DRMR-1	147.79*	151.92*	152.56*	5.32	6.64	5.05	21.49	24.01	26.32
42	ZEM-1 × NRCHB-101	142.47*	147.85*	149.28*	4.25	6.64	6.73	23.9	24.37	26.58
43	ZEM-1 × RH-30	146.52*	148.56*	150.68*	5.82	6.66	5.71	19.96	20.16	24.97
44	ZEM-1 × TM-4	144.08*	146.27*	148.23*	5.64	6.11	4.68	19.38	19.73	22.64
45	ZEM-1 × KBS-3	147.81*	150.02*	151.82*	6.03	7.54	5.82	22.2	20.38	23.88
46	DRMR-1 × NRCHB -101	183.61	186.18	187.97	7.82	8.26	9.42	36.32*	35.51*	33.16*
47	DRMR-1 × RH-30	186.14	187.93	189.49	7.09	7.88	6.96	33.55*	33.49*	34.41*
48	DRMR-1 × TM-4	186.1	189.75	190.15	6.92	8.52	7.6	36.69*	40.47*	36.27*
49	DRMR-1 × KBS-3	181.16	184.45	185.69	7.52	8.09	8.48	33.34*	33.99*	33.09*
50	NRCHB-101 × RH-30	179.96	182.3	183.99	7.75	8.26	7.16	35.37*	36.06*	32.11*
51	NRCHB-101 × TM-4	180.2	183.88	185.97	6.79	8.11	7.5	36.48*	38.43*	35.54*
52	NRCHB-101 × KBS-3	180.6	184.72	187.13	8.54	9.23	6.54	36.41*	39.18*	37.84*
53	RH-30 × TM-4	186.97	189.28	190.96	6.42	7.59	5.75	35.33*	36.59*	35.89*
54	RH-30 × KBS-3	186.27	186.97	188.63	7.47	7.97	5.79	35.16*	37.47*	36.47*
55	TM-4 × KBS-3	175.95	176.87	178.1	7.56	8.48	7.25	32.9*	35.85*	34.35*
56	Varuna (CHECK)	157.9	163.43	163.39	8.4	9.46	9.87	21.05	25.38	25.61
	Mean	174.29	176.8	178.28	7.42	7.57	7.18	28.63	30.11	30.08
	SE (d) ±	2.22	1.67	1.36	0.82	0.62	0.75	2.07	1.32	1.4
	CV (%)	1.27	0.94	0.76	11.1	8.2	10.39	7.23	4.39	4.65
	CD at 5%	4.47	3.36	2.74	1.66	1.25	1.51	4.18	2.67	2.82

*Significance at P≤ 0.05

Three Parents (same genotypes in all three conditions) exhibited superiority over the Check Varuna *viz.,* Jumka, ZEM-1 and KBS-3 for the character Plant Height. The range varied from 141.35 (KBS-3) to 196.5 cm (RNG-73) for control; 144.84 (KBS-3) to 197.09 cm (RNG-73) for condition of 75 Kg Nitrogen per ha and 145.84 (KBS-3) to 198.31 cm(RNG-73) for condition of 150 Kg Nitrogen per ha.

4.2.5 Number of Primary Branches per Plant

The number of primary branches per plant for crosses varied from 4.25 (ZEM-1 × NRCHB-101) to 8.77 (Jumka × Pusa Mustard-28) in case of control. None of the cross was significantly superior to check for the number of primary branches per plant.

In case of dose of 75 Kg Nitrogen per ha, the range of crosses for number of primary branches per plant varied from 5.08 (Gujarat Mustard-3 × NRCHB-101) to 9.25 (Jumka × RNG-3). Again none of the cross exhibited significant superiority over check.

In the condition of dose of 150 Kg Nitrogen per ha, the range of crosses varied from 4.68 (ZEM-1 × TM-4) to 9.5 (Gujarat Mustard-3 × DRMR-1) for number of primary branches per plant. None of the cross in this condition too showed superiority over check.

The range of parents for number of primary branches per plant varied from 6.03 (ZEM-1) to 8.81 (NRCHB-101) in case of control. In case of 75 Kg Nitrogen per ha, the range of parents varied from 4.91 (KBS-3) to 9.78 (RNG-73). The range for number of primary branches per plant varied from 5.3 (TM-4) to 9.64 (Jumka) in case of condition of 150 Kg Nitrogen per ha. In this case, again none of the parent was significantly superior to check.

4.2.6 Number of Secondary Branches per Plant

The number of secondary branches per plant for crosses varied from 10.14 to 40.31; 10.82 to 42.36 and 10.74 to 42.11 for control, condition of 75 Kg Nitrogen per ha and 150 Kg Nitrogen per ha, respectively. Thirty cross combinations *viz.*, RNG-73

× Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; RNG- 73 × ZEM-1; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × TM-4; RNG-73 × KBS-3; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; Pusamustard-28 × NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3;DRMR-1 × NRCHB -101; DRMR-1 × RH-30; DRMR-1 × TM-4; DRMR-1 × KBS-3; NRCHB-101 × RH-30; NRCHB-101 × TM-4; NRCHB-101 × KBS-3; RH-30 × TM-4; RH-30 × KBS-3 and TM-4 × KBS-3were significant and positive for this character under all three conditions. In addition, the cross- Pusa Mustard-28 × Gujarat Mustard-3 also exhibited superiority for this character under control and condition of 150 Kg Nitrogen per ha.

The parents varied from 10.33 (Jumka) to 40.07 (RH-30) for control for number of secondary branches per plant. The character varied from 10.71 (Jumka) to 38.49 (NRCHB-101) and 12.47 (Jumka) to 37.47 (RH-30) for conditions of 75 Kg and 150 Kg Nitrogen per ha, respectively. Seven parents *viz.*, RNG-73, Pusa Mustard-28, Gujarat Mustard-3, DRMR-1, NRCHB-101, RH-30 and TM-4 exhibited superiority for number of secondary branches per plant in all three conditions.

4.2.7 Length of Main Shoot (cm)

The Length of main shoot for crosses varied from 41.2 (Jumka × ZEM-1) to 63.47 cm (Pusa Mustard-28 × TM-4) in case of control; 42.14 (Jumka × RNG-3) to 60.82 cm (NRCHB-101 × RH-30) in case of dose of 75 Kg Nitrogen per ha and 44.27 (Jumka × ZEM-1) to 62.86 cm(Gujarat Mustard-3 × TM-4) in condition of 150 Kg Nitrogen per ha. However, none of the crosses were found significantly superior over the check Varuna

The length of main shoot varied from 40.79 (Jumka) to 62.75cm (RNG-73) in case of parents for control. The parents varied from 39.59 (Jumka) to 61.76 cm (NRCHB-101) and 37.64 (Jumka) to 63.33 cm (NRCHB-101) in case of conditions of 75 Kg and 150 Kg Nitrogen per ha, respectively. However none of the parents exhibited significant superiority over the check Varuna.

Table 4.9 *Per se* performance of genotypes for length of main shoot (cm), number of siliquae on main shoot and siliqua length (cm) under various nitrogen levels

	Genotypes	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua length (cm)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1	Jumka	40.79	39.59	37.64	32.81	35.71	33.94	7.49*	7.67*	7.48
2	RNG-73	62.75	59.1	59.25	41.1	42.34	36.97	6.39	6.66	7.32
3	Pusa Mustard-28	57.09	57.02	55.01	39.9	40.69	37.78	6.47	6.74	5.37
4	Gujarat Mustard-3	59.09	58.56	60.7	39.22	41.63	40.34	5.33	5.78	6.41
5	ZEM-1	53.72	54.63	53.55	34.76	37.29	35.83	5.36	5.88	5.54
6	DRMR-1	58.22	59.54	60.65	39.02	39.81	34.01	6.96	7.61*	5.62
7	NRCHB-101	61.55	61.79	63.33	31.65	34.77	34.84	6.59	6.9	4.94
8	RH-30	57.96	59.94	62.4	43.12	43.9	38.83	6.07	6.31	5.54
9	TM-4	54.75	55.21	57.93	34.14	35.53	34.23	5.91	6.1	5.83
10	KBS-3	52.32	54.08	55.69	32.13	33.8	30.91	6.03	6.41	5.62
11	Jumka × RNG-73	42.28	42.14	45.27	36.53	38.46	38.09	7.48*	7.47*	5.36
12	Jumka × Pusa Mustard-28	45.05	45.82	46.36	35.34	34.21	31.24	7.77*	7.36*	7.56
13	Jumka × Gujarat Mustard-3	43.06	43.14	46.13	33.31	34.15	33.04	7.86*	7.96*	6.92
14	Jumka × ZEM-1	41.2	43.09	44.27	32.65	32.75	31.01	7.1	7.45*	7.48
15	Jumka × DRMR-1	44.22	43.27	46.62	33.56	34.62	33.82	7.85*	8.33*	8.51*
16	Jumka × NRCHB-101	44.58	43.74	45.47	33.94	35.22	33.53	7.47*	6.49	7.41
17	Jumka × RH-30	44.44	44.42	46.24	32.2	35.22	32.28	7.41*	6.96	7.49
18	Jumka × TM-4	44.03	46.48	46.32	34.47	37.96	34.8	8.06*	8.17*	8.34*
19	Jumka × KBS-3	45.87	44.1	45.23	33.54	37.84	37.09	6.72	7.54*	7.38
20	RNG-73 × Pusa Mustard-28	61.19	58.84	61.68	39.85	42.73	43.47	6.72	6.85	6.61
21	RNG-73 × Gujarat Mustard-3	59.07	58.77	60.18	42.31	43.26	39.14	7.1	7.11	7.2
22	RNG- 73 × ZEM-1	59.02	58.59	61.1	37.93	40.02	40.19	6.5	6.95	7.21
23	RNG-73 × DRMR-1	59.79	58.03	62.1	41.49	43.66	41.79	7.39*	7.77*	7.01
24	RNG-73 × NRCHB-101	58.96	59.57	60.73	37.21	38.6	36.9	7.15	7.58*	6.68
25	RNG-73 × RH-30	55.87	56.78	59.24	41.59	40.37	37.08	6.26	7.01	6.45
26	RNG-73 × TM-4	60.18	55.84	62.3	43.51*	45.04	42.29	5.94	6.44	5.48
27	RNG-73 × KBS-3	58.15	55.8	60.3	39.34	41.95	40.85	5.75	6.21	6.02
28	Pusa Mustard-28 × Gujarat Mustard-3	57.87	56.08	59.94	39.07	41.19	40.75	6.72	6.57	6.1
29	Pusa Mustard-28 × ZEM-1	60.57	54.96	62.08	41.52	43.22	41.99	6.35	6.97	6.05
30	Pusa Mustard-28 × DRMR-1	58.32	59.76	60.38	44.2*	46.33	42.69	6.08	7.11	6.79

	Genotypes	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua length (cm)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
31	PusaMustard-28 × NRCHB-101	60.66	57.6	61.78	38.05	46.61	41.31	6.05	6.15	6.42
32	Pusa Mustard- 28 × RH-30	62.48	59.1	61.75	36.84	38.36	37.16	6.96	7.35*	7.5
33	Pusa Mustard- 28 × TM-4	63.47	57.91	59.88	40.52	41.22	38.49	6.3	6.97	7.1
34	Pusa Mustard-28 × KBS-3	58.42	57.9	61.28	40.68	41.45	42.18	6.33	7	6.87
35	Gujarat Mustard-3 × ZEM-1	60.16	58.29	61.4	44.08*	45.57	40.26	5.81	5.64	5.52
36	Gujarat Mustard-3 × NRCHB-101	60.25	60.77	61.27	41.01	42.14	39.9	5.66	5.44	6.43
37	Gujarat Mustard-3 × DRMR-1	59.56	59.25	59.16	42.96	42.17	38.63	4.94	5.13	5.97
38	Gujarat Mustard-3 × RH-30	59.22	58.95	60.31	39.07	40.33	38.6	5.14	5.43	5.66
39	Gujarat Mustard-3 × TM-4	61.52	57.41	62.86	44.48*	46.61	43.65	5.5	5.14	5.64
40	Gujarat Mustard-3 × KBS-3	58.95	58.12	60.76	39.66	43.49	45.12	5.38	5.9	5.79
41	ZEM-1 × DRMR-1	52.67	55.52	55.08	33.94	35.74	34.97	5.39	5.85	6.12
42	ZEM-1 × NRCHB-101	53.45	56.69	56.62	36.81	36.98	35.71	5.28	5.88	6
43	ZEM-1 × RH-30	55.39	55.57	57.56	36.9	37.69	37.28	5.37	5.29	5.37
44	ZEM-1 × TM-4	53.42	51.28	54.35	36.97	39.41	36.74	4.37	4.98	5.63
45	ZEM-1 × KBS-3	53.18	53.95	54.14	34.88	37.26	37.72	4.78	5.4	5.9
46	DRMR-1 × NRCHB -101	56.77	57.48	56	38.61	41.47	39.53	6.85	6.11	5.79
47	DRMR-1 × RH-30	58.24	55.91	60.1	39.01	41.15	38.39	5.78	5.84	5.51
48	DRMR-1 × TM-4	58.88	58.8	59.8	36.34	40.36	38.16	6.36	6.05	6.2
49	DRMR-1 × KBS-3	57.42	55.2	57.75	37.12	38.08	36.13	5.89	6.06	6.17
50	NRCHB-101 × RH-30	59.88	60.82	60.57	35.94	37.11	34.93	6.63	6.84	5.33
51	NRCHB-101 × TM-4	62.17	57.55	60.62	34.63	37.2	33.2	6.31	6.41	6.44
52	NRCHB-101 × KBS-3	60.44	60.7	60.67	33.39	35.68	34.51	6.09	6.01	6.26
53	RH-30 × TM-4	60.84	60.15	62.31	44.4*	46.08	42.18	6.07	6.09	5.59
54	RH-30 × KBS-3	56.85	59.31	59.03	45.3*	45.76	40.93	5.99	6.43	5.45
55	TM-4 × KBS-3	54.14	54.87	54.92	33.96	39.18	37.58	5.49	5.91	5.65
56	Varuna (CHECK)	62.22	60.97	63.03	39.62	46.3	46.3	6.18	6.27	6.38
	Mean	55.76	55.16	56.98	37.88	39.72	37.59	6.28	6.5	6.31
	SE (d) ±	1.67	2.35	1.06	1.85	1.83	2.78	0.54	0.49	0.69
	CV (%)	2.99	4.25	1.87	4.87	4.59	7.39	8.58	7.47	10.91
	CD at 5%	3.36	4.74	2.15	3.72	3.68	5.61	1.09	0.98	1.39

*Significance at P≤ 0.05

4.2.8 Number of Siliquae on Main Shoot

In case of control, the range of number of siliqua on main shoot for crosses varied from 32.2 (Jumka × RH-30) to 45.3 (RH-30 × KBS-3). Only six cross combinations exhibited significant superiority over the check Varuna *viz.*, RNG-73 × TM-4; Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; RH-30 × TM-4 and RH-30 × KBS-3.

The range for crosses varied from 32.75 (Jumka × ZEM-1) to 46.61 (Pusa Mustard-28 × NRCHB-101) in the condition of dose of 75 Kg Nitrogen per ha for number of siliqua on main shoot. None of the crosses exhibited significant superiority over check Varuna. The range varied from 31.01 (Jumka × ZEM-1) to 45.12 (Gujarat Mustard-3 × KBS-3) for crosses in the condition of dose of 150 Kg Nitrogen per ha.

The parents varied from 31.65 (NRCHB-101) to 43.12 (RH-30); 33.8 (KBS-3) to 43.9 (RH-30) and 30.91 (KBS-3) to 40.34 (Gujarat Mustard-3) for number of siliqua on main shoot in case of control, condition of doses of 75 Kg and 150 Kg Nitrogen per ha, respectively. None of the parent under all the nitrogen levels exhibited significant superiority over check Varuna.

4.2.9 Siliqua Length (cm)

The crosses varied from 4.37 (ZEM-1 × TM-4) to 8.06 cm (Jumka × TM-4) for the control. In this case, eight crosses were found significantly positive for siliqua length over the check Varuna *viz.*, RNG-73 × DRMR-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × RNG-73; Jumka × Pusa Mustard-28 and Jumka × Gujarat Mustard-3.

In case of condition of dose of 75 Kg Nitrogen per ha, the range of crosses varied from 4.98 (ZEM-1 × TM-4) to 8.33 cm (Jumka × DRMR-1) for siliqua length. Out of these crosses, 10 cross combinations performed significantly better than the check Varuna for the character *viz.*, Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × TM-4; Jumka × KBS-3; Pusa Mustard- 28 × RH-30; RNG-73 × DRMR-1 and RNG-73 × NRCHB-101.

In case of condition of 150 Kg Nitrogen per ha, the range of crosses for Siliqua length varied from 5.33 (NRCHB-101 × RH-30) to 8.51 cm (Jumka × DRMR-1). However only two crosses *viz.*, Jumka × DRMR-1 and Jumka × TM-4 exhibited significant superiority over the check Varuna for siliqua length.

The parents varied from 5.33 (Gujarat Mustard-3) to 7.49 cm (Jumka) for siliqua Length in case of control. In this case, Jumka performed significantly better than the check Varuna. In condition of dose of 75 Kg Nitrogen per ha, the range of parents for siliqua length varied from 5.68 to 7.67. In this case, Jumka and DRMR-1 performed significantly better for siliqua length over the check Varuna. The parents varied from 4.94 (NRCHB-101) to 7.48 (Jumka) for this character in case of dose of 150 Kg Nitrogen per ha. In this case, none of the parents exhibited significant superiority over the check Varuna.

4.2.10 Number of Seeds per Siliqua

The crosses varied from 11.08 (ZEM-1 × TM-4) to 26.05 (Jumka × DRMR-1) for number of seeds per siliqua in case of control. Nine cross combinations among crosses *viz.*, Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × KBS-3 were found significantly Positive for the character over the check Varuna.

In case of condition of 75 Kg Nitrogen per ha, the crosses varied from 11.01 (ZEM-1 × TM-4) to 18.88 (Gujarat Mustard-3 × NRCHB-101). None of the cross combinations exhibited significant superiority over the check Varuna for this character.

The range for number of seeds per siliqua under 150 Kg Nitrogen per ha condition for crosses varied from 10.18 (NRCHB-101 × TM-4) to 17.61 (Jumka × Pusa Mustard-28) for number of seeds per siliqua. However none among crosses exhibited significant superiority over the check Varuna.

The parents varied from 10.74 (ZEM-1) to 25.2 (Jumka); 11.04 (ZEM-1) to 18.4 (Gujarat Mustard-3) and 12.48 (DRMR-1) to 17.98 (Gujarat Mustard-3) for control, conditions of 75 Kg and 150 Kg Nitrogen per ha, respectively. In case of control, only one genotypes *viz.*, Jumka, found significantly superior to the check Varuna for number of seeds per siliqua in case of control. In case of dose of 75 Kg Nitrogen per ha, no genotype was found significantly positive over control Varuna for this character. Similar results were exhibited for number of seeds per siliqua in case of condition of dose of 150 Kg Nitrogen per ha.

4.2.11 1000 Seed Weight (g)

The crosses varied from 3.51 (Jumka × NRCHB-101) to 5.29g (NRCHB-101 × RH-30) in case of control for 1000 seed weight. None of the crosses were found significantly superior to the check Varuna for this character in control.

The range of crosses varied from 3.72 (Jumka × DRMR-1) to 5.28g (DRMR-1 × NRCHB-101) in case of dose of 75 Kg Nitrogen per ha for 100 seed weight. Among crosses, none of the cross combinations exhibited significant superiority over the check Varuna.

In the condition of dose of 150 Kg per ha, the range of crosses varied from 3.88 (Jumka × DRMR-1) to 5.37 g (NRCHB-101 × TM-4). In this case, none of the crosses were found significantly positive in performance over the check Varuna.

The parents varied from 3.43 to 5.07g; 3.93 to 5.39g and 3.57 to 5.41g for the character 1000 seed weight in Control, condition of dose of 75 Kg and 150 Kg Nitrogen per ha, respectively. Under all the three levels of nitrogen none of the parents were found significantly better than the check Varuna for the character.

4.2.12 Seed Yield per Plant (g)

The range for crosses varied from 8.52 (ZEM-1 × DRMR-1) to 36.8g (RNG-73 × NRCHB-101); 9.49 (ZEM-1 × TM-4) to 37.97g (RNG-73 × DRMR-1) and 10.41 (ZEM-1 × RH-30) to 37.98g (RNG-73 × DRMR-1) for control, condition of dose of 75 Kg and 150 Kg Nitrogen per ha, respectively.

Nineteen crosses *viz.*, Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; RNG- 73 × ZEM-1; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × TM-4; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × RH-30; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; DRMR-1 × TM-4; DRMR-1 × KBS-3; NRCHB-101 × RH-30; NRCHB-101 × TM-4; NRCHB-101 × KBS-3; RH-30 × TM-4; RH-30 × KBS-3 and TM-4 × KBS-3 were found significant and positive in performance for seed yield per plant in all three conditions.

In addition, the crosses namely, Gujarat Mustard-3 × RH-30 and Gujarat Mustard-3 × TM-4 also exhibited significantly better performance in control and in case of 75 Kg Nitrogen per ha. Similarly, the genotype Gujarat Mustard-3 × DRMR-1 and Gujarat Mustard-3 × KBS-3 were significantly positive for seed yield per plant for control and dose of 75 Kg Nitrogen per ha, respectively.

The parents varied from 12.33 (ZEM-1) to 36.45g (RH-30) in case of control. In case of conditions of dose of 75 Kg and 150 Kg Nitrogen per ha, the range for seed yield per plant varied from 12.77 (ZEM-1) to 37.86g (RH-30) and 12.71 (ZEM-1) to 38.8g (RH-30), respectively.

Eight parental genotypes *viz.*, Jumka, RNG-73, Pusa Mustard-28, DRMR-1, NRCHB-101, RH-30, TM-4 and KBS-3 also exhibited superiority for seed yield per plant over the check Varuna in all three conditions *viz.*, control, doses of 75 Kg and 150 Kg Nitrogen per ha. In addition to this, the genotype- Gujarat Mustard-3 was also found significantly better than the check Varuna for the character but only in case of control and dose of 75 Kg Nitrogen per ha.

Table 4.10 *Per se* performance of genotypes for number of seeds per siliqua, 1000 seed weight (g) and seed yield per plant (g) under various nitrogen levels

	Genotypes	Number of Seeds per Siliqua			1000 Seed Weight (g)			Seed Yield per Plant (g)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1	Jumka	25.2*	18.21	17.71	3.73	5.03	4.48	28.23	33.05	34.38*
2	RNG-73	16.84	15.9	13.96	4.76	5.39	5.27	34.97*	35.44*	36.42*
3	Pusa Mustard-28	18.62	17.69	15.29	3.83	4.83	4.93	19.95	21.56	20.41
4	Gujarat Mustard-3	17.95	18.4	17.98	4.69	5.35	5.21	16.51	17.6	16.61
5	ZEM-1	10.74	11.04	12.54	4.29	5.16	4.9	12.33	12.77	12.71
6	DRMR-1	15.06	14.3	12.48	5.07	5.39	5.41	22.56	23.48	23.06
7	NRCHB-101	16.72	15.88	15.98	4.76	5.01	4.72	35.19*	36.22*	34.28
8	RH-30	14.41	14.99	14.47	4.67	4.89	5.19	36.45*	37.86*	38.8*
9	TM-4	15.92	16.92	12.97	3.84	4.09	4.08	30.75*	33.93*	33.76
10	KBS-3	17.1	15.77	15.25	3.43	3.93	3.57	26.46	27.3	27.45
11	Jumka × RNG-73	20.96*	17.78	17.61	3.71	4.11	4.45	28.82	30.22	32.99
12	Jumka × Pusa Mustard-28	24.61*	18.69	15.06	3.7	3.78	4.15	33.49*	34.34*	31.03
13	Jumka × Gujarat Mustard-3	24.35*	15.43	14.36	4.19	4.02	4.16	30.57*	31.88	32.03
14	Jumka × ZEM-1	23.38*	16.07	15.32	3.91	4.07	4.42	29.67*	31.21	28.74
15	Jumka × DRMR-1	26.05*	17.26	14.95	3.88	3.72	3.88	30.09*	30.87	30.95
16	Jumka × NRCHB-101	23.48*	18.25	16.78	3.51	3.85	3.97	26.42	27.28	28.47
17	Jumka × RH-30	23.41*	17.41	16.6	4	4.4	4.89	27.67	28.22	29.1
18	Jumka × TM-4	21.95*	15.41	15.16	4.27	4.63	4.76	31.31*	30.37	30.75
19	Jumka × KBS-3	21.65*	16.44	14.93	3.99	4.31	4.76	28.57	30.13	31.77
20	RNG-73 × Pusa Mustard-28	15.04	14.34	15.33	4.5	4.84	4.89	33*	33.41*	33.39
21	RNG-73 × Gujarat Mustard-3	16.83	17.38	15.49	4.32	4.59	4.79	36.28*	36.42*	34.73*
22	RNG- 73 × ZEM-1	14.46	13.81	13.09	4.58	4.87	4.7	31.1*	33.56*	31.67
23	RNG-73 × DRMR-1	13.9	14.55	15.4	4.48	4.43	4.77	36.46*	37.97*	37.98*
24	RNG-73 × NRCHB-101	15.96	16	16.8	4.75	4.86	5.22	36.8*	35.6*	35.1*
25	RNG-73 × RH-30	15.04	14.93	14.48	4.43	4.72	5	32.98*	35.14*	33.24
26	RNG-73 × TM-4	15.58	15.72	15.22	4.36	4.78	4.93	35.21*	36.38*	36.26*
27	RNG-73 × KBS-3	12.92	13.15	12.07	3.72	4.4	4.69	35.93*	36.62*	33.54
28	Pusa Mustard-28 × Gujarat Mustard-3	16.18	16.65	13.87	4.08	4.53	4.77	21.37	21.94	23.83
29	Pusa Mustard-28 × ZEM-1	17.15	17.82	17.09	4.04	4.5	4.91	21.37	23.93	25.47
30	Pusa Mustard-28 × DRMR-1	17.48	17.42	15.05	3.94	4.3	4.68	24.45	25.01	27.8

	Genotypes	Number of Seeds per Siliqua			1000 Seed Weight (g)			Seed Yield per Plant (g)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
31	PusaMustard-28 × NRCHB-101	18.13	18.03	15.19	4.29	4.62	4.75	24.91	22.72	24.07
32	Pusa Mustard- 28 × RH-30	17.86	17.46	14.8	4.01	4.19	4.53	26.83	26.06	27.46
33	Pusa Mustard- 28 × TM-4	17.65	18.32	14.09	3.54	3.8	4.26	20.37	22.43	23.97
34	Pusa Mustard-28 × KBS-3	17.29	17.75	15.72	4.21	4.7	5.07	20.2	22.09	22.01
35	Gujarat Mustard-3 × ZEM-1	17.36	17.31	14.7	4.7	4.93	5.29	18.63	17.35	20.62
36	Gujarat Mustard-3 × NRCHB-101	18.79	18.88	12.13	4.73	4.77	4.84	19.13	17.71	19.62
37	Gujarat Mustard-3 × DRMR-1	16.77	17.05	14.85	4.85	4.84	5.08	19.63	13.7	16.26
38	Gujarat Mustard-3 × RH-30	18.51	17.92	15.3	4.65	5	4.93	18.51	17.15	18.43
39	Gujarat Mustard-3 × TM-4	18.43	18.33	14.14	4.09	4.55	4.95	17.16	14.98	14.06
40	Gujarat Mustard-3 × KBS-3	16.69	16.54	14.33	4.33	4.79	4.91	15.11	16	17.26
41	ZEM-1 × DRMR-1	11.92	11.47	10.44	4.55	4.75	4.69	8.52	10.34	11.65
42	ZEM-1 × NRCHB-101	11.52	11.51	12.45	4.38	4.78	4.98	10.99	12.38	14.78
43	ZEM-1 × RH-30	12.62	12.69	11.79	3.98	4.53	4.13	10.45	10.06	10.41
44	ZEM-1 × TM-4	11.08	11.01	10.86	4.27	4.65	4.72	10.07	9.49	12.27
45	ZEM-1 × KBS-3	11.9	11.4	12.83	4.64	5.11	5.03	12.47	10.14	10.95
46	DRMR-1 × NRCHB -101	14.66	14.66	12.27	5.08	5.28	5.24	21.83	23.47	24.77
47	DRMR-1 × RH-30	15.06	15.17	12.35	4.49	4.85	5.01	24.92	24.93	24.97
48	DRMR-1 × TM-4	14.86	14.46	12.3	5.11	5.14	5.13	21.83	23.06	21.96
49	DRMR-1 × KBS-3	15.13	15.11	13.9	4.61	5.05	5.22	21.04	22.01	22.47
50	NRCHB-101 × RH-30	17.51	17.79	14.15	5.29	5.22	5.14	31.21*	32.24	33.26
51	NRCHB-101 × TM-4	17.15	17.09	10.18	5.13	5.16	5.37	35.34*	36.46*	33.93
52	NRCHB-101 × KBS-3	18.14	18.52	12.34	4.43	4.56	4.62	35.49*	35.84*	34.39*
53	RH-30 × TM-4	15.15	15.24	12.16	4.3	4.55	4.7	34.74*	35.51*	33.71
54	RH-30 × KBS-3	14.05	13.85	13.59	4.91	5	5.34	35.07*	36.59*	35.8*
55	TM-4 × KBS-3	14.47	13.83	10.4	3.86	4.27	4.47	32.47*	32.78	34.45*
56	Varuna (CHECK)	18.23	18.9	18.71	4.76	4.96	4.87	25.46	30.28	30.36
	Mean	17.04	15.87	14.16	4.31	4.64	4.77	25.61	26.18	26.5
	SE (d) ±	1.04	1.11	2.56	0.29	0.27	0.34	1.95	1.46	2.02
	CV (%)	6.1	7.01	18.08	6.79	5.76	7.14	7.6	5.59	7.61
	CD at 5%	2.1	2.24	5.17	0.59	0.54	0.69	3.93	2.95	4.07

*Significance at P≤ 0.05

4.2.13 Biological Yield per Plant (g)

The range of biological yield per plant varied from 67.38 (ZEM-1 × NRCHB-101) to 258.3g (RNG-73 × TM-4) in case of crosses for control. In this case, 26 crosses exhibited better performance for the character over the check Varuna *viz.*, RNG-73 × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; RNG- 73 × ZEM-1; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × TM-4; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; PusaMustard-28 × NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × ZEM-1; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; DRMR-1 × TM-4; DRMR-1 × KBS-3; NRCHB-101 × RH-30; NRCHB-101 × TM-4; NRCHB-101 × KBS-3; RH-30 × TM-4; RH-30 × KBS-3; TM-4 × KBS-3.

In case of condition of dose of 75 Kg Nitrogen per ha, the range for biological yield per plant for crosses varied from 62.46 (ZEM-1 × DRMR-1) to 261.79g (RNG-73 × KBS-3). Twenty one crosses *viz.*, RNG-73 × KBS-3; RNG- 73 × ZEM-1; RNG-73 × NRCHB-101; RNG-73 × DRMR-1; Pusa Mustard-28 × ZEM-1; RNG-73 × TM-4; RNG-73 × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; RNG-73 × RH-30; RNG-73 × Gujarat Mustard-3; RH-30 × KBS-3; RH-30 × TM-4; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; Gujarat Mustard-3 × KBS-3; DRMR-1 × KBS-3; NRCHB-101 × RH-30; TM-4 × KBS-3 ; Pusa Mustard-28 × DRMR-1; Pusa Mustard- 28 × RH-30; PusaMustard-28 × NRCHB-101 were found significantly positive in performance for the character.

The crosses varied from 74.19 to 256.94 g in case of condition of dose of 150 Kg Nitrogen per ha for the character biological yield per plant. Eighteen cross combinations were found significantly superior in performance for the character in this case *viz.*, RNG-73 × Pusa Mustard-28; RNG-73 × NRCHB-101; RNG-73 × DRMR-1; RNG- 73 × ZEM-1; RNG-73 × KBS-3; RNG-73 × RH-30; RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; RH-30 × TM-4; NRCHB-101 × RH-30; RH-30 × KBS-3; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; Pusa Mustard-28 × ZEM-1;

TM-4 × KBS-3 ; Pusa Mustard- 28 × TM-4; Pusa Mustard- 28 × RH-30 and PusaMustard-28 × NRCHB-101.

The parental genotypes varied from 75.35 (ZEM-1) to 243.35 g (RNG-73 in case of control, six parents *viz.,* RNG-73; NRCHB-101; RH-30; KBS-3; TM-4 and DRMR-1 exhibited significant superiority over the check. Under 75 Kg N/ha, parental genotypes ranged from 93.65 (ZEM-1) to 243.5 (KBS-3), again six parental genotypes *viz.,* KBS-3; RNG-73; NRCHB-101; RH-30; DRMR-1; TM-4 showed significant superiority over the check Varuna. Whereas, in case of 150 Kg N/ha condition values range varied from 95.42 (ZEM-1) to 255.94 (KBS-3). Here again six parents *viz.,* KBS-3; RNG-73; RH-30; NRCHB-101; Pusa Mustard-28; TM-4 showed significantly superior over check Varuna.

4.2.14 Harvest Index (%)

The range of crosses varied from 10.27 (Pusa Mustard-28 × ZEM-1) to 23.52% (Jumka × Pusa Mustard-28) in case of control for the character- Harvest Index. Only three cross combinations *viz.,* Jumka × Pusa Mustard-28; Jumka × DRMR-1; Jumka × Gujarat Mustard-3 were found significantly superior for Harvest Index over the check Varuna.

In case of 75 Kg Nitrogen per ha condition the range of crosses for Harvest Index varied from 8.49 (Gujarat Mustard-3 × KBS-3) to 23.75% (Jumka × Pusa Mustard-28). In this case, only one cross combinations *viz.,* Jumka × Pusa Mustard-28 was found significantly positive in performance over the check Varuna. The genotypes among crosses varied from 11.44 (ZEM-1 × DRMR-1) to 22.63 (Jumka × RNG-3) for Harvest Index in case of condition of 150 Kg Nitrogen per ha. None of the cross exhibited significant superiority over the check Varuna for this character.

The parents varied from 12.75 (DRMR-1) to 20.35% (Jumka); 11.01 (KBS-3) to 23.5% (Jumka) and 10.38 (KBS-3) to 23.78% (Jumka) in case of control, condition of dose of 75 Kg and 150 Kg Nitrogen per ha, respectively. In case of control none of the parent was significantly superior to the check, whereas under 75 Kg N/ha and 150 Kg N/ha only Jumka was significantly superior to the check Varuna.

4.2.15 Seed Oil Content (%)

Seed oil content among crosses varied from 34.06 (Jumka × KBS-3) to 42.24 % (RH-30 × KBS-3) in control for oil content. One cross *i.e.* RH-30 × KBS-3 was found significantly superior over the check Varuna for oil content. In case of condition of dose of 75 Kg Nitrogen per ha, the range for oil content among crosses varied from 34.23 (Jumka × KBS-3) to 41.82% (ZEM-1 × TM-4). The crosses varied from 33.95 (Jumka × Gujarat Mustard-3) to 41.76% (ZEM-1 × KBS-3) in case of dose 150 Kg Nitrogen per ha. However in both the cases of Nitrogen dose, none of the genotypes among crosses exhibited significantly better performance over the check Varuna for oil content.

The parents varied from 35.57 (TM-4) to 40.87 (RH-30); 35.45 (TM-4) to 40.95 (RH-30) and 35.89 (Pusa Mustard-28) to 40.06 (ZEM-1) in case of control and condition of doses of 75 Kg and 150 Kg Nitrogen per ha, respectively for oil content. However none of the parental genotypes were found significantly superior for oil content over the check Varuna.

4.2.16 Seed Nitrogen Content (%)

The crosses varied from 1.2102 (ZEM-1 × KBS-3) to 1.4345% (NRCHB-101 × KBS-3); 1.2824 (Jumka × Pusa Mustard-28) to 1.4403% (NRCHB-101 × KBS-3) and 1.2857 (ZEM-1 × RH-30) to 1.4505% (NRCHB-101 × KBS-3) in case of control and condition of doses of 75 Kg and 150 Kg Nitrogen per ha, respectively for seed nitrogen. However none of the crosses exhibited significant level of superiority over the check Varuna for seed nitrogen in any of the three conditions.

In case of parents, the range for seed nitrogen varied from 1.2469 (ZEM-1) to 1.3879% (KBS-3) for control. In case of doses of 75 Kg and 150 Kg Nitrogen per ha, the range varied from 1.285 (Gujarat Mustard-3) to 1.4133% (KBS-3) and 1.3196 (ZEM-1) to 1.4414% (KBS-3), respectively. Here again, none of the genotypes were found significantly positive for seed nitrogen over the check Varuna in any of the conditions.

Table 4.11 *Per se* performance of genotypes for biological yield per plant (g) , Harvest Index (%) and seed oil content (%) under various nitrogen levels

	Genotypes	Biological Yield per Plant (g)			Harvest Index (%)			Seed Oil Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1	Jumka	142.6	140.64	147.18	20.35	23.5*	23.78*	36.81	37.41	36.26
2	RNG-73	243.35*	227.45*	241.29*	14.49	15.65	15.08	37.99	38.23	36.77
3	Pusa Mustard-28	148.2	170.22	184.7*	13.19	12.46	10.94	36.83	36.99	35.89
4	Gujarat Mustard-3	123.98	142.18	125.55	13.12	12.29	13.42	37.21	36.87	37.55
5	ZEM-1	75.35	93.65	95.42	15.26	13.4	13.68	40.29	40.15	40.06
6	DRMR-1	174.04*	194.03*	164.27	12.75	11.94	13.94	38.58	39.71	38.98
7	NRCHB-101	206.87*	226.26*	212.84*	16.93	16.56	15.98	37.05	37.95	38.36
8	RH-30	202.32*	208.86*	223.71*	17.94	18.23	17.63	40.87	40.95	39.84
9	TM-4	180.32*	193.79*	183.33*	17.01	17.81	18.19	35.57	35.45	36.36
10	KBS-3	192.62*	243.5*	255.94*	13.55	11.01	10.38	36.48	36.67	36.98
11	Jumka × RNG-73	144.76	148.92	145.37	20.72	21.28	22.63	35.46	36.39	38.26
12	Jumka × Pusa Mustard-28	142.89	144.82	136.71	23.52*	23.75*	22.05	36.6	36.84	37.75
13	Jumka × Gujarat Mustard-3	141.88	145.1	146.04	21.42*	22	21.87	35.04	34.7	33.95
14	Jumka × ZEM-1	149.01	142.28	139.98	20.09	21.24	20.13	37.48	37.03	37.8
15	Jumka × DRMR-1	130.28	145.62	141.04	22.74*	21.84	22.21	35.96	36.11	38.67
16	Jumka × NRCHB-101	140.56	135.09	150.45	18.55	19.36	19.33	36.91	36.46	36.94
17	Jumka × RH-30	150.81	146.99	150.33	18.18	18.59	19.28	36.18	37.01	38.64
18	Jumka × TM-4	152.51	162.07	156.64	20.51	19.02	19.75	34.72	35.51	37.24
19	Jumka × KBS-3	157.36	153.33	142.06	18.99	20.49	21.91	34.06	34.23	35.23
20	RNG-73 × Pusa Mustard-28	242.55*	247.83*	256.94*	13.73	13.41	12.84	38.66	38.71	38.51
21	RNG-73 × Gujarat Mustard-3	239.49*	235.04*	241.67*	15.4	15.5	14.26	38.45	38.53	38.18
22	RNG- 73 × ZEM-1	239.71*	254.97*	253.65*	12.89	13.29	12.42	39	39.97	39.56
23	RNG-73 × DRMR-1	250.7*	251.24*	254.19*	14.27	14.82	14.89	36.83	37.3	38.22
24	RNG-73 × NRCHB-101	237.91*	254.73*	256.66*	15.53	14.05	13.69	36.25	36.53	35.46
25	RNG-73 × RH-30	227.95*	237.49*	251.46*	14.46	14.9	12.94	37.94	37.78	37.63
26	RNG-73 × TM-4	258.3*	250.15*	246.89*	13.31	14.35	14.88	36.53	34.84	35.59
27	RNG-73 × KBS-3	253.44*	261.79*	251.72*	14.42	14.47	13.35	36.77	36.29	36.9
28	Pusa Mustard-28 × Gujarat Mustard-3	204.02*	245.16*	151.71	10.44	8.72	15.75	37.23	38.37	37.91
29	Pusa Mustard-28 × ZEM-1	207.22*	250.45*	206.36*	10.27	9.42	12.61	37.28	36.89	36.86
30	Pusa Mustard-28 × DRMR-1	207.68*	192.36*	167.78	12.29	13.1	16.66	36.45	37.61	36.02

	Genotypes	Biological Yield per Plant (g)			Harvest Index (%)			Seed Oil Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
31	PusaMustard-28 × NRCHB-101	201.1*	183.21*	177.45*	12.42	12.9	13.53	36.11	36.55	37.82
32	Pusa Mustard- 28 × RH-30	229.44*	188.93*	190.75*	11.75	14.15	14.52	36.07	37.37	37.87
33	Pusa Mustard- 28 × TM-4	178.22*	170.95	194.86*	11.53	13.11	12.39	36.83	36.24	37.61
34	Pusa Mustard-28 × KBS-3	196.08*	169.95	142.09	10.45	12.96	15.34	36.05	35.97	36.74
35	Gujarat Mustard-3 × ZEM-1	170.61*	147.58	154.41	10.83	11.78	13.35	36.79	37.41	38.88
36	Gujarat Mustard-3 × NRCHB-101	162.76	139.08	147.84	11.77	12.85	13.39	38.36	37.6	38.6
37	Gujarat Mustard-3 × DRMR-1	153.46	133.86	134.48	13.01	10.46	12.32	38.36	39.17	38.66
38	Gujarat Mustard-3 × RH-30	147.97	122.61	141.69	12.49	13.48	13.19	38.37	38.24	37.85
39	Gujarat Mustard-3 × TM-4	130.89	123.21	107.09	12.74	12.1	13.32	39.58	40.38	40.35
40	Gujarat Mustard-3 × KBS-3	133.56	207.25*	132.49	11.34	8.49	13.08	37.25	38.38	39.39
41	ZEM-1 × DRMR-1	80.4	62.46	103.3	11.05	14.98	11.44	42.06	41.2	41.34
42	ZEM-1 × NRCHB-101	67.38	87.77	103.71	15.82	13.42	14.09	38.74	38.46	37.73
43	ZEM-1 × RH-30	78.7	67.22	95.7	12.27	13.26	11.77	39.38	39.94	39.39
44	ZEM-1 × TM-4	90	78.83	77.49	11.4	12.99	15.51	41.18	41.82	41.3
45	ZEM-1 × KBS-3	91.91	73.69	74.19	13.35	13.85	15.19	41.25	39.83	41.76
46	DRMR-1 × NRCHB -101	182.81*	164.07	133.67	11.71	14.43	18.53	39.12	39.76	39.47
47	DRMR-1 × RH-30	219.42*	152.59	127.52	11.8	15.9	19.48	39.39	40.83	39.42
48	DRMR-1 × TM-4	167.94*	159.93	127.75	13.03	14.61	17.23	41.12	40.47	40.52
49	DRMR-1 × KBS-3	174.93*	205.51*	141.8	11.99	11.22	15.96	38.02	37.69	38.7
50	NRCHB-101 × RH-30	216.94*	199.65*	227.31*	14.25	16.29	14.82	37.06	36.73	38.96
51	NRCHB-101 × TM-4	204.77*	210.5*	216.52*	17.35	17.53	15.75	37.83	37.81	37.14
52	NRCHB-101 × KBS-3	213.19*	217.53*	216.56*	16.81	16.55	15.84	39.65	40.62	39.59
53	RH-30 × TM-4	214.58*	221.78*	227.57*	15.88	15.82	14.56	39.12	39.81	41.11
54	RH-30 × KBS-3	205.19*	224.78*	225.06*	16.86	16.43	15.76	42.24*	40.83	39.54
55	TM-4 × KBS-3	203.27*	198.19*	199.26*	16.3	16.46	17.53	36.63	37.25	37.84
56	Varuna (CHECK)	133.8	146.1	146.3	19.03	20.73	21.56	40.24	40.48	40.72
	Mean	175.13	175.96	171.59	14.73	15.07	15.66	37.83	38.01	38.22
	SE (d) ±	14.48	16.17	11.02	1.16	1.37	1.31	0.92	0.93	1.4
	CV (%)	8.27	9.19	6.42	7.88	9.09	8.4	2.43	2.46	3.66
	CD at 5%	29.21	32.62	22.24	2.34	2.76	2.65	1.86	1.89	2.83

*Significance at P≤ 0.05

Table 4.12 *Per se* performance of genotypes for seed nitrogen content (%) and chaff nitrogen content (%) under various nitrogen levels

	Genotypes	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1	Jumka	1.2933	1.3278	1.3504	0.4474	0.452	0.451
2	RNG-73	1.3195	1.3539	1.3626	0.5203	0.5326	0.5373
3	Pusa Mustard-28	1.3043	1.3441	1.3925	0.6347	0.6421	0.6465
4	Gujarat Mustard-3	1.257	1.2877	1.358	0.3279	0.331	0.3352
5	ZEM-1	1.2469	1.285	1.3196	0.7268	0.7289*	0.7309*
6	DRMR-1	1.2931	1.3167	1.3529	0.4509	0.4599	0.4544
7	NRCHB-101	1.3442	1.3671	1.3812	0.8145	0.8211*	0.8219*
8	RH-30	1.3427	1.3511	1.3854	0.7478	0.7554*	0.7585*
9	TM-4	1.316	1.3559	1.4021	0.6229	0.7592*	0.7581*
10	KBS-3	1.3879	1.4133	1.4414	0.6246	0.6332	0.6395
11	Jumka × RNG-73	1.3322	1.359	1.4026	0.4479	0.4554	0.4477
12	Jumka × Pusa Mustard-28	1.2617	1.2824	1.3551	0.4278	0.4475	0.4537
13	Jumka × Gujarat Mustard-3	1.303	1.323	1.3958	0.4758	0.4564	0.459
14	Jumka × ZEM-1	1.3212	1.3419	1.3899	0.4622	0.4592	0.4662
15	Jumka × DRMR-1	1.2812	1.3135	1.3566	0.4459	0.4531	0.4593
16	Jumka × NRCHB-101	1.2918	1.3306	1.3626	0.4439	0.4456	0.4513
17	Jumka × RH-30	1.334	1.3748	1.3903	0.4752	0.4523	0.4594
18	Jumka × TM-4	1.292	1.3337	1.3817	0.4429	0.4443	0.4519
19	Jumka × KBS-3	1.3247	1.3596	1.3617	0.4439	0.4608	0.4587
20	RNG-73 × Pusa Mustard-28	1.3078	1.3653	1.4006	0.5303	0.5299	0.534
21	RNG-73 × Gujarat Mustard-3	1.3135	1.3438	1.3716	0.5417	0.54	0.5424
22	RNG- 73 × ZEM-1	1.2954	1.3258	1.364	0.537	0.5366	0.5411
23	RNG-73 × DRMR-1	1.2503	1.2884	1.3542	0.5258	0.5424	0.4957
24	RNG-73 × NRCHB-101	1.2794	1.298	1.3415	0.5201	0.5263	0.5307
25	RNG-73 × RH-30	1.2603	1.2947	1.3553	0.5236	0.5269	0.5283
26	RNG-73 × TM-4	1.3278	1.359	1.3983	0.5168	0.5183	0.5297
27	RNG-73 × KBS-3	1.285	1.2986	1.3442	0.5314	0.5309	0.528
28	Pusa Mustard-28 × Gujarat Mustard-3	1.3417	1.3707	1.3938	0.6307	0.6386	0.6321
29	Pusa Mustard-28 × ZEM-1	1.349	1.3579	1.3985	0.6367	0.643	0.6374
30	Pusa Mustard-28 × DRMR-1	1.3891	1.4004	1.4319	0.6356	0.6386	0.6394

	Genotypes	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
31	PusaMustard-28 × NRCHB-101	1.41	1.4273	1.4313	0.6235	0.6289	0.6314
32	Pusa Mustard- 28 × RH-30	1.3361	1.366	1.4091	0.6335	0.6414	0.6481
33	Pusa Mustard- 28 × TM-4	1.369	1.4029	1.4285	0.6327	0.639	0.6334
34	Pusa Mustard-28 × KBS-3	1.3566	1.3648	1.4227	0.638	0.6438	0.638
35	Gujarat Mustard-3 × ZEM-1	1.2942	1.3213	1.358	0.3253	0.3315	0.3316
36	Gujarat Mustard-3 × NRCHB-101	1.2678	1.297	1.3216	0.3245	0.3317	0.3357
37	Gujarat Mustard-3 × DRMR-1	1.335	1.3592	1.3812	0.3235	0.3326	0.335
38	Gujarat Mustard-3 × RH-30	1.3214	1.3495	1.3994	0.3312	0.3356	0.3445
39	Gujarat Mustard-3 × TM-4	1.2904	1.3206	1.3665	0.3298	0.3407	0.3484
40	Gujarat Mustard-3 × KBS-3	1.3344	1.3581	1.324	0.3413	0.3396	0.376
41	ZEM-1 × DRMR-1	1.2756	1.3068	1.3118	0.7258	0.7272*	0.7327*
42	ZEM-1 × NRCHB-101	1.3189	1.3439	1.3642	0.729	0.736*	0.7407*
43	ZEM-1 × RH-30	1.2493	1.2941	1.2875	0.7252	0.7266*	0.7315*
44	ZEM-1 × TM-4	1.3483	1.3553	1.3303	0.7317	0.74*	0.7393*
45	ZEM-1 × KBS-3	1.2102	1.2967	1.2857	0.736	0.7419*	0.7458*
46	DRMR-1 × NRCHB -101	1.3123	1.3265	1.3778	0.4564	0.4616	0.4709
47	DRMR-1 × RH-30	1.3132	1.3298	1.3591	0.4507	0.4534	0.4572
48	DRMR-1 × TM-4	1.3311	1.361	1.3541	0.4475	0.4544	0.4631
49	DRMR-1 × KBS-3	1.2577	1.3123	1.3536	0.4483	0.4492	0.4534
50	NRCHB-101 × RH-30	1.3613	1.3697	1.3919	0.8165	0.821*	0.8238*
51	NRCHB-101 × TM-4	1.3961	1.4224	1.407	0.8359*	0.8345*	0.8437*
52	NRCHB-101 × KBS-3	1.4345	1.4403	1.4505	0.8403*	0.8441*	0.8398*
53	RH-30 × TM-4	1.3239	1.3733	1.3668	0.7473	0.766*	0.7635*
54	RH-30 × KBS-3	1.3736	1.4028	1.3864	0.7502	0.752*	0.7596*
55	TM-4 × KBS-3	1.2967	1.341	1.3571	0.6273	0.6512*	0.6611
56	Varuna (CHECK)	1.3715	1.3984	1.4226	0.6333	0.6424	0.6409
	Mean	1.3167	1.3458	1.374	0.5592	0.5666	0.5691
	SE (d) ±	0.0327	0.0242	0.0259	0.0948	0.0033	0.0119
	CV (%)	2.4868	1.795	1.8849	0.9572	0.5851	2.0827
	CD at 5%	0.0661	0.0487	0.0523	0.1914	0.0067	0.0239

*Significance at P≤ 0.05

4.2.17 Chaff Nitrogen Content (%)

The chaff nitrogen for crosses varied from 0.3235 (Gujarat Mustard-3 × DRMR-1) to 0.8403% (NRCHB-101 × KBS-3) in case of control. In this case, the crosses NRCHB-101 × TM-4 and NRCHB-101 × KBS-3 were found significantly superior over the check Varuna for chaff nitrogen.

In case of condition of dose of 75 Kg Nitrogen per ha, the range for chaff nitrogen varied from 0.3315 (Gujarat Mustard-3 × ZEM-1) to 0.8441% (NRCHB-101 × KBS-3) for crosses. Range from 0.3316 (Gujarat Mustard-3 × ZEM-1) to 0.8437% (NRCHB-101 × TM-4) was found for crosses in case of condition of dose of 150 Kg Nitrogen per ha. In both conditions, same five crosses *viz.,* NRCHB-101 × RH-30; NRCHB-101 × TM-4; NRCHB-101 × KBS-3; RH-30 × TM-4 and RH-30 × KBS-3 exhibited significantly better performance for chaff nitrogen over the check Varuna. However the genotype- TM-4 × KBS-3 was found performing significantly superior in case of dose of 75 Kg Nitrogen per ha only.

The genotypes among parents varied from 0.3279 (Gujarat Mustard-3) to 0.8145% (NRCHB-101) in control for chaff nitrogen. None of the parents were found significantly superior over the check Varuna for this character. In case of condition of dose of 75 Kg Nitrogen per ha, the range of parents for chaff nitrogen varied from 0.331 (Gujarat Mustard-3) to 0.8211 (NRCHB-101). The range among parental genotypes varied from 0.3352 (Gujarat Mustard-3) to 0.8219 (NRCHB-101) in case of condition of dose of 150 Kg Nitrogen per ha. Four parental genotypes *viz.,* ZEM-1, NRCHB-101, RH-30 and TM-4 exhibited significant level of superiority for the character over the check Varuna in both condition of nitrogen doses.

The mean performance has been used by Kumhalkar *et al.* (1999) for identification of potential crosses for seed yield in Indian mustard. Acharya and Swain (2004); Goswami and Bahal (2005); Patel *et al.* (2012); Dholu *et al.* (2014); Chaurasia *et al.* (2018), Singh *et al.* (2019) and Kaur *et al.* (2019) used *per se* performances along with the estimates of heterosis and combining abilities for identification of potential cross combinations for various traits including seed yield and oil content. Singh and Lallu (2004) also determined the *per se* performance of the crosses in Indian mustard for the exploitation of heterosis. Gul *et al.* (2018) also observed crosses combinations with high *per se* performance and high *sca* in *Brassica napus*.

Rao and Gulati (2002) used the *per se* performance for evaluation of genotypes and found it in correlation with *sca* and *gca* effects. Similar correlation can be seen through the results in the present research endeavor. Singh and Dixit (2007) also suggested association of *per se* performance and *gca* effects which can also be seen in the present study. Some parents with high *gca* effects did not compulsorily seem exhibiting high *per se* performance which was in line with the studies of Aher *et al.* (2009).

4.3 Nitrogen uptake pattern and its effect on different yield attributes

The nitrogen uptake per plant was further divided into Seed Nitrogen Uptake and Stover Nitrogen Uptake, which were obtained by multiplying Nitrogen Content with respective dry matter accumulations of seed and stover. The effect of Nitrogen doses in comparison to control for different yield attributes along with Nitrogen uptake are given here under (Table 4.13 & 4.14) by using Student's T- Test.

4.3.1 Days to Flower Initiation

The days to Flower Initiation decreased in 75 Kg Nitrogen per ha condition and seem to increase in 150 Kg Nitrogen per ha condition when compared with mean of control (Fig. 4.1). Kumar and Kumar (2008) observed decrease in number of flowering days when higher dose of nitrogen was applied. However the difference in both cases was found non- significant on application of Student's T- Test.

4.3.2 Days to Fifty Percent Flowering

The days to fifty percent flowering increased in both 75 Kg and 150 Kg Nitrogen per ha condition (Fig. 4.1). Kumar and Kumar (2008) found similar results in their studies. However the increase in only 150 Kg Nitrogen per ha condition was found significant on comparing the mean in respective condition with control with help of Student's T- Test.

Table 4.13 Overall mean values of genotypes for various characters under different nitrogen conditions (A)

	CHARACTERS									
CONDITIONS	**DFI**	**DFF**	**DTM**	**PH**	**PBPP**	**SBPP**	**LMS**	**SMS**	**SL**	**SPS**
Control	56.34	75.83	135.3	174.29	7.47	28.63	55.76	37.97	6.3	17.13
75 Kg/ha	55.97	76.28	135.27	176.8	7.61	30.11*	55.16	39.87	6.53*	15.96
150Kg/ha	56.59	77.02*	136.5*	178.28*	7.26	30.08*	56.98	37.81	6.33	14.26*
Overall Mean	56.3	76.38	135.69	176.46	7.45	29.61	55.97	38.55	6.39	15.78
SE	0.18	0.35	0.41	1.16	0.1	0.49	0.54	0.66	0.07	0.83

*Significance P≤ 0.05

DFI= Days to flower initiation; **DFF**= Days to fifty percent flowering; **DTM**= Days to Maturity; **PH**= Plant Height; **PBPP**= No. of Primary Branches per plant; **SBPP**= No. of Secondary branches per plant; **LMS**= Length of Main Shoot; **SMS**= No. of siliquae on main shoot; **SL**= Siliqua Length and **SPS**= No. of seeds per siliqua

Table 4.14 Overall mean values of genotypes for various characters under different nitrogen conditions (B)

	CHARACTERS								
CONDITIONS	**TW**	**SYPP**	**BYPP**	**HI**	**OC**	**SN**	**CN**	**SNU**	**CNU**
Control	4.33	25.83	175.54	14.86	37.83	1.317	0.559	0.34	0.837
75 Kg/ha	4.65	26.49	176.73	15.23	38.01	1.346	0.567	0.357	0.852
150Kg/ha	4.78*	26.8*	172.09	15.83*	38.22*	1.374*	0.569*	0.368*	0.827
Overall Mean	4.59	26.37	174.79	15.31	38.02	1.346	0.565	0.355	0.839
SE	0.13	0.29	1.39	0.28	0.11	0.016	0.003	0.008	0.007

*Significance P≤ 0.05

TW= 1000 Seed weight; **SYPP**= Seed yield Per Plant; **BYPP**= Biological Yield Per Plant; **HI**= Harvest Index; **OC**= Oil Content; **SN**= Seed Nitrogen(%); **CN**= Chaff Nitrogen(%); **SNU**= Seed Nitrogen uptake (g); **CNU**= Chaff Nitrogen Uptake(g)

4.3.3 Days to Maturity

The increase in duration of days to maturity was observed in both 75 Kg and 150 Kg Nitrogen per ha condition (Fig. 4.1). However, the increase was found significant only in case of 150 Kg Nitrogen per ha condition over control on comparing means of different genotypes with Student's T- Test.

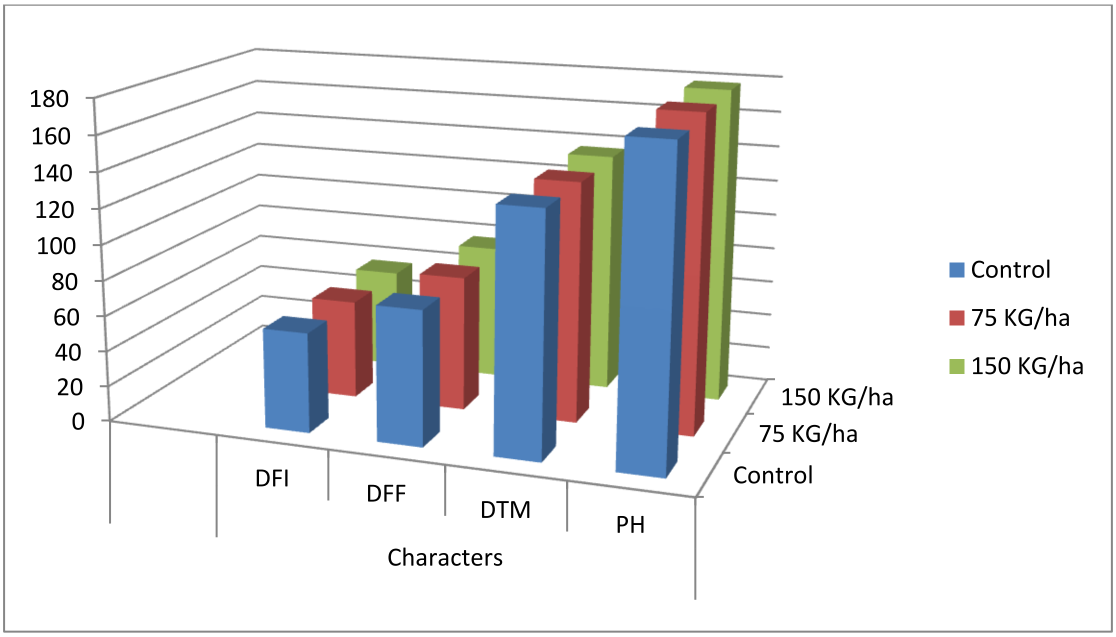


Fig.4.1 Histogram showing overall mean comparison for various characters under different Nitrogen conditions

DFI= Days to flower initiation; **DFF**= Days to fifty percent flowering; **DTM**= Days to Maturity and **PH**= Plant Height

4.3.4 Plant Height (cm)

The plant height increased over the control in 75 Kg and 150 Kg Nitrogen per ha condition (Fig. 4.1). Dongarkar *et al.* (2005) also found that increase in quantity of nitrogen resulted in increase of height of Indian mustard. Here also, the significant increase in Plant Height was only observed in 150 Kg Nitrogen per ha condition on comparing the mean with control with Student's T- Test.

4.3.5 Number of Primary Branches per Plant

A non-significant variation was observed in both Nitrogen doses for number of primary branches per plant on applying Student's T-test of mean of different genotypes in each condition with mean of control. Therefore the trait does not seem to be effected by given Nitrogen dose. (Fig. 4.2)

4.3.6 Number of Secondary Branches per Plant

Application of Student's T- Test of mean of different genotypes in each of the Nitrogen dose condition with control revealed a significant level of increase in the number of secondary branches per plant. Therefore the variation in trait was significant in both 75 Kg and 150 Kg Nitrogen per ha condition and hence the trait was found effected by change in Nitrogen levels (Fig. 4.2). Thakur *et al.* (2005) in their investigation found increase in number of secondary branches with higher nitrogen dose 120 Kg /ha.

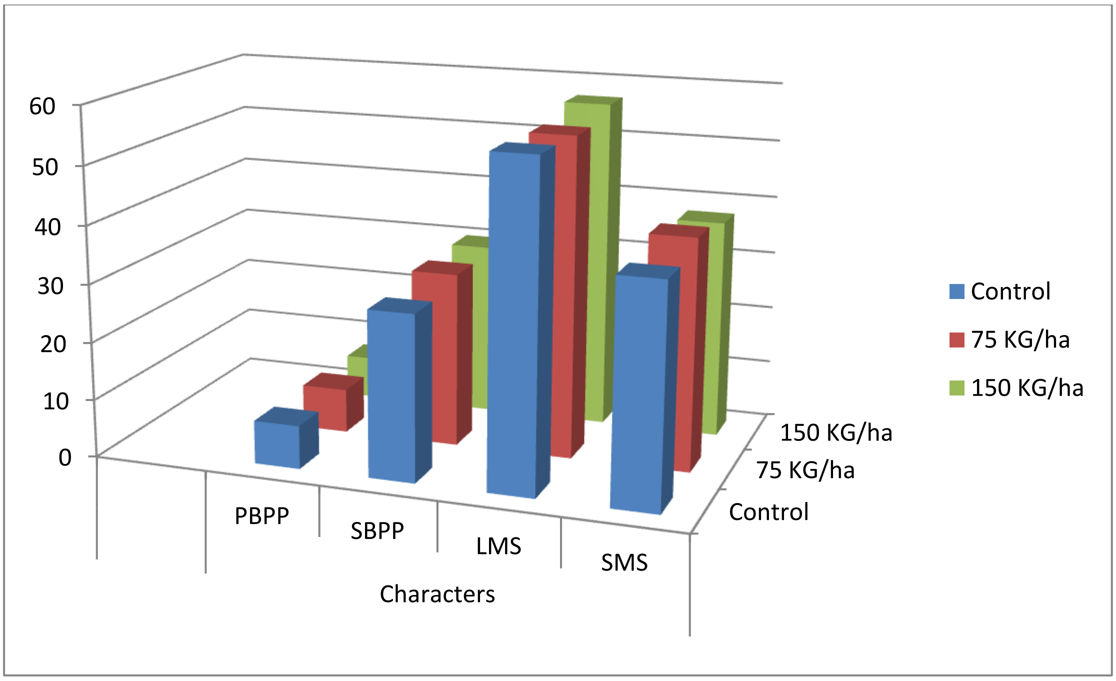


Fig.4.2 Histogram showing overall mean comparison for various characters under different Nitrogen conditions

PBPP= No. of Primary Branches per plant; **SBPP**= No. of Secondary branches per plant; **LMS**= Length of Main Shoot and **SMS**= No. of siliquae on main shoot

4.3.7 Length of Main Shoot (cm)

No clear trend was observed for the relation between the increased Nitrogen level and the Length of Main Shoot (Fig. 4.2). The variation so observed between mean of the both Nitrogen level conditions *i.e.* 75 Kg and 150 Kg Nitrogen per ha were found non significant when compared with control using Student's T- Test.

4.3.8 Number of Siliqua on Main Shoot

The number of siliqua on main shoot did not seem to be effected by Nitrogen levels as the application of Student's T- Test revealed a non significant variation for the trait on comparing the mean of different genotypes in each of the Nitrogen condition with mean for the trait in control (Fig. 4.2).

4.3.9 Siliqua Length (cm)

The siliqua length seems to increase with the level of Nitrogen (Fig. 4.3). Singh *et al.* (2002) observed increase in siliqua length with the higher nitrogen dose of 120 Kg/ha. However, the trait was significantly different with control only in case of 75 Kg Nitrogen per ha condition. In case of 150 Kg Nitrogen per ha condition, the siliqua length was found at par with the control.

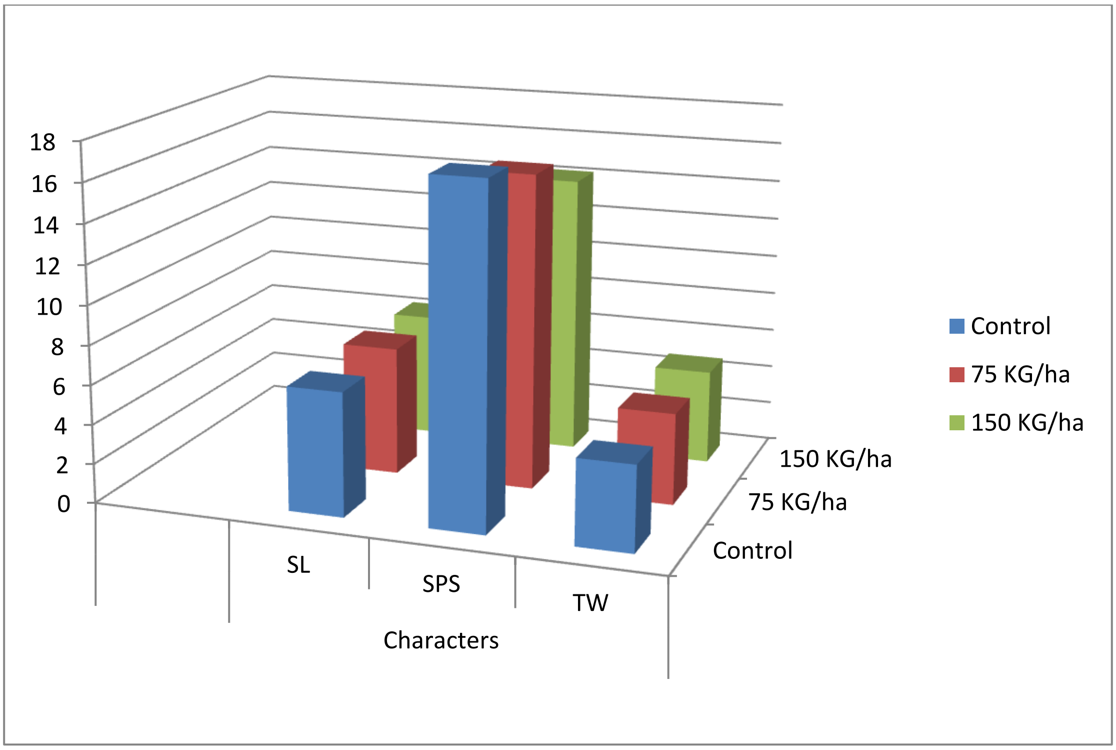


Fig.4.3 Histogram showing overall mean comparison for various characters under different Nitrogen conditions

SL= Siliqua Length; **SPS**= No. of seeds per siliqua and **TW**= 1000 Seed weight

4.3.10 Number of Seeds per Siliqua

The number of seeds per siliqua appeared to decrease in Nitrogen dose condition over control (Fig. 4.3). Application of Student's T- Test revealed a significant level of decrease only in case of 150 Kg Nitrogen per ha condition. In other case *i.e.* 75 Kg Nitrogen per ha condition, the increase was found non-significant. Singh *et al.* (2002) also observed similar results.

4.3.11 1000 Seed Weight (g)

The 1000 Seed weight increased with the increase in level of Nitrogen. Singh and Brar (1999) also observed increase in 1000 seed weight with dose of 100 Kg/ha. However a significant increase was only found in case of 150 Kg Nitrogen per ha condition on application of Student's T- Test of the mean of different genotypes in the condition with control. In case of 75 Kg Nitrogen per ha condition, the variation so observed was found non-significant (Fig. 4.3).

4.3.12 Seed Yield per Plant (g)

An increase was found for seed yield per plant with increase in Nitrogen level (Fig. 4.4). Deekshitulu *et al.* (1998) also observed same trend that found increase in seed yield with successive increase of nitrogen level up to 150 Kg/ha**.** Application of Student's T- Test between the mean in Nitrogen dose conditions and control revealed that the increase was non-significant in case of 75 Kg Nitrogen per ha condition and significant for 150 Kg Nitrogen per ha condition. Therefore, the trait seems to be effected by change in given Nitrogen levels.

4.3.13 Biological Yield per Plant (g)

A non-significant variation was observed on application of Student's T- Test of mean of different genotypes in 75 Kg and 150 Kg Nitrogen per ha condition with mean in control. No clear trend was observed on comparing the values in all of the conditions (Fig. 4.4).

4.3.14 Harvest Index (%)

The value of Harvest Index tends to increase with the level of nitrogen application (Fig. 4.4). The increase in 150 Kg Nitrogen per ha condition was found significant. On the other hand, the increase in case of 75 Kg Nitrogen per ha condition was found non-significant on application of Student's T- Test with the mean obtained in control.

4.3.15 Seed Oil Content (%)

The oil content of seeds seems to increase with increase in nitrogen levels (Fig. 4.4). However application of Student's T- Test revealed non-significant increase in 75 Kg Nitrogen per ha conditions and a significant increase in 150 Kg Nitrogen per ha condition. Arora *et al.* (1994) observed that significant increase of nitrogen level upto 30 Kg /ha resulted in increases oil content while there was reduction at higher dose of 90 Kg/ha.

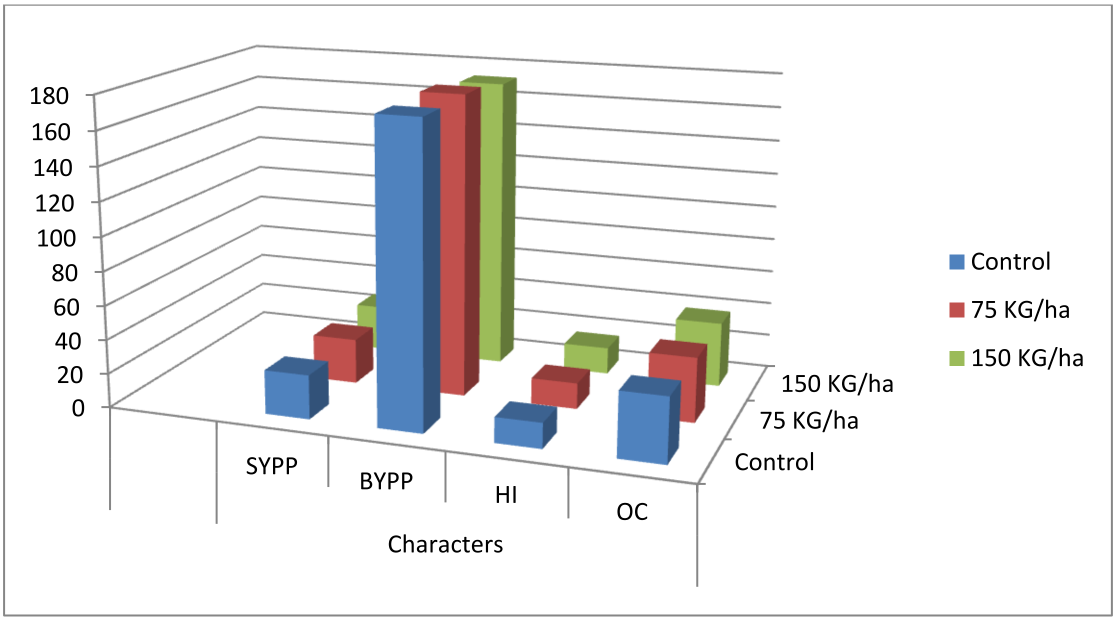


Fig.4.4 Histogram showing overall mean comparison for various characters under different Nitrogen conditions

SYPP= Seed yield Per Plant; **BYPP**= Biological Yield Per Plant; **HI**= Harvest Index and **OC**= Oil Content

4.3.16 Seed Nitrogen Content (%)

The seed nitrogen increased with increase in Nitrogen level (Fig. 4.5), possibly due to increase in nitrogen uptake. On comparing the mean observed for various genotypes for each nitrogen condition along with mean of control using Student's T-Test, the significant level of variation was only observed in case of 150 Kg Nitrogen per ha condition. In other case *i.e.* 75 Kg Nitrogen per ha condition, the variation so observed was found non-significant.

4.3.17 Chaff Nitrogen Content (%)

Similar trend was observed for chaff nitrogen as in seed nitrogen (Fig. 4.5). Application of Student's T- Test of mean with control revealed a non-significant increase in chaff nitrogen content for 75 Kg Nitrogen per ha condition and a significant increase for the trait in 150 Kg Nitrogen per ha condition.

4.3.18 Seed Nitrogen Uptake

The seed nitrogen uptake increased with increase in level of nitrogen (Fig. 4.5). However, significant variation was only found for 150 Kg Nitrogen per ha condition. In other case of 75 Kg Nitrogen per ha condition, the variation so observed was non-significant. Yadav *et al.* (2007) found similar results.

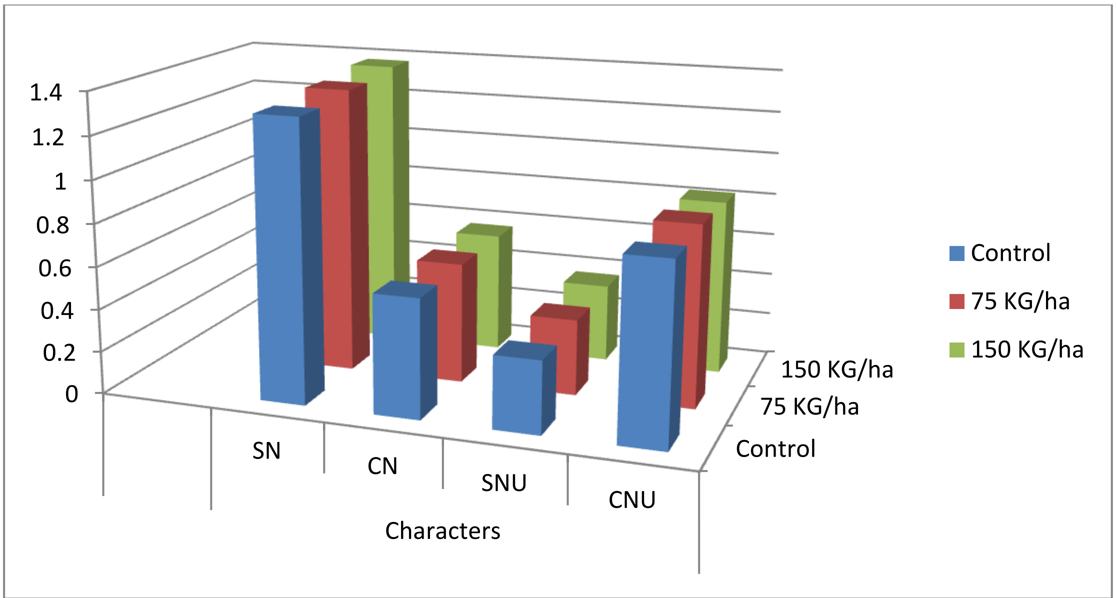


Fig.4.5 Histogram showing overall mean comparison for various characters under different Nitrogen conditions

SN= Seed Nitrogen Content(%); **CN**= Chaff Nitrogen content(%); **SNU**= Seed Nitrogen uptake (g) and **CNU**= Chaff Nitrogen Uptake(g)

4.3.19 Stover Nitrogen Uptake

A non-significant variation was observed for the stover nitrogen uptake (Fig. 4.5). In case of 75 Kg Nitrogen per ha condition, the trait exhibited a non-significant increase. However, a non-significant decrease was observed in case of 150 Kg Nitrogen per ha condition due to reduction in biological yield possibly caused by nutrient imbalance.

4.4 Pooled analysis of variance based on GGE biplot model

The pooled analysis of variance of fifty five genotypes including ten parents and their forty five crosses without reciprocals for seventeen different characters based on the GGE biplot model is presented in Tables 4.15 & 4.16. The mean squares due to genotypes were significant for all the characters. Similarly, the mean squares due to environment were also significant for all the characters except siliqua length, biological yield per plant and oil content. The G × E interaction was insignificant for majority of the traits except for siliqua length and seed nitrogen where it was highly significant. The G × E interaction was further partitioned into three Interaction Principle Component Analysis (IPCA) axis and for every trait IPCA-I and IPCA-II jointly explain the percent variation which is more than sixty percent of the total variation. IPCA-I was significant for all the traits except for the trait- seed nitrogen. Similarly IPCA-II was also significant for all the traits except for plant height, siliqua length, test weight, seed yield per plant, seed oil content and seed & chaff nitrogen content. IPCA-III was significant for only secondary branches per plant, Seeds per siliqua and biological yield per plant.

4.4.1 GGE Biplot display

To investigate the main effects and interactions across different environments, GGE biplot were constructed for yield and its various attributing traits. The genotype those are farthest from the origin being more responsive. The concentric circles on the GGE biplot help in the visualization of the length of environment vector. The length of environment vector is directly proportional to the standard deviation within that specific environment. More the length of vector, more is the standard deviation and hence more is discriminating ability of that specific environment. The environments with short vector length should not be used for testing as these are non-discriminating and give little information on the genotypes. The average environment axis (AEA) is drawn from the point of origin and passes through the average environment which comprises of average coordinates of all test environments. This AEA is used for determination of representativeness of the test environments. The environments with lesser angle with AEA are deemed to be more representatives than others. Same environment can be discriminating and representative at the same time. Such environments are good for selection of generally adapted genotypes. The specifically adapted genotypes can be tested in discriminating environments that are nor representative. Such environments are utilized for removal of unstable genotypes in case of single mage environment. The environments that possess short vector length in GGE biplot are non discriminating test environments. These environments can be utilized only under narrow circumstances because they provide very less information about the genotypes.

The "which-won-where" function of a GGE biplot reveals the information about genotype is top performer in the respective environment and ideal for which particular environment. The genotypes that are located farthest from the point of origin in GGE biplot are connected to form a polygon in such a way that all other genotypes lie within the boundaries of polygon. This polygon is divided into sectors with help of perpendicular lines also called as equality lines falling on each side of polygon from biplot origin. The genotypes which are located on the vertexes are the best or poorest performing in the sector where more than one environment may also be located.

The GGE biplot for the seventeen traits studied under the research endeavour are described below.

4.4.1.1 Days to Flower Initiation

The condition of 75 Kg N/ha (E2) was most discriminating and representative as represented through the graphs (Fig 4.6) and therefore can be used for selecting generally adapted genotypes. All the environments *i.e.* 150 Kg N/ha (E1), 75 Kg N/ha (E2) and control (E3) restrained into the same sector in which DRMR-1 (G1) was the worst performer for days to flower initiation. In addition the genotype ZEM-1 × TM-4 was located away from the sector at the vertex depicting desirable earliness for the trait.

Table 4.15 GGE biplot analysis of variance for various traits in Indian mustard (A)

Source	df	DFI	DFF	DTM	PH	PBPP	SBPP	LMS	SMS
Genotype	54	47.69**	217.02**	102.99**	2553.75**	3.134**	535.33**	222.54**	76.57*
Environment	2	45.33*	69.42*	295.31*	432.98*	40.96*	316.35*	64.77**	174.109**
G × E Interaction	108	2.033	1.55	0.762	1.157	0.169	1.443	1.00	1.726
PC1	56	43.02**	224.80**	145.43 **	2489.97**	4.197**	510.43*	216.41**	70.265**
PC2	54	3.415**	3.205**	5.216 **	2.003	3.13**	6.211*	3.811098*	5.522*
PC3	52	1.853	1.282	3.1312	0.313	0.925	5.110 *	2.806111	1.196
Residual	120	-1.879	-7.612	-5.481	-145.90	0.250	-36.291	-11.288	-0.426

*Significance P≤ 0.05 **Significance P≤ 0.01

DFI= Days to flower initiation; **DFF**= Days to fifty percent flowering; **DTM**= Days to Maturity; **PH**= Plant Height; **PBPP**= No. of Primary Branches per plant; **SBPP**= No. of Secondary branches per plant; **LMS**= Length of Main Shoot; **SMS**= No. of siliquae on main shoot

Table 4.16 GGE biplot analysis of variance for various traits in Indian mustard (B)

Source	df	SL	SPS	TW	SYPP	BYPP	HI	OC	SN	CN
Genotype	54	3.59**	35.13**	0.774**	399.11**	14713.7**	61.919**	16.244**	0.007**	0.132**
Environment	2	2.874	63.93*	6.152*	22.80*	708.93	25.10**	4.40	0.090**	0.0029**
G × E Interaction	108	0.143**	4.902	0.054	2.361	538.23	3.151	0.814	0.0004**	0.0003
PC1	56	3.511**	37.19**	0.753*	385.67*	14339.46*	62.49**	16.673*	0.0077	0.128*
PC2	54	0.492	5.045**	0.063	3.633	587.13*	4.300**	1.054	0.0006	0.0004
PC3	52	0.121	2.865*	0.046	0.968	499.61*	1.809	0.475	0.012	0.007
Residual	120	0.028	-3.304	0.056	-14.760	-814.28	-1.502	-0.872	0.0001	-0.057

*Significance P≤ 0.05 **Significance P≤ 0.01

SL= Siliqua Length and **SPS**= No. of seeds per siliqua **TW**= 1000 Seed weight; **SYPP**= Seed yield Per Plant; **BYPP**= Biological Yield Per Plant; **HI**= Harvest Index; **OC**= Oil Content (%); **SN**= Seed Nitrogen(%); **CN**= Chaff Nitrogen(%)

4.4.1.2 Days to Fifty Percent Flowering

The perusal of the GGE biplot graphs (Fig 4.7) depicted that all the three environments were nearly equally discriminating for the trait. However, here again 75 Kg Nitrogen/ha level (E2) was most representative among the three environments. The environments were confined into the same sector where crosses Gujarat Mustard-3 × TM-4 followed by Gujarat Mustard-3 × RH-30 were the worst performer for days to fifty percent flowering. The check variety Varuna was the best performer owing to its vertex positions away from the sector representing earliness for fifty percent flowering.

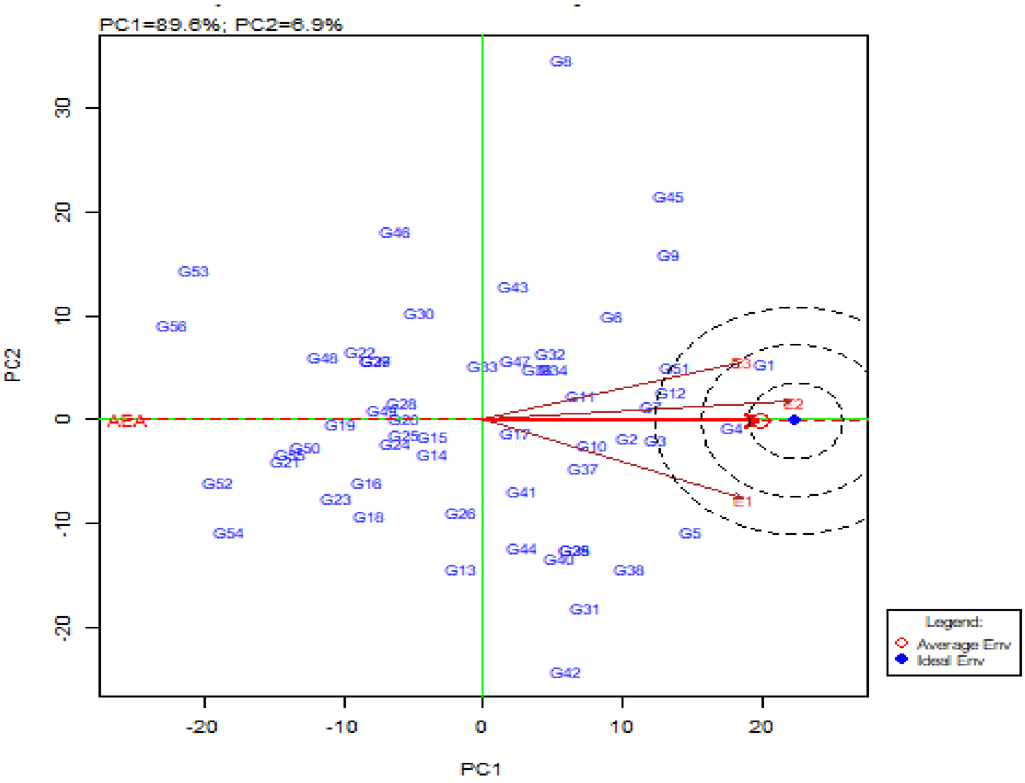
4.4.1.3 Days to Maturity

For this trait, the condition of 150 Kg N/ha (E1) and 75 Kg N/ha (E2) were found nearly equally discriminating (Fig 4.8). However, control (E3) was non-discriminating but most representative owing to its least angle with the AEA abscissa. Here again, all the environments were restricted into single sector which depicts close correlation between them. The genotypes Jumka and Jumka × RNG-73 were located at the vertex away from the sector where the environments were located depicting earliness for days to maturity. On the other hand the genotype ZEM-1 was located at the end of vertex in the sector where all three environments were located which represents its undesirability for the trait due to late maturity.

4.4.1.4 Plant Height (cm)

The perusal of GGE biplot graphs (Fig 4.9) for Plant height depicted that all the environments were nearly equal for discriminativeness and representativeness depicting very close correlation between them due to their occupation of position within the same sector & very acute angle between them. The Genotype RNG-73 × Gujarat Mustard-3 (G42) and RH-30 (G36) occupied the vertex position in the polygon which shows their undesirability to plant height. The crosses Jumka × KBS-3 (G16) and Jumka × RH-30 (G19) were the best performer for Plant Height as exhibited short heights represented by their far positions on the vertex away from the sector carrying all three environments.

Discriminativeness *vs* Representativeness



Which won Where/what

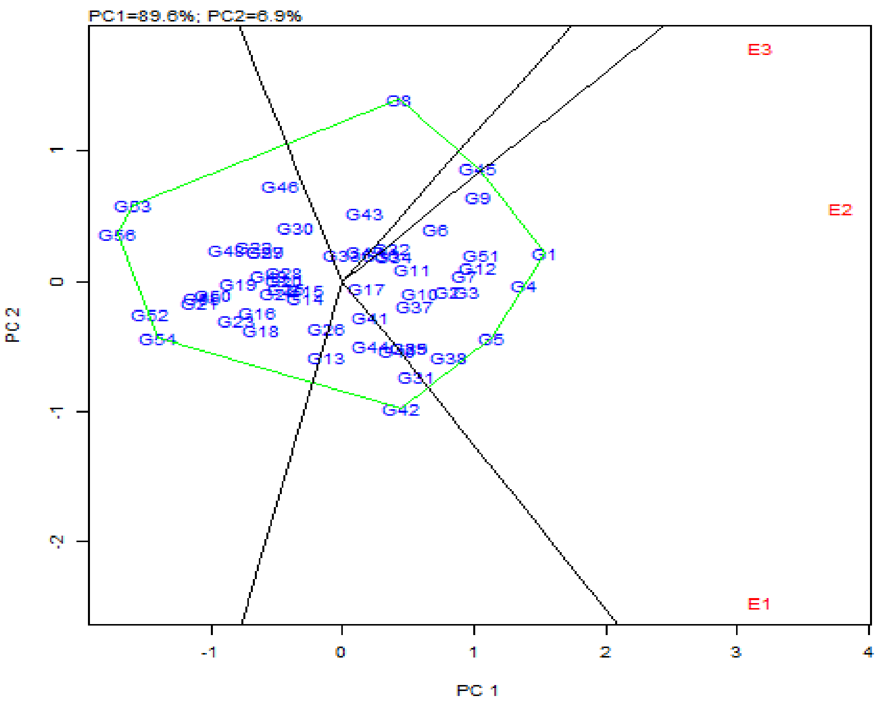


Fig 4.6 GGE biplot for days to flower initiation

Table 4.17 Codes used in GGE Biplot Graphs

Genotypes	Codes	Genotypes	Codes
DRMR-1	G1	PUSA MUSTARD- 28 × TM-4	G29
DRMR-1 × KBS-3	G2	PUSA MUSTARD-28	G30
DRMR-1 × NRCHB -101	G3	PUSA MUSTARD-28 × DRMR-1	G31
DRMR-1 × RH-30	G4	PUSA MUSTARD-28 × GUJRAT MUSTARD-3	G32
DRMR-1 × TM-4	G5	PUSA MUSTARD-28 × KBS-3	G33
GUJRAT MUSTARD-3	G6	PUSA MUSTARD-28 × ZEM-1	G34
GUJRAT MUSTARD-3 × DRMR-1	G7	PUSAMUSTARD-28 × NRCHB-101	G35
GUJRAT MUSTARD-3 × KBS-3	G8	RH-30	G36
GUJRAT MUSTARD-3 × NRCHB-101	G9	RH-30 × KBS-3	G37
GUJRAT MUSTARD-3 × RH-30	G10	RH-30 × TM-4	G38
GUJRAT MUSTARD-3 × TM-4	G11	RNG- 73 × Zem-1	G39
GUJRAT MUSTARD-3 × ZEM-1	G12	RNG-73	G40
Jumka	G13	RNG-73 × DRMR-1	G41
JUMKA × DRMR-1	G14	RNG-73 × GUJRAT MUSTARD-3	G42
JUMKA × GUJRAT MUSTAD-3	G15	RNG-73 × KBS-3	G43
JUMKA × KBS-3	G16	RNG-73 × NRCHB-101	G44
JUMKA × NRCHB-101	G17	RNG-73 × PUSA MUSTAD-28	G45
JUMKA × PUSA MUSTARD-28	G18	RNG-73 × RH-30	G46
JUMKA × RH-30	G19	RNG-73 × TM-4	G47
JUMKA × RNG-73	G20	TM-4	G48
JUMKA × TM-4	G21	TM-4 × KBS-3	G49
JUMKA × ZEM-1	G22	VARUNA (CHECK)	G50
KBS-3	G23	ZEM-1	G51
NRCHB-101	G24	ZEM-1 × DRMR-1	G52
NRCHB-101 × KBS-3	G25	ZEM-1 × KBS-3	G53
NRCHB-101 × RH-30	G26	ZEM-1 × NRCHB-101	G54
NRCHB-101 × TM-4	G27	ZEM-1 × RH-30	G55
PUSA MUSTARD- 28 × RH-30	G28	ZEM-1 × TM-4	G56

Environment	Code
150 Kg Nitrogen/ha	E1
75 Kg Nitrogen/ha	E2
Control	E3

4.4.1.5 Number of Primary Branches per Plant

The GGE Biplot for number of primary branches per plant depicted that the condition of 150 Kg per ha (E1) was most discriminating environment while the control (E3) was more representative environment owing to its short acute angle with AEA axis (Fig 4.10). All three environments were distributed to three different sectors. In case of 150 Kg N/ha (E1), the genotype Jumka (G13) was the best performer. The best performer for condition of 75 Kg N/ ha (E2) and control (E3) were RNG-73 × TM-4 (G47) and RNG-73 (G40), respectively.

4.4.1.6 Number of Secondary Branches per Plant

The perusal of GGE biplot graphs for number of secondary branches per plant depicted that the 75 Kg N/ha condition (E2) was most discriminating environment. On the other hand, the condition of control (E3) and 75 Kg N/ha (E2) were found nearly equal in representativeness (Fig 4.11). The condition of 75 Kg N/ha (E2) and control (E3) were confined within the same sector having the crosses RNG-73 × KBS-3 (G43) and RNG-73 × TM-4 (G47) as best performers. However the environment E1 (150 Kg N/ha) was located in different sector where the genotype RNG-73 × DRMR-1 (G41) emerged as the best performing genotype.

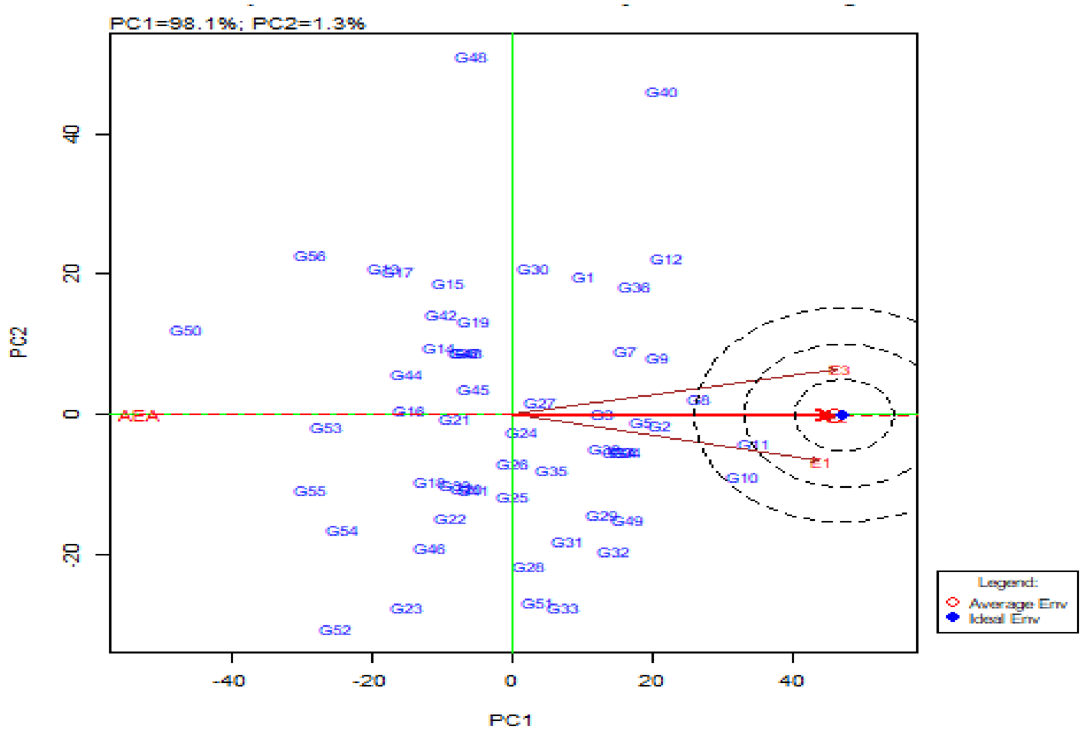
4.4.1.7 Length of Main Shoot (cm)

All the three environments were found nearly equally discriminating for length of main shoot on studying the GGE biplot graphs (Fig 4.12). However, control (E3) was the most representing environment out of the three owing to its least angle with the AEA axis. All the three environments were confined to the same sector where the two genotypes Varuna (G50) and NRCHB-101 (G24) were the best performers for length of main shoot.

4.4.1.8 Number of Siliquae on Main Shoot

For number of siliquae on main shoot, the condition of 75 Kg N/ha (E2) and control (E3) were found equally discriminating owing to the length of the vectors (Fig 4.13). However, 75 Kg N/ha (E2) was the most representative environment among the three conditions. In case of 150 Kg N/ha condition (E1), the genotype Varuna (G50) was the best performer as evident through its vertex position in the sector. The environments E2 (75 Kg N/ha) and E3 (Control) were limited in a single sector where the genotype RH-30 × KBS-3 (G37) was the best performer for number of siliquae on main shoot.

Discriminativeness *vs* Representativeness



Which won Where/what

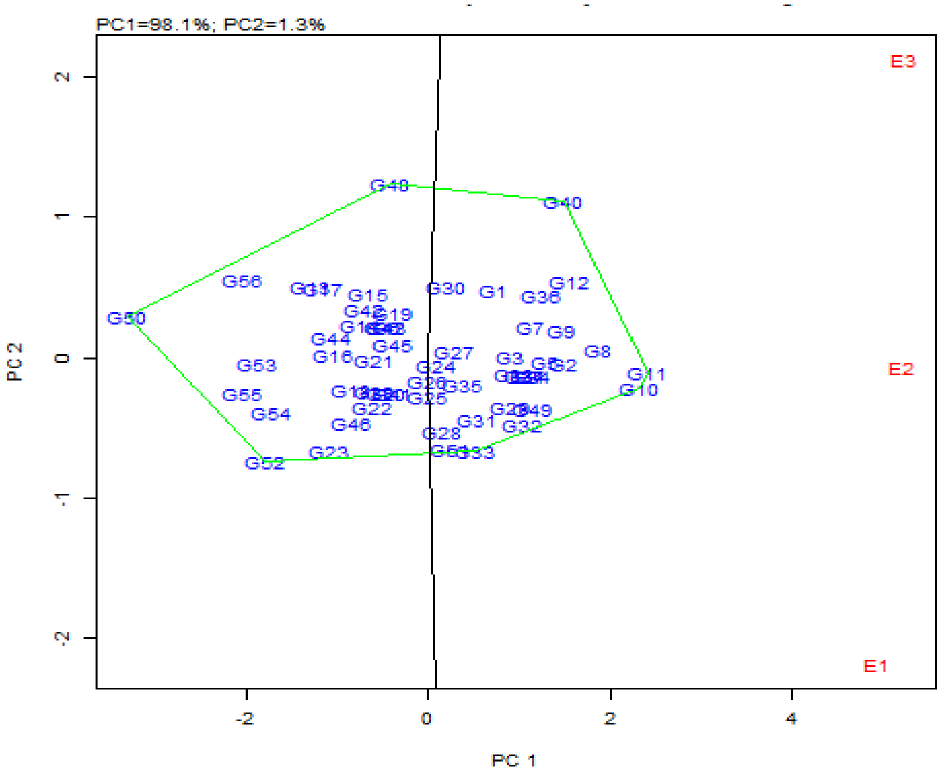
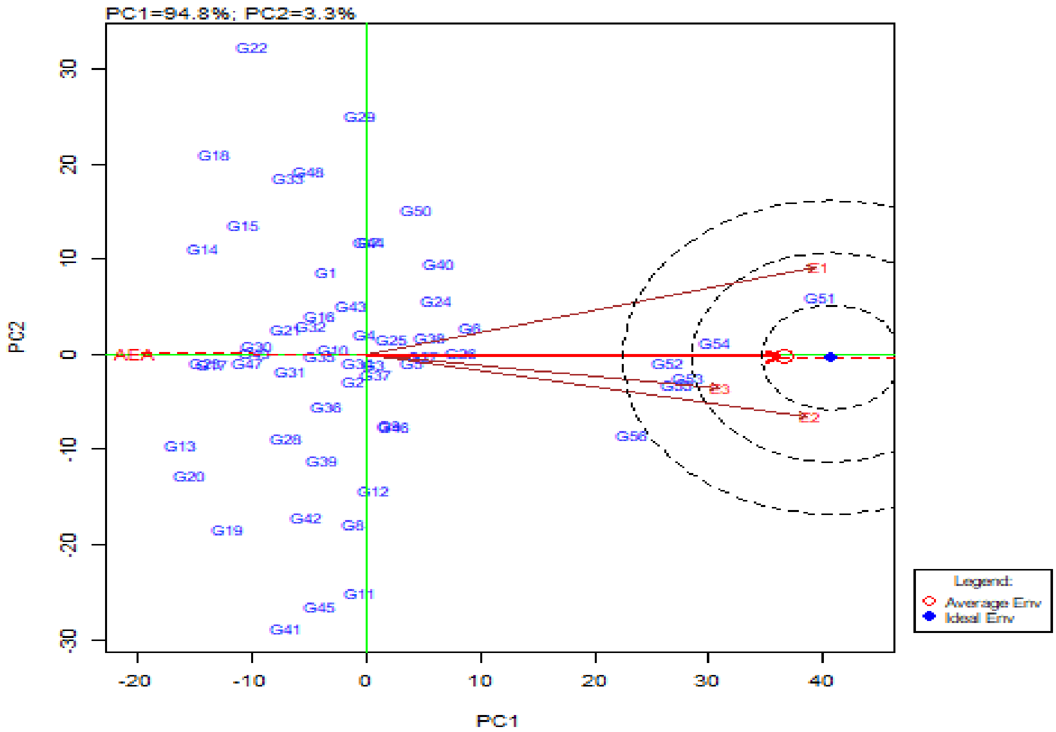


Fig 4.7 GGE biplot for days to fifty percent flowering

Discriminativeness *vs* Representativeness



Which won Where/what

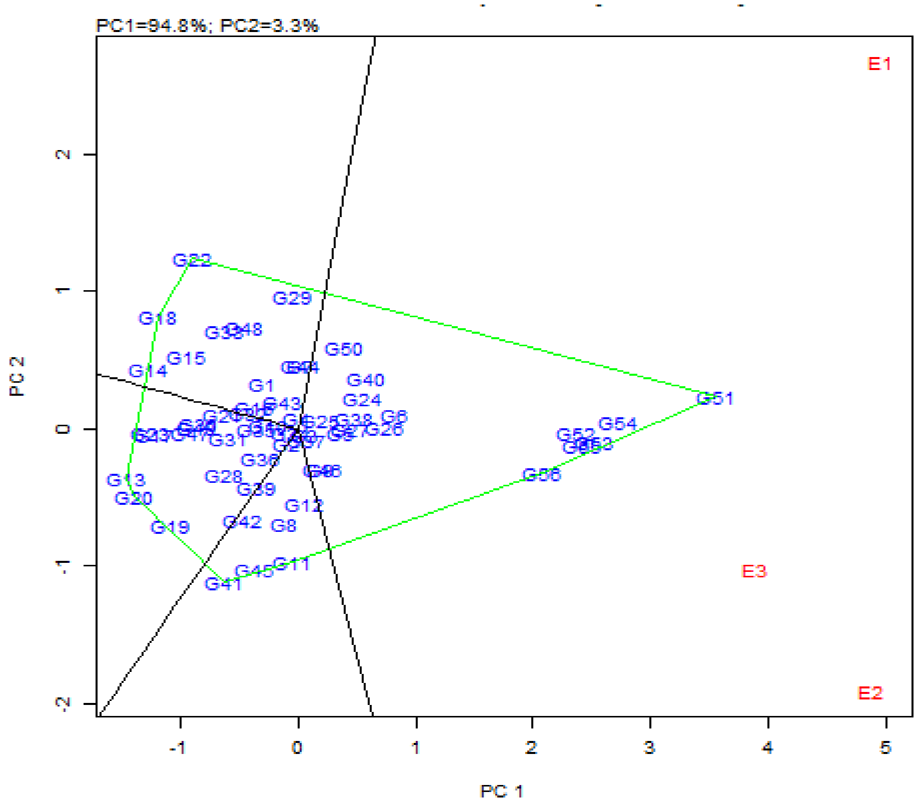
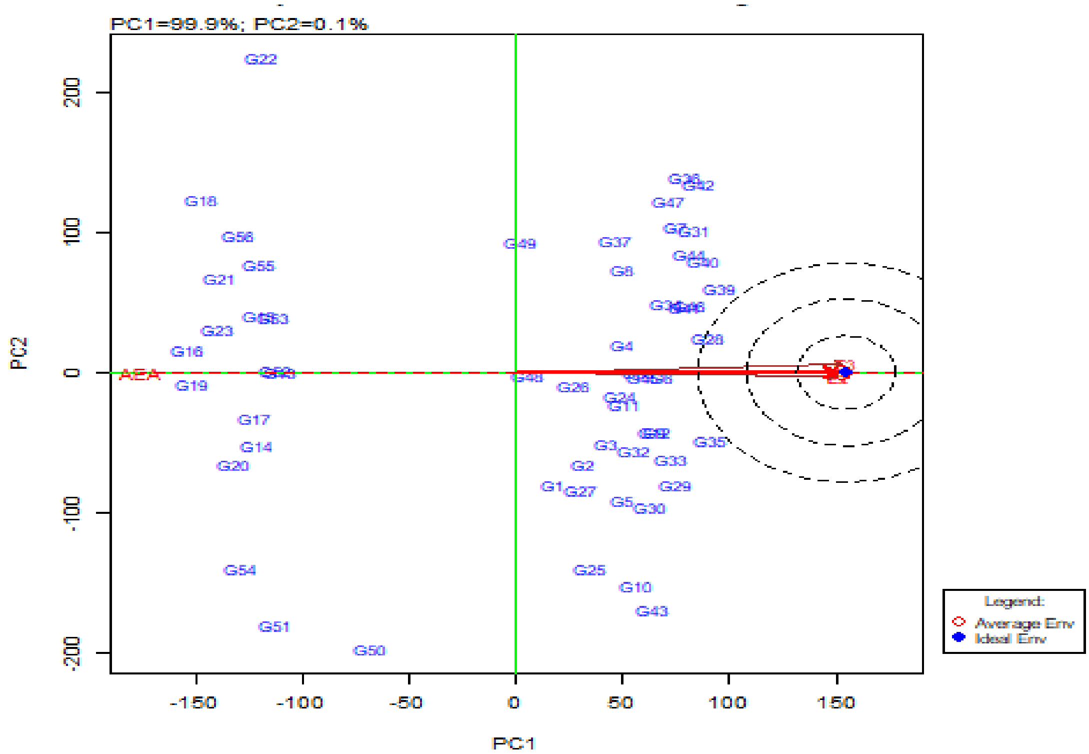


Fig 4.8 GGE biplot for days to maturity

Discriminativeness *vs* Representativeness



Which won Where/what

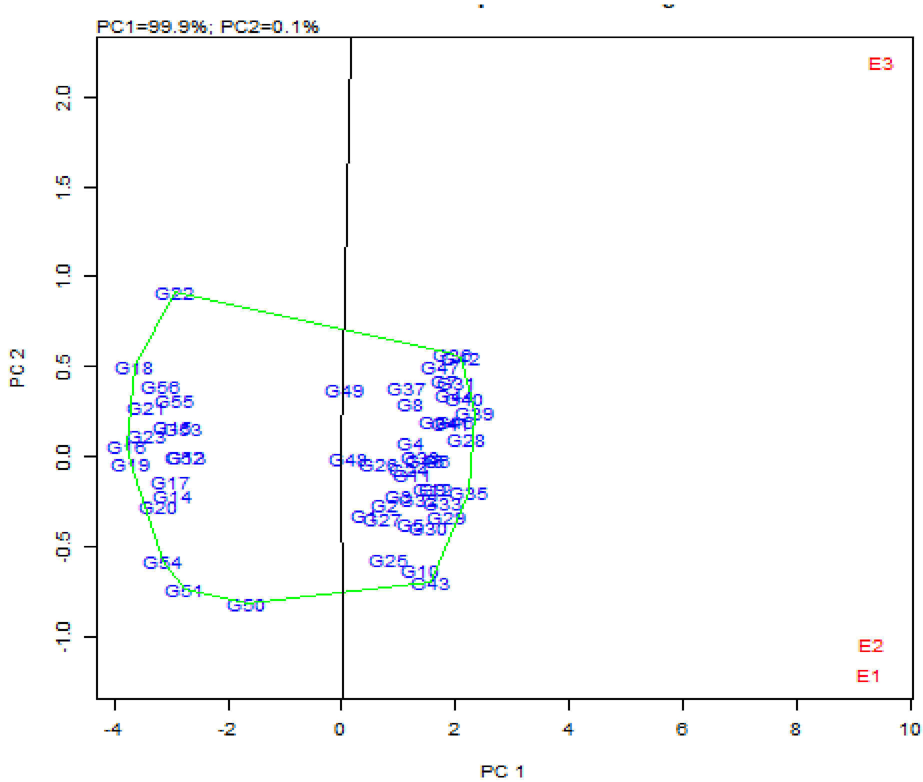
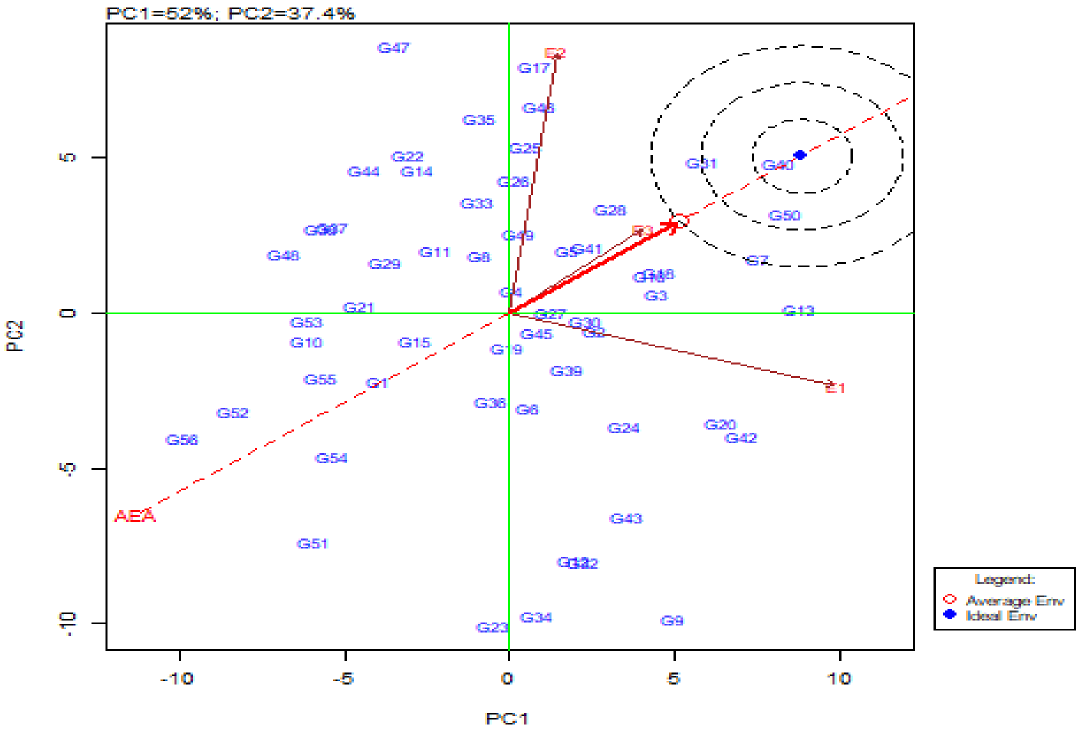


Fig 4.9 GGE biplot for plant height (cm)

Discriminativeness *vs* Representativeness



Which won Where/what

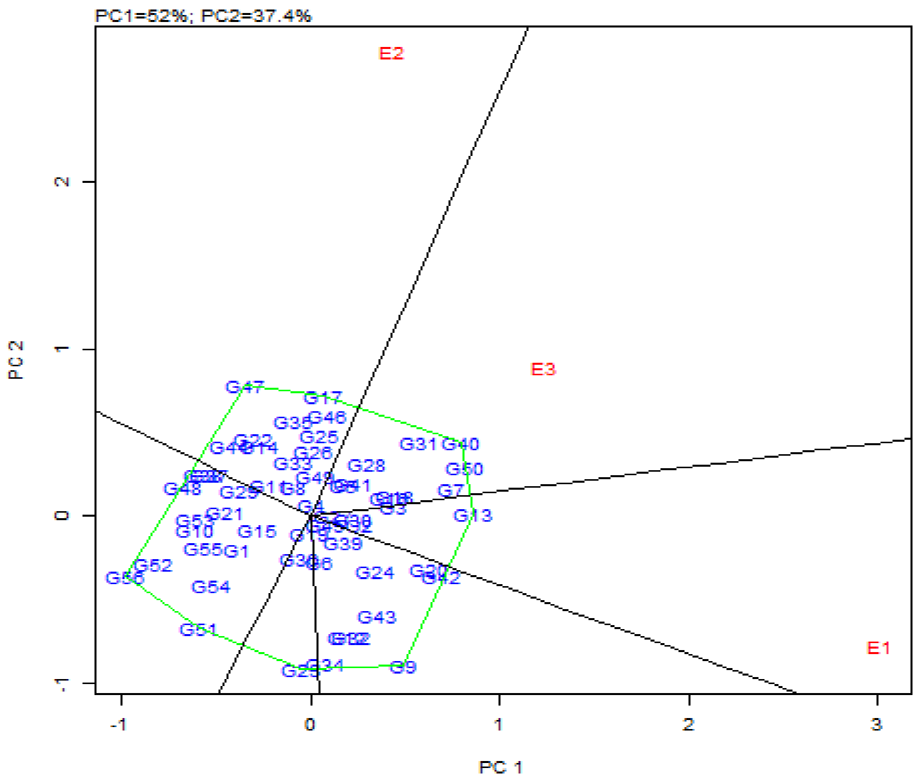
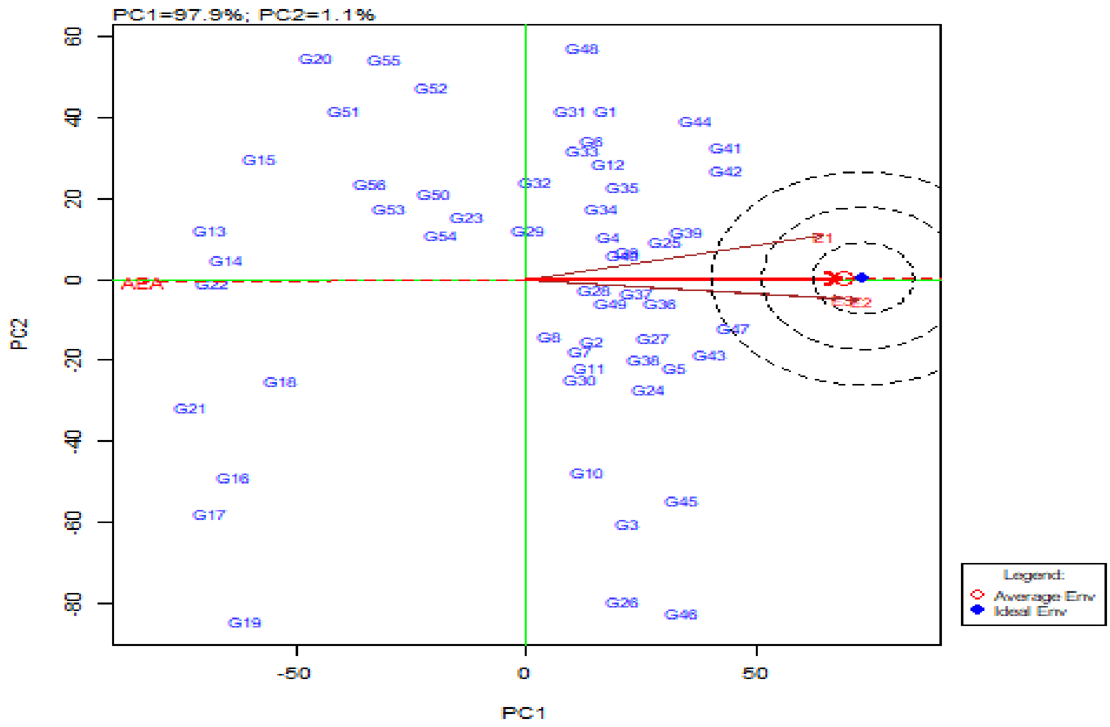


Fig 4.10 GGE biplot for number of primary branches per plant

Discriminativeness *vs* Representativeness



Which won Where/what

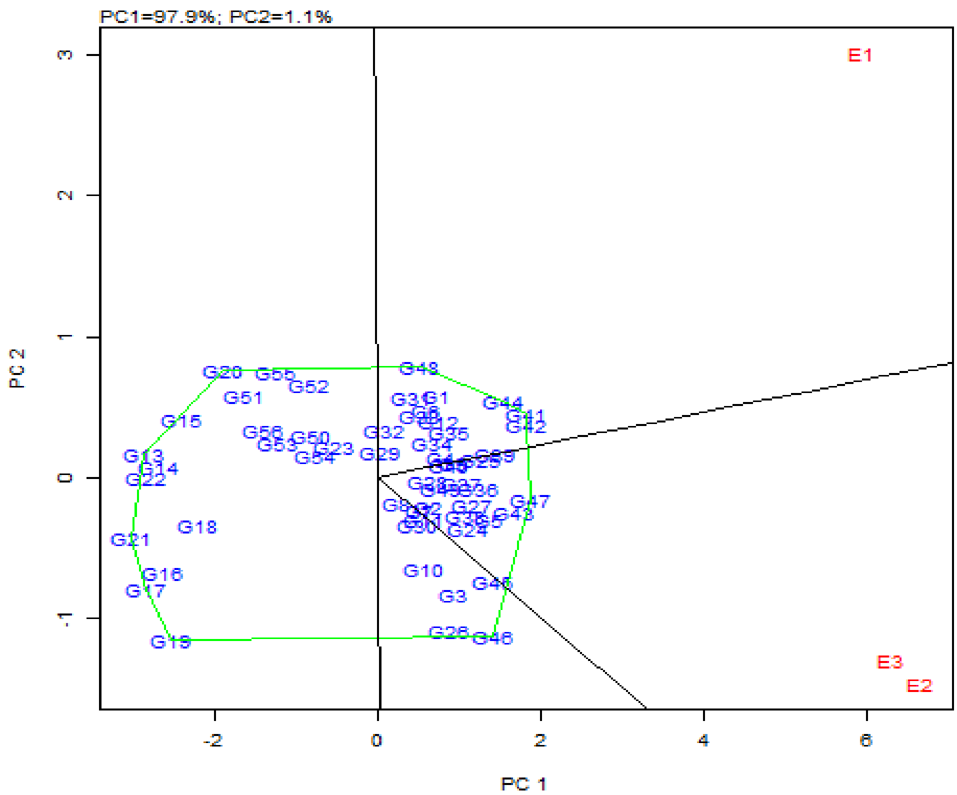
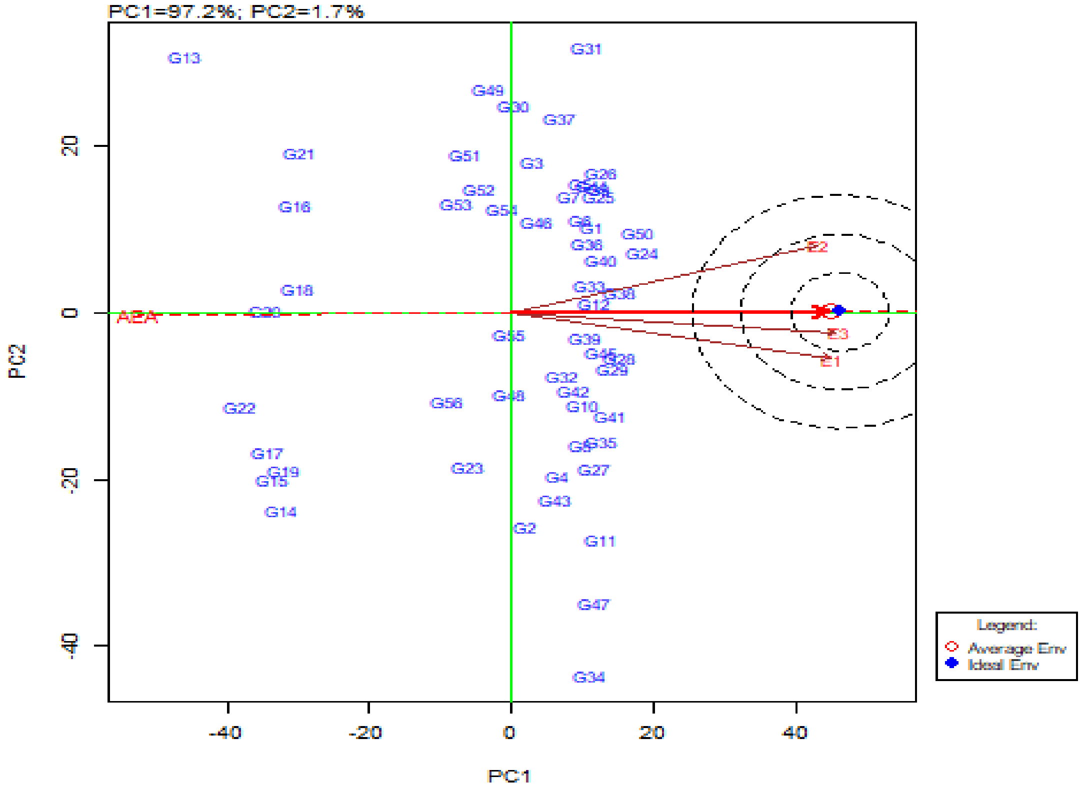


Fig 4.11 GGE biplot for number of secondary branches per plant

Discriminativeness *vs* Representativeness



Which won Where/what

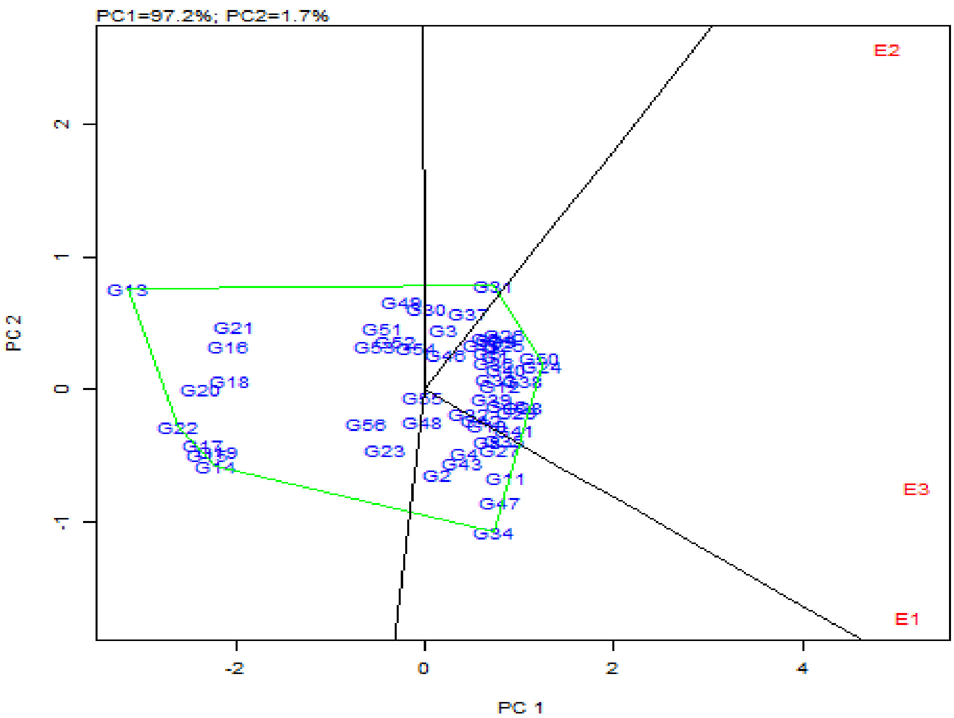
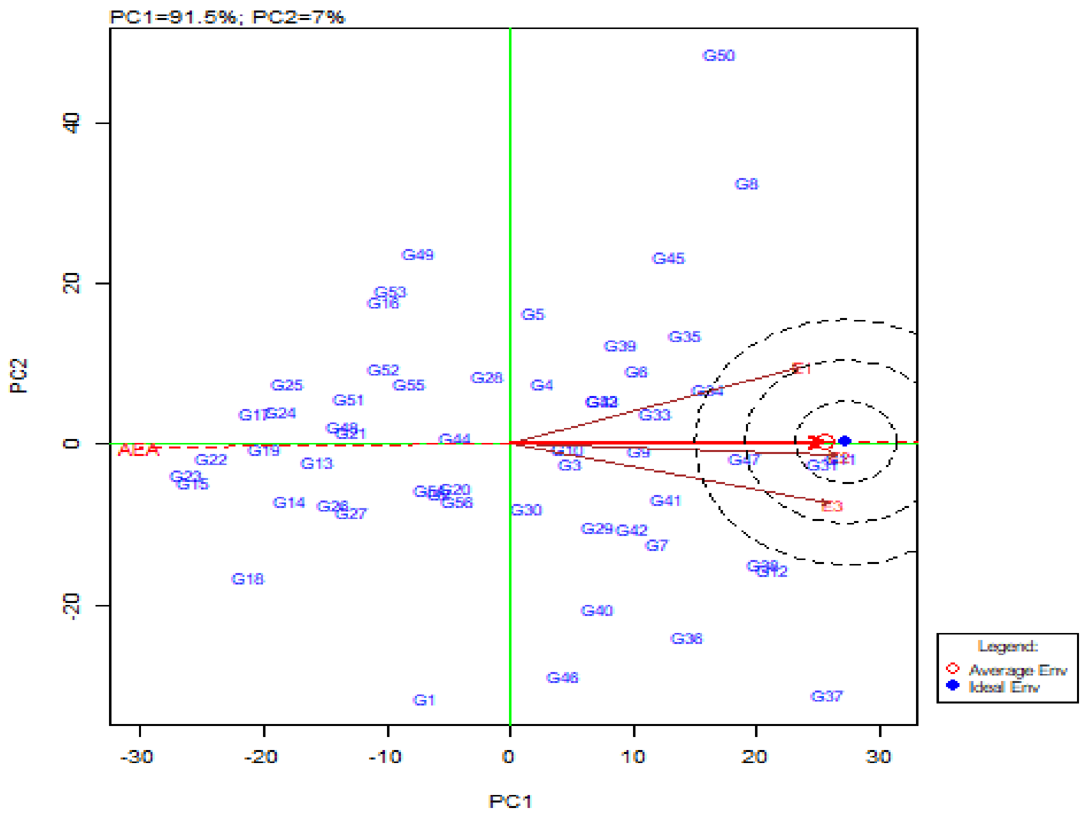


Fig 4.12 GGE biplot for length of main shoot (cm)

Discriminativeness *vs* Representativeness



Which won Where/what

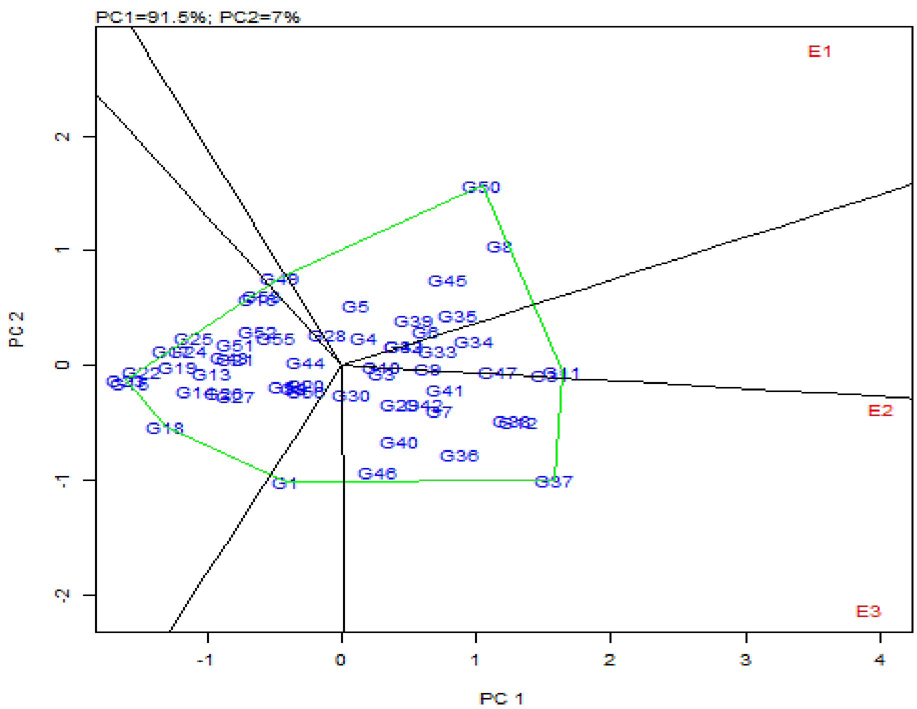
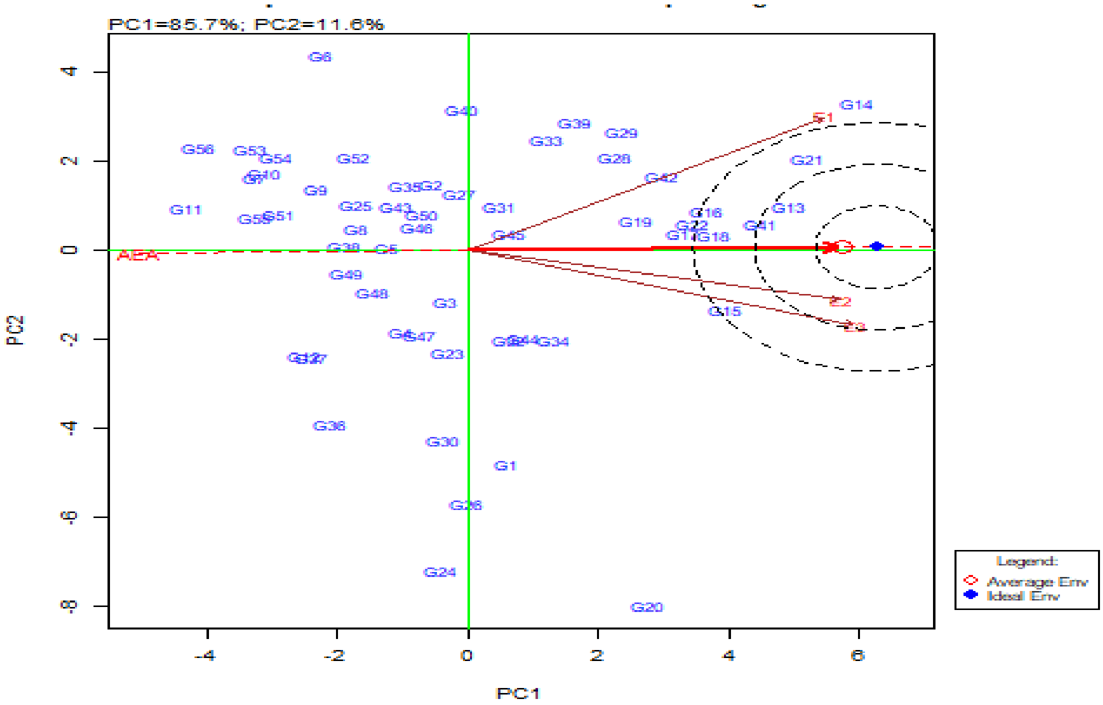


Fig 4.13 GGE biplot for number of siliquae on main shoot

Discriminativeness *vs* Representativeness



Which won Where/what

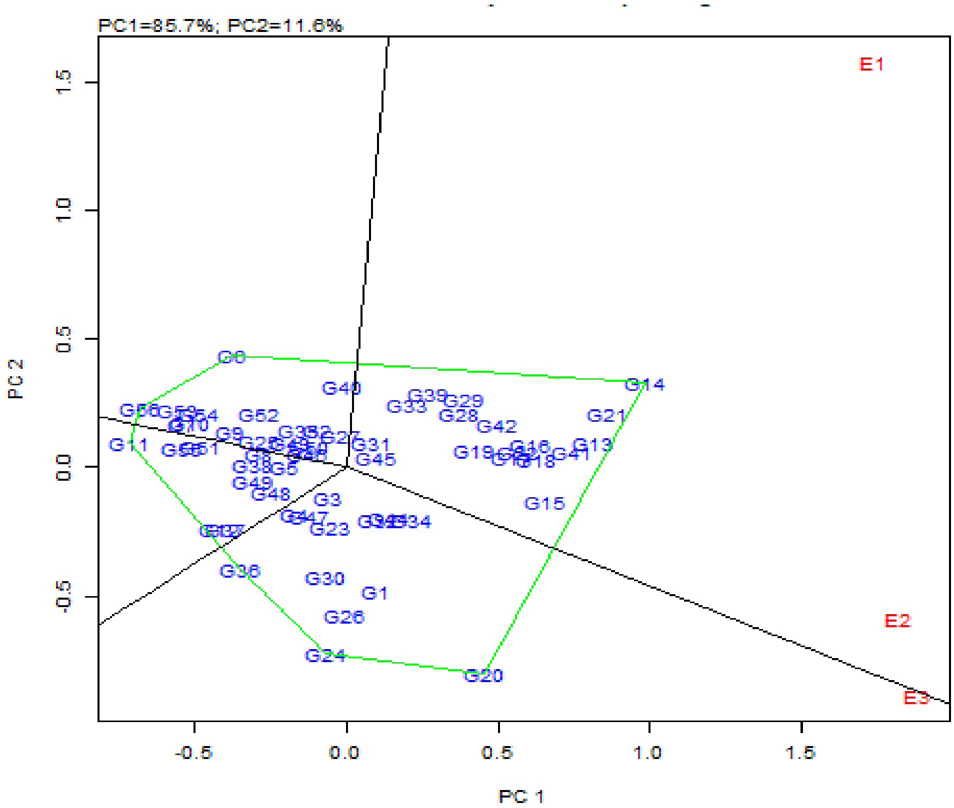


Fig 4.14 GGE biplot for siliqua length (cm)

4.4.1.9 Siliqua Length (cm)

The perusal of the GGE biplot for siliqua length depicted that 150 Kg N/ha condition (E1) was most discriminating for siliqua length **(**Fig 4.14**).** However, 75 Kg N/ha condition (E2) and control (E3) were also found discriminating with high degree. On the other hand 75 Kg N/ha condition (E2) was found most representative for this trait. The environments E1 (150 Kg N/ha) and E2 (75 Kg N/ha) were grouped into a single sector where the genotype Jumka × DRMR-1 (G14) was the best performer. The environment E3 (control) was located in different sector on GGE Biplot graphs, where the genotype Jumka × RNG-73 (G20) came out as best performer for siliqua length.

4.4.1.10 Number of Seeds per Siliqua

The condition of control (E3) came out to be the most discriminating environment for the trait- number of seeds per siliqua as depicted by the length of vector of E3 in GGE Biplot for the trait (Fig 4.15). On the other hand, the condition of 75 Kg N/ha (E2) was the most representing environment for number of seeds per siliqua as depicted through the least acute angle formed by vector of E2 with AEA axis. The condition of control (E3) and 75 Kg N/ha (E2) were confined into the sme sector of the graph having the genotype Jumka (G13) as the best performer. The genotypes Varuna (G50), ZEM-1 (G51), ZEM-1 × DRMR-1 (G52) and ZEM-1 × NRCHB-101 (G54) were the best performing genotypes in the environment E1 (150 Kg N/ha) which was positioned in different sector from E2 and E3.

4.4.1.11 1000 Seed weight (g)

The perusal of GGE biplot depicted that the environment E3 (Control) was most discriminating for 1000 seed weight while environment E2 (75 Kg N/ha) was most representative for the trait (Fig 4.16). The condition of 150 Kg N/ha (E1) and 75 Kg N/ha (E2) were placed inside the same sector in the GGE biplot graph where the genotypes DRMR-1 (G1) and RNG-73 (G40) came out to be the best performers, while the condition of control (E3) was placed inside different sector in which the crosses NRCHB-101 × RH-301 (G26) and NRCHB-101 × TM-4 (G27) occupied in the vertex position in the polygon exhibiting superiority for the trait in the respective environment (E3).

4.4.1.12 Seed Yield per Plant (g)

The condition of 150 Kg N/ha (E1) and control (E3) were found nearly equally discriminating for seed yield per plant based upon their vector length in the GGE biplot graphs (Fig 4.17). On the other hand E2 (75 Kg N/ha) was found most representative environment for seed yield per plant. All the genotypes were limited inside single sector in the graphs where four genotypes *viz.*, Jumka, RH-30, RNG-73 and RNG-73 × Gujarat Mustard-3 were the best performers.

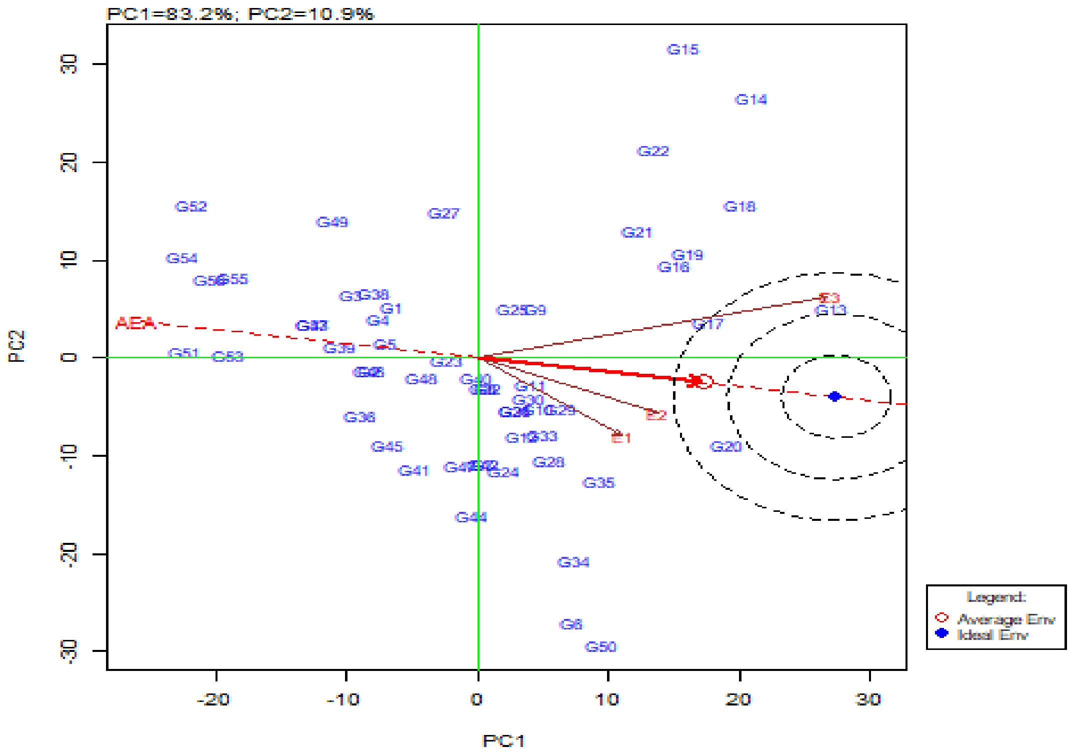
4.4.1.13 Biological Yield per Plant (g)

For biological yield per plant Control (E3) and 75 Kg N/ha (E2) were nearly equally discriminating based upon their respective vector lengths in the respective GGE biplot graph (Fig 4.18). Similarly here environment 75 Kg N/ha (E2) was most representative environment for this particular character. In case of which won where graph three environments were divided into two sectors in which environment E2 and E3 were separated into one sector whereas E1 was partitioned into separate sector. Genotype (G23) KBS-3 was best performer for E1 environment, whereas (G43) RNG-73 × KBS-3 was best performer in E2 and E3.

4.4.1.14 Harvest Index (%)

For discriminativeness and representativeness among the three environments, 75 Kg N/ha (E2) was most discriminating as well as most representative based upon its vector length and angle with AEA, respectively. In case of which won where graph environment 150 Kg N/ha (E1) was divided into separate sector whereas 75 Kg N/ha (E2) and control (E3) were divided into separate sector. In case of which won where graph genotype Jumka performed better for 150 Kg N/ha (E1) whereas, for E2 and E3, RNG-73 × RH-30 was best performer based upon their vertex positions (Fig 4.19).

Discriminativeness *vs* Representativeness



Which won Where/what

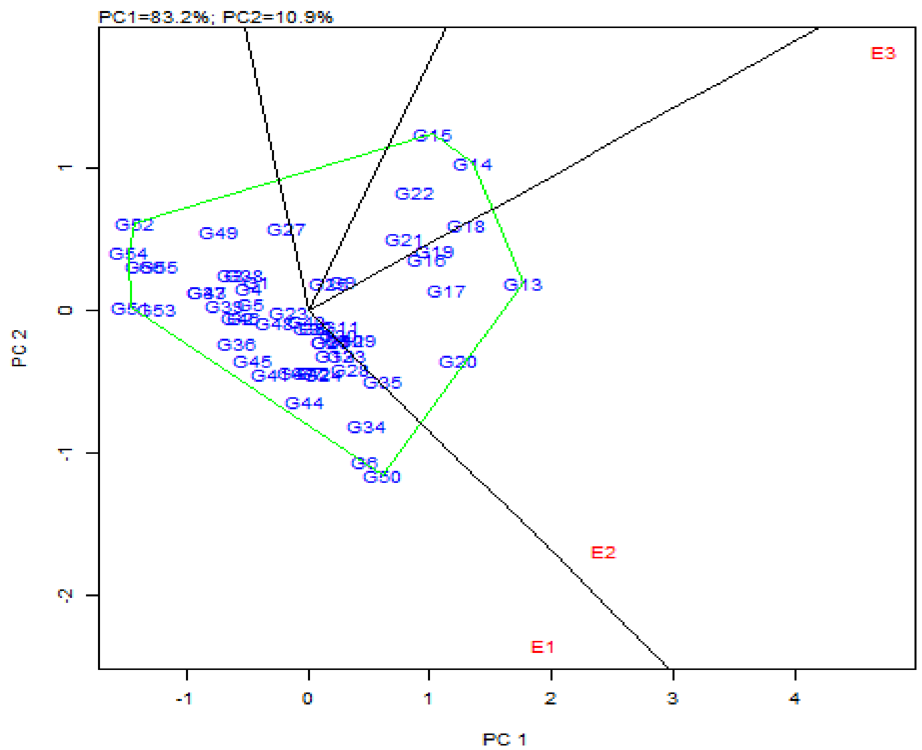
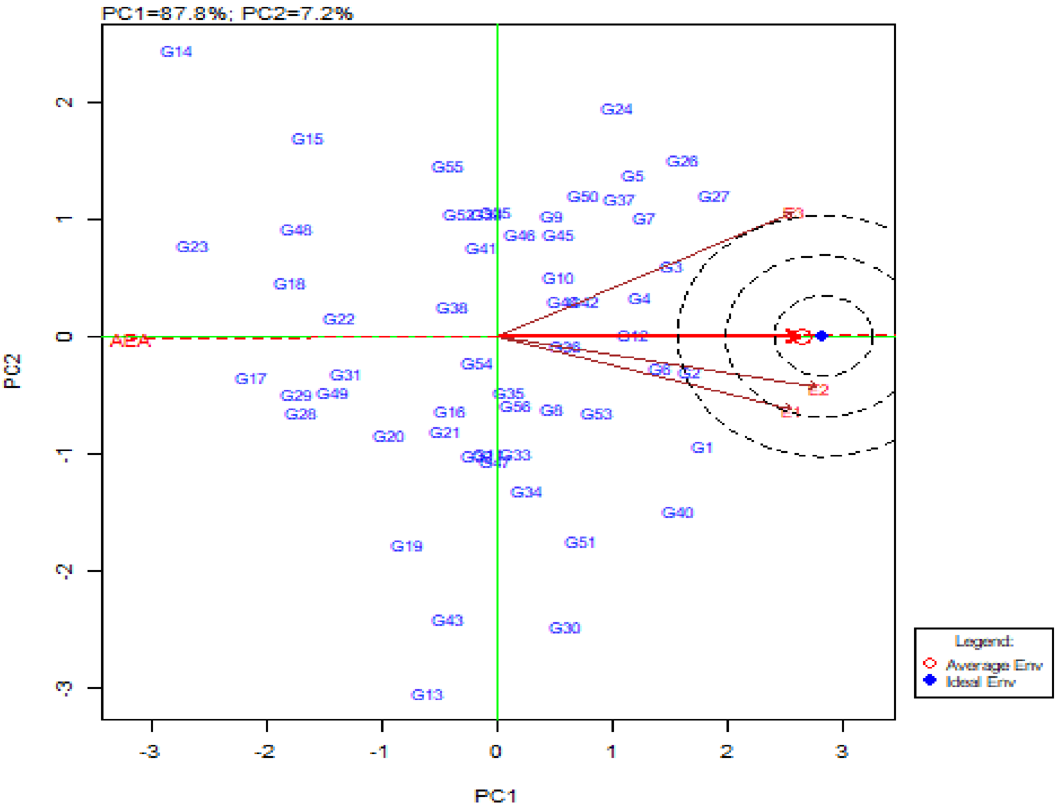


Fig 4.15 GGE biplot for number of seeds per siliqua

Discriminativeness *vs* Representativeness



Which won Where/what

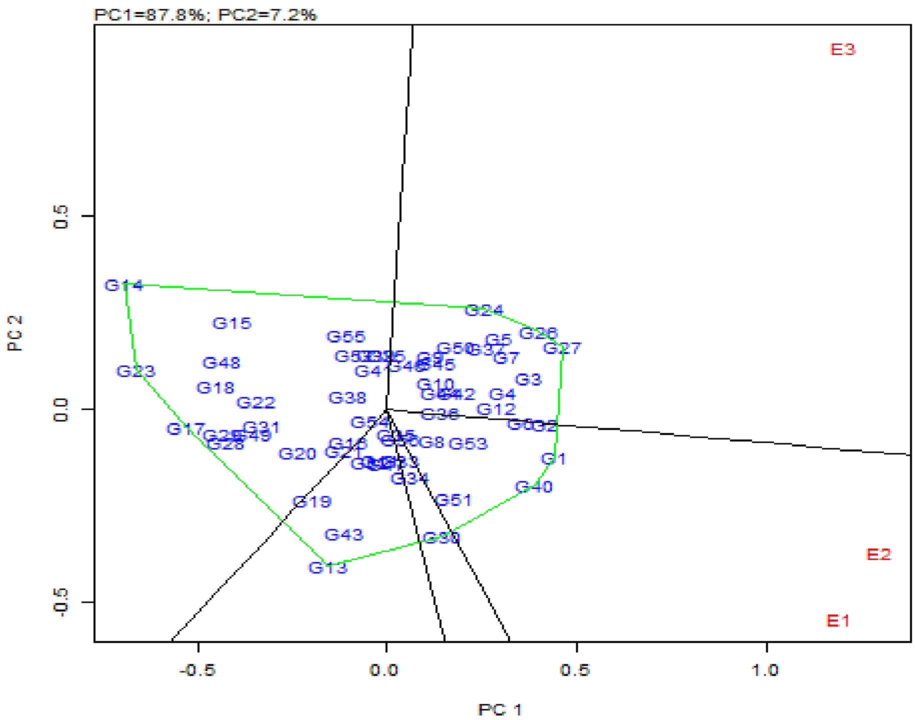
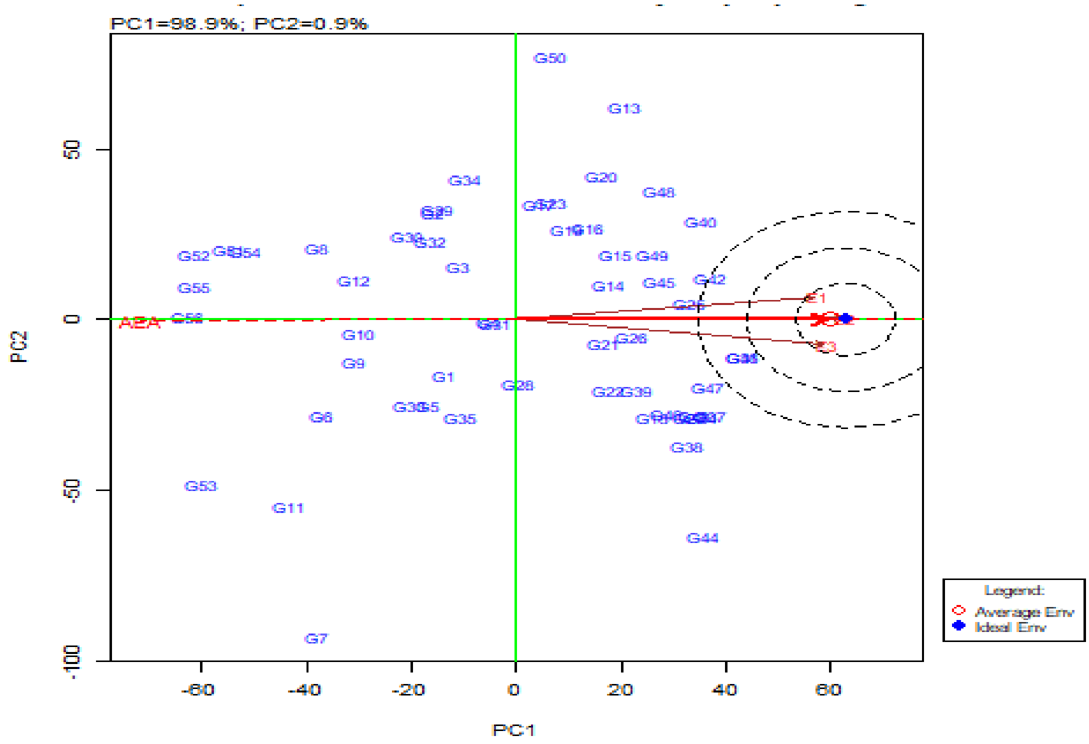


Fig 4.16 GGE biplot for 1000 seed weight (g)

Discriminativeness *vs* Representativeness



Which won Where/what

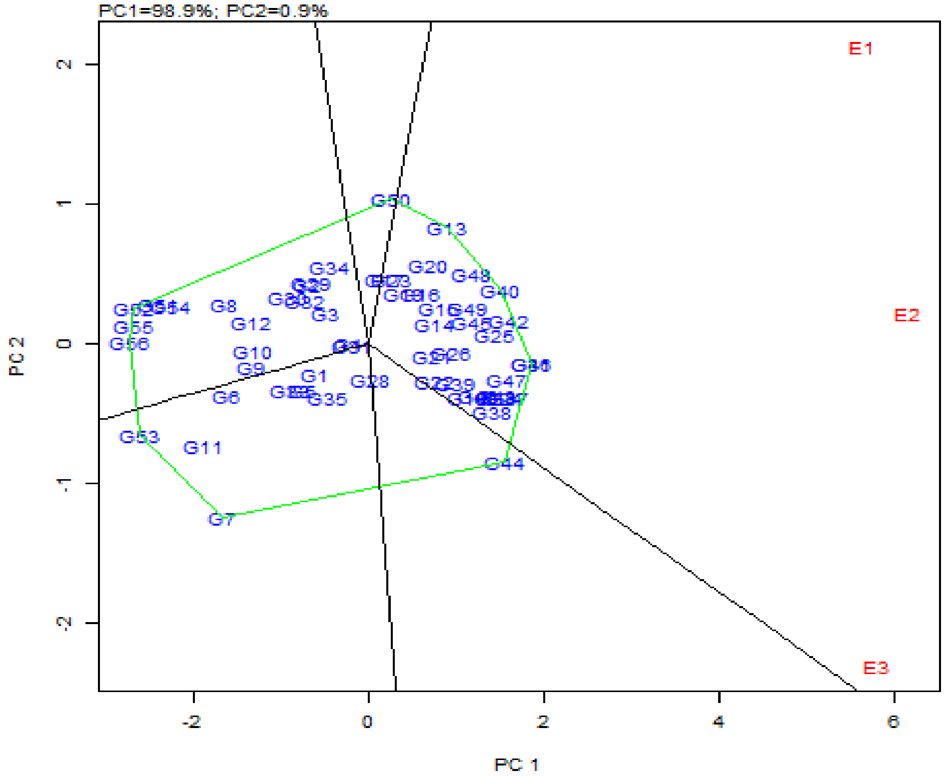
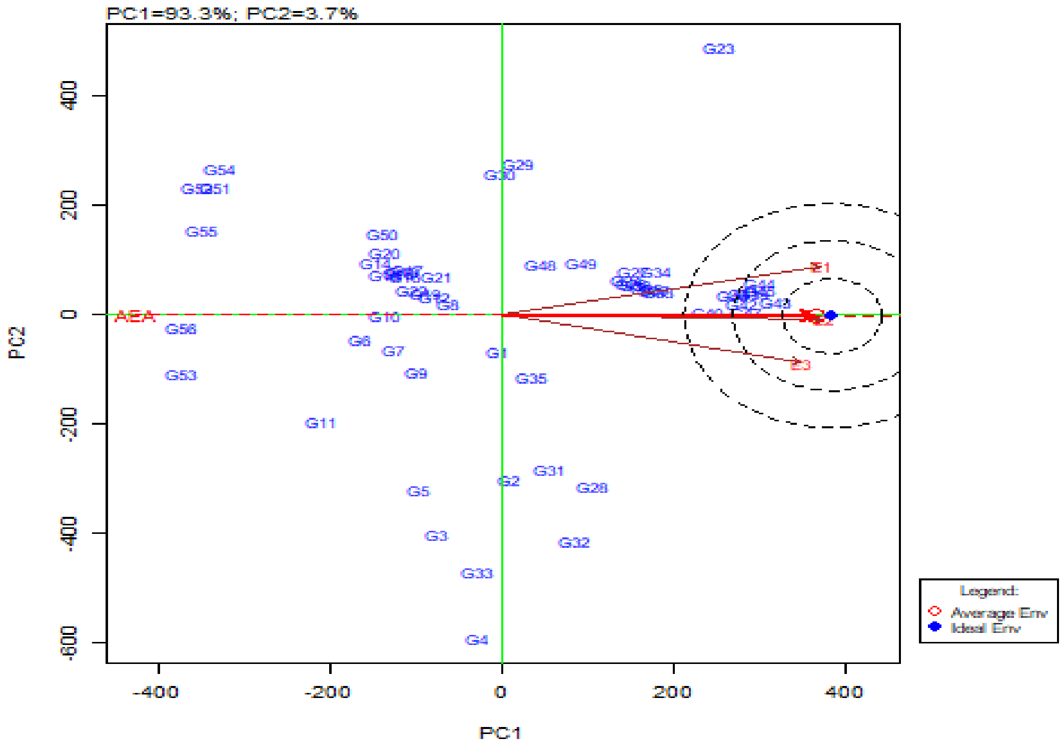


Fig 4.17 GGE biplot for seed yield per plant (g)

Discriminativeness *vs* Representativeness



Which won Where/what

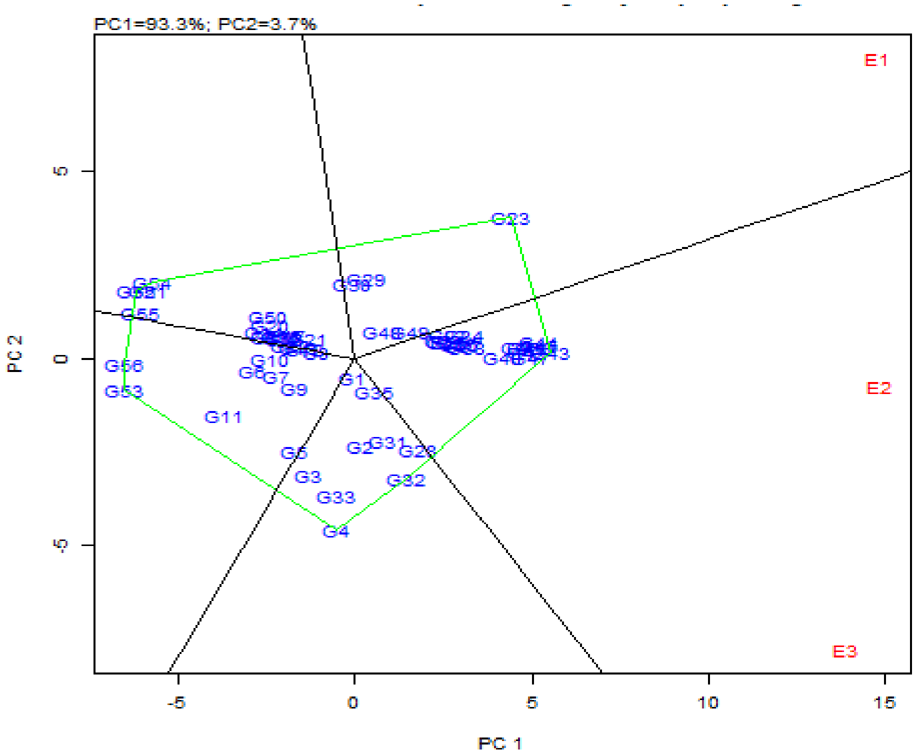
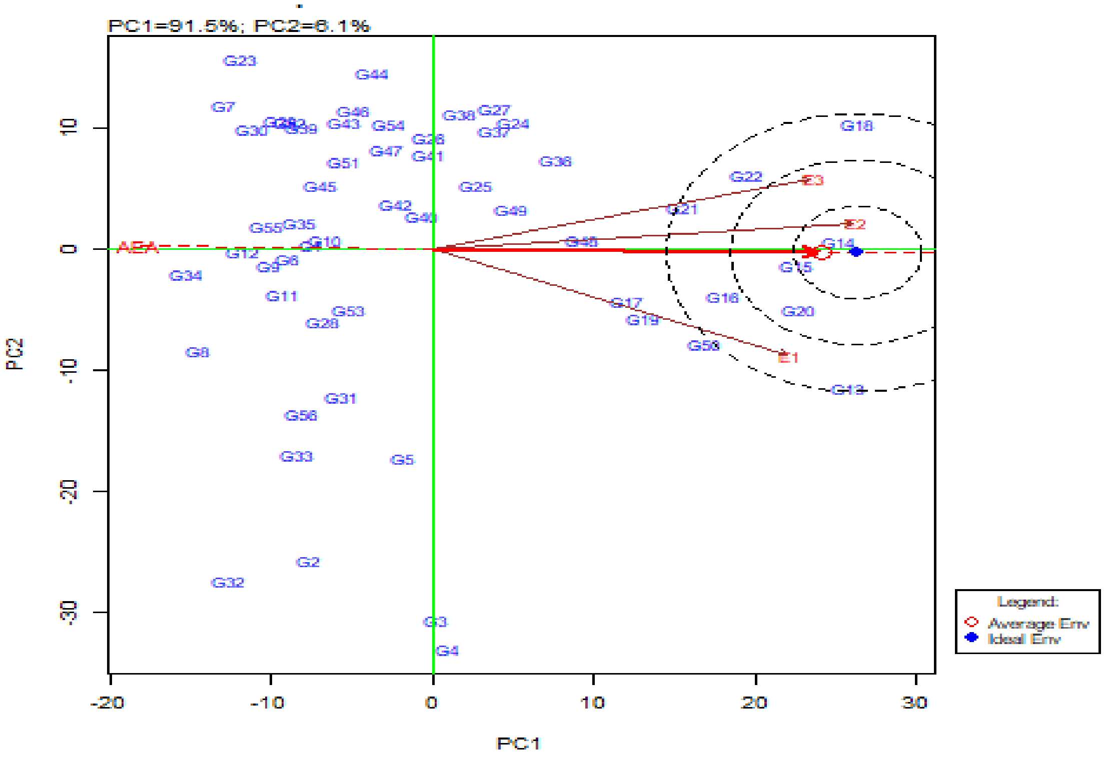


Fig 4.18 GGE biplot for biological yield per plant (g)

Discriminativeness *vs* Representativeness



Which won Where/what

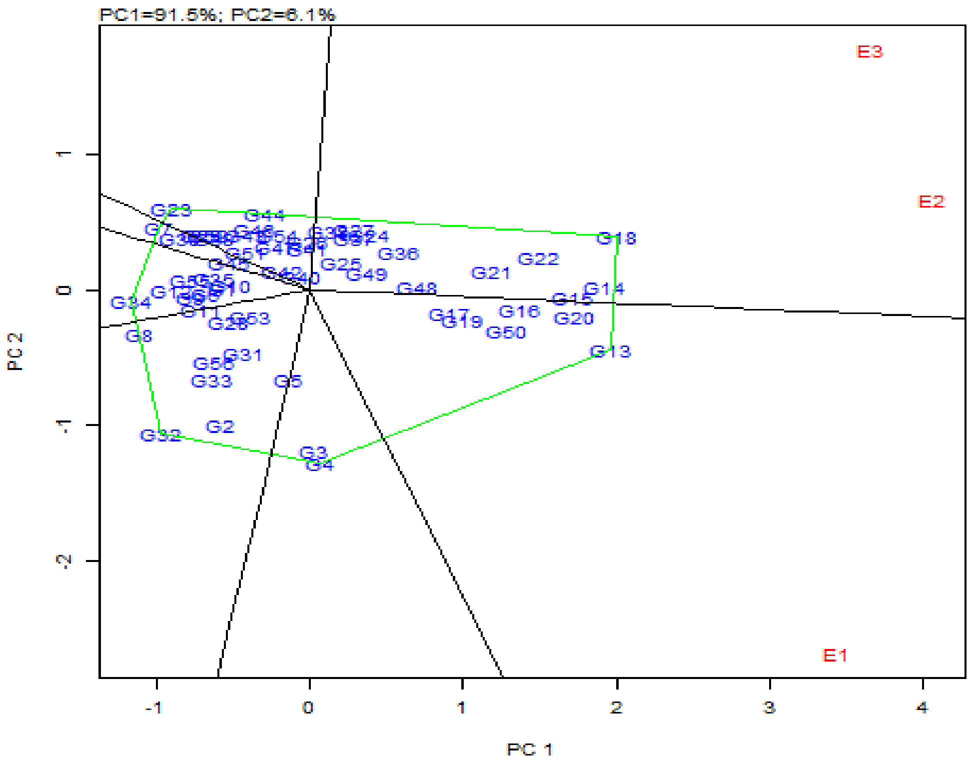
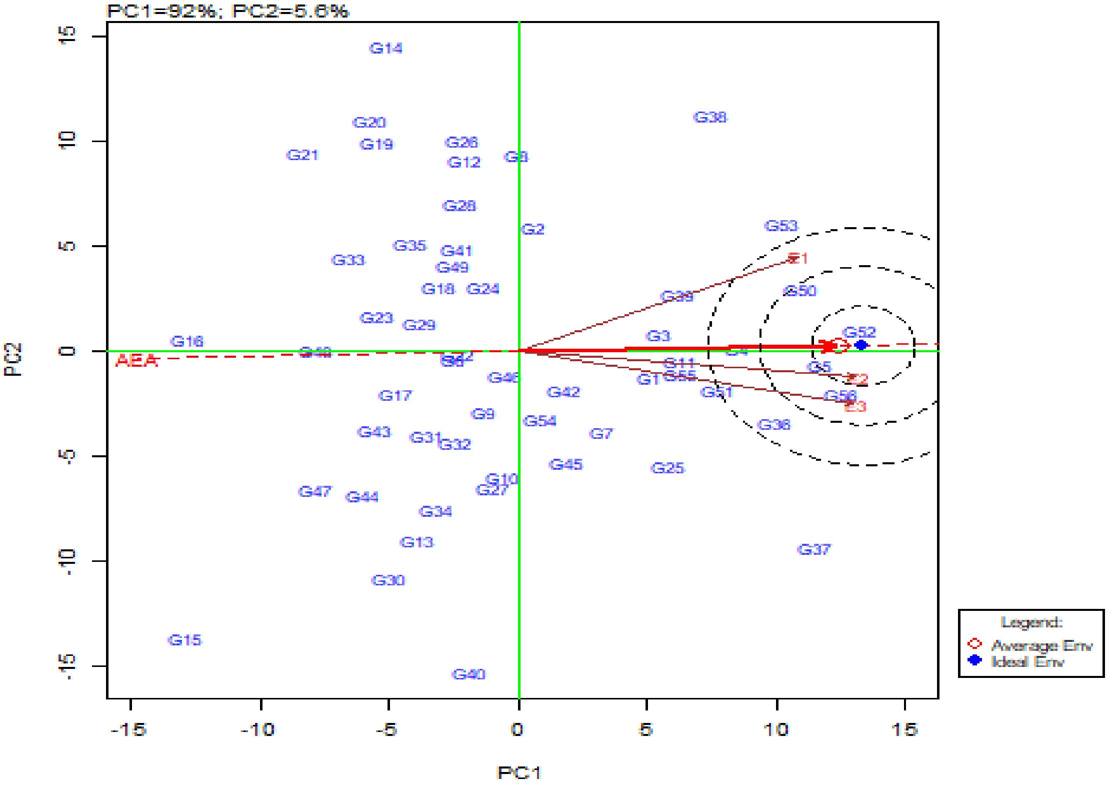


Fig 4.19 GGE biplot for Harvest Index (%)

Discriminativeness *vs* Representativeness



Which won Where/what

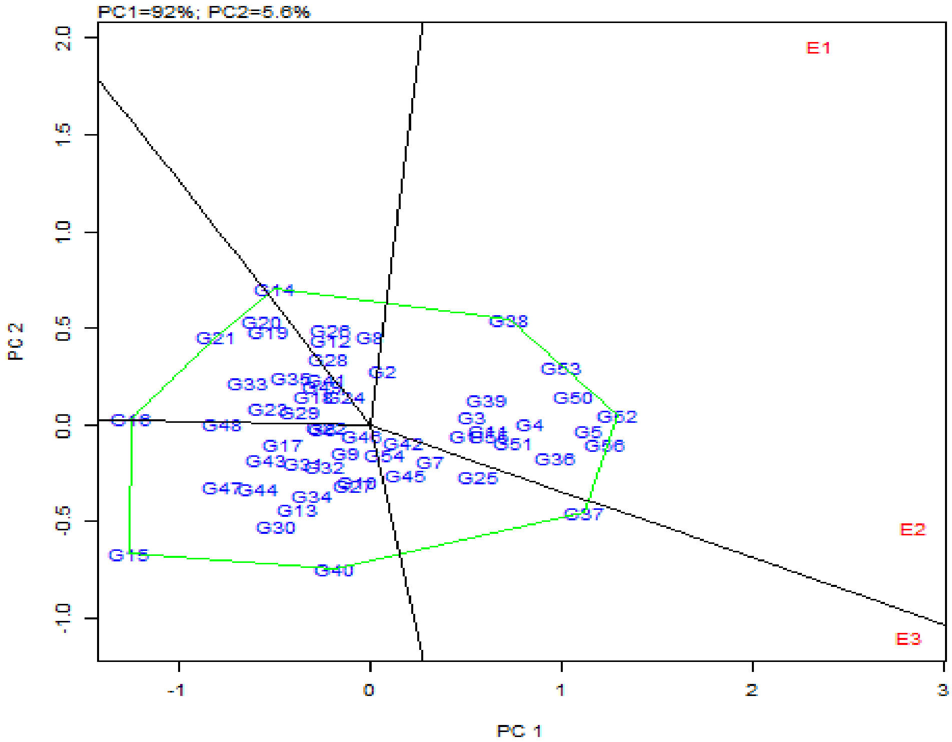
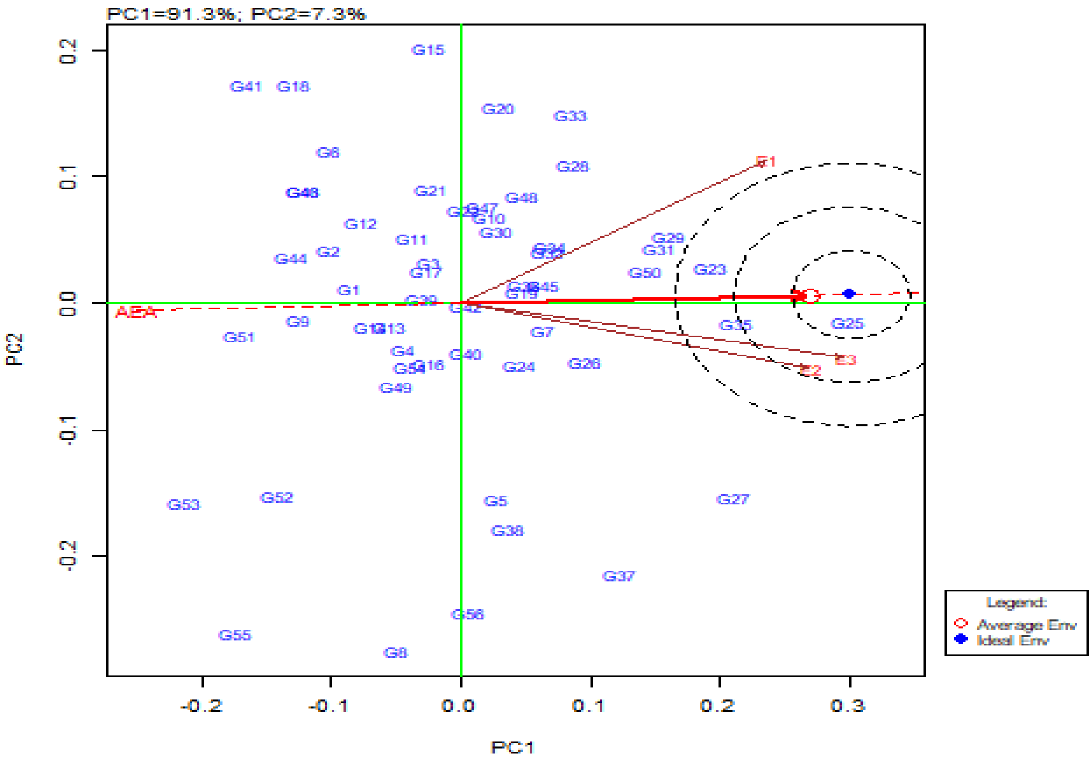


Fig 4.20 GGE biplot for seed oil content (%)

Discriminativeness *vs* Representativeness



Which won Where/what

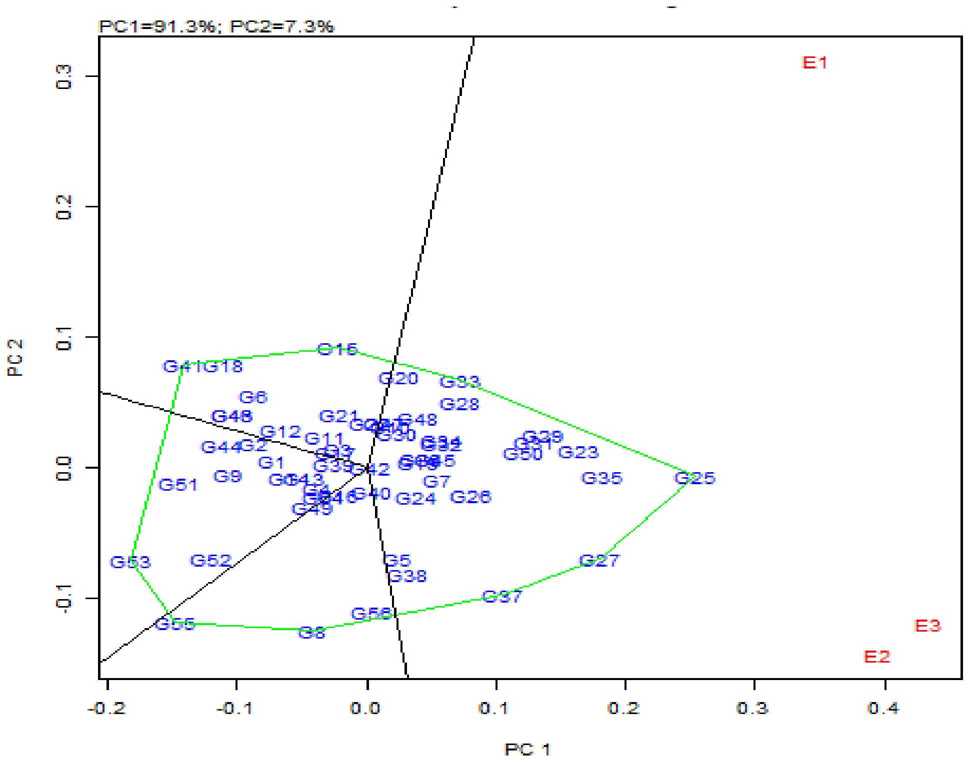
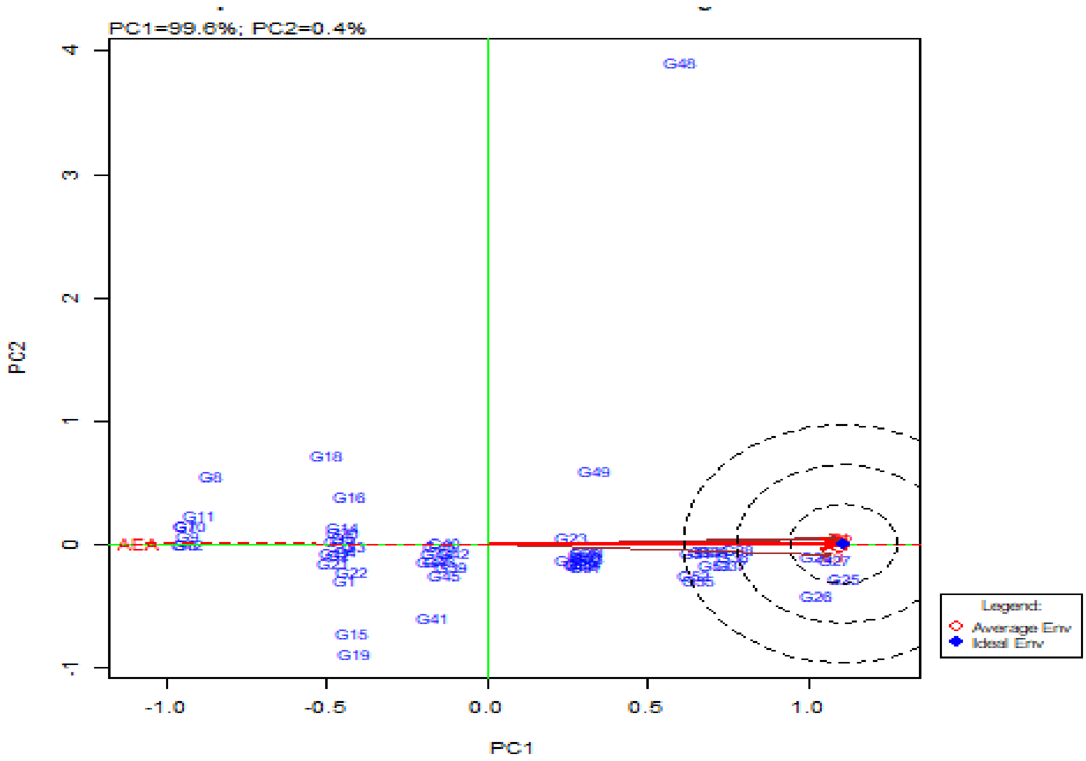


Fig 4.21 GGE biplot for seed nitrogen content (%)

Discriminativeness *vs* Representativeness



Which won Where/what

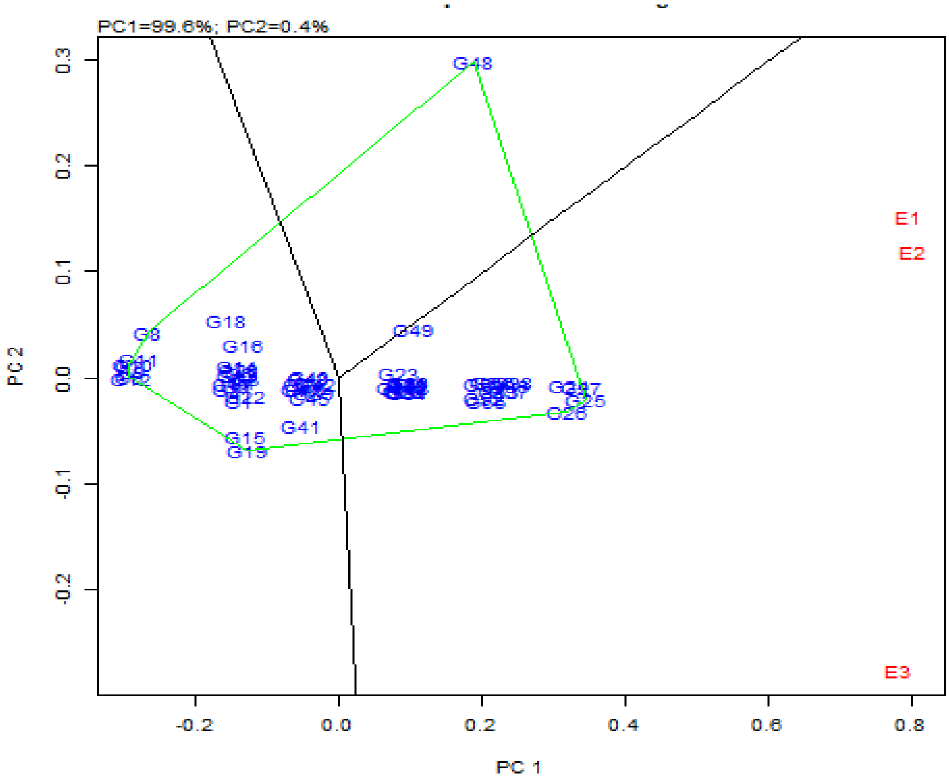


Fig 4.22 GGE biplot for chaff nitrogen content (%)

4.4.1.15 Seed Oil Content (%)

For seed oil content 75 Kg N/ha (E2) and Control (E3) condition were nearly equally discriminating whereas, 150 Kg N/ha condition (E1) was least discriminating. The condition of 75 Kg N/ha (E2) was most representative for the seed oil content based on their vector length and angle with AEA. Which won where graph depicted that genotype RH-30 × TM-4 was best performer for (E1) 150 Kg N/ha and ZEM-1 × DRMR-1 was best performer for (E2) 75 Kg N/ha. Under control (E3) genotype RH-30 × KBS-3 was performer for oil content (Fig 4.20).

4.4.1.16 Seed Nitrogen Content (%)

For seed nitrogen content among the three levels of nitrogen, control (E3) condition was most discriminating and representative too based upon its vector length from the origin point and acute angle with the AEA abscissa. The condition of 150 Kg N/ha was least discriminating. For which won where graph all the environments were confined to only one sector here genotype NRCHB-101 × KBS-3 was best performer for all the environments based upon its vertex position (Fig 4.21).

4.4.1.17 Chaff Nitrogen Content (%)

For chaff nitrogen content all the levels of nitrogen *viz.*, control (E3), 75 Kg N/ha (E2) and 150 Kg N/ha (E1) there was not clear cut difference among the environments (Fig 4.22). Therefore they can be considered equally decimating and representative. For which won where /what three crosses namely, NRCHB-101 × KBS-3, NRCHB-101 × RH-30 and NRCHB-101 × TM-4 performed better depending on their vertex positions among all the environments *viz.*, control, 75 Kg N/ha and 150 Kg N/ha.

4.5 Combining Ability Analysis

The results and outcome of the breeding programmes is dependent upon the choice of parents and the strategies adopted for breeding. The combining ability analysis helps in the identification of the parents with good general and specific combining abilities so that appropriate parents may be selected in hybridization program for exploitation of heterosis.

4.5.1 Analysis of variance for combining ability:

The procedure in Method-II given by Griffing (1956) was used for carrying out analysis of variance of combining ability. The total genetic variance is partitioned into general combining ability, (*gca*) which represents additive gene action and specific combining ability (*sca*) which represents non-additive type of gene action. The analysis of variance for combining ability for all the characters under different nitrogen levels are presented in Table 4.18 to 4.23.

Mean sum of square variance due to *gca* as was highly significant for all the traits studied under all the three conditions, whereas *sca* was also significant for most of the traits studied under all three conditions except number of primary branches per plant (control condition), siliqua length (control condition), seeds per siliqua (N 150Kg /ha), 1000 seed weight (g) (control condition) and oil content (%) (N 150Kg /ha). The magnitude of *gca* variance components was lower for most of the characters studied under all three conditions depicting predominant role of dominance gene action in inheritance of the traits.

Significant differences for *sca* and *gca* effects in Indian Mustard for various traits including seed yield were also observed by Sarkar and Singh (2001); Mahato and Haider (2004); Monalisa *et al.* (2005); Azzizinia *et al.* (2012); Singh *et al.* (2018); Gul *et al.* (2018) and Yadav *et al.* (2020). The predominance of dominant gene action for various traits in *Brassica juncea* was also reported by Acharya and Swain (2004) and Nasimi *et al.* (2006). Singh *et al.* (2005) also established predominance of dominance gene action for plant height and biological yield.

However, Verma and Kushwaha (1999); Tak and Khan (2000); Katiyar *et al.* (2005); Turi *et al.* (2010) and Lal *et al.* (2018) found the role of both additive and non additive gene action for inheritance of the traits in Indian mustard. On the other hand Rai *et al.* (2005); Goswami and Bahal (2005) and Kumar and Srivastava (2007) found relatively greater magnitude of contribution for inheritance of the traits in *Brassica juncea*.

Table 4.18 ANOVA for combining ability for days to flower initiation, fifty percent flowering and maturity under various nitrogen levels

Source	d.f.	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
gca	9	25.1954**	31.2732**	24.4676**	135.6843**	112.2972**	114.3843**	63.2593**	93.5833**	79.1537**
sca	45	3.8019**	5.5595**	4.5893**	21.7100**	20.5816**	18.5383**	7.5966**	11.7035**	13.6295**
Error	54	0.5951	0.7913	0.5034	0.3805	0.9786	0.4978	0.5737	0.8034	0.6990
gca:*sca*	-	0.639	0.923	0.488	0.528	0.473	0.526	0.743	0.709	0.505

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.19 ANOVA for combining ability for plant height (cm), no. of primary and secondary branches per plant under various nitrogen levels

Source	d.f.	Plant Height (cm)			No. of Primary Branches per Plant			No. of Secondary Branches per Plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
gca	9	1915.4824**	1855.9454**	1852.2917**	2.9707**	2.54084**	4.03318**	448.4015**	489.4454**	395.0796**
sca	45	140.8920**	135.1489**	132.8558**	0.3350	1.16237**	1.43199**	16.9509**	21.7480**	17.0326**
Error	54	2.3224	1.5042	0.7786	0.3678	0.20089	0.26897	1.9421	0.9573	0.9702
gca:*sca*	-	1.150	1.156	1.168	-6.61	0.202	1.95	2.478	1.95	2.044

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.20 ANOVA for combining ability for length of main shoot (cm), no. of siliquae on main shoot and siliqua length (cm) under various nitrogen levels

Source	d.f.	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua Length (cm)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
gca	9	204.5696**	184.7864**	206.3061**	44.6343**	36.8741**	31.6583**	3.1107**	2.5391**	2.3992**
sca	45	6.7588**	5.4444*	4.5964**	7.7095**	8.8084**	6.8467*	0.2542	0.2913*	0.3912
Error	54	1.4305	2.7392	0.5436	1.7118	1.6756	3.5914	0.1760	0.1426	0.2562
gca:*sca*	-	3.17	5.60	4.23	0.59	0.411	0.71	3.12	1.34	1.32

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.21 ANOVA for combining ability for no. of seeds per siliqua, 1000 seed weight (g) and seed yield per plant (g) under various nitrogen levels

Source	d.f.	Number of Seeds Per Siliqua			1000 Seed Weight (g)			Seed Yield per Plant (g)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
gca	9	72.6722**	17.7593**	12.4120**	0.4799**	0.2849**	0.2396**	255.9361**	277.9769**	241.7444**
sca	45	2.4874**	2.1825**	1.9550	0.0758	0.1338**	0.1196*	28.2336**	32.7410**	26.1939**
Error	54	0.6293	0.6537	2.6490	0.0562	0.0402	0.0601	1.7803	0.9231	2.2268
gca:*sca*	-	3.23	0.93	-1.17	1.80	0.21	0.25	0.800	0.72	0.832

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.22 ANOVA for combining ability for biological yield per plant (g), Harvest Index (%) and seed oil content(%) under various nitrogen levels

Source	d.f.	Biological Yield per Plant (g)			Harvest Index (%)			Seed Oil content (%)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	75 Kg N/ha	**150 Kg N/ha**	**Control**	75 Kg N/ha	150 Kg N/ha
gca	9	9725.6287**	9069.5639**	10013.9546**	49.4696**	60.4196**	46.4841**	9.4350**	8.7502**	7.6646**
sca	45	966.6575**	1458.2179**	1287.4248**	3.3997**	3.3705**	2.8881**	1.9952**	2.1577**	1.4015
Error	54	112.4978	134.6285	64.3768	0.7853	0.8922	0.8370	0.3852	0.3938	0.8975
gca:*sca*	-	0.937	0.56	0.67	1.55	2.00	1.85	0.46	0.39	1.11

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.23 ANOVA for combining ability for seed nitrogen content (%) and chaff nitrogen content (%) under various nitrogen levels

Source	d.f.	Seed Nitrogen Content (%)			Chaff Nitrogen (%)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
gca	9	0.0042**	0.00365**	0.00329**	0.08267**	0.08751**	0.08765**
sca	45	0.0012*	0.00093**	0.00084**	0.00947**	0.00971**	0.00927**
Error	54	0.0005	0.00026	0.00029	0.00004**	0.00001	0.00007
gca:*sca*	-	0.48	0.41	0.45	0.73	0.75	0.79

*Significance P ≤0.05; ** Significance P ≤0.01

4.5.2 General Combining Ability (*gca)* Effects

The estimates of *gca* effects for ten parents for each of the 17 characters in three conditions are represented in Tables 4.24 to 4.29. The characteristic description with respect to general combining ability effects are described as under:-

4.5.2.1 Days to Flower Initiation

Early flowering is considered desirable trait. Therefore, the parental genotypes with negative *gca* are considered desirable for this trait. The *gca* effects for days to flower initiation varied from -2.525 (ZEM-1) to 2.183 (Gujarat Mustard-3) for control (Table 4.24). In this case, the good general combiners with desirable significantly negative *gca* effects were ZEM-1 followed by Jumka, KBS-3, TM-4 and NRCHB-101. In addition, four genotypes *viz.*, Gujarat Mustard-3, DRMR-1, Pusa Mustard-28 and RH-30 were found poor general combiners with significantly positive *gca* effects.

Under 75 Kg Nitrogen per ha condition, the range of *gca* effects varied from -2.958 (ZEM-1) to 2.375 (DRMR-1) and the good general combiners with desirable significantly negative *gca* effects were ZEM-1 followed by Jumka, TM-4, KBS-3 and NRCHB-101. Three genotypes *viz.,* DRMR-1, Gujarat Mustard-3 and RNG-73 were found to be poor general combiners having significantly positive *gca* effects. The range of parental genotypes varied from -2.917 (ZEM-1) to 2.250 (DRMR-1) for 150 Kg Nitrogen per ha. The good general combiners having significantly desirable negative *gca* effect were ZEM-1 followed by KBS-3, Jumka and TM-4. Five genotypes were found as poor general combiners with significantly positive *gca* effects *viz.*, ZEM-1, Gujarat Mustard-3, Pusa Mustard-28, RH-30 and RNG-73. Singh *et al.* (2005), Goswami and Bahal (2005) also found similar findings.

4.5.2.2 Days to Fifty Percent Flowering

The genotypes with negative *gca* are preferred as earliness for days to 50% flowering is considered desirable. The range of *gca* effects for days to 50% flowering varied from -5.825 (ZEM-1) to 6.425 (Gujarat Mustard-3), -4.933 (ZEM-1) to 5.150 (Gujarat Mustard-3) and -5.042 (ZEM-1) to 5.250 (Gujarat Mustard-3) for control and condition of 75 Kg and 150 Kg Nitrogen per ha, respectively.

In all three conditions, the good general combiners having significantly desirable negative *gca* effects were ZEM-1 followed by Jumka, RNG-73 and NRCHB-101. The parental genotype KBS-3 was significantly negative for *gca* effects in case of control only. In control, the poor general combiners having significantly positive *gca* effects were Gujarat Mustard-3, DRMR-1, RH-30, TM-4 and Pusa Mustard-28. Under 75 Kg Nitrogen per ha condition, five genotypes were found to be poor general combiners having significantly positive *gca* effects *viz.*, Gujarat Mustard-3, DRMR-1, Pusa Mustard-28, RH-30 and TM-4. For 150 Kg Nitrogen per ha case, the genotypes Gujarat Mustard-3, DRMR-1, Pusa Mustard-28, TM-4 and RH-30 were found poor general combiners having significantly positive and undesirable *gca* effects. Singh *et al.* (2007), Akbar *et al.* (2008) had similar findings.

4.5.2.3 Days to Maturity

Earliness in maturity is a desirable character. Therefore, parents with negative *gca* effects are considered more preferable. The range for *gca* effects in case of control varied from -4.167 (Jumka) to 5.042 (ZEM-1). The desirable and significantly negative *gca* effects with good general combining ability were exhibited by the parent- Jumka followed by Pusa Mustard-28 and KBS-3 along with high *per se* performance except for Pusa Mustard-28. Three parents were found as poor general combiners having significantly positive *gca* effects *viz.*, ZEM-1, NRCHB-101 and RH-30.

Under dose of 75 Kg and 150 Kg Nitrogen per ha, the range of *gca* effects varied from -4.750 (Jumka) to 5.917 (ZEM-1) and -4.350 (Jumka) to 5.358 (ZEM-1), respectively. Same three parental genotypes were found to be good general combiners having significantly negative *gca* effects *viz.*, Jumka, Pusa Mustard-28 and RNG-73 for the character- days to 50% flowering in both conditions. However, three genotypes *viz.*, ZEM-1, NRCHB-101 and RH-30 also exhibited significantly positive *gca* effects in case of 75 Kg N/ha condition. Similarly the genotypes- ZEM-1, NRCHB-101 and TM-4 also showed significantly positive and undesirable *gca* effects representing their poor general combining ability under 150 Kg N/ha condition.

Table 4.24 General combining ability (*gca*) estimates for days to flower initiation, fifty percent flowering and maturity under different nitrogen levels

Genotypes	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
Jumka	-1.525 **	-1.500 **	-0.833 **	-3.992 **	-4.350 **	-4.292 **	-4.167 **	-4.750 **	-4.350 **
RNG-73	0.267	0.833 **	0.458 *	-1.033 **	-1.392 **	-1.625 **	-0.042	-1.000 **	-1.558 **
Pusa Mustard-28	0.683 **	0.458	0.500 *	0.800 **	1.733 **	1.708 **	-1.458 **	-2.833 **	-1.975 **
Gujarat Mustard-3	2.183 **	2.208 **	1.375 **	6.425 **	5.150 **	5.250 **	0.125	0.292	-0.267
ZEM-1	-2.525 **	-2.958 **	-2.917 **	-5.825 **	-4.933 **	-5.042 **	5.042 **	5.917 **	5.358 **
DRMR-1	1.933 **	2.375 **	2.250 **	1.925 **	2.025 **	1.958 **	0.042	0.125	0.067
NRCHB-101	-0.442 *	-0.167	0.250	-0.783 **	-0.933 **	-0.583 **	1.042 **	1.542 **	2.150 **
RH-30	0.558 *	0.125	0.500 *	1.675 **	1.650 **	1.417 **	0.625 **	1.000 **	0.442
TM-4	-0.525 *	-0.833 **	-0.500 *	1.258 **	1.317 **	1.583 **	-0.208	0.042	0.567 *
KBS-3	-0.608 **	-0.542 *	-1.083 **	-0.450 *	-0.267	-0.375	-1.000 **	-0.333	-0.433

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.25 General combining ability (*gca*) estimates for plant height (cm), no. of primary and secondary branches per plant under different nitrogen levels

Genotypes	Plant Height (cm)			Number of Primary Branches per Plant			Number of Secondary Branches per Plant		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
Jumka	-27.817 **	-27.650 **	-27.500 **	0.682 **	0.264 *	0.320 *	-15.222 **	-15.881 **	-14.873 **
RNG-73	12.808 **	12.183 **	12.083 **	0.565 **	0.402 **	0.678 **	6.983 **	6.602 **	6.282 **
Pusa Mustard-28	10.683 **	10.725 **	10.625 **	0.152	0.148	0.441 **	1.282 **	2.003 **	1.644 **
Gujarat Mustard-3	9.725 **	9.350 **	9.708 **	0.086	-0.677 **	0.482 **	1.774 **	2.211 **	2.273 **
ZEM-1	-14.275 **	-13.900 **	-14.000 **	-1.123 **	-0.907 **	-0.717 **	-4.801 **	-5.897 **	-3.443 **
DRMR-1	3.308 **	3.600 **	3.625 **	-0.035	-0.007	0.145	2.270 **	2.036 **	2.627 **
NRCHB-101	3.808 **	4.267 **	4.083 **	0.207	0.485 **	0.212	3.070 **	3.457 **	2.032 **
RH-30	5.683 **	5.183 **	5.208 **	-0.085	0.164	-0.534 **	3.516 **	2.428 **	1.407 **
TM-4	1.267 **	1.142 **	1.208 **	-0.252	0.289 *	-1.080 **	1.028 **	2.227 **	1.665 **
KBS-3	-5.192 **	-4.900 **	-5.042 **	-0.198	-0.161	0.053	0.099	0.815 **	0.386

*Significance P ≤0.05; ** Significance P ≤0.01

for the character under 150 Kg Nitrogen per ha condition. Singh *et al.* (2007), Nair *et al.* (2008) also had similar results.

4.5.2.4 Plant Height (cm)

Dwarfness in Plant Height is a desirable character for better yields. Therefore parents with negative *gca* effects are considered desirable for this character. The range of *gca* effects for plant height varied from -27.817 (Jumka) to 12.808 (RNG-73), -27.650 (Jumka) to 12.183 (RNG-73) and -27.500 (Jumka) to 12.083 (RNG-73) for conditions of control and doses of 75 Kg and 150 Kg Nitrogen per ha, respectively.

The good general combiners with desirable significantly negative *gca* effect were Jumka followed by ZEM-1 and KBS-3 under all three conditions along with high *per se* performance. Rest of all parental genotypes *viz.*, RNG-73, Pusa Mustard-28, Gujarat Mustard-3, RH-30, NRCHB-101, DRMR-1 and TM-4 exhibited significantly positive and undesirable estimates of *gca* effects in all three conditions representing their poor general combining ability. Verma *et al.* (2011) had similar findings.

4.5.2.5 Number of Primary Branches per Plant

The parental genotypes with positive *gca* effects for number of primary branches per plant are considered desirable as it is favourable attribute for yield. In case of control, the range for *gca* effects for the character varied from -1.123 (ZEM-1) to 0.682 (Jumka). The good general combiners with desirable significantly positive *gca* effect were Jumka and RNG-73. However none of the genotypes were found associated with high *per se* performance. The parent ZEM-1 was found as poor general combiner with significantly negative *gca* effects under this condition.

Under 75 Kg Nitrogen per ha condition, the range for *gca* effects for number of primary branches per plant varied from -0.907 (ZEM-1) to 0.485 (NRCHB-101). The good general combiners with significantly positive *gca* effects were NRCHB-101, RNG-73, TM-4 and Jumka. None of the genotypes exhibited high *per se* performance. Two Parents *i.e.* ZEM-1 and Gujarat Mustard-3 also exhibited significantly negative *gca* effects for this case representing their poor general combining ability.

The range for *gca* effects for the character varied from -1.080 (TM-4) to 0.678 (RNG-73) in case 150 Kg Nitrogen per ha condition. The good general combiners with desirable significantly positive *gca* effects were RNG-73, Gujarat Mustard-3, Pusa Mustard-28 and Jumka. However none of the parents were found associated with high *per se* performance. Three parental genotypes *viz.*, TM-4, ZEM-1 and RH-30 were found as poor general combiners with undesirable significantly negative *gca* effects for number of primary branches per plant under this condition.

4.5.2.6 Number of Secondary branches per plant

The number of secondary branches per plant is favourable character for yield. The parental genotypes with positive *gca* effects for this character are considered desirable. In case of control, the range of *gca* effects varied from -15.222 (Jumka) to 6.983 (RNG-73). The good general combiners with desirable significantly positive *gca* effect were RNG-73, RH-30, NRCHB-101, DRMR-1, Gujarat Mustard-3, Pusa Mustard-28 and TM-4 having high *per se* performance.

Under 75 Kg Nitrogen per ha condition, the range for *gca* effects varied from -15.881 (Jumka) to 6.602 (RNG-73) and good general combiners with significantly positive *gca* effects were RNG-73, NRCHB-101, RH-30, TM-4, Gujarat Mustard-3, DRMR-1, Pusa Mustard-28 and KBS-3 which also showed high *per se* performance except for the parental genotype- KBS-3.

The range for *gca* effects for number of secondary branches per plant varied from -14.873 (Jumka) to 6.282 (RNG-73) in case 150 Kg Nitrogen per ha. The good general combiners with desirable significantly positive *gca* effects for the character were RNG-73, DRMR-1, Gujarat Mustard-3, NRCHB-101, TM-4, Pusa Mustard-28 and RH-30 having high *per se* performance. In addition, in all three conditions, the significantly negative *gca* effects were observed in only two genotypes *viz.*, Jumka and ZEM-1 representing their poor general combining ability.

Table 4.26 General combining ability (*gca*) estimates for length of main shoot (cm), no. of siliquae on main shoot and siliqua length (cm) under different nitrogen levels

Genotypes	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua Length (cm)		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
Jumka	-11.228 **	-10.777 **	-11.435 **	-3.708 **	-3.783 **	-3.442 **	1.211 **	1.025 **	1.082 **
RNG-73	2.409 **	1.719 **	2.086 **	2.083 **	1.508 **	1.308 *	0.203	0.308 **	0.261
Pusa Mustard-28	2.547 **	1.798 **	1.515 **	1.458 **	1.467 **	1.642 **	0.219	0.358 **	0.219
Gujarat Mustard-3	1.955 **	1.761 **	2.236 **	2.208 **	2.050 **	2.225 **	-0.427 **	-0.458 **	-0.198
ZEM-1	-1.333 **	-0.968 *	-1.014 **	-0.958 **	-1.033 **	-0.317	-0.598 **	-0.425 **	-0.293 *
DRMR-1	1.092 **	1.540 **	1.390 **	0.500	0.342	-0.108	0.148	0.117	0.078
NRCHB-101	2.167 **	2.407 **	1.986 **	-1.875 **	-1.325 **	-1.525 **	0.040	-0.192	-0.343 *
RH-30	1.438 **	1.894 **	2.036 **	1.458 **	1.050 **	0.100	-0.218	-0.263 *	-0.448 **
TM-4	1.201 **	0.686	1.127 **	0.083	0.425	0.267	-0.277 *	-0.304 **	-0.168
KBS-3	-0.249	-0.060	0.073	-1.250 **	-0.700	-0.150	-0.302 *	-0.167	-0.189

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.27 General combining ability (*gca*) estimates for no. of seeds per siliqua, 1000 seed weight (g) and seed yield per plant (g) under different nitrogen levels

Genotypes	No. of Seeds per Siliqua			1000 Seed Weight (g)			Seed Yield per Plant (g)		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
Jumka	6.183 **	1.333 **	1.792 **	-0.395 **	-0.321 **	-0.320 **	3.225 **	4.125 **	4.325 **
RNG-73	-0.983 **	-0.333	0.667	0.063	0.108	0.109	7.517 **	7.792 **	7.158 **
Pusa Mustard-28	1.058 **	1.458 **	0.958 *	-0.195 **	-0.113 *	-0.032	-1.525 **	-1.417 **	-1.133 **
Gujarat Mustard-3	0.850 **	1.333 **	0.792	0.163 *	0.129 *	0.147 *	-4.775 **	-5.708 **	-5.175 **
ZEM-1	-3.108 **	-2.542 **	-1.125 *	0.009	0.100	0.005	-8.858 **	-8.833 **	-8.300 **
DRMR-1	-0.858 **	-0.583 *	-1.000 *	0.188 **	0.096	0.113	-2.442 **	-2.375 **	-2.342 **
NRCHB-101	-0.150	0.417	0.125	0.259 **	0.171 **	0.092	2.433 **	1.708 **	1.492 **
RH-30	-1.150 **	-0.458 *	-0.458	0.109	0.025	0.068	2.767 **	2.667 **	2.242 **
TM-4	-0.817 **	-0.042	-1.083 *	-0.099	-0.125 *	-0.103	1.350 **	1.458 **	1.158 **
KBS-3	-1.025 **	-0.583 *	-0.667	-0.103	-0.071	-0.078	0.308	0.583 *	0.575

*Significance P ≤0.05; ** Significance P ≤0.01

4.5.2.7 Length of Main shoot (cm)

The parental genotypes with positive *gca* effects for length of main shoot are considered desirable due to favourability of the trait for yield. In case of control, the *gca* effects varied from -11.228 (Jumka) to 2.547 (Pusa Mustard-28). The good general combiners with desirable significantly positive *gca* effects were Pusa Mustard-28, RNG-73, NRCHB-101, Gujarat Mustard-3, EH-30, TM-4 and DRMR-1.

Under 75 Kg Nitrogen per ha condition, the range of *gca* effects for the character varied from -10.777 (Jumka) to 2.407 (NRCHB-101) and the good general combiners with desirable significantly positive *gca* effect were NRCHB-101, RH-30, Pusa Mustard-28, Gujarat Mustard-3, RNG-73 and DRMR-1.

In case of 150 Kg Nitrogen per ha condition, the *gca* effects varied from -11.435 (Jumka) to 2.236 (Gujarat Mustard-3). The good general combiners were Gujarat Mustard-3, RNG-73, RH-30, NRCHB-101, Pusa Mustard-28, DRMR-1 and TM-4.

Two parental genotypes *viz.*, Jumka and ZEM-1 were poor general combiners with significantly negative *gca* effect for length of main shoot under all three conditions.

4.5.2.8 Number of Siliqua on Main Shoot

The parents with positive *gca* effects are more desirable for number of siliqua on main shoot. Under control, the *gca* effects for the character varied from -3.708 (Jumka) to 2.208 (Gujarat Mustard-3). The good general combiners with desirable significantly positive *gca* effect were Gujarat Mustard-3, RNG-73, Pusa Mustard-28 and NRCHB-101. None of the genotypes showed high *per se* performance. Four parents *viz.*, Jumka, NRCHB-101, KBS-3 and ZEM-1 also exhibited significantly negative *gca* effects representing their poor general combining ability for the character under control.

Under 75 Kg Nitrogen per ha condition, the range for *gca* effects varied from -3.783 (Jumka) to 2.050 (Gujarat Mustard-3). The good general combiners were

Gujarat Mustard-3, RNG-73, Pusa Mustard-28 and RH-30 but none exhibited high *per se* performance. In this case, three parents *viz.*, Jumka, NRCHB-101 and ZEM-1 were poor general combiners with undesirable significantly negative *gca* effects.

For 150 Kg Nitrogen per ha condition, the range for *gca* effects varied from -3.442 (Jumka) to 2.225 (Gujarat Mustard-3) and good general combiners with significantly positive and desirable *gca* effects were Gujarat Mustard-3, Pusa Mustard-28 and RNG-73 but none with high *per se* performance. Two parents namely Jumka and NRCHB-101 were found as poor general combiners under this condition for number of siliqua on main shoot.

4.5.2.9 Siliqua Length (cm)

Greater siliqua length being a desirable attribute for more yield, the positive *gca* effects are considered for this character. For control *gca* effects varied from -0.598 (ZEM-1) to 1.211 (Jumka) and the good general combiner with desirable significantly positive *gca* effect for siliqua length was Jumka only along with high *per se* performance. The genotypes with poor general combining ability with undesirable significantly negative *gca* effects were ZEM-1, Gujarat Mustard-3, KBS-3 and TM-4 in case of control.

Under 75 Kg nitrogen per ha condition, the range for *gca* effects varied from -0.458 (Gujarat Mustard-3) to 1.025 (Jumka). The good general combiners with desirable significantly positive *gca* effects were Jumka, Pusa Mustard-28 and RNG-73. High *per se* performance was exhibited by Jumka only. Four parental genotypes *viz.*, Gujarat Mustard-3, ZEM-1, TM-4 and RH-30 were found as poor general combiners with significantly negative *gca* effects.

Under 150 Kg Nitrogen per ha condition, the *gca* effects varied from -0.448 (RH-30) to 1.082 (Jumka). Jumka was the only good general combiner with desirable significantly positive *gca* effect for siliqua length. However the genotype did not exhibited high *per se* performance. Three parental genotypes *viz.*, RH-30, NRCHB-101 and ZEM-1 were found associated with undesirable significantly negative *gca* effects under this condition showing their poor general combining ability.

4.5.2.10 Number of Seeds per Siliqua

The positive *gca* effects of parental genotypes are considered desirable for number of seeds per siliqua. Under control the range of *gca* effects varied from -3.108 (ZEM-1) to 6.183 (Jumka). The good general combiners with significantly positive *gca* effect were Jumka, Pusa Mustard-28 and Gujarat Mustard-3. High *per se* performance was shown by Jumka only. In addition, six parent *viz.,* ZEM-1, RH-30, KBS-3, RNG-73, DRMR-1 and TM-4 exhibited significantly negative *gca* effects under this condition showing their poor general combining ability.

In case of 75 Kg Nitrogen per ha condition, the range for *gca* effects for number of seeds per siliqua varied from -2.542 (ZEM-1) to 1.458 (Pusa Mustard-28). The good general combiners under this condition with desirable significantly positive *gca* effect were Pusa Mustard-28, Jumka and Gujarat Mustard-3. High *per se* performance was not exhibited by any of the genotypes. Four parents *viz.,* ZEM-1, KBS-3, DRMR-1 and RH-30 were found as poor general combiners for number seeds per siliqua under this condition.

Under 150 Kg Nitrogen per ha condition, the range for *gca* effects varied from -1.125 (ZEM-1) to 1.792 (Jumka). The Parental genotype Jumka and Pusa Mustard-28 were found as good general combiners with desirable significantly positive *gca* effects. High *per se* performance was not observed for any genotype. However, three parental genotypes *viz.,* ZEM-1, TM-4 and DRMR-1 also exhibited undesirable significantly negative *gca* effects for number of seeds per siliqua under this condition.

4.5.2.11 1000 Seed Weight (g)

Greater 1000 seed weight also known as test weight is desirable. Therefore positive *gca* effect are considered for this character. Under the condition of control, the range of *gca* effects for this trait varied from -0.395 (Jumka) to 0.259 (NRCHB-101). The good general combiners with desirable significantly positive *gca* effects were NRCHB-101, DRMR-1 and Gujarat Mustard-3 but none with high *per se* performance of the genotypes. Two parent *viz.,* Jumka and Pusa Mustard-28 were found as poor general combiners under control for 1000 seed weight.

Table 4.28 General combining ability (*gca*) estimates for biological yield per plant (g), Harvest Index (%), seed oil content (%) under different nitrogen levels

Genotypes	Biological Yield per Plant (g)			Harvest Index (%)			Seed Oil Content (%)		
	Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	150 Kg N/ha	**Control**	75 Kg N/ha	150 Kg N/ha
Jumka	-30.742 **	-29.467 **	-23.733 **	5.336 **	5.713 **	5.277 **	-1.616 **	-1.538 **	-1.149 **
RNG-73	53.842 **	51.450 **	61.058 **	-0.020	0.120	-0.893 **	-0.299	-0.380 *	-0.674 *
Pusa Mustard-28	13.217 **	15.492 **	8.475 **	-1.647 **	-1.738 **	-1.287 **	-0.824 **	-0.634 **	-0.862 **
Gujarat Mustard-3	-17.075 **	-11.842 **	-24.483 **	-1.525 **	-2.325 **	-1.207 **	-0.220	-0.197	-0.337
ZEM-1	-50.658 **	-47.592 **	-40.983 **	-1.251 **	-1.369 **	-1.567 **	1.455 **	1.245 **	1.172 **
DRMR-1	-1.783	-9.300 **	-20.108 **	-1.206 **	-0.537 *	0.394	0.813 **	0.887 **	0.892 **
NRCHB-101	9.883 **	4.867	11.808 **	0.430	0.162	-0.316	-0.133	0.032	-0.120
RH-30	16.675 **	5.825	12.725 **	-0.016	0.616 *	-0.019	0.913 **	1.058 **	0.959 **
TM-4	0.425	-1.675	2.808	0.385	0.532 *	0.214	0.038	-0.088	0.118
KBS-3	6.217 *	22.242 **	12.433 **	-0.487 *	-1.174 **	-0.597 *	-0.128	-0.384 *	0.001

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.29 General combining ability (*gca*) estimates for seed nitrogen content (%) and chaff nitrogen content (%) under different nitrogen levels

Genotypes	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
	Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
Jumka	-0.014 *	-0.010 *	0.000	-0.099 **	-0.104 **	-0.102 **
RNG-73	-0.017 **	-0.014 **	-0.004	-0.035 **	-0.037 **	-0.040 **
Pusa Mustard-28	0.023 **	0.020 **	0.030 **	0.044 **	0.043 **	0.044 **
Gujarat Mustard-3	-0.011	-0.013 **	-0.004	-0.154 **	-0.159 **	-0.156 **
ZEM-1	-0.024 **	-0.022 **	-0.031 **	0.076 **	0.074 **	0.073 **
DRMR-1	-0.018 **	-0.020 **	-0.017 **	-0.063 **	-0.065 **	-0.071 **
NRCHB-101	0.027 **	0.022 **	0.015 **	0.089 **	0.087 **	0.088 **
RH-30	0.010	0.006	0.000	0.069 **	0.065 **	0.064 **
TM-4	0.014 *	0.017 **	0.007	0.036 **	0.057 **	0.059 **
KBS-3	0.011	0.014 **	0.004	0.038 **	0.039 **	0.042 **

*Significance P ≤0.05; ** Significance P ≤0.01

For 75 Kg Nitrogen per ha condition, the *gca* effects for 1000 seed weight varied from -0.321 (Jumka) to 0.171 (NRCHB-101). The desirable significantly positive *gca* effect representing good general combining ability were shown by NRCHB-101 and Gujarat Mustard-3, but none of the genotypes were found associated with high *per se* performance. In addition, three parental genotypes *viz.*, Jumka, Pusa Mustard-28 and TM-4 exhibited significantly negative *gca* effect for the trait under this condition representing their poor general combining ability.

For 150 Kg Nitrogen per ha condition, the variation in *gca* effects for the trait was from -0.320 (Jumka) to 0.147 (Gujarat Mustard-3). However, only rhe parental genotype Gujarat Mustard-3 was found as good general combiner. But none of the genotypes exhibited high *per se* performance for the character. Only one parent *viz.*, Jumka was found associated with significantly negative *gca* effect for 1000 seed weight under this condition.

4.5.2.12 Seed Yield per Plant (g)

The seed yield per plant is one of the most important characters for yield. The positive *gca* effect in parents are considered desirable for this trait. The *gca* effects for the trait varied from -8.858 (ZEM-1) to 7.517 (RNG-73), -8.833 (ZEM-1) to 7.792 (RNG-73) and -8.300 (ZEM-1) to 7.158 (RNG-73) for control and under 75 Kg and 150 Kg Nitrogen per ha conditions, respectively.

In all three conditions, the good general combiners with desirable significantly positive *gca* effects were RNG-73, Jumka, RH-30, NRCHB-101 and TM-4. However the parent KBS-3 also exhibited significantly positive and desirable *gca* effect under 75 Kg Nitrogen per ha condition. High *per se* performance was associated with RH-30 in all three conditions. However, NRCHB-101 and TM-4 exhibited high *per se* performance only under control and condition of 75 Kg Nitrogen per ha.

In addition four parental genotypes *viz.,* ZEM-1, Gujarat Mustard-3, DRMR-1 and Pusa Mustard-28 were poor general combiners with significantly negative and undesirable *gca* effects for seed yield per plant in all three conditions.

4.5.2.13 Biological Yield per Plant (g)

The positive *gca* effect are considered for the character biological yield per plant. Under control, the range for *gca* effects varied from -50.658 (ZEM-1) to 53.842 (RNG-73). The good general combiners with desirable significantly positive *gca* effects were RNG-73, RH-30, Pusa Mustard-28, NRCHB-101 and KBS-3 under control condition along with high *per se* performance except for Pusa Mustard-28. In this case, three parent *viz.,* ZEM-1, Jumka and Gujarat Mustard-3 also exhibited undesirable significantly negative *gca* effect representing poor general combining ability.

Under 75 Kg Nitrogen per ha condition, the range of *gca* effect varied from -47.592 (ZEM-1) to 51.450 (RNG-73) and the desirable significantly positive *gca* effects representing good general combining ability was exhibited by the parental genotypes RNG-73, KBS-3 and Pusa Mustard-28 along with high *per se* performance except for Pusa Mustard-28. Four parent *viz.,* ZEM-1, Jumka, Gujarat Mustard-3 and DRMR-1 were found as poor general combiners.

For 150 Kg Nitrogen per ha condition, the range of *gca* effects observed for the parental genotypes was from -40.983 (ZEM-1) to 61.058 (RNG-73). The good general combiners with desirable significantly positive *gca* effects were RNG-73, RH-30, KBS-3, NRCHB-101 and Pusa Mustard-28. High *per se* performance was also observed in these genotypes under this condition. In addition four genotypes were found poor general combiners with undesirable significantly negative and *gca* effects *viz.,* ZEM-1, Gujarat Mustard-3, Jumka and DRMR-1.

4.5.2.14 Harvest Index (%)

Greater Harvest Index is favourable for yield. Therefore, the parental genotypes with positive *gca* effects are considered desirable for the trait- Harvest Index. In case of control, the range of *gca* effects varied from -1.647 (Pusa Mustard-28) to 5.336 (Jumka). Under 75 Kg and 150 Kg Nitrogen per ha condition, the range of *gca* effects varied from -2.325 (Gujarat Mustard-3) to 5.713 (Jumka) and -1.567 (ZEM-1) to 5.277 (Jumka), respectively.

In all three conditions, the genotype Jumka was found as good general combiner with significantly positive and desirable *gca* effect. The genotype RH-30 and TM-4 were also found as good general combiner under 75 Kg Nitrogen per ha condition. The genotype Jumka also exhibited high *per se* performance under 75 Kg and 150 Kg Nitrogen per ha condition.

Under control, the genotypes – Pusa Mustard-28, Gujarat Mustard-3, ZEM-1, DRMR-1 and KBS-3 were found as poor general combiner exhibiting undesirable significantly negative *gca* effects. For 75 Kg Nitrogen per ha condition, five parent *viz.,* Gujarat Mustard-3, Pusa Mustard-28, ZEM-1, KBS-3 and DRMR-1 also exhibited significantly negative *gca* effect representing their poor combining ability. On other hand, five parents *viz.*, ZEM-1, Pusa Mustard-28, Gujarat Mustard-3, RNG-73 and KBS-3 were found as poor general combiners for Harvest Index under 150 Kg Nitrogen per ha condition.

4.5.2.15 Seed Oil Content (%)

The range for *gca* effects for oil content varied from -1.616 (Jumka) to 1.455 (ZEM-1), -1.538 (Jumka) to 1.245 (ZEM-1) and -1.149 (Jumka) to 1.1772 (ZEM-1) under control, 75 Kg and 150 Kg Nitrogen per ha condition, respectively.

In all three cases, the good general combiners with desirable significantly positive *gca* effect were ZEM-1, RH-30 and DRMR-1. In case of control, the significantly negative *gca* effects were associated with the parent Jumka and Pusa Mustard-28. Under 75 Kg nitrogen per ha condition, the four parent *viz.*, Jumka, Pusa Mustard-28, KBS-3 and RNG-73 were identified as poor general combiner. Three parental genotypes *viz.*, Jumka, Pusa Mustard-28 and RNG-73 had undesirable significantly negative *gca* effects for Oil content under 150 Kg Nitrogen per ha condition showing their poor general combining ability.

4.5.2.16 Seed Nitrogen Content (%)

The positive *gca* effects are desirable for this trait. In case of control, the range of *gca* effects for seed nitrogen varied from -0.024 (ZEM-1) to 0.027 (NRCHB-101). The good general combiners with desirable significantly positive *gca* effects were

NRCHB-101, Pusa Mustard-28 and TM-4. Four parent *viz.*, ZEM-1, DRMR-1, RNG-73 and Jumka were found as poor general combiners as evident from undesirable significantly negative *gca* effects for seed nitrogen under control.

Under 75 Kg nitrogen per ha condition, the range for *gca* effects varied from -0.022 (ZEM-1) to 0.022 (NRCHB-101). The good general combiners with significantly positive *gca* effect were NRCHB-101, Pusa Mustard-28, TM-4 and KBS-3. The significantly negative *gca* effects were shown by five parent *viz.,* ZEM-1, DRMR-1, RNG-73, Gujarat Mustard-3 and Jumka representing their poor general combining ability in case of this condition for seed nitrogen.

Under 150 Kg Nitrogen per ha condition, the range from -0.031 (ZEM-1) to 0.030 (Pusa Mustard-28) was observed for *gca* effect for the trait- Seed Nitrogen. Only two genotypes *viz.,* Pusa Mustard-28 and NRCHB-101 were found as good general combiners for the character. Two genotypes *viz.,* ZEM-1 and DRMR-1 were found poor general combiners with undesirable significantly negative *gca* effects for seed nitrogen under this condition.

4.5.2.17 Chaff Nitrogen Content (%)

The range for *gca* effects for chaff nitrogen varied from -0.154 (Gujarat Mustard-3) to 0.089 (NRCHB-101), -0.159 (Gujarat Mustard-3) to 0.087 (NRCHB-101) and -0.156 (Gujarat Mustard-3) to 0.088 (NRCHB-101) under control, 75 Kg and 150 Kg Nitrogen per ha conditions, respectively.

Under control, the genotypes NRCHB-101, ZEM-1, RH-30, Pusa Mustard-28, KBS-3 and TM-4 were found as good general combiners with desirable significantly positive for *gca* effects for the character chaff nitrogen.

Under both 75 Kg and 150 Kg Nitrogen per ha condition, the good general combiners with desirable significantly positive *gca* effects were NRCHB-101, ZEM-1, RH-30, TM-4, Pusa Mustard-28 and KBS-3. High *per se* performances were observed for four parent *viz.,* ZEM-1, NRCHB-101, RH-30 and TM-4 in both conditions. In all three conditions, four parent *viz.,* Gujarat Mustard-3, Jumka, DRMR-1 and RNG-73 exhibited undesirable significantly negative *gca* effects for chaff nitrogen which represents their poor general combining ability.

The results so obtained were in line with classical heterosis studies of Shull (1909); Jones (1970) and East (1936) which establish the fact that certain lines produce more desirable hybrids. The crosses involving atleast one of the promising general combiners had high *sca* effects which were in line with the studies of Arifullah *et al.* (2012). Good general combiners have been identified for various characters including seed yield and oil content by Singh and Dixit (2007); Akbar *et al.* (2008); Verma *et al.* (2011); Saeed *et al.* (2013); Tomar and Singh (2016); Dahiya *et al.* (2017); Mohan *et al.* (2017); Kumar *et al.* (2018); Kaur *et al.* (2019) and Yadav *et al.* (2020).

4.5.3 Specific Combining Ability (*sca)* Effects

The estimates of *sca* effects for the seventeen characters are presented in Table 4.30; 4.31; 4.32; 4.33; 4.34 and 4.35. Significant positive *sca* values are considered to be desirable for all the characters except days to flower initiations, days to 50% flowering, days to maturity and plant height. Results with respect to *sca* effects are given as follows:

4.5.3.1 Days to Flower Initiation

Under control, the estimates of *sca* effects for days to flower initiation varied from -4.799 (ZEM-1 × DRMR-1) to 4.451 (RNG-73 × Pusa Mustard-28). Out of 45 crosses, eleven crosses *viz.*, ZEM-1 × DRMR-1; ZEM-1 × NRCHB-101; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; Jumka × Pusa Mustard-28; ZEM-1 × RH-30; Jumka × DRMR-1; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard- 28 × RH-30; Jumka × Gujarat Mustard-3; NRCHB-101 × RH-30 were found as good specific combiners with desirable significantly negative *sca* effects for this trait, while twelve crosses namely Gujarat Mustard-3 × ZEM-1; RNG-73 × Pusa Mustard-28; Jumka × ZEM-1; DRMR-1 × RH-30; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × KBS-3; RNG-73 × KBS-3; DRMR-1 × TM-4; RH-

30 × KBS-3; DRMR-1 × NRCHB -101 and Jumka × NRCHB-101 also showed significantly positive undesirable *sca* effects representing their poor specific combining ability.

On the other hand, under 75 Kg N/ha condition *sca* effects for this trait ranged from -4.462 (ZEM-1 × DRMR-1) to 5.455 (Pusa Mustard-28 × ZEM-1). Nine crosses out of 45 crosses *viz.*, ZEM-1 × DRMR-1; Pusa Mustard- 28 × RH-30; Pusa Mustard-28 × DRMR-1; ZEM-1 × TM-4; Jumka × TM-4; RNG-73 × RH-30; RNG-73 × DRMR-1; Jumka × RH-30 and Jumka × Gujarat Mustard-3 manifested significant negative *sca* effects desirable for early flowering representing their good specific combining ability. Only the cross ZEM-1 × TM_4 exhibited high *per se* performance for this trait. In addition, eleven crosses *viz.*, Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; RNG-73 × Pusa Mustard-28; RH-30 × TM-4; Jumka × NRCHB-101; DRMR-1 × TM-4; RH-30 × KBS-3; Pusa Mustard- 28 × TM-4; DRMR-1 × RH-30; Jumka × ZEM-1 and Pusa Mustard-28 × NRCHB-101 were found as poor specific combiners with undesirable significantly positive *sca* effects.

In the condition of 150Kg Nitrogen/ha, *sca* effects varied from -4.095 (RNG-73 × RH-30) to 4.905 (Gujarat Mustard-3 × ZEM-1). Twelve cross combinations *viz.*, RNG-73 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × TM-4; ZEM-1 × KBS-3; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × NRCHB-101; Pusa Mustard- 28 × RH-30; Jumka × DRMR-1; NRCHB-101 × TM-4; Jumka × RH-30; Pusa Mustard-28 × Gujarat Mustard-3; RNG-73 × DRMR-1 were found as good specific combiners with desirable significantly negative *sca* effects. Only two crosses ZEM-1 × TM-4 and ZEM-1 × KBS-3 exhibited high *per se* performance. However, in this case, twelve crosses were found poor specific combiners exhibiting undesirable significantly positive *sca* effects *viz.*, Gujarat Mustard-3 × ZEM-1; RH-30 × TM-4; DRMR-1 × TM-4; RH-30 × KBS-3; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × NRCHB-101; DRMR-1 × RH-30; RNG-73 × Gujarat Mustard-3; Gujarat Mustard-3 × DRMR-1; DRMR-1 × KBS-3 and Pusa Mustard-28 × DRMR-1.

Table 4.30 Specific combining ability (*sca*) estimates for days to flower initiation, days to fifty percent flowering and days to maturity under different nitrogen levels

	Genotypes	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1.	Jumka × RNG-73	0.367	-1.379	-0.761	1.398 *	3.633 **	3.598 **	-0.610	0.023	-2.019 *
2.	Jumka × Pusa Mustard-28	-2.049 **	-1.004	-0.803	-2.436 **	-1.492	-1.735 *	0.307	0.356	2.898 **
3.	Jumka × Gujarat Mustard-3	-1.549 *	-1.754 *	-1.178	-5.061 **	-4.909 **	-5.277 **	-1.277	-0.269	1.689 *
4.	Jumka × ZEM-1	2.659 **	1.913 *	1.114	5.189 **	6.174 **	6.515 **	-4.693 **	-8.394 **	-1.936 *
5.	Jumka × DRMR-1	-1.799 *	-1.420	-2.053 **	-1.561 **	-2.284 *	-1.985 **	-0.693	-2.602 **	-0.644
6.	Jumka × NRCHB-101	1.576 *	3.621 **	0.947	-0.352	-1.826	-1.943 **	-0.693	-3.019 **	-3.727 **
7.	Jumka × RH-30	-0.924	-2.170 *	-1.803 **	0.689	0.091	0.057	-0.777	0.523	-3.019 **
8.	Jumka × TM-4	-0.841	-2.712 **	-1.303	-0.894	-0.076	-0.610	0.557	2.481 **	1.356
9.	Jumka × KBS-3	0.242	-1.004	0.780	-1.686 **	-0.492	-1.152	1.848 *	4.356 **	3.856 **
10.	RNG-73 × Pusa Mustard-28	3.159 **	4.163 **	-0.095	-1.894 **	-2.951 **	-2.402 **	2.682 **	3.106 **	-0.894
11.	RNG-73 × Gujarat Mustard-3	-2.841 **	-1.587	2.030 **	-8.519 **	-8.367 **	-7.943 **	0.098	-1.019	-2.102 **
12.	RNG- 73 × ZEM-1	1.367	-0.420	0.322	2.731 **	3.216 **	3.848 **	-7.318 **	-4.644 **	-6.227 **
13.	RNG-73 × DRMR-1	-2.091 **	-2.254 **	-1.345 *	-4.019 **	-2.742 **	-2.152 **	0.182	-0.852	-4.436 **
14.	RNG-73 × NRCHB-101	-0.216	0.288	1.155	-3.811 **	-3.784 **	-3.610 **	-0.318	-1.769 *	0.981
15.	RNG-73 × RH-30	-0.716	-2.504 **	-4.095 **	-6.769 **	-4.367 **	-3.610 **	0.598	1.773 *	1.689 *
16.	RNG-73 × TM-4	0.867	1.455	-0.095	-2.352 **	-3.534 **	-2.777 **	-2.568 **	-3.769 **	-3.436 **
17.	RNG-73 × KBS-3	1.951 **	0.663	-0.011	-0.644	-1.451	-0.818	1.723 *	-0.394	2.064 *
18.	Pusa Mustard-28 × Gujarat Mustard-3	-1.758 *	-0.212	-1.511 *	-3.352 **	-1.492	-1.277	-0.985	0.814	0.814
19.	Pusa Mustard-28 × ZEM-1	2.451 **	5.455 **	2.780 **	10.398 **	8.591 **	9.015 **	-4.902 **	-2.311 **	-3.311 **
20.	Pusa Mustard-28 × DRMR-1	-0.508	-2.879 **	1.614 *	-1.352 *	-0.867	-0.485	0.098	-0.519	-1.019
21.	PusaMustard-28 × NRCHB-101	0.367	1.663 *	2.114 **	1.356 *	0.591	1.057	-1.402	0.064	-1.602 *
22.	Pusa Mustard- 28 × RH-30	-1.633 *	-3.129 **	-2.136 **	-3.102 **	-2.992 **	-1.443 *	1.015	-1.894 *	-2.394 **

	Genotypes	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	150 Kg N/ha	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
23.	Pusa Mustard- 28 × TM-4	0.451	2.330 **	2.864 **	1.314 *	1.841 *	1.390 *	1.848 *	0.064	3.981 **
24.	Pusa Mustard-28 × KBS-3	1.034	-0.462	0.447	0.523	0.924	2.348 **	0.140	-1.561	1.481
25.	Gujarat Mustard-3 × ZEM-1	4.451 **	4.205 **	4.905 **	8.773 **	6.674 **	6.473 **	-3.985 **	-4.936 **	-6.019 **
26.	Gujarat Mustard-3 × NRCHB-101	-0.508	0.871	-2.261 **	-0.477	-0.284	-0.527	0.015	1.856 *	0.773
27.	Gujarat Mustard-3 × DRMR-1	2.367 **	0.413	1.739 *	0.731	0.674	0.515	-0.485	-3.061 **	-0.311
28.	Gujarat Mustard-3 × RH-30	-0.633	-0.379	0.489	3.273 **	5.091 **	5.015 **	-1.568 *	-2.519 **	-1.102
29.	Gujarat Mustard-3 × TM-4	0.951	0.080	0.989	4.689 **	5.424 **	5.348 **	0.265	1.939 *	-2.727 **
30.	Gujarat Mustard-3 × KBS-3	2.034 **	1.288	-2.428 **	3.898 **	4.008 **	4.307 **	0.057	1.814 *	-1.227
31.	ZEM-1 × DRMR-1	-4.799 **	-4.462 **	-3.470 **	-7.727 **	-6.201 **	-4.735 **	3.598 **	6.231 **	6.648 **
32.	ZEM-1 × NRCHB-101	-2.924 **	-1.420	-0.970	-3.519 **	-3.742 **	-2.193 **	4.098 **	6.314 **	6.564 **
33.	ZEM-1 × RH-30	-1.924 **	-0.712	-0.720	-7.477 **	-7.826 **	-6.193 **	4.015 **	5.356 **	6.273 **
34.	ZEM-1 × TM-4	-1.341	-2.754 **	-2.720 **	-5.061 **	-7.992 **	-7.860 **	5.348 **	3.814 **	3.648 **
35.	ZEM-1 × KBS-3	-1.258	-1.545	-2.636 **	-4.352 **	-4.409 **	-4.402 **	6.640 **	6.689 **	7.648 **
36.	DRMR-1 × NRCHB -101	1.617 *	1.246	0.864	3.231 **	3.299 **	2.807 **	-1.902 **	-0.394	-1.644 *
37.	DRMR-1 × RH-30	2.617 **	1.955 *	2.114 **	1.773 **	1.716	2.307 **	-1.985 **	-0.352	0.064
38.	DRMR-1 × TM-4	1.701 *	2.413 **	3.114 **	3.189 **	3.049 **	2.640 **	1.348	2.106 *	1.439
39.	DRMR-1 × KBS-3	1.284	1.121	1.697 *	5.898 **	5.633 **	5.598 **	0.140	0.481	-0.061
40.	NRCHB-101 × RH-30	-1.508 *	-0.004	-0.386	-1.519 *	-1.326	-0.652	0.515	1.731 *	1.481
41.	NRCHB-101 × TM-4	0.076	-1.545	-1.886 **	0.898	0.508	0.182	0.348	1.189	-0.144
42.	NRCHB-101 × KBS-3	-0.341	-0.837	-0.303	0.106	1.091	1.140	-0.360	0.564	-0.144
43.	RH-30 × TM-4	1.076	4.163 **	3.864 **	1.439 *	1.424	1.682 *	0.265	2.231 **	2.064 *
44.	RH-30 × KBS-3	1.659 *	2.371 **	2.947 **	3.648 **	4.008 **	4.140 **	0.057	0.606	0.564
45.	TM-4 × KBS-3	-1.258	0.330	-0.553	4.064 **	4.841 **	4.973 **	-2.610 **	-3.436 **	-4.061 **

*Significance P ≤0.05; ** Significance P ≤0.01

4.5.3.2 Days to Fifty Percent Flowering

Under controlled condition *sca* effects estimates for this character ranged from -8.519 (RNG-73 × Gujarat Mustard-3) to 10.398 (Pusa Mustard-28 × ZEM-1). Nineteen crosses namely, Jumka × Pusa Mustard-28, Jumka × Gujarat Mustard-3, Jumka × DRMR-1, RNG-73 × Gujarat Mustard-3, Jumka × KBS-3, RNG-73 × Pusa Mustard-28, RNG-73 × DRMR-1, RNG-73 × NRCHB-101, RNG-73 × RH-30, RNG-73 × TM-4, Pusa Mustard-28 × Gujarat Mustard-3, Pusa Mustard-28 × DRMR-1, Pusa Mustard- 28 × RH-30, ZEM-1 × DRMR-1, ZEM-1 × NRCHB-101, ZEM-1 × RH-30, ZEM-1 × TM-4, NRCHB-101 × RH-30, ZEM-1 × KBS-3 were found as good specific combiners with desired significantly negative *sca* effects with high *per se* performance. Whereas Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; DRMR-1 × KBS-3; Jumka × ZEM-1; Gujarat Mustard-3 × TM-4; TM-4 × KBS-3; Gujarat Mustard-3 × KBS-3; RH-30 × KBS-3; Gujarat Mustard-3 × RH-30; DRMR-1 × NRCHB -101; DRMR-1 × TM-4; RNG- 73 × ZEM-1; DRMR-1 × RH-30; RH-30 × TM-4; Jumka × RNG-73; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4 were found as poor specific combiners owing to their undesired significantly positive *sca* effects.

Range for *sca* effects under 75 Kg N/ha varied from -8.367 (RNG-73 × Gujarat Mustard-3) to 8.591 (Pusa Mustard-28 × ZEM-1). Various cross combinations *viz.*, Jumka × Gujarat Mustard-3, Jumka × NRCHB-101, RNG-73 × Pusa Mustard-28, RNG-73 × Gujarat Mustard-3, RNG-73 × DRMR-1, RNG-73 × NRCHB-101, RNG-73 × RH-30, RNG-73 × TM-4, Pusa Mustard- 28 × RH-30, ZEM-1 × DRMR-1, ZEM-1 × NRCHB-101, ZEM-1 × RH-30, ZEM-1 × TM-4, ZEM-1 × KBS-3 were found good specific combiners with desirable significantly negative *sca* effects. On the other side fourteen crosses *viz.*, Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Jumka × ZEM-1; DRMR-1 × KBS-3; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × RH-30; TM-4 × KBS-3; Gujarat Mustard-3 × KBS-3; RH-30 × KBS-3; Jumka × RNG-73; DRMR-1 × NRCHB -101; RNG- 73 × ZEM-1; DRMR-1 × TM-4 and Pusa Mustard- 28 × TM-4 were found as poor specific combiners.

Under 150 Kg N/ha level estimates of *sca* effects ranged from -7.943 (RNG-73 × Gujarat Mustard-3) to 9.015 (Pusa Mustard-28 × ZEM-1). Sixteen cross combinations *viz.*, Jumka × Pusa Mustard-28, Jumka × Gujarat Mustard-3, Jumka × DRMR-1, Jumka × NRCHB-101, RNG-73 × Pusa Mustard-28, RNG-73 × Gujarat Mustard-3, RNG-73 × DRMR-1, RNG-73 × NRCHB-101, RNG-73 × RH-30, RNG-73 × TM-4, Pusa Mustard- 28 × RH-30, ZEM-1 × DRMR-1, ZEM-1 × NRCHB-101, ZEM-1 × RH-30, ZEM-1 × TM-4, ZEM-1 × KBS-3 were found as good specific combiners with desirable significantly negative *sca* effects. Only the crosses Jumka × Pusa Mustard 28 and ZEM-1 × TM-4 exhibited high *per se* performance for this trait. However the cross combinations *viz.*, Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Gujarat Mustard-3 × ZEM-1; DRMR-1 × KBS-3; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × RH-30; TM-4 × KBS-3; Gujarat Mustard-3 × KBS-3; RH-30 × KBS-3; RNG- 73 × ZEM-1; Jumka × RNG-73; DRMR-1 × NRCHB -101; DRMR-1 × TM-4; Pusa Mustard-28 × KBS-3; DRMR-1 × RH-30; RH-30 × TM-4 and Pusa Mustard- 28 × TM-4 showed poor specific combining ability owing to their undesirable significantly positive *sca* effects.

4.5.3.3 Days to Maturity

Earliness for this trait is desirable. Therefore the crosses with negative *sca* effects are considered for this trait. In case of control, the *sca* effects varied from -7.318 (RNG-73 × ZEM-1) to 6.640 (ZEM-1 × KBS-3). The good specific combiners with desirable significantly negative *sca* effect were RNG-73 × ZEM-1; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Gujarat Mustard-3 × ZEM-1; TM-4 × KBS-3; RNG-73 × TM-4; DRMR-1 × RH-30, DRMR-1 × NRCHB-101 and Gujarat Mustard-3 × RH-30. Only the cross combination Jumka × ZEM-1 exhibited high *per se* performance. However, nine crosses *viz.*, ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × DRMR-1; RNG-73 × Pusa Mustard-28; Jumka × KBS-3; Pusa Mustard- 28 × TM-4 and RNG-73 × KBS-3 were found as poor specific combiners.

Under 75 Kg Nitrogen per ha condition the range for *sca* effects for the character varied from -8.394 (Jumka × ZEM-1) to 6.689 (ZEM-1 × KBS-3). The good specific combiners with desirable significantly negative *sca* effects were Jumka × ZEM-1; Gujarat Mustard-3 × ZEM-1; RNG-73 × ZEM-1; RNG-73 × TM-4; TM-4 × KBS-3; Gujarat Mustard-3 × DRMR-1; Jumka × NRCHB-101; Jumka × DRMR-1; Gujarat Mustard-3 × RH-30; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × RH-30 and RNG-73 × NRCHB-101. All crosses except Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1 and Gujarat Mustard-3 × RH-30 also exhibited high *per se* performance for earliness in maturity. While fifteen crosses *viz.,* ZEM-1 × KBS-3; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × RH-30; Jumka × KBS-3; ZEM-1 × TM-4; RNG-73 × Pusa Mustard-28; Jumka × TM-4; RH-30 × TM-4; DRMR-1 × TM-4; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × KBS-3; RNG-73 × RH-30 and NRCHB-101 × RH-30 were found as poor specific combiners.

Under 150 Kg Nitrogen per ha condition, -6.227 (RNG-73 × ZEM-1) to 7.648 (ZEM-1 × KBS-3) was the range for *sca* effects for days to maturity. The good specific combiners with desirable significantly negative *sca* effect were RNG-73 × ZEM-1; Gujarat Mustard-3 × ZEM-1; RNG-73 × DRMR-1; TM-4 × KBS-3; Jumka × NRCHB-101; RNG-73 × TM-4; Pusa Mustard-28 × ZEM-1; Jumka × RH-30; Gujarat Mustard-3 × TM-4; Pusa Mustard-28 × RH-30; RNG-73 × Gujarat Mustard-3; Jumka × RNG-73; Jumka × ZEM-1; DRMR-1 × NRCHB-101 and Pusa Mustard-28 × NRCHB-101 along with high *per se* performance. In this condition twelve crosses were found as poor specific combiners with significantly positive *sca* effects *viz.*, ZEM-1 × KBS-3; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × RH-30; Jumka × KBS-3; ZEM-1 × TM-4; RNG-73 × Pusa Mustard-28; Jumka × TM-4; RH-30 × TM-4; DRMR-1 × TM-4; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × KBS-3; RNG-73 × RH-30 and NRCHB-101 × RH-30.

4.5.3.4 Plant Height (cm)

The cross combinations with negative *sca* effects are considered for this trait as it is a desirable trait. In case of control, the *sca* effects ranged from -21.152 (ZEM-1 × NRCHB-101) to 23.848 (RNG-73 × ZEM-1). The good specific combiners with desirable significantly negative *sca* effect were ZEM-1 × NRCHB-101; ZEM-1 × RH-30; Jumka × RNG-73; ZEM-1 × TM-4; Jumka × Pusa Mustard-28; ZEM-1 × DRMR-1; Jumka × RH-30; RNG-73 × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × Gujarat Mustard-3; ZEM-1 × KBS-3; Jumka × TM-4; Jumka × NRCHB-101; Jumka × DRMR-1; Gujarat Mustard-3 × RH-30; NRCHB-101 × RH-30 and Jumka × KBS-3. All these crosses exhibited high *per se* performance for the plant height except RNG-73 × Pusa Mustard-28; Pusa-Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × RH-30 and NRCHB-101 × RH-30. On the other hand, 18 cross combinations were found as poor specific combiners w *viz.*, RNG- 73 × ZEM-1; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Jumka × ZEM-1; RH-30 × KBS-3; Pusa Mustard-28 × KBS-3; DRMR-1 × KBS-3; NRCHB-101 × KBS-3; Gujarat Mustard-3 × KBS-3; RH-30 × TM-4; Pusa Mustard-28 × DRMR-1; Pusa Mustard-28 × NRCHB-101; DRMR-1 × TM-4; RNG-73 × KBS-3; TM-4 × KBS-3; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × DRMR-1 and RNG-73 × TM-4.

Under 75Kg N/ha condition, the value of *sca* effects varied from -19.439 (ZEM-1 × NRCHB-101) to 18.977 (Gujarat Mustard -3 × ZEM-1). The good specific combiners were ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × TM-4; Jumka × Pusa Mustard-28; ZEM-1 × DRMR-1; Jumka × RNG-73; Jumka × RH-30; RNG-73 × Pusa Mustard-28; Jumka × Gujarat Mustard-3; ZEM-1 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × TM-4' Jumka × NRCHB-101; Jumka × DRMR-1; NRCHB-101 × RH-30; RNG-73 × Gujarat Mustard-3; Jumka × KBS-3 and RNG-73 × Gujarat Mustard-3. High *per se* performance was observed for all these crosses except RNG-73 × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; NRCHB-101 × RH-30 and RNG-73 × Gujarat Mustard-3. Eighteen crosses *viz.*, RNG- 73 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Pusa Mustard-28 × KBS-3; RH-30 × KBS-3; NRCHB-101 × KBS-3; DRMR-1 × KBS-3; RNG-73 × KBS-3; DRMR-1 × TM-4; RH-30 × TM-4; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × RH-30; Pusa Mustard-28 × DRMR-1; TM-4 × KBS-3 and Gujarat Mustard-3 ×

DRMR-1 were found as poor specific combiners owing to their undesirable significantly positive *sca* effects.

For 150 Kg N/ha condition the estimates of *sca* effects were ranged from -19.254 (ZEM-1 × RH-30) to 22.871 (RNG-73 × ZEM-1). The good specific combiners were ZEM-1 × RH-30; ZEM-1 × NRCHB-101; Jumka × Pusa Mustard-28; ZEM-1 × TM-4; ZEM-1 × DRMR-1; Jumka × RNG-73; Jumka × RH-30; Jumka ×; Gujarat Mustard-3; RNG-73 × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; ZEM-1 × KBS-3; Jumka × TM-4; Jumka × NRCHB-101; Jumka × DRMR-1; NRCHB-101 × RH-30; Jumka × KBS-3 and RNG-73 × Gujarat Mustard-3. Twenty three cross combinations *viz.*, RNG- 73 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Pusa Mustard-28 × KBS-3; RH-30 × KBS-3; NRCHB-101 × KBS-3; DRMR-1 × KBS-3; RNG-73 × KBS-3; DRMR-1 × TM-4; Gujarat Mustard-3 × KBS-3; RH-30 × TM-4; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; Pusa Mustard- 28 × RH-30; Pusa Mustard-28 × DRMR-1; TM-4 × KBS-3; RNG-73 × TM-4; Gujarat Mustard-3 × DRMR-1; DRMR-1 × RH-30; RNG-73 × DRMR-1; DRMR-1 × NRCHB -101 and NRCHB-101 × TM-4 were found to be poor specific combiners. All these crosses exhibited high *per se* performance except for four combinations *viz.*, RNG-73 × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; NRCHB-101 × RH-30 and RNG-73 × Gujarat Mustard-3.

4.5.3.5 Number of Primary Branches per Plant

The estimates of *sca* effects ranged from -1.991 (ZEM-1 × NRCHB-101) to 0.951 (RNG-73 × ZEM-1) in case of control. The entire cross combinations were found to be average specific combiners.

For 75Kg N /ha condition *sca* effects ranged from -1.900 (Gujarat Mustard-3 × NRCHB-101) to 1.658 (Jumka × ZEM-1). The good specific combiners with desirable significantly positive *sca* effect were Jumka × ZEM-1; Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × DRMR-1; RNG-73 × TM-4; ZEM-1 × KBS-3; RNG-73 × RH-30; Jumka × NRCHB-101; Gujarat Mustard-3 × TM-4; NRCHB-101 × KBS-3; Pusa Mustard- 28 × RH-30 and Pusa Mustard-28 × KBS-3. None of the crosses exhibited high *per se* performance.

Table 4.31 Specific combining ability (*sca*) estimates for plant height (cm), number of primary branches per plant and secondary branches per plant under different nitrogen levels

	Genotypes	Plant Height (cm)			No. of Primary Branches/ Plant			No. of Secondary Branches /Plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1.	Jumka × RNG-73	-16.610 **	-14.606 **	-14.629 **	-0.153	-1.500 **	0.987 *	-3.516 **	-5.928 **	-0.561
2.	Jumka × Pusa Mustard-28	-16.485 **	-17.648 **	-17.670 **	-0.441	0.254	0.625	-1.516	1.172	-1.023
3.	Jumka × Gujarat Mustard-3	-10.027 **	-9.773 **	-10.254 **	0.026	-0.421	-1.967 **	-3.058 *	-2.536 **	-0.553
4.	Jumka × ZEM-1	15.973 **	12.977 **	12.955 **	0.884	1.658 **	-0.967 *	2.367	2.272 *	1.264
5.	Jumka × DRMR-1	-4.610 **	-4.023 **	-3.670 **	-0.453	0.758	-1.630 **	-4.154 **	-4.661 **	-3.757 **
6.	Jumka × NRCHB-101	-5.110 **	-4.689 **	-4.629 **	0.605	1.016 *	-1.096 *	-5.504 **	-5.082 **	-6.611 **
7.	Jumka × RH-30	-13.485 **	-13.106 **	-11.754 **	-0.503	-0.763	0.250	-2.800 *	-2.153 *	-5.286 **
8.	Jumka × TM-4	-5.568 **	-5.564 **	-6.254 **	0.314	-1.188 **	-1.005 *	-4.862 **	-5.803 **	-6.244 **
9.	Jumka × KBS-3	-3.110 *	-3.023 *	-3.004 **	-0.341	0.612	1.012 *	-1.333	-1.391	-3.415 **
10.	RNG-73 × Pusa Mustard-28	-10.110 **	-9.981 **	-9.254 **	-0.074	-0.884 *	-0.984 *	2.480	0.689	-1.978 *
11.	RNG-73 × Gujarat Mustard-3	-1.652	-3.106 **	-2.837 **	0.293	-0.559	1.125 *	1.588	3.130 **	3.293 **
12.	RNG- 73 × ZEM-1	23.848 **	23.144 **	22.871 **	0.951	0.020	0.625	5.113 **	9.889 **	6.160 **
13.	RNG-73 × DRMR-1	2.265	1.644	1.746 *	-0.186	0.320	-0.188	1.442	2.605 **	3.089 **
14.	RNG-73 × NRCHB-101	2.765	1.977	1.288	-0.578	-0.021	-2.605 **	-1.158	-0.816	2.335 *
15.	RNG-73 × RH-30	0.390	1.061	0.163	0.514	1.050 *	-0.409	-0.004	1.514	-2.890 **
16.	RNG-73 × TM-4	3.307 *	2.102	2.163 *	0.430	1.175 **	-1.363 **	3.734 **	4.014 **	2.652 **
17.	RNG-73 × KBS-3	5.265 **	7.644 **	7.913 **	-0.224	-1.825 **	0.754	3.763 **	3.726 **	2.331 *
18.	Pusa Mustard-28 × Gujarat Mustard-3	-8.527 **	-7.648 **	-7.879 **	0.055	-1.655 **	0.112	0.188	-7.420 **	-2.619 **
19.	Pusa Mustard-28 × ZEM-1	19.973 **	18.602 **	18.830 **	0.814	-1.875 **	1.062 *	6.963 **	8.239 **	6.447 **
20.	Pusa Mustard-28 × DRMR-1	5.890 **	4.102 **	3.705 **	0.426	1.625 **	1.050 *	-3.008 *	-1.395	-0.273
21.	PusaMustard-28 × NRCHB-101	5.890 **	5.936 **	5.746 **	0.584	0.733	-1.517 **	0.442	-0.066	2.372 *
22.	Pusa Mustard- 28 × RH-30	4.515 **	4.519 **	4.121 **	0.126	0.904 *	0.979 *	-1.104	-0.236	0.447

	Genotypes	Plant Height (cm)			No. of Primary Branches/ Plant			No. of Secondary Branches /Plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
23.	Pusa Mustard- 28 × TM-4	4.432 **	5.561 **	5.121 **	-0.057	-0.221	-0.625	-5.116 **	-2.186 *	-2.761 **
24.	Pusa Mustard-28 × KBS-3	10.390 **	10.602 **	10.871 **	0.289	0.879 *	-1.009 *	0.313	0.626	2.268 *
25.	Gujarat Mustard-3 × ZEM-1	18.932 **	18.977 **	19.246 **	0.230	-0.150	1.570 **	6.821 **	8.230 **	6.718 **
26.	Gujarat Mustard-3 × NRCHB-101	1.348	1.477	1.621	0.543	-1.900 **	1.308 **	0.850	2.047 *	0.697
27.	Gujarat Mustard-3 × DRMR-1	4.348 **	2.811 *	2.163 *	0.151	1.258 **	1.691 **	-1.950	-1.724	-2.157 *
28.	Gujarat Mustard-3 × RH-30	-4.027 **	-2.106	-0.962	-1.257 *	0.229	-1.513 **	-1.145	0.005	-2.432 *
29.	Gujarat Mustard-3 × TM-4	0.390	-0.064	1.538	-0.241	0.954 *	-0.067	0.592	0.105	-1.540
30.	Gujarat Mustard-3 × KBS-3	7.348 **	5.977 **	6.288 **	0.155	1.304 **	-0.900	-1.279	-0.582	-2.011 *
31.	ZEM-1 × DRMR-1	-15.652 **	-15.773 **	-15.670 **	-0.749	0.029	-1.442 **	-4.625 **	-2.245 *	-2.386 *
32.	ZEM-1 × NRCHB-101	-21.152 **	-19.439 **	-19.129 **	-1.991 **	-0.163	-0.059	-3.775 **	-2.766 **	-2.790 **
33.	ZEM-1 × RH-30	-19.027 **	-19.356 **	-19.254 **	0.051	0.108	-0.163	-7.820 **	-6.286 **	-3.365 **
34.	ZEM-1 × TM-4	-16.610 **	-17.814 **	-17.254 **	-0.632	-0.617	-0.667	-4.783 **	-7.286 **	-5.773 **
35.	ZEM-1 × KBS-3	-7.152 **	-7.773 **	-7.504 **	-0.336	1.133 **	-0.800	-1.954	-5.224 **	-3.744 **
36.	DRMR-1 × NRCHB -101	1.765	1.561	1.746 *	-0.028	0.087	1.129 *	1.955	1.101	-1.861 *
37.	DRMR-1 × RH-30	2.390	2.144	2.121 *	-0.036	0.158	0.475	-0.291	-0.770	0.764
38.	DRMR-1 × TM-4	5.807 **	6.686 **	6.621 **	0.080	0.583	1.570 **	4.996 **	5.430 **	2.706 **
39.	DRMR-1 × KBS-3	8.265 **	8.727 **	8.371 **	-0.024	0.383	0.837	1.425	1.443	-0.165
40.	NRCHB-101 × RH-30	-3.610 *	-3.523 **	-3.337 **	0.522	0.366	0.008	0.959	0.759	-1.640
41.	NRCHB-101 × TM-4	0.807	1.519	1.663 *	-0.461	-0.409	1.504 **	3.596 **	1.759	2.402 *
42.	NRCHB-101 × KBS-3	7.765 **	9.061 **	8.913 **	0.834	0.941 *	-0.580	4.225 **	4.072 **	5.381 **
43.	RH-30 × TM-4	5.932 **	6.602 **	6.038 **	-0.120	0.012	-0.250	2.250	2.789 **	2.327 *
44.	RH-30 × KBS-3	10.890 **	9.644 **	9.788 **	0.176	0.362	-1.384 **	1.530	4.501 **	4.006 **
45.	TM-4 × KBS-3	4.807 **	3.686 **	3.288 **	0.293	0.737	1.112 *	3.217 *	2.501 **	2.197 *

*Significance P ≤0.05; ** Significance P ≤0.01

On the other hand seven crosses were found as poor specific combiners with undesirable significantly negative *sca* effects *viz.,* Gujarat Mustard-3 × NRCHB-101; Pusa Mustard-28 × ZEM-1; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × RNG-73; Jumka × TM-4 and RNG-73 × Pusa Mustard-28.

The estimates of *sca* effects for 150 Kg N/ha case varied from -2.605 (RNG-73 × NRCHB-101) to 1.691 (Gujarat Mustard-3 × DRMR-1). The good specific combiners were Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × ZEM-1; DRMR-1 × TM-4; NRCHB-101 × TM-4; Gujarat Mustard-3 × NRCHB-101; DRMR-1 × NRCHB -101; RNG-73 × Gujarat Mustard-3; TM-4 × KBS-3; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; Jumka × KBS-3; Jumka × RNG-73 and Pusa Mustard- 28 × RH-30. None of the crosses had high *per se* performance. However, 13 crosses were found as poor specific combiners *viz.,* RNG-73 × NRCHB-101; Jumka × Gujarat Mustard-3; Jumka × DRMR-1; Pusa Mustard-28 × NRCHB-101; Gujarat Mustard-3 × RH-30; ZEM-1 × DRMR-1; RH-30 × KBS-3; RNG-73 × TM-4; Jumka × NRCHB-101; Pusa Mustard-28 × KBS-3; Jumka × TM-4; RNG-73 × Pusa Mustard-28 and Jumka × ZEM-1.

4.5.3.6 Number of Secondary Branches per Plant

The *sca* effects estimates ranged from -7.820 (ZEM-1 × RH-30) to 6.963 (Pusa Mustard-28 × ZEM-1). The good specific combiners with desired significantly positive *sca* effects were Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; RNG- 73 × ZEM-1; DRMR-1 × TM-4; NRCHB-101 × KBS-3; RNG-73 × KBS-3; RNG-73 × TM-4; NRCHB-101 × TM-4 and TM-4 × KBS-3 along with high *per se* performance under control. Whereas, 12 combinations were found as poor specific combiners with significantly negative *sca* effects *viz.,* ZEM-1 × RH-30; Jumka × NRCHB-101; Pusa Mustard- 28 × TM-4; Jumka × TM-4; ZEM-1 × TM-4; ZEM-1 × DRMR-1; Jumka × DRMR-1; ZEM-1 × NRCHB-101; Jumka × RNG-73; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × DRMR-1 and Jumka × RH-30.

Under 75Kg N/ha, the estimates of *sca* effects ranged from -7.420 (Pusa Mustard-280 × Gujarat Mustard-3) to 9.889 (RNG-73 × ZEM-1). The good specific combiners were RNG- 73 × ZEM-1; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 ×

ZEM-1; DRMR-1 × TM-4; RH-30 × KBS-3; NRCHB-101 × KBS-3; RNG-73 × TM-4; RNG-73 × KBS-3; RNG-73 × Gujarat Mustard-3; RH-30 × TM-4; RNG-73 × DRMR-1; TM-4 × KBS-3; Jumka × ZEM-1 and Gujarat Mustard-3 × NRCHB-101. All the above cross combinations exhibited high *per se* performance except Jumka × ZEM-1. On the other hand 13 crosses were found as poor specific combiners namely Pusa Mustard-28 × Gujarat Mustard-3; ZEM-1 × TM-4; ZEM-1 × RH-30; Jumka × RNG-73; Jumka × TM-4; ZEM-1 × KBS-3; Jumka × NRCHB-101; Jumka × DRMR-1; ZEM-1 × NRCHB-101; Jumka × Gujarat Mustard-3; ZEM-1 × DRMR-1; Pusa Mustard- 28 × TM-4 and Jumka × RH-30.

For 150Kg N/ha condition, the estimates of *sca* effects ranged from -6.611 (Jumka × NRCHB-101) to 6.718 (Gujarat Mustard-3 × ZEM-1). The good specific combiners with desired significantly positive *sca* effects were Gujarat Mustard-3 × ZEM-1; RNG- 73 × ZEM-1; NRCHB-101 × KBS-3; RH-30 × KBS-3; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; DRMR-1 × TM-4; RNG-73 × TM-4; NRCHB-101 × TM-4; Pusa Mustard-28 × NRCHB-101; RNG-73 × NRCHB-101; RNG-73 × KBS-3; RH-30 × TM-4; Pusa Mustard-28 × KBS-3 and TM-4 × KBS-3 along with high *per se* performance. However, 19 crosses were found as poor specific combiners with undesirable significantly negative *sca* effects *viz.*, Jumka × NRCHB-101; Pusa Mustard-28 × ZEM-1; Jumka × TM-4; ZEM-1 × TM-4; Jumka × RH-30; Jumka × DRMR-1; ZEM-1 × KBS-3; Jumka × KBS-3; ZEM-1 × RH-30; RNG-73 × RH-30; ZEM-1 × NRCHB-101; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × RH-30; ZEM-1 × DRMR-1; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × KBS-3; RNG-73 × Pusa Mustard-28; DRMR-1 × NRCHB -101.

4.5.3.7 Length of Main Shoot (cm)

Length of main shoot under control ranged from -4.089 (Jumka × RNG-73) to 4.344 (Pusa Mustard-28 × TM-4). Only nine crosses Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; RH-30 × TM-4; NRCHB-101 × TM-4; Pusa Mustard- 28 × RH-30; NRCHB-101 × KBS-3; RNG- 73 × ZEM-1; Gujarat Mustard-3 × TM-4 were found as good specific combiners with desirable significantly positive *sca* effects. Seven cross combinations *viz.*, Jumka × RNG-73, Jumka × Pusa Mustard-28, Jumka × Gujarat Mustard-3, Jumka × NRCHB-101, RNG-73 × RH-30, ZEM-1 × TM-4, TM-4 × KBS-3 were found as poor specific combiners.

Whereas under 75 Kg N/ha condition estimates of *sca* effects for length of main shoot ranged from -4.064 (Jumka × NRCHB-101) to 3.424 (Gujarat Mustard-3 × ZEM-1). Only one cross combination *i.e.* Gujarat Mustard-3 × ZEM-1 was found good specific combiners out of 45 crosses, whereas four crosses namely, Jumka × Gujarat Mustard-3, Jumka × DRMR-1, Jumka × NRCHB-101, ZEM-1 × TM-4 were found as poor specific combiners with undesirable significantly negative *sca* effects.

Under 150 Kg N/ha condition estimates of *sca* effects varied from -3.846 (DRMR-1 × NRCHB-101) to 4.879 (Pusa Mustard-28 × ZEM-1). The good specific combiners with significantly positive *sca* effects were *viz.*, Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; RNG- 73 × ZEM-1; RNG-73 × TM-4; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × TM-4; RNG-73 × DRMR-1; RH-30 × TM-4; Gujarat Mustard-3 × KBS-3; NRCHB-101 × KBS-3; Pusa Mustard-28 × NRCHB-101 and RNG-73 × KBS-3. Ten crosses *viz.*, DRMR-1 × NRCHB -101; TM-4 × KBS-3; RNG-73 × RH-30; ZEM-1 × TM-4; Jumka × RNG-73; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; Gujarat Mustard-3 × DRMR-1; Jumka × NRCHB-101 and ZEM-1 × NRCHB-101 were found as poor specific combiners

4.5.3.8 Number of Siliquae on Main Shoot

For control, estimates of *sca* effects varied from -3.955 (Jumka × Gujarat Mustard-3) to 7.837 (RH-30 × KBS-3). Eight cross combinations *viz.*, RH-30 × KBS-3; Gujarat Mustard-3 × ZEM-1; RH-30 × TM-4; Gujarat Mustard-3 × TM-4; Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × ZEM-1; RNG-73 × TM-4; Pusa Mustard-28 × KBS-3 were found as good specific combiners with desirable significantly positive *sca* effects. The entire crosses also showed high *per se* performance except Gujarat Mustard-3 × DRMR-1 and Pusa Mustard-28 × ZEM-1. However, 7 crosses namely, Jumka × Gujarat Mustard-3; Pusa Mustard- 28 × RH-30; Jumka × RH-30; TM-4 × KBS-3; NRCHB-101 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × RH-30 were found as poor specific combiners.

Table 4.32 Specific combining ability (*sca*) estimates for length of main shoot (cm), number of siliquae on main shoot and siliqua length (cm) under different nitrogen levels

	Genotypes	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua Length (cm)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	150 Kg N/ha	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
1.	Jumka × RNG-73	-4.089 **	-2.276	-2.171 **	1.170	0.966	0.970	0.185	-0.070	-1.822 **
2.	Jumka × Pusa Mustard-28	-2.477 *	-0.805	-0.400	-1.205	-3.492 **	-3.864 *	-0.032	-0.570	-0.130
3.	Jumka × Gujarat Mustard-3	-2.885 *	-3.368 *	-1.271	-3.955 **	-5.076 **	-4.447 *	0.564	0.697	0.037
4.	Jumka × ZEM-1	-1.547	-1.489	0.279	-0.788	-1.492	-1.405	0.335	0.464	0.283
5.	Jumka × DRMR-1	-0.922	-3.097 *	-0.275	-0.246	-1.367	-0.614	0.089	0.572	1.062 *
6.	Jumka × NRCHB-101	-2.847 *	-4.064 *	-1.671 *	0.129	0.299	0.803	0.247	-0.470	0.333
7.	Jumka × RH-30	-1.068	-3.001	-1.021	-3.205 *	-1.076	-1.322	0.006	-0.349	0.237
8.	Jumka × TM-4	-1.431	1.607	-0.312	0.170	0.549	0.511	0.514	0.693	0.908
9.	Jumka × KBS-3	1.069	1.453	-0.158	1.004	2.174	2.928	0.039	0.305	0.278
10.	RNG-73 × Pusa Mustard-28	0.686	0.349	0.429	-1.496	-0.784	2.386	-0.373	-0.403	-0.259
11.	RNG-73 × Gujarat Mustard-3	-1.122	-1.014	-0.692	-1.246	-0.867	-2.197	1.022 *	0.914 *	1.058 *
12.	RNG- 73 × ZEM-1	2.315 *	2.766	3.158 **	0.420	1.216	2.345	0.593	0.480	0.953 *
13.	RNG-73 × DRMR-1	1.890	0.757	2.004 **	0.962	1.341	1.136	0.897 *	0.989 **	1.033 *
14.	RNG-73 × NRCHB-101	-1.035	0.791	-0.492	-1.163	-1.492	-0.447	0.156	0.297	0.003
15.	RNG-73 × RH-30	-3.456 **	-1.497	-2.742 **	0.004	-1.867	-2.572	-0.536	-0.032	0.008
16.	RNG-73 × TM-4	1.082	-0.589	2.517 **	2.879 *	2.258	2.761	-0.028	-0.091	-0.622
17.	RNG-73 × KBS-3	-0.018	-0.843	1.371 *	0.712	0.883	1.178	-0.403	-0.478	-0.251
18.	Pusa Mustard-28 × Gujarat Mustard-3	-2.010	-1.543	-0.721	-2.121	-1.826	-1.530	0.656	0.314	-0.151
19.	Pusa Mustard-28 × ZEM-1	3.978 **	0.036	4.879 **	3.045 *	3.258 **	3.011	0.727	0.830 *	0.095
20.	Pusa Mustard-28 × DRMR-1	-1.147	2.578	0.225	4.087 **	4.883 **	3.803 *	-0.469	-0.211	-0.026
21.	PusaMustard-28 × NRCHB-101	0.078	-0.889	1.629 *	0.962	6.049 **	3.220	-0.561	-0.703 *	0.095
22.	Pusa Mustard- 28 × RH-30	2.657 *	0.974	1.329	-3.371 **	-3.826 **	-0.905	0.447	0.518	1.199 *

	Genotypes	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua Length (cm)		
		Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	150 Kg N/ha	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
23.	Pusa Mustard- 28 × TM-4	4.344 **	1.332	0.538	1.004	-0.201	-1.072	0.356	0.709 *	1.020 *
24.	Pusa Mustard-28 × KBS-3	1.394	2.328	2.392 **	2.837 *	1.424	1.845	0.131	0.122	0.691
25.	Gujarat Mustard-3 × ZEM-1	3.069 **	3.424 *	3.308 **	4.795 **	4.674 **	1.428	0.672	-0.003	-0.588
26.	Gujarat Mustard-3 × NRCHB-101	0.344	2.016	0.704	-0.163	0.299	0.220	-0.373	-0.695	-0.309
27.	Gujarat Mustard-3 × DRMR-1	-1.431	-0.401	-1.792 *	3.712 **	1.966	1.136	-0.715	-0.536	-0.138
28.	Gujarat Mustard-3 × RH-30	1.098	-1.089	-0.792	-2.121	-2.409 *	-0.989	-0.507	-0.316	0.016
29.	Gujarat Mustard-3 × TM-4	2.236 *	0.070	2.017 **	4.254 **	4.216 **	3.345	-0.598	-0.774 *	-0.713
30.	Gujarat Mustard-3 × KBS-3	2.136	0.716	1.921 **	1.587	2.841 *	5.261 **	0.077	0.139	-0.042
31.	ZEM-1 × DRMR-1	-2.168	-0.905	-2.046 **	-2.496 *	-2.117	-0.739	-0.353	-0.278	0.037
32.	ZEM-1 × NRCHB-101	-2.043	-0.822	-1.392 *	1.879	0.549	0.178	-0.594	-0.370	0.108
33.	ZEM-1 × RH-30	-0.464	-0.959	-0.592	-2.455 *	-2.826 *	-0.447	-0.286	-0.349	-0.088
34.	ZEM-1 × TM-4	-3.127 **	-3.301 *	-2.583 **	-0.080	0.299	-1.614	-0.678	-0.607	-0.367
35.	ZEM-1 × KBS-3	-1.527	-0.555	-2.029 **	-1.246	-1.076	0.303	-0.503	-0.395	-0.147
36.	DRMR-1 × NRCHB -101	-1.368	-1.930	-3.846 **	2.420	2.674 *	2.470	0.260	-0.511	0.037
37.	DRMR-1 × RH-30	-0.389	-2.318	0.154	-1.913	-0.701	1.345	0.018	-0.191	-0.209
38.	DRMR-1 × TM-4	0.748	2.141	0.413	-1.538	-0.076	1.678	-0.023	-0.499	-0.238
39.	DRMR-1 × KBS-3	1.098	-2.514	-0.133	-0.205	-0.951	-1.405	-0.148	-0.236	0.183
40.	NRCHB-101 × RH-30	0.386	1.116	-0.092	-2.538 *	-3.034 *	-2.239	0.627	0.818 *	-0.138
41.	NRCHB-101 × TM-4	2.823 *	-0.676	0.517	-1.163	-1.409	-2.405	0.135	0.309	0.683
42.	NRCHB-101 × KBS-3	2.323 *	2.770	1.721 *	-1.830	-2.284	-1.489	-0.290	-0.328	0.203
43.	RH-30 × TM-4	3.053 **	2.736	1.967 **	4.504 **	3.716 **	2.970	-0.107	-0.020	0.087
44.	RH-30 × KBS-3	0.453	2.182	-0.229	7.837 **	6.841 **	2.886	-0.032	-0.157	-0.442
45.	TM-4 × KBS-3	-2.710 *	0.091	-3.321 **	-2.788 *	-1.034	0.220	0.027	-0.066	-0.272

*Significance P ≤0.05; ** Significance P ≤0.01

On the other side, under 75Kg N/ha level, the estimates of *sca* effects varied from -5.076 (Jumka × Gujarat Mustard-3) to 6.841 (RH-30 × KBS-3). Nine cross combinations out of forty five crosses were found as good specific combiners with desirable significantly positive *sca* effects *viz.,* RH-30 × KBS-3; Pusa Mustard-28 × NRCHB-101; Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; RH-30 × TM-4; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × KBS-3 and DRMR-1 × NRCHB -101 but none with high *per se* performance. Six crosses were found as poor specific combiners with significantly negative *sca* effects *viz.,* Jumka × Gujarat Mustard-3; Pusa Mustard- 28 × RH-30; Jumka × Pusa Mustard-28; NRCHB-101 × RH-30; ZEM-1 × RH-30 and Gujarat Mustard-3 × RH-30.

Under 150Kg N/ha condition, *sca* effects ranged from -4.447 (Jumka × Gujarat Mustard-3) to 5.261 (Gujarat Mustard-3 × KBS-3). Only two crosses were found as good specific combiners with significantly positive *sca* effects *viz.,* Gujarat Mustard-3 × KBS-3 and Pusa Mustard-28 × DRMR-1 but none of the of the crosses exhibited high *per se* performance. Two cross combinations *viz.,* Jumka × Gujarat Mustard-3 and Jumka × Pusa Mustard-28 were found as poor specific combiners with undesirable significantly negative *sca* effects.

4.5.3.9 Siliqua Length (cm)

For siliqua length under control estimates of *sca* effects ranged from -0.715 (Gujarat Mustard-3 × DRMR-10) to 1.022 (RNG-73 × Gujarat Mustard-3). The entire cross combinations were found to be average specific combiners.

Whereas, for 75Kg N/ha condition, *sca* effects varied from -0.774 (Gujarat Mustard-3 × TM-4) to 0.989 (RNG-73 × DRMR-1). Five crosses namely RNG-73 × DRMR-1; RNG-73 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; NRCHB-101 × RH-30; Pusa Mustard-28 × TM-4 were found as good specific combiners with desirable significantly positive *sca* effects. High *per se* performance was associated with RNG-73 × DRMR-1 only. On the other side, only 2 crosses showed significantly negative *sca* effects *viz.,* Gujarat Mustard-3 × TM-4; Pusa Mustard-28 × NRCHB-101 representing their poor specific combining ability.

The *sca* effects for Siliqua length under 150Kg/ha Nitrogen varied from -1.822 (Jumka × RNG-73) to 1.199 (Pusa Mustard- 28 × RH-30). Six cross combinations exhibited significant and positive *sca* effects *viz.,* Pusa Mustard- 28 × RH-30; Jumka × DRMR-1; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; Pusa Mustard- 28 × TM-4; RNG- 73 × ZEM-1. High *per se* performance was exhibited by Jumka × DRMR-1 only. Only one cross combination showed significant and negative *sca* effects *viz.,* Jumka × RNG-73.

4.5.3.10 Number of Seeds per Siliqua

Positive *sca* effects are desirable for this trait. The estimates for *sca* effects under control varied from -2.860 (ZEM-1 × NRCHB-101) to 3.057(Jumka × DRMR-1). The good specific combiners with desirable significantly positive *sca* effects were Jumka × DRMR-1; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Gujarat Mustard-3 × ZEM-1; NRCHB-101 × KBS-3 and NRCHB-101 × RH-30. High *per se* performance was exhibited by Jumka × DRMR-1 and Jumka × ZEM-1 only. Eight cross combinations namely, ZEM-1 × NRCHB-101; RNG-73 × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; ZEM-1 × TM-4; ZEM-1 × DRMR-1; RNG-73 × KBS-3; DRMR-1 × NRCHB -101; ZEM-1 × KBS-3 were found as poor specific combiners with undesirable significantly negative *sca* effects.

Under 75Kg N/ha level, *sca* effects estimates ranged from -3.576 (Jumka × Gujarat Mustard-3) to 3.174 (Pusa Mustard-28 × ZEM-1). Six cross combinations *viz.,* Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; NRCHB-101 × KBS-3; Jumka × RNG-73; Gujarat Mustard-3 × NRCHB-101; NRCHB-101 × RH-30 were found as good specific combiners with desirable significantly positive *sca* effects but none with high *per se* performance. The poor specific combiners with significantly negative *sca* effects were Jumka × Gujarat Mustard-3; ZEM-1 × NRCHB-101; RNG-73 × Pusa Mustard-28; ZEM-1 × TM-4 and Pusa Mustard-28 × Gujarat Mustard-3.

The range of *sca* effects for seeds per siliqua under 150 Kg N/ha varied from -2.723 (NRCHB-101 × TM-4) to 3.485 (Pusa Mustard-28 × ZEM-1). The entire cross combinations were found to be average specific combiners.

Table 4.33 Specific combining ability (*sca*) estimates for number of seeds per siliqua, 1000 seed weight (g) and seed yield per plant (g) under different nitrogen levels

	Genotypes	Number of Seeds Per Siliqua			1000 seed weight			Seed yield per plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1.	Jumka × RNG-73	0.182	2.091 **	1.360	-0.040	-0.088	0.030	-7.587 **	-8.371 **	-5.720 **
2.	Jumka × Pusa Mustard-28	0.140	-0.701	-1.432	0.118	-0.217	-0.178	5.455 **	4.837 **	2.072
3.	Jumka × Gujarat Mustard-3	0.348	-3.576 **	-2.265	-0.040	-0.458 *	-0.408	5.705 **	6.629 **	6.114 **
4.	Jumka × ZEM-1	2.807 **	0.799	0.152	0.014	-0.329	-0.016	10.288 **	10.254 **	7.239 **
5.	Jumka × DRMR-1	3.057 **	0.841	-0.473	-0.315	-0.825 **	-0.774 **	3.371 **	2.795 **	2.780 *
6.	Jumka × NRCHB-101	-0.152	-0.159	0.902	-0.536 *	-0.550 **	-0.353	-5.504 **	-4.788 **	-3.553 *
7.	Jumka × RH-30	0.848	0.216	0.485	-0.136	-0.054	0.322	-4.337 **	-4.246 **	-3.303 *
8.	Jumka × TM-4	-0.485	-1.201	0.610	0.272	0.296	0.392	0.080	-1.538	-1.220
9.	Jumka × KBS-3	0.223	0.841	0.193	0.327	0.142	0.467 *	-0.879	-1.163	-0.636
10.	RNG-73 × Pusa Mustard-28	-2.693 **	-2.534 **	-0.807	0.410	0.104	0.042	0.663	0.670	1.239
11.	RNG-73 × Gujarat Mustard-3	-0.485	-0.409	-0.140	0.052	-0.088	0.013	6.413 **	7.462 **	7.780 **
12.	RNG- 73 × ZEM-1	0.973	0.966	-0.723	0.006	-0.108	-0.395	7.496 **	7.587 **	5.905 **
13.	RNG-73 × DRMR-1	-0.277	0.008	1.652	-0.173	-0.404 *	-0.203	6.080 **	6.129 **	5.447 **
14.	RNG-73 × NRCHB-101	0.015	0.008	1.527	-0.094	-0.179	0.017	1.205	-0.455	-1.386
15.	RNG-73 × RH-30	-0.485	-0.617	-0.890	0.006	-0.133	-0.158	-2.629 *	-1.913 *	-3.636 *
16.	RNG-73 × TM-4	0.682	0.466	1.735	-0.086	0.017	0.113	0.788	0.795	-0.053
17.	RNG-73 × KBS-3	-1.610 *	-1.492	-1.682	-0.382	-0.088	0.038	1.330	1.170	-0.470
18.	Pusa Mustard-28 × Gujarat Mustard-3	-2.027 **	-1.701 *	-1.932	-0.140	-0.017	-0.095	1.455	2.670 **	3.072 *
19.	Pusa Mustard-28 × ZEM-1	2.932 **	3.174 **	3.485 *	0.114	0.113	0.247	6.538 **	7.795 **	8.197 **
20.	Pusa Mustard-28 × DRMR-1	0.182	0.716	0.360	-0.415	-0.433 *	-0.412	3.121 *	2.337 *	2.739
21.	PusaMustard-28 × NRCHB-101	0.973	1.216	0.735	-0.086	-0.008	0.009	-2.254	-4.246 **	-3.095 *
22.	Pusa Mustard- 28 × RH-30	0.973	1.091	0.818	-0.486 *	-0.512 **	-0.416	-0.087	-2.205 *	-0.845

	Genotypes	Number of Seeds Per Siliqua			1000 seed weight			Seed yield per plant		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
23.	Pusa Mustard- 28 × TM-4	1.140	1.174	0.443	-0.278	-0.362	-0.295	-4.670 **	-3.996 **	-2.761
24.	Pusa Mustard-28 × KBS-3	0.848	1.216	0.527	0.227	0.283	0.230	-3.629 **	-3.621 **	-5.678 **
25.	Gujarat Mustard-3 × ZEM-1	2.640 **	2.799 **	1.152	0.206	0.021	0.317	5.788 **	5.587 **	6.739 **
26.	Gujarat Mustard-3 × NRCHB-101	1.390	1.841 *	-1.473	-0.073	-0.125	-0.191	-0.129	-0.371	-0.220
27.	Gujarat Mustard-3 × DRMR-1	-1.318	-1.159	0.402	0.106	0.000	0.130	-3.504 **	-8.455 **	-7.053 **
28.	Gujarat Mustard-3 × RH-30	1.182	1.216	-0.015	-0.044	-0.004	-0.095	-5.337 **	-5.413 **	-4.303 **
29.	Gujarat Mustard-3 × TM-4	0.848	0.799	0.110	-0.186	-0.104	0.126	-5.920 **	-7.205 **	-8.220 **
30.	Gujarat Mustard-3 × KBS-3	0.057	0.341	-0.307	0.018	0.092	0.151	-5.879 **	-4.830 **	-4.136 **
31.	ZEM-1 × DRMR-1	-1.652 *	-1.284	-2.057	-0.169	-0.296	-0.349	-5.045 **	-4.746 **	-4.095 **
32.	ZEM-1 × NRCHB-101	-2.860 **	-2.784 **	-2.182	-0.340	-0.321	-0.128	-7.420 **	-6.330 **	-5.428 **
33.	ZEM-1 × RH-30	-0.860	-0.909	-1.098	-0.090	-0.125	-0.503 *	-9.754 **	-10.288 **	-8.678 **
34.	ZEM-1 × TM-4	-1.693 *	-1.826 *	-0.473	0.068	0.125	0.167	-8.337 **	-9.580 **	-8.095 **
35.	ZEM-1 × KBS-3	-1.485 *	-1.284	0.610	0.272	0.321	0.342	-5.295 **	-7.705 **	-8.511 **
36.	DRMR-1 × NRCHB -101	-1.610 *	-1.242	-1.307	0.081	0.233	0.163	-3.337 **	-2.288 *	-1.386
37.	DRMR-1 × RH-30	-0.110	0.133	-0.223	0.131	0.179	0.238	-1.670	-1.746	-1.136
38.	DRMR-1 × TM-4	-0.443	-0.284	0.902	0.439	0.379 *	0.209	-2.754 *	-3.038 **	-4.053 **
39.	DRMR-1 × KBS-3	-0.735	-0.242	0.985	0.393	0.475 *	0.534 *	-2.712 *	-2.663 **	-0.970
40.	NRCHB-101 × RH-30	1.682 *	1.633 *	0.652	0.310	0.254	0.209	0.455	1.670	1.530
41.	NRCHB-101 × TM-4	0.848	0.716	-2.723	0.568 *	0.454 *	0.530 *	5.371 **	5.879 **	4.614 **
42.	NRCHB-101 × KBS-3	2.057 **	2.258 **	-1.140	-0.028	-0.100	-0.145	5.413 **	6.754 **	6.197 **
43.	RH-30 × TM-4	-0.152	-0.409	-0.640	-0.082	-0.100	-0.045	5.038 **	4.920 **	3.364 *
44.	RH-30 × KBS-3	-1.443	-1.367	-0.557	0.472 *	0.296	0.280	7.080 **	6.795 **	5.447 **
45.	TM-4 × KBS-3	-0.777	-0.784	-1.932	-0.269	-0.304	-0.149	4.496 **	4.504 **	5.530 **

*Significance P ≤0.05; ** Significance P ≤0.01

4.5.3.11 1000 Seed Weight (g)

The cross combinations with positive *sca* effects are considered for this trait as it is a desirable trait The estimates of *sca* effects under control ranged from -0.536 (Jumka × NRCHB-101) to 0.568 (NRCHB-101 × TM-4). The entire cross combinations were found to be average specific combiners.

For the 75Kg N/ha condition, the estimates of *sca* effects ranged from -0.825 (Jumka × DRMR-1) to 0.475 (DRMR-1 × KBS-3). Only three crosses *viz.,* DRMR-1 × KBS-3; NRCHB-101 × TM-4; DRMR-1 × TM-4 were found as good specific combiners with desirable significantly positive *sca* effects for the trait but none with high *per se* performance. Six cross combinations *viz.,* Jumka × DRMR-1; Jumka × NRCHB-101; Pusa Mustard- 28 × RH-30; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × DRMR-1; RNG-73 × DRMR-1 were found as poor specific combiners with undesirable significantly negative *sca* effects.

Under 150 Kg N/ha condition *sca* effects varied from -0.774 (Jumka × DRMR-1) to 0.534 (DRMR-1 × KBS-3). Three cross combinations *viz.,* DRMR-1 × KBS-3; NRCHB-101 × TM-4 and Jumka × KBS-3 were found as good specific combiners with desirable significantly positive *sca* effects. None of the cross combinations exhibited high *per se* performance. Undesirable significantly negative *sca* effects representing poor specific combining ability were observed for only two crosses *viz.,* Jumka × DRMR-1; ZEM-1 × RH-30.

4.5.3.12 Seed Yield per Plant (g)

Positive *sca* effects are desirable for this trait. Under control *sca* effects estimates ranged from -9.754 (ZEM-1 × RH-30) to 10.288 (Jumka × ZEM-1). Fifteen cross combinations *viz.*, Jumka × ZEM-1; RNG-73 × ZEM-1; RH-30 × KBS-3; Pusa Mustard-28 × ZEM-1; RNG-73 × Gujarat Mustard-3 ; RNG-73 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Jumka × Gujarat Mustard-3; Jumka × Pusa Mustard-28 ; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; RH-30 × TM-4; TM-4 × KBS-3; Jumka × DRMR-1 and Pusa Mustard-28 × DRMR-1 were found as good specific combiners with desirable significantly positive *sca* effects along with high *per se* performance except for Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Jumka × Gujarat Mustard-3 and Pusa Mustard-28 × DRMR-1. While eighteen crosses *viz.,* ZEM-1 × RH-30; ZEM-1 × TM-4; Jumka × RNG-73; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Jumka × NRCHB-101; Gujarat Mustard-3 × RH-30; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; Pusa Mustard- 28 × TM-4; Jumka × RH-30; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × DRMR-1; DRMR-1 × NRCHB -101; DRMR-1 × TM-4; DRMR-1 × KBS-3 and RNG-73 × RH-30 were found as poor specific combiners with significantly negative *sca* effects.

On the other hand, under 75Kg N/ha condition, estimates of *sca* varied from -10.288 (ZEM-1 × RH-30) to 10.254 (Jumka × ZEM-1) for the seed yield per plant. Sixteen crosses out of forty five crosses *viz.*, Jumka × ZEM-1; Pusa Mustard-28 × ZEM-1; RNG- 73 × ZEM-1; RNG-73 × Gujarat Mustard-3; RH-30 × KBS-3; NRCHB-101 × KBS-3; Jumka × Gujarat Mustard-3; RNG-73 × DRMR-1; NRCHB-101 × TM-4; Gujarat Mustard-3 × ZEM-1; RH-30 × TM-4; Jumka × Pusa Mustard-28; TM-4 × KBS-3; Jumka × DRMR-1; Pusa Mustard-28 × Gujarat Mustard-3 and Pusa Mustard-28 × DRMR-1 were found as good specific combiners with desirable significantly positive *sca* effects. High *per se* performance was associated with only RNG-73 × ZEM-1; RNG-73 × Gujarat Mustard-3; RH-30 × KBS-3; NRCHB-101 × KBS-3; RNG-73 × DRMR-1; NRCHB-101 × TM-4; RH-30 × TM-4 and Jumka × Pusa Mustard-28. On the other side, twenty crosses *viz.*, ZEM-1 × RH-30; ZEM-1 × TM-4; Gujarat Mustard-3 × DRMR-1; Jumka × RNG-73; ZEM-1 × KBS-3; Gujarat Mustard-3 × TM-4; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × KBS-3; Jumka × NRCHB-101; ZEM-1 × DRMR-1; Jumka × RH-30; RNG-73 × RH-30; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × KBS-3; DRMR-1 × TM-4; DRMR-1 × KBS-3; DRMR-1 × NRCHB -101; Pusa Mustard- 28 × RH-30were found as poor specific combiners with undesirable significantly negative *sca* effects

For 150 Kg N/ha condition *sca* effects estimates varied from -8.678 (ZEM-1 × RH-30) to 8.197 (Pusa Mustard-28 × ZEM-1). Fourteen crosses *viz.*, Pusa Mustard-28 × ZEM-1; RNG-73 × Gujarat Mustard-3; Jumka × ZEM-1; Gujarat Mustard-3 × ZEM-1; NRCHB-101 × KBS-3; Jumka × Gujarat Mustard-3; RNG- 73 × ZEM-1;

TM-4 × KBS-3; RNG-73 × DRMR-1; RH-30 × KBS-3; NRCHB-101 × TM-4; RH-30 × TM-4; Pusa Mustard-28 × Gujarat Mustard-3 and Jumka × DRMR-1 were found as good specific combiners with desirable significantly positive *sca* effects. But high *per se* performance for the trait were associated with RNG-73 × Gujarat Mustard-3; NRCHB-101 × KBS-3; TM-4 × KBS-3; RNG-73 × DRMR-1 and RH-30 × KBS-3. Sixteen cross combinations *viz.,* ZEM-1 × RH-30; ZEM-1 × KBS-3; Gujarat Mustard-3 × TM-4; ZEM-1 × TM-4; Gujarat Mustard-3 × DRMR-1; Jumka × RNG-73; Pusa Mustard-28 × KBS-3; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × KBS-3; ZEM-1 × DRMR-1;DRMR-1 × TM-4; RNG-73 × RH-30; Jumka × NRCHB-101; Jumka × RH-30 and Pusa Mustard-28 × NRCHB-101were found as poor specific combiners with undesirable significantly negative *sca* effects.

4.5.3.13 Biological Yield per Plant (g)

Positive *sca* effects are considered for this trait. Under control the range for *sca* effects for biological yield per plant varied from -63.409 (Jumka × RNG-73) to 65.508 (RNG-73 × ZEM-1). The good specific combiners with desirable significantly positive *sca* effect were RNG- 73 × ZEM-1; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Gujarat Mustard-3 × ZEM-1; RNG-73 × Gujarat Mustard-3; Pusa Mustard-28 × RH-30; Pusa Mustard-28 × Gujarat Mustard-3; RH-30 × TM-4; NRCHB-101 × KBS-3 and NRCHB-101 × TM-4. All the above crosses except Jumka × ZEM-1 also exhibited high *per se* performance for the trait. Ten crosses *viz.,* Jumka × RNG-73; ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; ZEM-1 × TM-4; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4 and Pusa Mustard- 28 × TM-4 were found as poor specific combiners with undesirable significantly negative *sca* effects for biological yield per plant under control.

Under 75Kg/ha condition *sca* effects ranged from -75.568 (ZEM-1 × KBS-3) to 102.182 (Pusa Mustard-28 × ZEM-1). For the trait, nine cross combinations *viz.,* Pusa Mustard-28 × ZEM-1; RNG- 73 × ZEM-1; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × ZEM-1; RH-30 × TM-4; NRCHB-101 × TM-4; Gujarat Mustard-3 × ZEM-1; RNG-73 × Gujarat Mustard-3 and RNG-73 × DRMR-1 were found as good specific combiners with desirable significantly positive *sca* effects along with high *per se* performance except for Jumka × ZEM-1 and Gujarat Mustard-3 × ZEM-1. Thirteen cross combinations *viz.*, ZEM-1 × KBS-3; Jumka × RNG-73; ZEM-1 × RH-30; ZEM-1 × TM-4; ZEM-1 × DRMR-1; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × RH-30; Gujarat; Mustard-3 × TM-4; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × NRCHB-101; Jumka × KBS-3; Pusa Mustard- 28 × TM-4 showed undesirable significantly negative *sca* effects representing their poor specific combining ability.

In case of 150 Kg Nitrogen per ha condition, the range of *sca* effects varied from -75.523 (ZEM-1 × KBS-3) to 70.936 (Pusa Mustard-28 × ZEM-1). The good specific combiners with desirable significantly positive *sca* effects were Pusa Mustard-28 × ZEM-1; RNG- 73 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Jumka × ZEM-1; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; RH-30 × TM-4; NRCHB-101 × TM-4; NRCHB-101 × RH-30; RH-30 × KBS-3; NRCHB-101 × KBS-3; Jumka × Gujarat Mustard-3; Gujarat Mustard-3 × NRCHB-101 and Pusa Mustard-28 × TM-4. High *per se* performance was associated with all the above crosses except for Gujarat Mustard-3 × ZEM-1; Jumka × ZEM-1; Jumka × Gujarat Mustard-3 and Gujarat Mustard-3 × NRCHB-101. In addition, fourteen crosses *viz.*, ZEM-1 × KBS-3; Jumka × RNG-73; Pusa Mustard-28 × KBS-3; ZEM-1 × TM-4; ZEM-1 × RH-30; Gujarat Mustard-3 × TM-4; ZEM-1 × NRCHB-101; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; DRMR-1 × TM-4; Gujarat Mustard-3 × KBS-3; DRMR-1 × KBS-3; Gujarat Mustard-3 × DRMR-1 and Gujarat Mustard-3 × RH-30 were found as poor specific combiners with undesirable significantly negative *sca* effects.

4.5.3.14 Harvest Index (%)

The positive *sca* effects are considered for this trait because of its desirability. In case of control, the *sca* effects varied from -2.599 (ZEM-1 × TM-4) to 4.591 (Jumka × Pusa Mustard- 28). The good specific combiners with desirable significantly positive *sca* effects were Jumka × Pusa Mustard-28; Jumka × DRMR-1; Jumka × Gujarat Mustard-3; RH-30 × KBS-3; TM-4 × KBS-3; ZEM-1 × NRCHB-101; Jumka × ZEM-1 and RNG-73 × DRMR-1. High *per se* performance was associated with Jumka × Pusa Mustard-28; Jumka × DRMR-1 and Jumka × Gujarat Mustard-3 only. However six crosses *viz.,* ZEM-1 × TM-4; Jumka × NRCHB-101; Pusa Mustard-28 × KBS-3; Jumka × RH-30; DRMR-1 × NRCHB -101 and ZEM-1 × RH-30 were found as poor specific combiners with undesirable significantly negative *sca* effects for the trait Harvest Index under this condition.

Under 75 Kg Nitrogen per ha condition, the range for *sca* effects varied from –2.985 (Gujarat Mustard-3 × KBS-3) to 4.336 (Jumka × Pusa Mustard-28). Eight crosses *viz.,* Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; NRCHB-101 × KBS-3; TM-4 × KBS-3; Jumka × DRMR-1; RH-30 × KBS-3; Jumka × ZEM-1 and RNG-73 × Gujarat Mustard-3 were found as good specific combiners with desirable significantly positive *sca* effects. High *per se* performance was exhibited by Jumka × Pusa Mustard-28 only. Nine crosses *viz.,* Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × DRMR-1; Jumka × RH-30; Pusa Mustard-28 × ZEM-1; Jumka × NRCHB-101; DRMR-1 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × TM-4 and ZEM-1 × RH-30 were found as poor specific combiners for Harvest Index.

For 150 Kg Nitrogen per ha condition, -2.701 (ZEM-1 × DRMR-1) to 3.133 (DRMR-1 × RH-30) was the range for *sca* effects. The good specific combiners were DRMR-1 × RH-30; DRMR-1 × NRCHB -101; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × RNG-73; Jumka × Gujarat Mustard-3 and Jumka × Pusa Mustard-28 but none with high *per se* performance. In addition four crosses *viz.,* ZEM-1 × DRMR-1; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × DRMR-1 and Gujarat Mustard-3 × NRCHB-101 were found as poor specific combiners with undesirable significantly negative *sca* effects.

4.5.3.15 Seed Oil Content (%)

Due to the desirability of oil content, the positive *sca* effects are considered for this trait. Under control, the range for estimates of *sca* effects for oil content varied from -2.057 (Gujarat Mustard-3 × ZEM-1) to 3.493 (RH-30 × KBS-3). The good specific combiners with desirable significantly positive *sca* effects were RH-30 × KBS-3; DRMR-1 × TM-4; ZEM-1 × DRMR-1; ZEM-1 × TM-4; ZEM-1 × KBS-3; NRCHB-101 × KBS-3; RNG-73 × Pusa Mustard-28; Gujarat Mustard-3 × TM-4 and

Jumka × Pusa Mustard-28. However, high *per se* performance for oil content was only exhibited by the cross- RH-30 × KBS-3. On the other hand, undesirable significantly negative *sca* effects were exhibited by eight crosses *viz.*, Gujarat Mustard-3 × ZEM-1; NRCHB-101 × RH-30; RNG-73 × DRMR-1; Jumka × KBS-3; Jumka × TM-4; Pusa Mustard- 28 × RH-30; Jumka × RH-30 and Jumka × DRMR-1 representing their poor specific combining ability under control.

In case of 75 Kg Nitrogen per ha condition, the range for *sca* effects varied from -2.587 (RNG-73 × TM-4) to 2.688 (ZEM-1 × TM-4). Nine crosses *viz.*, ZEM-1 × TM-4; NRCHB-101 × KBS-3; Gujarat Mustard-3 × TM-4; RH-30 × KBS-3; RNG-73 × Pusa Mustard-28; DRMR-1 × TM-4; Gujarat Mustard-3 × DRMR-1 and Jumka × Pusa Mustard-28 and RNG-73 × Gujarat Mustard-3 were found as good specific combiners with desirable significantly positive *sca* effects for oil content under this condition. In addition, eight crosses *viz.*, RNG-73 × TM-4; NRCHB-101 × RH-30; Gujarat Mustard-3 × ZEM-1; Jumka × KBS-3; Gujarat Mustard-3 × NRCHB-101; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1 and Jumka × RH-30 were found as poor specific combiners with undesirable significantly negative *sca* effects.

Under 150 Kg nitrogen per ha condition, the range for *sca* effects varied from -2.736 (Jumka × Gujarat Mustard-3) to 1.956 (ZEM-1 × KBS-3). The entire cross combinations were found to be average specific combiners.

4.5.3.16 Seed Nitrogen Content (%)

Positive *sca* effects are desirable for the trait- seed nitrogen. In case of control, the range for *sca* effects varied from -0.077 (ZEM-1 × KBS-3) to 0.077 (NRCHB-101 × KBS-3). Only three crosses *viz.*, NRCHB-101 × KBS-3 followed by Pusa Mustard-28 × DRMR-1 and NRCHB-101 × TM-4 were found as good specific combiners with desirable significantly positive *sca* effects for the trait. However, none of the crosses exhibited high *per se* performance. Three crosses *viz.*, ZEM-1 × KBS-3; Jumka × Pusa Mustard-28 and RNG-73 × NRCHB-101 were found as poor specific combiners with undesirable significantly negative estimates of *sca* effects for the trait.

Table 4.34 Specific combining ability (*sca*) estimates for biological yield per plant (g), Harvest Index (%) and seed oil content (%) under different nitrogen levels

	Genotypes	Biological yield/plant (g)			Harvest Index (%)			Seed Oil Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1.	Jumka × RNG-73	-63.409 **	-59.402 **	-65.398 **	1.256	0.497	2.361 **	-0.407	0.313	1.552
2.	Jumka × Pusa Mustard-28	-15.784	-18.443	-9.814	4.591 **	4.336 **	1.987 *	1.418 *	1.367 *	1.639
3.	Jumka × Gujarat Mustard-3	13.508	7.390	21.644 **	2.600 **	3.488 **	2.123 *	-0.986	-1.420 *	-2.736 **
4.	Jumka × ZEM-1	52.591 **	48.640 **	40.144 **	1.812 *	2.016 *	0.856	-0.111	-0.662	-0.444
5.	Jumka × DRMR-1	-9.784	-0.652	11.269	3.493 **	2.170 *	1.143	-1.269 *	-1.154	0.535
6.	Jumka × NRCHB-101	-11.451	-5.818	-11.648	-2.508 **	-2.305 *	-1.212	0.827	0.050	0.097
7.	Jumka × RH-30	-11.242	-0.777	-10.564	-1.892 *	-2.503 **	-1.130	-1.319 *	-1.225 *	-0.082
8.	Jumka × TM-4	7.008	9.723	5.352	-0.576	-1.830 *	-1.487	-1.444 *	-0.529	0.010
9.	Jumka × KBS-3	-7.784	-23.693 *	-13.773	0.137	0.802	0.584	-1.528 *	-1.883 **	-1.623
10.	RNG-73 × Pusa Mustard-28	3.633	6.640	11.394	0.032	-0.166	-0.146	1.752 **	2.009 **	1.464
11.	RNG-73 × Gujarat Mustard-3	30.424 **	27.973 *	37.352 **	1.136	1.771 *	1.173	1.147	1.171 *	1.289
12.	RNG- 73 × ZEM-1	65.508 **	67.723 **	57.852 **	-0.463	-0.635	-0.694	0.222	1.130	1.181
13.	RNG-73 × DRMR-1	14.133	26.932 *	34.477 **	1.702 *	0.703	-0.305	-1.536 *	-1.062	-0.290
14.	RNG-73 × NRCHB-101	5.966	17.265	8.561	-0.163	-1.266	-1.115	-0.990	-0.908	-1.228
15.	RNG-73 × RH-30	-6.826	8.307	-1.356	-0.778	-1.460	-1.562	-0.636	-0.733	-0.457
16.	RNG-73 × TM-4	14.924	20.307	10.561	-0.697	-1.041	-0.891	-0.611	-2.587 **	-1.615
17.	RNG-73 × KBS-3	16.633	4.890	10.936	-0.444	-0.015	-1.022	-0.594	-0.941	-0.848
18.	Pusa Mustard-28 × Gujarat Mustard-3	25.049 *	60.432 **	-7.564	-0.948	-1.950 *	2.559 **	0.222	0.825	0.177
19.	Pusa Mustard-28 × ZEM-1	60.133 **	102.182 **	70.936 **	-0.844	-2.327 *	-0.628	-0.953	-1.366 *	-1.682
20.	Pusa Mustard-28 × DRMR-1	16.758	10.890	6.561	0.759	0.011	0.869	-1.061	-0.658	-1.253
21.	PusaMustard-28 × NRCHB-101	-0.409	-27.277 *	-12.356	-1.267	-0.343	-0.834	-0.415	-0.654	0.560
22.	Pusa Mustard- 28 × RH-30	25.299 *	-14.235	-4.773	-1.462	-0.006	-0.087	-1.361 *	-0.779	0.031

	Genotypes	Biological yield/plant (g)			Harvest Index (%)			Seed Oil Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
23.	Pusa Mustard- 28 × TM-4	-19.951 *	-23.235 *	15.644 *	-1.219	-0.533	-2.629 **	0.014	-0.683	0.122
24.	Pusa Mustard-28 × KBS-3	1.758	-45.152 **	-57.981 **	-1.944 *	0.713	1.296	-0.969	-0.987	-0.161
25.	Gujarat Mustard-3 × ZEM-1	50.924 **	28.015 *	50.894 **	-0.806	0.540	-0.322	-2.057 **	-2.054 **	-0.357
26.	Gujarat Mustard-3 × NRCHB-101	6.549	-15.777	17.019 *	-0.769	0.538	-1.851 *	-0.315	-1.445 *	-0.978
27.	Gujarat Mustard-3 × DRMR-1	-16.117	-34.443 **	-20.898 **	-0.614	-2.671 **	-2.628 **	1.081	1.709 **	0.785
28.	Gujarat Mustard-3 × RH-30	-27.409 **	-41.402 **	-19.314 *	-0.778	0.431	-0.724	-0.515	-0.816	-1.294
29.	Gujarat Mustard-3 × TM-4	-24.659 *	-38.902 **	-46.398 **	-1.430	-1.306	-0.871	1.710 **	2.430 **	1.597
30.	Gujarat Mustard-3 × KBS-3	-33.951 **	20.182	-25.523 **	-0.983	-2.985 **	-0.470	-0.323	0.625	1.214
31.	ZEM-1 × DRMR-1	-41.367 **	-49.027 **	-10.481	-0.809	1.452	-2.701 **	2.010 **	0.813	1.264
32.	ZEM-1 × NRCHB-101	-60.034 **	-37.193 **	-42.898 **	1.915 *	-0.557	0.577	-0.694	-1.133	-1.073
33.	ZEM-1 × RH-30	-57.326 **	-56.152 **	-49.814 **	-1.787 *	-1.796 *	-1.344	-0.790	-0.158	-0.803
34.	ZEM-1 × TM-4	-37.076 **	-53.152 **	-57.898 **	-2.599 **	-1.562	0.601	1.885 **	2.688 **	1.389
35.	ZEM-1 × KBS-3	-38.367 **	-75.568 **	-73.523 **	-0.242	1.224	1.317	1.852 **	1.134	1.956 *
36.	DRMR-1 × NRCHB -101	0.091	-18.985	-34.273 **	-1.796 *	0.496	3.031 **	0.597	0.925	0.556
37.	DRMR-1 × RH-30	19.299	-12.443	-32.689 **	-1.414	0.273	3.133 **	0.302	0.900	0.077
38.	DRMR-1 × TM-4	-4.951	-10.943	-29.273 **	-1.026	-0.664	0.701	2.927 **	1.946 **	1.768 *
39.	DRMR-1 × KBS-3	-0.242	16.640	-21.898 **	-1.388	-2.188 *	1.221	-0.457	-0.808	-0.065
40.	NRCHB-101 × RH-30	13.633	11.890	23.894 **	-0.661	0.528	-0.917	-1.603 **	-2.195 **	-0.261
41.	NRCHB-101 × TM-4	21.883 *	32.390 **	29.811 **	1.177	0.837	0.030	0.272	-0.050	-0.769
42.	NRCHB-101 × KBS-3	22.591 *	12.473	23.186 **	1.076	2.238 *	1.088	1.839 **	2.596 **	0.897
43.	RH-30 × TM-4	23.591 *	40.932 **	33.394 **	0.971	-0.327	-0.822	0.327	1.125	1.702
44.	RH-30 × KBS-3	17.299	14.015	23.269 **	2.337 **	2.060 *	0.715	3.493 **	2.121 **	0.968
45.	TM-4 × KBS-3	9.549	0.015	14.186	1.929 *	2.173 *	1.490	-0.882	-0.183	-0.290

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.35 Specific combining ability (*sca*) estimates for seed nitrogen content (%) and chaff nitrogen content (%) under different nitrogen levels

	Genotypes	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
1.	Jumka × RNG-73	0.030	0.029	0.036 *	0.023 **	0.030 **	0.033 **
2.	Jumka × Pusa Mustard-28	-0.064 **	-0.065 **	-0.043 **	-0.081 **	-0.060 **	-0.055 **
3.	Jumka × Gujarat Mustard-3	0.004	0.003	0.026	0.166 **	0.152 **	0.145 **
4.	Jumka × ZEM-1	0.038	0.028	0.043 **	-0.074 **	-0.075 **	-0.076 **
5.	Jumka × DRMR-1	0.016	0.000	-0.007	0.049 **	0.059 **	0.063 **
6.	Jumka × NRCHB-101	-0.028	-0.016	-0.019	-0.104 **	-0.099 **	-0.104 **
7.	Jumka × RH-30	0.014	0.030	0.017	-0.051 **	-0.077 **	-0.073 **
8.	Jumka × TM-4	-0.016	-0.016	-0.001	-0.050 **	-0.074 **	-0.076 **
9.	Jumka × KBS-3	-0.008	-0.004	-0.017	-0.051 **	-0.040 **	-0.041 **
10.	RNG-73 × Pusa Mustard-28	0.014	0.019	-0.004	-0.035 **	-0.037 **	-0.037 **
11.	RNG-73 × Gujarat Mustard-3	0.027	0.032 *	0.010	0.166 **	0.170 **	0.170 **
12.	RNG- 73 × ZEM-1	0.036	0.021	0.027	-0.064 **	-0.062 **	-0.062 **
13.	RNG-73 × DRMR-1	-0.041	-0.027	-0.003	0.068 **	0.077 **	0.042 **
14.	RNG-73 × NRCHB-101	-0.056 *	-0.058 **	-0.045 **	-0.091 **	-0.091 **	-0.087 **
15.	RNG-73 × RH-30	-0.038	-0.042 **	-0.019	-0.067 **	-0.064 **	-0.062 **
16.	RNG-73 × TM-4	0.002	0.002	0.013	-0.039 **	-0.065 **	-0.058 **
17.	RNG-73 × KBS-3	-0.040	-0.050 **	-0.023	-0.037 **	-0.037 **	-0.037 **
18.	Pusa Mustard-28 × Gujarat Mustard-3	0.007	0.018	0.001	0.187 **	0.190 **	0.184 **
19.	Pusa Mustard-28 × ZEM-1	0.031	0.017	0.028	-0.040 **	-0.042 **	-0.041 **
20.	Pusa Mustard-28 × DRMR-1	0.054 *	0.045 **	0.039 *	0.098 **	0.097 **	0.103 **
21.	PusaMustard-28 × NRCHB-101	0.030	0.033 *	0.017	-0.066 **	-0.066 **	-0.066 **
22.	Pusa Mustard- 28 × RH-30	-0.008	-0.001	0.013	-0.036 **	-0.034 **	-0.032 **

	Genotypes	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
		Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
23.	Pusa Mustard- 28 × TM-4	0.012	0.023	0.020	-0.004	-0.031 **	-0.030 **
24.	Pusa Mustard-28 × KBS-3	-0.004	-0.019	0.013	-0.002	-0.002	-0.008
25.	Gujarat Mustard-3 × ZEM-1	0.004	0.005	0.022	-0.149 **	-0.145 **	-0.150 **
26.	Gujarat Mustard-3 × NRCHB-101	-0.017	-0.008	-0.017	-0.012	-0.006 *	-0.004
27.	Gujarat Mustard-3 × DRMR-1	0.008	0.016	0.006	-0.168 **	-0.164 **	-0.165 **
28.	Gujarat Mustard-3 × RH-30	0.010	0.007	0.021	-0.143 **	-0.137 **	-0.137 **
29.	Gujarat Mustard-3 × TM-4	-0.014	-0.024	-0.007	-0.104 **	-0.119 **	-0.121 **
30.	Gujarat Mustard-3 × KBS-3	-0.001	-0.001	-0.053 **	-0.103 **	-0.105 **	-0.077 **
31.	ZEM-1 × DRMR-1	0.002	0.002	-0.015	0.152 **	0.151 **	0.157 **
32.	ZEM-1 × NRCHB-101	-0.013	-0.009	-0.002	0.003	0.008 **	0.008
33.	ZEM-1 × RH-30	-0.031	-0.028	-0.057 **	0.025 **	0.025 **	0.026 **
34.	ZEM-1 × TM-4	0.034	0.016	-0.009	0.062 **	0.044 **	0.044 **
35.	ZEM-1 × KBS-3	-0.077 **	-0.032 *	-0.056 **	0.065 **	0.062 **	0.062 **
36.	DRMR-1 × NRCHB -101	-0.010	-0.022	-0.002	-0.126 **	-0.127 **	-0.119 **
37.	DRMR-1 × RH-30	0.002	-0.006	-0.001	-0.111 **	-0.110 **	-0.102 **
38.	DRMR-1 × TM-4	0.023	0.023	-0.004	-0.082 **	-0.102 **	-0.097 **
39.	DRMR-1 × KBS-3	-0.039	-0.025	-0.010	-0.085 **	-0.089 **	-0.087 **
40.	NRCHB-101 × RH-30	0.008	0.002	0.007	0.103 **	0.107 **	0.099 **
41.	NRCHB-101 × TM-4	0.043 *	0.047 **	0.019	0.144 **	0.120 **	0.128 **
42.	NRCHB-101 × KBS-3	0.077 **	0.064 **	0.068 **	0.152 **	0.153 **	0.143 **
43.	RH-30 × TM-4	-0.005	0.007	-0.020	0.089 **	0.077 **	0.069 **
44.	RH-30 × KBS-3	0.039	0.035 *	0.003	0.085 **	0.085 **	0.086 **
45.	TM-4 × KBS-3	-0.041	-0.041 **	-0.034 *	-0.002	-0.011 **	-0.005

*Significance P ≤0.05; ** Significance P ≤0.01

Under 75Kg Nitrogen per ha condition, the *sca* effects for the character Seed Nitrogen Content varied from -0.065 (Jumka × Pusa Mustard-28) to 0.064 (NRCHB-101 × KBS-3). The good specific combiners with desirable significantly positive *sca* effect were NRCHB-101 × KBS-3; NRCHB-101 × TM-4; Pusa Mustard-28 × DRMR-1; RH-30 × KBS-3; Pusa Mustard-28 × NRCHB-101 and RNG-73 × Gujarat Mustard-3. None of the crosses exhibited high *per se* performance. In addition, six crosses *viz.,* Jumka × Pusa Mustard-28; RNG-73 × NRCHB-101; RNG-73 × KBS-3; RNG-73 × RH-30; TM-4 × KBS-3 and ZEM-1 × KBS-3 were found as poor specific combiners with undesirable significantly negative *sca* effects..

For 150 Kg Nitrogen per ha, the *sca* effects for the trait varied from -0.057 (ZEM-1 × RH-30) to 0.068 (NRCHB-101 × KBS-3). The good specific combiners with significantly positive *sca* effects were NRCHB-101 × KBS-3; Jumka × ZEM-1; Pusa Mustard-28 × DRMR-1 and Jumka × RNG-73. None of the crosses showed high *per se* performance for the trait. However six crosses *viz.,* ZEM-1 × RH-30; ZEM-1 × KBS-3; Gujarat Mustard-3 × KBS-3; RNG-73 × NRCHB-101; Jumka × Pusa Mustard-28 and TM-4 × KBS-3 were found as poor specific combiners with undesirable significantly negative *sca* effects under this condition for Seed Nitrogen Content.

4.5.3.17 Chaff Nitrogen Content (%)

Greater nitrogen content in chaff is more desirable. Hence positive *sca* effect are considered for this trait. For control, the range of *sca* effects varied from -0.168 (Gujarat Mustard-3 × DRMR-1) to 0.187 (Pusa Mustard-28 × Gujarat Mustard-3). The good specific combiners with desirable significantly positive *sca* effect were Pusa Mustard-28 × Gujarat Mustard-3; Jumka × Gujarat Mustard-3; RNG-73 × Gujarat Mustard-3; ZEM-1 × DRMR-1; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; NRCHB-101 × RH-30; Pusa Mustad-28 × DRMR-1; RH-30 × TM-4; RH-30 × KBS-3; RNG-73 × DRMR-1; ZEM-1 × KBS-3; ZEM-1 × TM-4; Jumka × DRMR-1; ZEM-1 × RH-30 and Jumka × RNG-73 along with high *per se* performance. In addition, twenty four crosses *viz.,* Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × RH-30; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; Jumka ×

NRCHB-101; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; RNG-73 × NRCHB-101; DRMR-1 × KBS-3; DRMR-1 × TM-4; Jumka × Pusa Mustard-28; Jumka × ZEM-1; RNG-73 × RH-30; Pusa Mustard-28 × NRCHB-101; RNG- 73 × ZEM-1; Jumka × RH-30; Jumka × KBS-3; Jumka × TM-4; Pusa Mustard-28 × ZEM-1; RNG-73 × TM-4; RNG-73 × KBS-3; Pusa Mustard- 28 × RH-30 and RNG-73 × Pusa Mustard-28 were found as poor specific combiners with undesirable significantly negative *sca* effect for Chaff Nitrogen.

In case of 75 Kg Nitrogen per ha condition, the range of *sca* effects varied from -0.164 (Gujarat Mustard-3 × DRMR-1) to 0.190 (Pusa Mustard-28 × Gujarat Mustard-3). The good specific combiners with desirable significantly positive *sca* effect were Pusa Mustard-28 × Gujarat Mustard-3; RNG-73 × Gujarat Mustard-3; NRCHB-101 × KBS-3; Jumka × Gujarat Mustard-3; ZEM-1 × DRMR-1; NRCHB-101 × TM-4; NRCHB-101 × RH-30; Pusa Mustard-28 × DRMR-1; RH-30 × KBS-3; RNG-73 × DRMR-1; RH-30 × TM-4; ZEM-1 × KBS-3; Jumka × DRMR-1; ZEM-1 × TM-4; Jumka × RNG-73; ZEM-1 × RH-30 and ZEM-1 × NRCHB-101 along with high *per se* performance. Undesirable significantly negative *sca* effects were exhibited by twenty seven crosses *viz.*, Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × RH-30; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × TM-4; DRMR-1 × RH-30; Gujarat Mustard-3 × KBS-3; DRMR-1 × TM-4; Jumka × NRCHB-101; RNG-73 × NRCHB-101; DRMR-1 × KBS-3; Jumka × RH-30; Jumka × ZEM-1; Jumka × TM-4; Pusa Mustard-28 × NRCHB-101; RNG-73 × TM-4; RNG-73 × RH-30; RNG- 73 × ZEM-1; Jumka × Pusa Mustard-28; Pusa Mustard-28 × ZEM-1; Jumka × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × KBS-3; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; TM-4 × KBS-3 and Gujarat Mustard-3 × NRCHB-101 representing their poor specific combining ability.

Under 150 Kg Nitrogen per ha condition, the range of *sca* effects varied from -0.165 (Gujarat Mustard-3 × DRMR-1) to 0.184 (Pusa Mustard-28 × Gujarat Mustard-3). Sixteen cross combinations *viz.*, Pusa Mustard-28 × Gujarat Mustard-3; RNG-73 × Gujarat Mustard-3; ZEM-1 × DRMR-1; Jumka × Gujarat Mustard-3; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; Pusa Mustard-28 × DRMR-1; NRCHB-101 × RH-30; RH-30 × KBS-3; RH-30 × TM-4; Jumka × DRMR-1; ZEM-1

× KBS-3; ZEM-1 × TM-4; RNG-73 × DRMR-1; Jumka × RNG-73 and ZEM-1 × RH-30 were found as good specific combiners. The above crosses also exhibited high *per se* performance for chaff nitrogen. Twenty five crosses *viz.,* Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; DRMR-1 × NRCHB -101; Jumka × NRCHB-101; DRMR-1 × RH-30; DRMR-1 × TM-4; RNG-73 × NRCHB-101; DRMR-1 × KBS-3; Gujarat Mustard-3 × KBS-3; Jumka × ZEM-1; Jumka × TM-4; Jumka × RH-30; Pusa Mustard-28 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × RH-30; RNG-73 × TM-4; Jumka × Pusa Mustard-28; Jumka × KBS-3; Pusa Mustard-28 × ZEM-1; RNG-73 × Pusa Mustard-28; RNG-73 × KBS-3; Pusa Mustard- 28 × RH-30 and Pusa Mustard-28 × TM-4 were found as poor specific combiners.

The cross combinations with good combining ability for various characters including seed yield, oil content and earliness in flowering & maturity based on the *sca* effects have been identified by Goswami and Bahal (2005); Verma *et al.* (2011); Turi *et al.* (2011); Saeed *et al.* (2013); Dahiya *et al.* (2017); Mohan *et al.* (2017); Lal *et al.* (2018); Chaudhari *et al.* (2019) and Malviya *et al.* (2019) in Indian mustard. Ramesh (2012) suggested that the crosses showing negative *sca* effects for plant height included atleast one parent with negative *gca* effects which was found in line with results obtained in the present study. Vaghela at al (2011) also identified the cross combinations with significantly high *sca* effects and found them in correlation with the magnitude of standard heterosis such kind of correlation can also be seen in the results obtained in the study conducted.

4.6 Components of genetic variance and graphical analysis under various nitrogen levels

The data pertaining to parents and their crosses for each trait were subjected to component analysis under various nitrogen levels *viz.,* control, 75 Kg N /ha and 150 Kg N /ha. Components of genetic variance under various nitrogen levels were calculated in addition to graphical analysis where additive-dominance model was found adequate as revealed by insignificant differences of b (*Wr, Vr*) from one, but significant deviation of b from zero (Hayman, 1954b). In those cases where additive dominance model was not adequate under all three nitrogen levels, only graphical analysis was performed to obtain genetic information regarding the parents.

The diallel analysis has some assumptions including absence of multiple alleles, absence of linkage, no maternal effects, diploid segregations, absence of G × E interactions and absence of lethal genes. The parental genotypes were tested for these assumptions. These assumptions were found difficult to evaluate independent of each other and thus collective evaluation was made by using t-test in which deviation of regression coefficient b from Zero and unity were employed to diallel analysis for each of the trait.

The information regarding the dominance was given where additive dominance model did not fit but regression coefficient was significant. The character wise results of regression coefficient (Table 4.36 to 4.41), genetic components of variation (Table 4.42; 4.43 and 4.44) and graphical analysis (Fig 4.23 to 4.73) have been presented and discussed as under.

4.6.1 Days to Flower Initiation

The additive dominance model did not fit well to the data pertaining to days to flower initiation under all three nitrogen levels *viz.*, control, 75Kg N/ha and 150Kg N/ha (Table 4.36). For this particular trait graphical analysis was performed under all the nitrogen levels to obtain genetic information about the parents. The regression line intercepted *Wr*-axis below the origin point indicating over dominance under all three conditions (Fig 4.23, 4.24 & 4.25). Under control, the parents Jumka , RNG-73, Pusa Mustard-28 and Gujarat Mustard-3 were located near to the origin showing presence of more dominant alleles. Whereas parents NRCHB-101, RH-30, TM-4 and KBS-3 were located in the middle location, indicating equal distribution of dominant and recessive alleles. Two parents ZEM-1 and DRMR-1 were located away from the origin suggesting presence of more recessive alleles. On the other hand under 75Kg /ha nitrogen level, Jumka and Gujarat Mustard-3 were located near to origin indicating presence of dominant alleles. Whereas, parents ZEM-1, DRMR-1 and TM-4 were located away from the origin point indicating presence of more recessive alleles.

Table 4.36 Regression coefficient of *Wr* on *Vr* with their standard error, deviation from zero, unity and t^2 value for days to flower initiation, days to fifty percent flowering and days to maturity under various nitrogen levels.

Source of Variations	Days to Flower Initiation			Days to Fifty Percent Flowering			Days to Maturity		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
b *Wr,Vr*	0.738	0.603	0.681	0.686	0.678	0.793	0.282	0.355	0.101
SE(b)	0.237	0.277	0.186	0.201	0.149	0.150	0.210	0.170	0.161
b-0	-3.096	-2.140	2.627*	-2.665	2.611*	3.676**	-0.831	1.075	0.287
b-1	-1.123	-1.470	-2.745*	-2.310	-4.091*	-2.989*	-3.932*	-4.823**	-5.907**
t^2 value	0.001**	0.004	1.688	0.940	5.043*	2.955*	2.159	4.721*	5.978*

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.37 Regression coefficient of *Wr* on *Vr* with their standard error, deviation from zero, unity and t^2 value for plant height (cm), no. of primary and secondary branches per plant under various nitrogen levels

Source of Variations	Plant Height (cm)			Number of Primary Branches/Plant			Number of Secondary Branches/Plant		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
b *Wr* ,*Vr*	0.843	0.857	0.856	0.774	0.144	0.483	0.948	0.907	0.954
SE(b)	0.173	0.157	0.161	0.093	0.303	0.459	0.097	0.122	0.095
b-0	-4.438*	4.702*	4.675**	-3.452*	0.412	1.560	-8.407**	6.097**	8.967**
b-1	-1.341	-1.654	-1.553	-7.334**	-2.893*	-0.618	-1.914	-2.098**	-1.603
t^2value	0.243	0.656	0.514	19.977**	0.173	1.708	1.820	1.800	1.216

*Significance P ≤0.05; ** Significance P ≤0.01

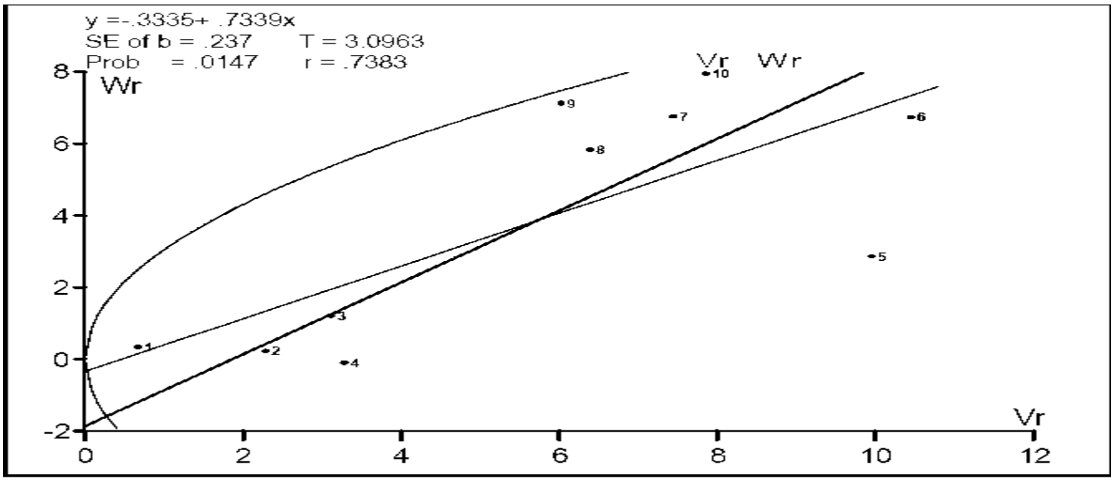


Fig 4.23 *Wr- Vr* graph for days to flower initiation under control condition

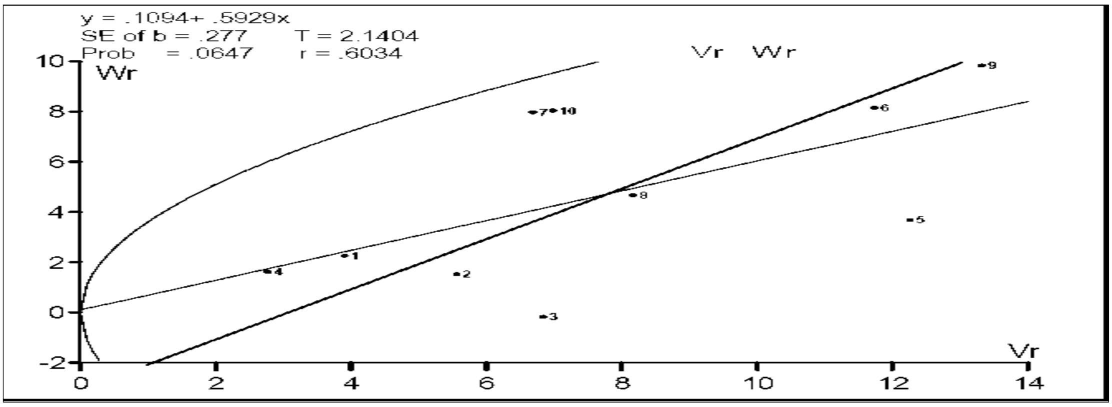


Fig 4.24 *Wr- Vr* graph for days to flower initiation under 75Kg N /ha

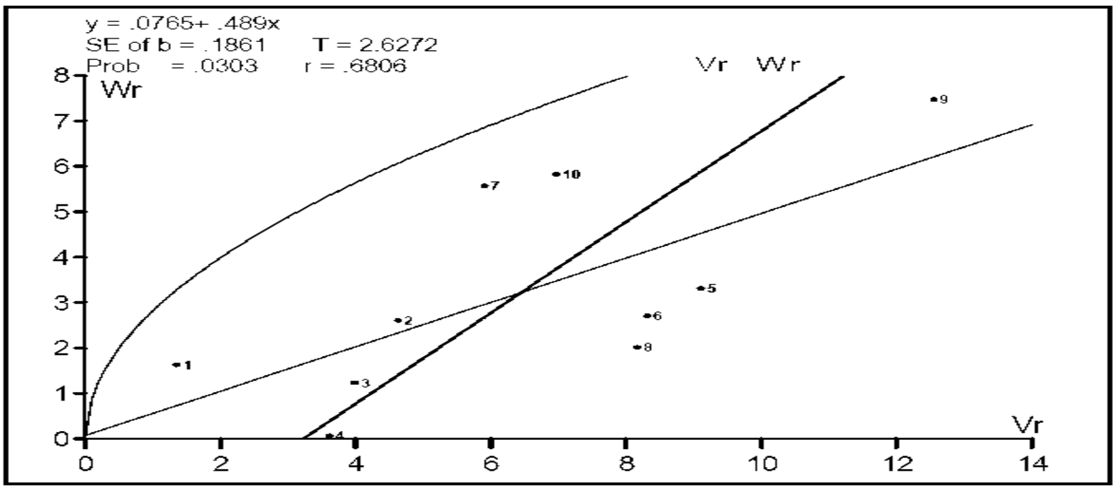


Fig 4.25 *Wr- Vr* graph for days to flower initiation under 150 Kg N /ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

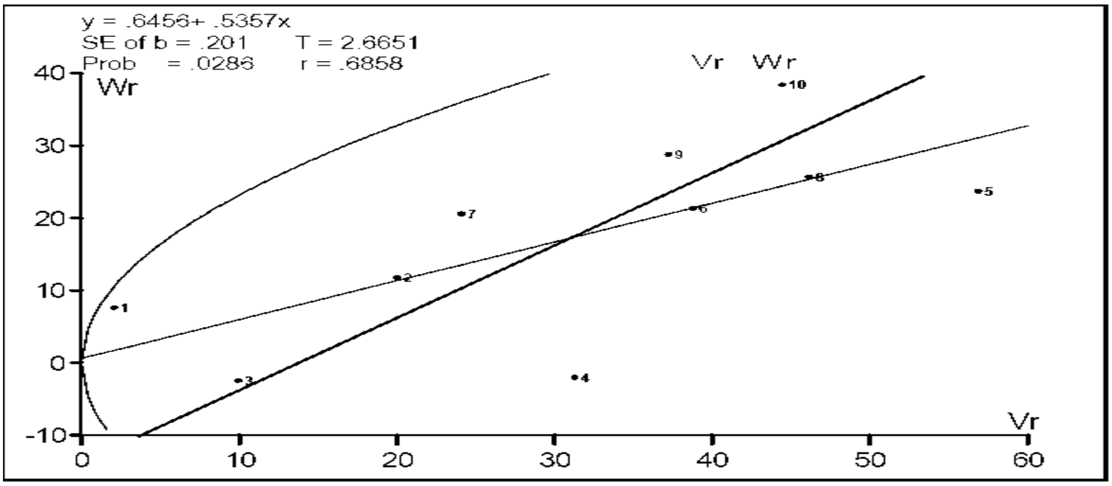


Fig 4.26 ***Wr- Vr*** **graph for days to fifty percent flowering under Control**

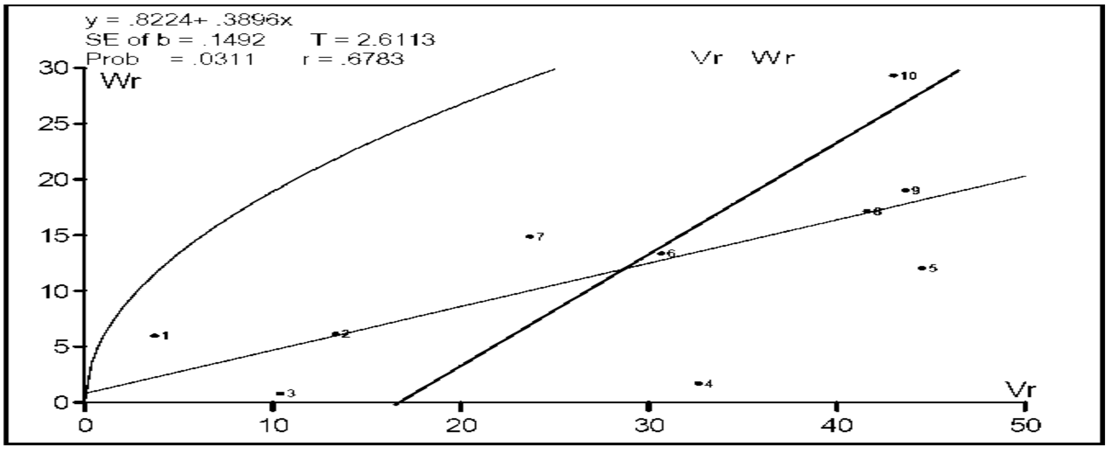


Fig 4.27 ***Wr- Vr*** **graph for days to fifty percent flowering under 75Kg N/ha**

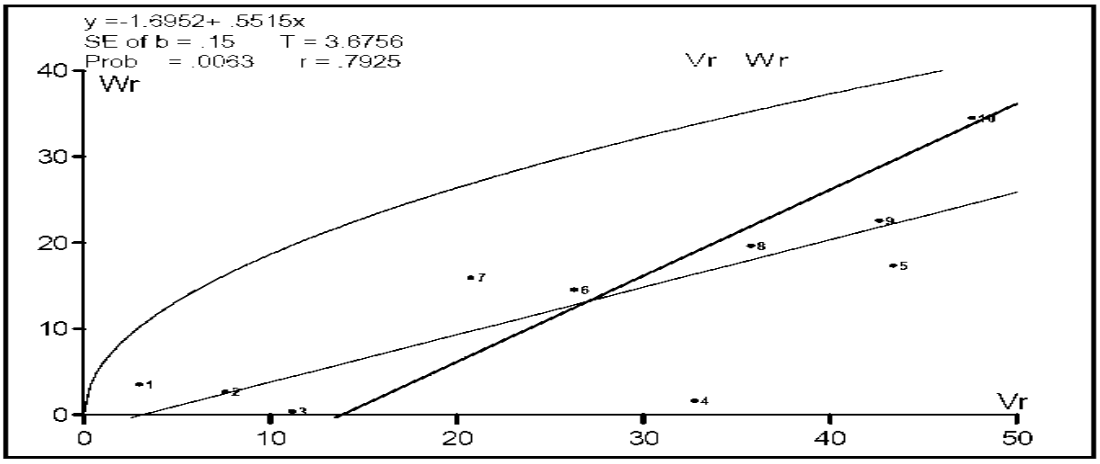


Fig 4.28 ***Wr- Vr*** **graph for days to fifty percent flowering under 150Kg N/ha**

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

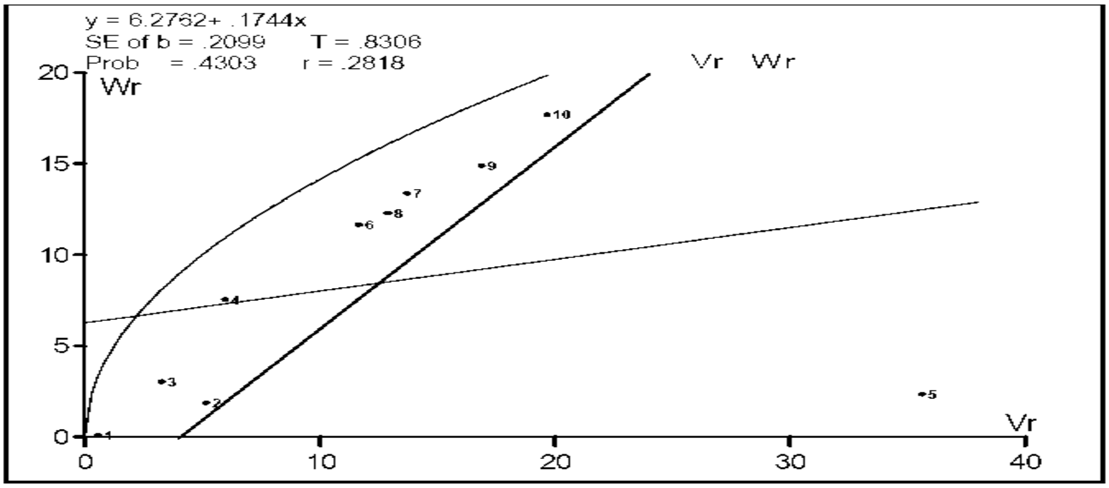


Fig 4.29 *Wr- Vr* graph for days to maturity under control

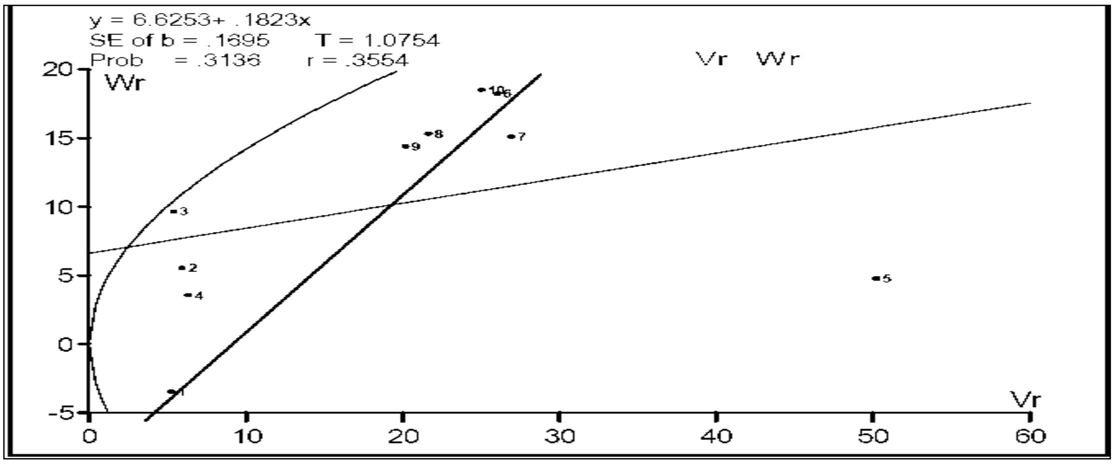


Fig 4.30 *Wr- Vr* graph for days to maturity under 75Kg N/ha

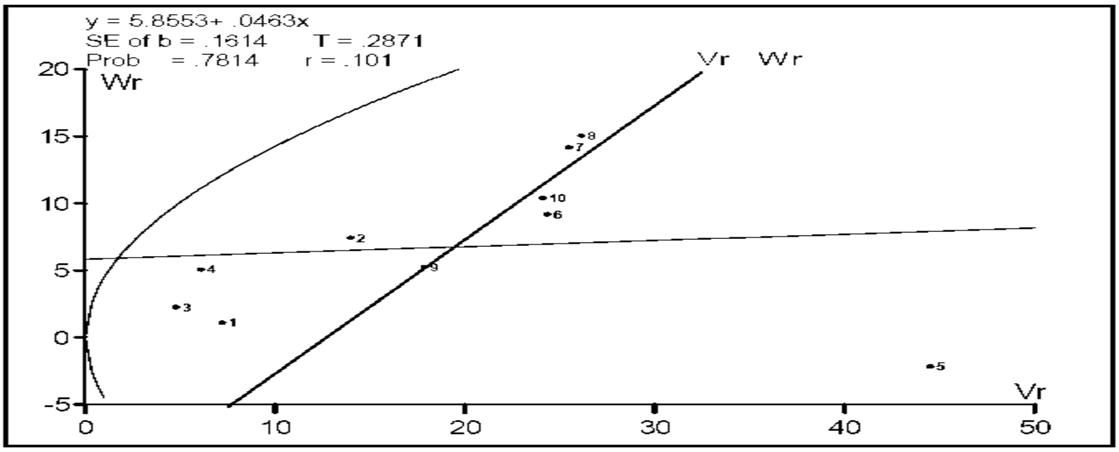


Fig 4.31 *Wr- Vr* graph for days to maturity under 150 Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

Remaining parents were scattered in the middle location showing presence of equal frequency of dominant and recessive alleles. Since all the parents were well scattered under all three nitrogen levels therefore they may be considered diverse.

4.6.2 Days to Fifty Percent Flowering

The additive dominance model under all three nitrogen levels also did not fit well to this trait (Table 4.36). Therefore, for days to fifty percent flowering graphical analysis was performed under all three conditions to know about the genetic information regarding the parents. In all three conditions, the regression line intercepted *Wr*-axis below to origin indicating over dominance for the trait (Fig 4.26, 4.27 & 4.28) The parents Jumka and Pusa Mustard-28 in case of control condition were located near to origin indicating presence of more dominant alleles whereas, parents RNG-73, Gujarat Mustard -3 and NRCHB-101 were located in middle portion suggesting equal distribution of alleles. Five parents namely, ZEM-1, DRMR-1, RH-30, TM-4 and KBS-3 were located away from origin showing presence of recessive alleles. In case of 75Kg N/ha and 150Kg N/ha conditions parents Jumka, RNG-73 and Pusa Mustard-28 were located near to the origin showing presence of dominant alleles, Parents namely Gujarat Mustard-3, DRMR-1 and NRCHB-101 were in middle location indicating presence of equal distribution of allele whereas, four parents namely ZEM-1, RH-30, TM-4 and KBS-3 were located away from origin showing presence of recessive alleles. Since all the parents were well scattered under all three nitrogen levels therefore may be considered diverse

4.6.3 Days to Maturity

The additive dominance model for this trait was found inadequate under all three nitrogen levels (Table 4.36). In all three nitrogen levels *viz.*, control, 75Kg N/ha and 150Kg N/ha regression line intercepted the *Wr* axis below the point of origin indicating over dominance for the trait (Fig 4.29, 4.30 & 4.31)). The parents namely Jumka, RNG-73, Pusa Mustard-28 and Gujarat Mustard were near to point of origin indicating presence of dominant alleles where as other parents *viz.*, DRMR-1, NRCHB-101, RH-30, TM-4 and KBS-3 were in middle location from point of origin showing equal distribution of alleles the under all three nitrogen levels. Only one parent namely ZEM-1 under all three nitrogen levels was located away from the point of origin and below the regression line showing presence of complementary gene action. Since all the parents were well scattered under all three nitrogen levels therefore may be considered diverse.

4.6.4 Plant Height (cm)

The additive dominance model for plant height was found adequate under all three Nitrogen levels (Table 4.37). The regression line intercepted the *Wr*-axis below the point of origin under all three nitrogen levels indicating over dominance for Plant Height. The genotype Jumka is located near to the origin under all nitrogen levels indicating presence of dominant alleles (Fig 4.32, 4.33 & 4.34). Six genotypes namely RNG-73, Pusa Mustard-28, Gujarat Mustard-3, DRMR-1, NRCHB-101 and TM-4 were found with equal frequency of dominant and recessive alleles based on their intermediate location from the origin in all three nitrogen levels. The genotypes ZEM-1, RH-30 and KBS-3 were located farthest from the origin point in all three conditions indicating presence of more recessive alleles.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.42) indicating role of additive and non-additive component in the genetic expression of this trait under all three nitrogen levels. However the F value under 150 Kg N/ha condition was negative and significant denoting existence of recessive alleles in excess to the dominant alleles in parents. On the other hand the perusal of F values under control and 75 Kg N/ha suggested equal proportion of the dominant and recessive alleles for plant height. The ratio of mean degree of dominance was more than one for all three cases indicating presence of overdominance. The regression line which intercepted *Wr*-axis below the origin point also indicated presence overdominance. The value of H2/4H1 was below 0.25 under all three nitrogen levels indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles under all three nitrogen levels. The heritability in case of control was moderate (0.58) on the on the hand heritability for plant height was high in 75 and 150 Kg n/ha condition (0.75 and 0.76, respectively).

Table 4.38 Regression coefficient of *Wr* on *Vr* with their standard error, deviation from zero, unity and t^2 value for length of main shoot (cm), no. of siliquae on main shoot and siliqua length (cm) under various nitrogen levels

Source of Variations	Length of Main Shoot (cm)			Number of Siliquae on Main Shoot			Siliqua Length (cm)		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
b *Wr* ,*Vr*	0.952	0.949	0.881	0.654	0.398	0.632	0.633	0.856	0.497
SE(b)	0.090	0.112	0.131	0.252	0.385	0.342	0.200	0.113	0.463
b-0	-8.805**	8.547**	5.280**	-2.445*	1.229	2.309*	-2.315*	4.685**	1.618
b-1	-2.263**	-0.357	-2.364*	-1.519*	-1.366	-0.616	-2.690*	-4.172**	-0.541
t^2value	2.790	0.010	2.177	0.048	0.287	0.667	1.363	7.496**	1.904

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.39 Regression coefficient of *Wr* on *Vr* with their standard error, deviation from zero, unity and t^2 value for no. of seeds per siliqua, 1000 seed weight (g) and seed yield per plant (g) under various nitrogen levels

Source of Variations	Number of Seeds per Siliqua			1000 Seed Weight (g)			Seed Yield per Plant (g)		
	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
b *Wr* ,*Vr*	0.943	0.838	0.812	0.716	-0.382	0.323	0.786	0.793	0.783
SE(b)	0.092	0.198	0.151	0.207	0.411	0.505	0.238	0.226	0.238
b-0	-7.995**	4.339**	3.934**	2.900*	1.169	0.965	3.590	3.679**	3.557**
b-1	-2.864*	-0.701	-2.710*	-1.931*	-3.602**	-1.014	-0.617	-0.747	-0.647
t^2 value	4.486*	0.020	2.419	0.514	0.502	1.607	0.144	0.048	0.126

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.40 Regression coefficient of *Wr* on *Vr* with their standard error, deviation from zero, unity and t^2 value for biological yield per plant (g), Harvest Index (%) and seed oil content (%) under various nitrogen levels

Source of Variations	Biological Yield per Plant (g)			Harvest Index (%)			Seed Oil Content (%)		
	Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	75 Kg N/ha	150 Kg N/ha	**Control**	75 Kg N/ha	**150 Kg N/ha**
b *Wr* ,*Vr*	0.510	0.232	0.647	0.736	0.885	0.877	0.846	0.772	0.767
SE(b)	0.279	0.301	0.263	0.213	0.162	0.165	0.107	0.159	0.191
b-0	1.677	0.675	2.399*	3.071*	5.376*	5.156**	4.495*	3.440**	3.380*
b-1	-1.904	-2.645*	-1.407	-1.634	-0.784	0.909	-4.875*	-2.852*	-1.857
t^2 value	0.079	0.150	0.009	0.250	0.007	0.033	10.114*	2.463	0.584

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.41 Regression coefficient of *Wr* on *Vr* with their standard error, deviation from zero, unity and t^2 value for seed nitrogen content (%) and chaff nitrogen content (%) under various nitrogen levels

Source of Variations	Seed Nitrogen Content (%)			Chaff Nitrogen Content (%)		
	Control	**75 Kg N/ha**	**150 Kg N/ha**	**Control**	**75 Kg N/ha**	**150 Kg N/ha**
b *Wr* ,*Vr*	0.789	0.689	0.695	0.914	0.930	0.931
SE(b)	0.143	0.154	0.172	0.135	0.132	0.129
b-0	3.637*	2.690*	2.733*	6.362**	7.145**	7.214**
b-1	-3.345*	-3.787**	-3.079*	-1.043	0.444	-0.509
t^2 value	3.884*	4.254*	2.481	0.185	0.009	0.001

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.42 Estimates of components of genetic variance for plant height (cm), no. of secondary branches per plant, length of main shoot (cm) and no. of siliquae on main shoot under various nitrogen levels

Source of Variations	Plant Height (cm)			Number of Secondary Branches/Plant		Length of Main Shoot (cm)	Number of Siliquae on Main Shoot
	Control	**75 Kg N/ha**	150 Kg N/ha	**Control**	150 Kg N/ha	**75 Kg N/ha**	150 Kg N/ha
D (Additive Effect)	9.30*	392.77*	399.12*	3.80*	58.85*	33.81*	3.80*
F (Mean Fr over arrays)	21.46	-66.00	-58.34*	-1.76*	-53.80*	-24.35	-1.76*
H1(Dominannce Effect)	19.80*	700.65*	692.39*	20.60*	92.35*	21.84*	20.60*
H2	16.83*	455.10*	448.28*	14.31*	52.31*	11.94*	14.31*
h^2 (Heritabillity)	11.26	-0.58	-0.09	15.34	2.74	1.89	15.34
E (Environ.Comp.)	2.80	1.61	0.77	4.10	0.95	2.76*	4.10
Mean Degree of Dominance	1.30	1.34	1.32	2.33	1.25	0.80	2.33
: : of Genes with +/- Effects in Parents	0.16	0.16	0.16	0.17	0.14	0.14	0.17
: : of Dominant & Recessive Genes in Parents	0.93	0.88	0.90	0.82	0.47	0.38	0.82
Va (Additive Gene Effects)	17.48	352.16	350.79	5.93	76.34	34.03	5.93
Vd (Dominance Deviations)	4.21	113.77	112.07	3.58	13.08	2.98	3.58
h2 / H2 (No.of Gene Groups)	0.00	0.00	0.00	1.07	0.05	0.16	1.07
h^2(Heritability in Narrow Sense)	0.58	0.75	0.76	0.44	0.85	0.86	0.44

*Significance P ≤0.05; ** Significance P ≤0.01

4.6.5 Number of Primary Branches per Plant

The additive dominance model for primary braches per plant was not found adequate under all the nitrogen conditions *viz.,* control, 75 Kg/ha and 150 Kg N/ha (Table 4.37). Therefore only graphical analysis was performed to know the genetic components of the trait.

The regression line intercepted *Wr*-axis below the origin point indicating overdominance in all three levels of nitrogen (Fig 4.35, 4.36 & 4.37). In control, the parental genotypes Jumka, RNG-73 and Pusa Mustard-28 were located near to origin point suggesting presence of more dominant alleles whereas Gujarat Mustard-3, DRMR-1, RH-30, TM-4 and KBS-3 were located in the middle position from the origin point indicating equal distribution of alleles. On the other hand two genotypes namely ZEM-1 and NRCHB-101 were far away from origin point showing presence of dominant alleles under control condition. In case of 75 Kg/ha nitrogen level parental genotypes namely Jumka., NRCHB-101, RH-30 and TM-4 were located near to the origin point suggesting presence of dominant alleles while, RNG-73, Gujarat Mustard-28, DRMR-1 and KBS-3 were in the middle position indicating equal contribution of alleles whereas, only one genotype Pusa-Mustard-28 was located farthest from origin point indicated presence of recessive alleles. In case of 150 Kg N/ha condition, the genotypes Pusa Mustard- 28 and RH-30 were located closest to the origin point indicating presence of dominant alleles in these genotypes. The intermediate position of the five genotypes *viz.,* ZEM-1, DRMR-1, NRCHB-101, TM-4 and KBS-3 denoted equal frequency of dominant and recessive alleles. However, the genotypes Jumka, RNG-73 and Gujarat Mustard-3 depicted the presence of more number of recessive alleles owing to their far position from the origin point. All the parental genotypes were scattered well over the graphs which showed diversity among the parents.

4.6.6 Number of Secondary Branches per Plant

The additive dominance model for secondary branches per plant was found adequate only under control and 150 Kg N/ha condition (Table 4.37). Therefore both graphical and component analysis was carried for this character under these condition and only graphical analysis was carried out for 75 Kg N/ha condition.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.42) indicating role of additive and non-additive component in the genetic expression of this trait under control and 150 Kg N/ha level. However, the F value under this condition was negative and significant denoting existence of recessive alleles in excess to the dominant alleles in parents. The ratio of mean degree of dominance was more than one for these cases indicating presence of overdominance. The value of H2/4H1 was below 0.25 under above mentioned condition indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles under aforesaid nitrogen levels. The heritability in case of control was moderate (0.44) on the on the hand heritability was high in 150 Kg n/ha condition (0.85).

The regression line under all three nitrogen levels intersected with *Wr*-axis below the origin point indicating the presence of over dominance for this character (Fig 4.38, 4.39 & 4.40). The genotypes Jumka, RNG-73 and Pusa Mustard-28 were located close to the origin point under control which denoted presence of dominant alleles. Three genotypes namely RH-30, TM-4 and KBS-3 were located far from the origin point depicting presence of more recessive alleles. Remaining four genotypes exhibited equal frequency of dominant and recessive alleles. In case of 75 Kg N/ha condition, only the parent Jumka showed presence of dominant alleles and the parental genotype Pusa Mustard-28 exhibited equal frequency of dominant and recessive alleles based on their near and intermediate position, respectively from the origin point. Rest of all eight parental genotypes depicted presence of more recessive alleles owing to their far positions from the origin. In case of 150 Kg N/ha condition, the parent Jumka was located near to the origin point denoting presence of dominant alleles for the trait. Three genotypes *viz.*, RNG-73, Pusa Mustard-28 and Gujarat Mustard-3 were located near to the mid position indicated equal frequency of dominant and recessive alleles. Rest of the genotypes exhibited more recessive alleles under this condition.

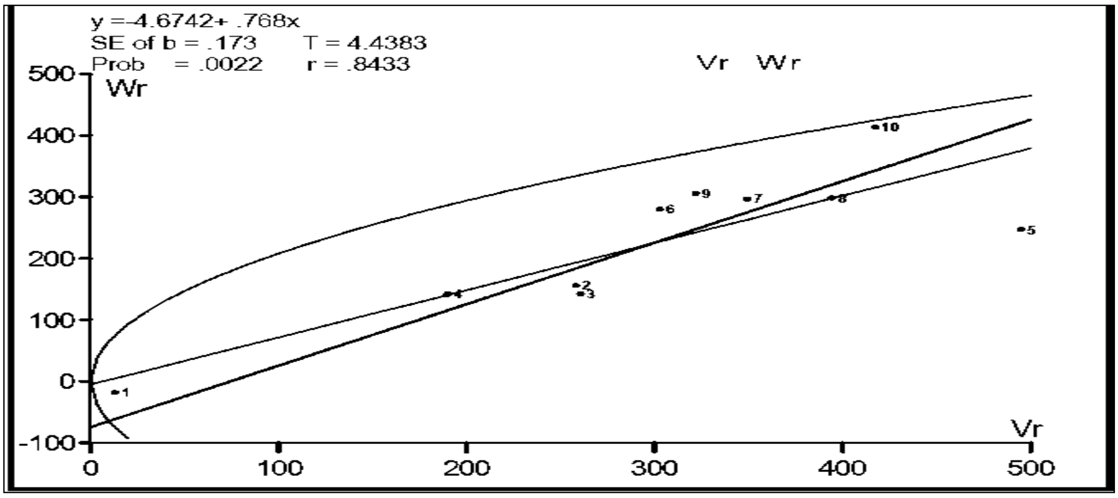


Fig 4.32 *Wr- Vr* graph for plant height (cm) under control

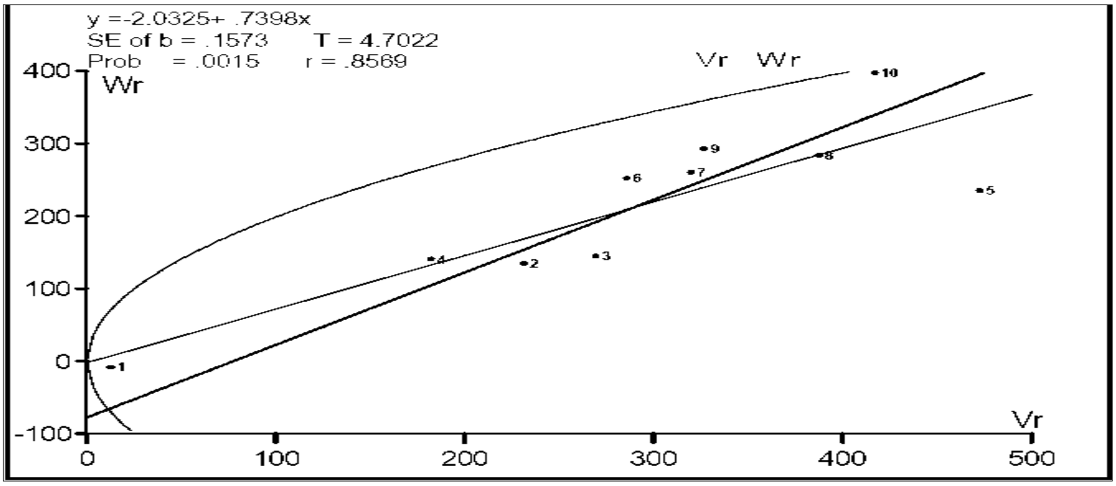


Fig 4.33 *Wr- Vr* graph for plant height (cm) under 75Kg N/ha

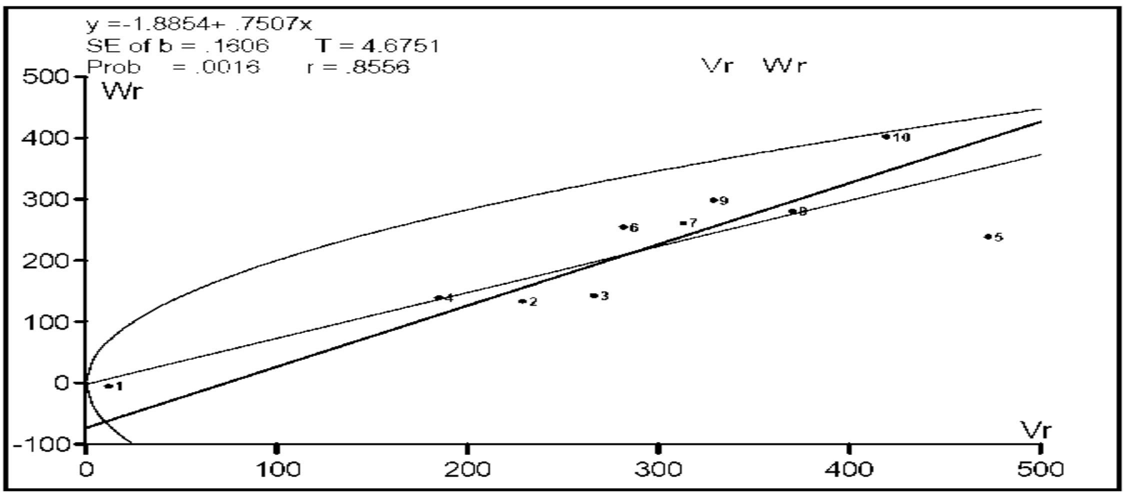


Fig 4.34 *Wr- Vr* graph for plant height (cm) under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

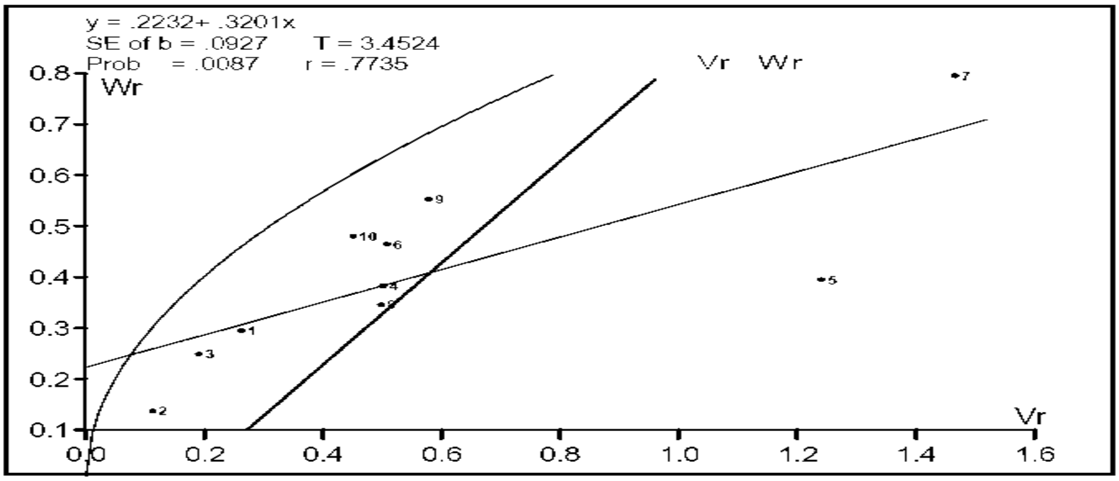


Fig 4.35 *Wr- Vr* graph for no. of primary branches/plant under Control

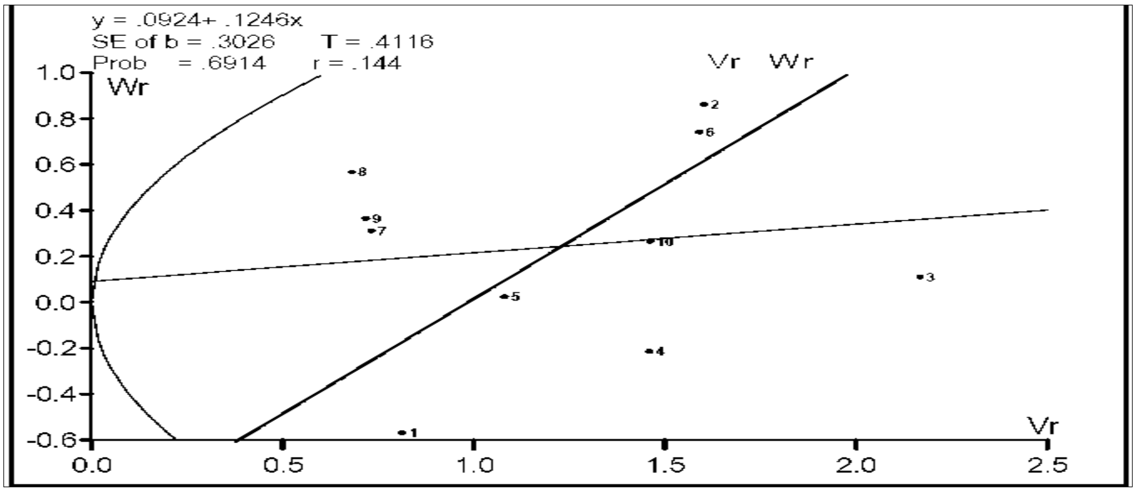


Fig 4.36 *Wr- Vr* graph for no. of primary branches/plant under 75 Kg N/ha

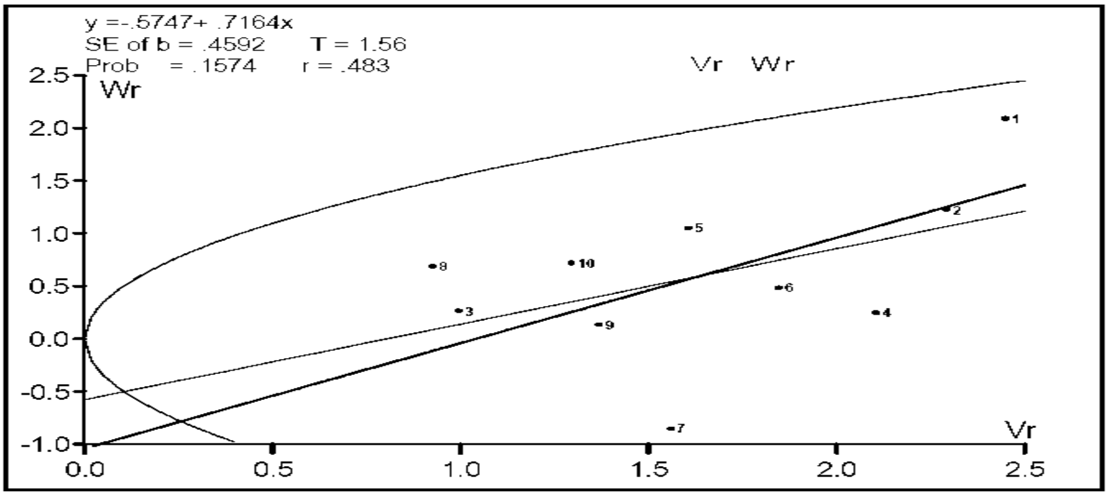


Fig 4.37 *Wr- Vr* graph for no. of primary branches/ plant under 150 Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

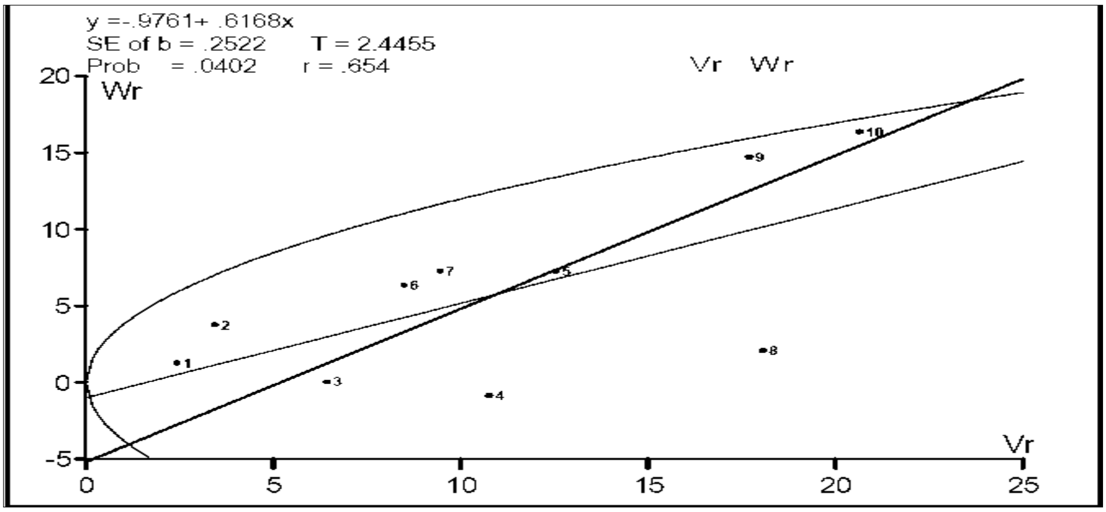


Fig 4.38 *Wr- Vr* graph for no. of secondary branches/plant under Control

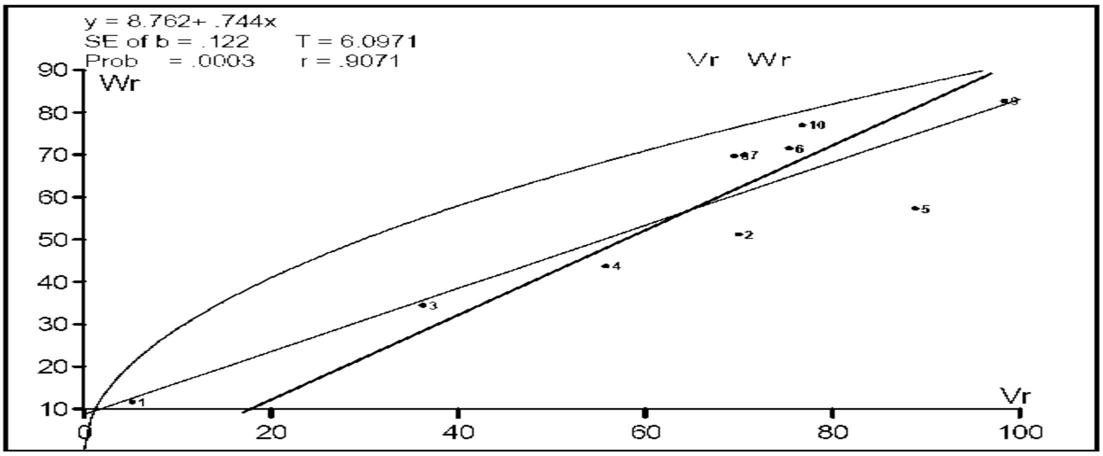


Fig 4.39 *Wr- Vr* graph for no. of secondary branches/plant under 75 Kg N/ha

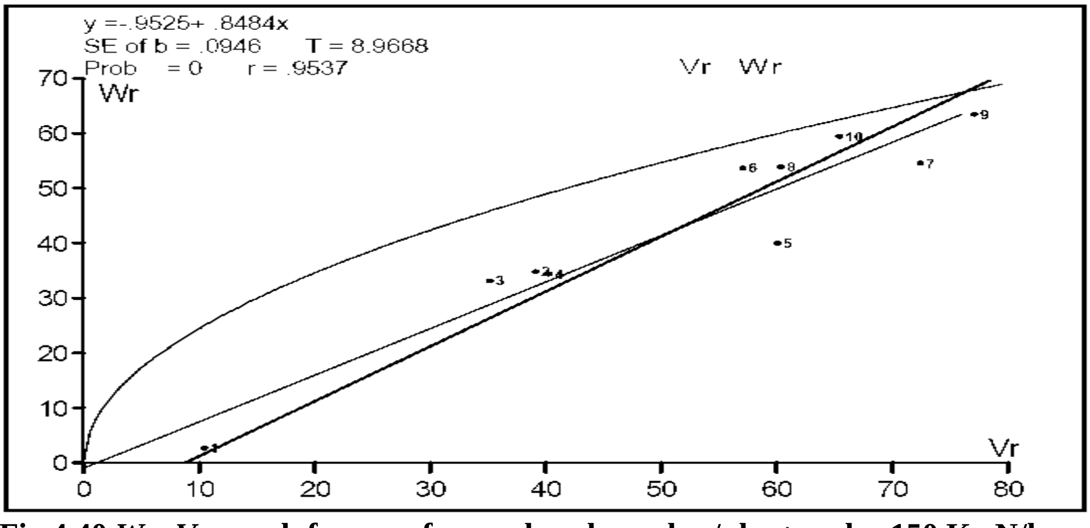


Fig 4.40 *Wr- Vr* graph for no. of secondary branches/plant under 150 Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

4.6.7 Length of Main Shoot (cm)

The additive dominance model only found adequate in case of 75 Kg N/ha level (Table 4.38), whereas for control and 150 Kg N/ha level it was inadequate therefore, for these only graphical analysis was performed. In case of control, regression line intercepted *Wr*-axis near to the origin point which shows presence of complete dominance. Whereas, it was partial dominance and overdominance for the condition of 75 Kg and 150 Kg nitrogen per hectare, respectively as interpreted from their respective positions of interception with *Wr*-axis *i.e.* above and below from the origin (Fig 4.41, 4.42 & 4.43).

In control, the genotype Jumka was present near to the origin point denoting presence of dominant allele for the character. Two genotypes *viz.*, DRMR-1 and KBS-3 were located in the middle region from the origin which pointed towards equal frequency of recessive and dominant alleles. Remaining eight parental genotypes were located far away from the point of origin which shows presence of more recessive alleles for the trait in respective parents.

In case of 75 Kg N/ha, the genotype Jumka was present near to the origin while three genotypes *viz.*, Pusa Mustard -28, TM-4 and KBS-3 were present in the intermediate position from the origin which depicts presence of dominant alleles and equal presence of dominant & recessive alleles in the genotypes, respectively. The remaining six parental genotypes exhibited presence of more recessive alleles owing to their far position from the point of origin. In case of 150 Kg N/ha condition, all genotypes exhibited presence of more recessive alleles due to their far positions from the origin except the parent- Jumka which was located near to the point of origin representing the presence of dominant alleles for length of main shoot.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.42) indicating role of additive and non-additive component in the genetic expression of this trait under 75 Kg N/ha level. The F value under 75 Kg N/ha was non significant suggesting equal proportion of the dominant and recessive alleles for the character.

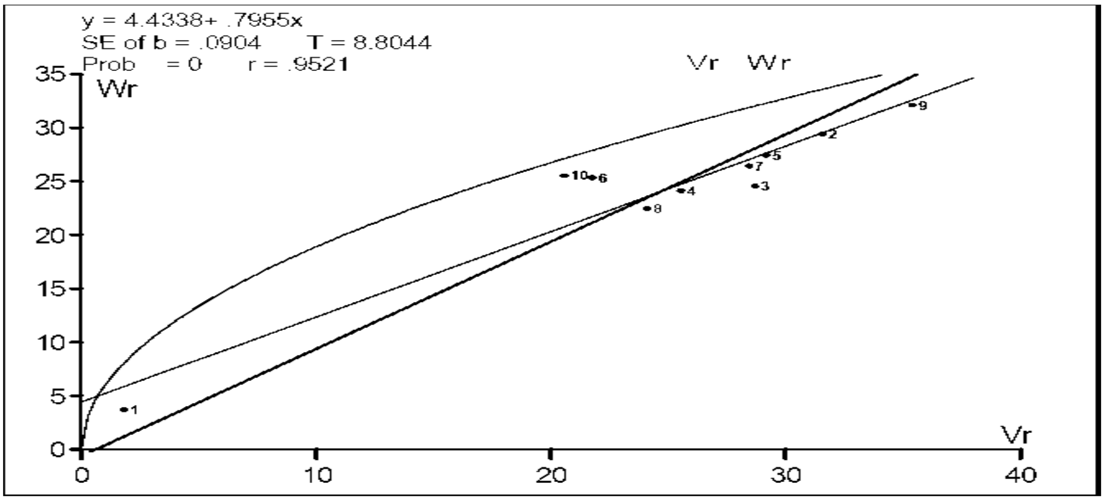


Fig 4.41 ***Wr- Vr*** **graph for length of main shoot (cm) under control**

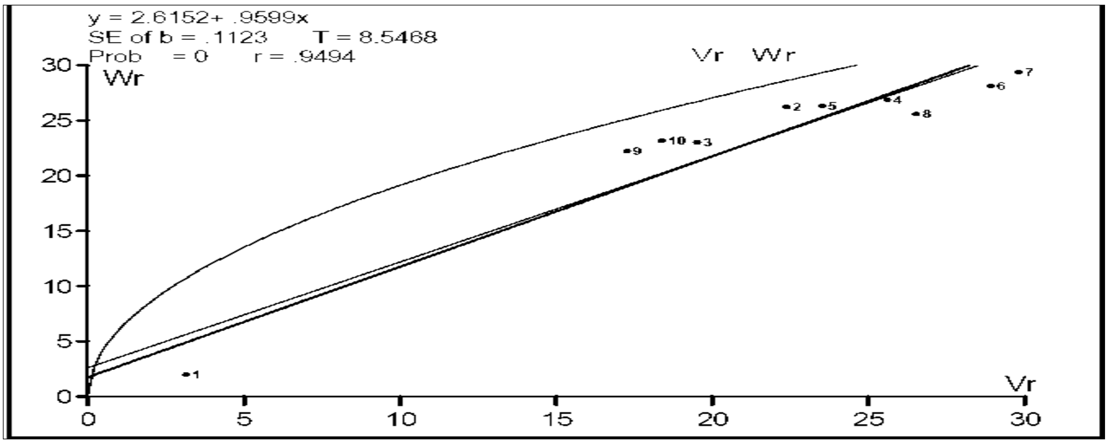


Fig 4.42 ***Wr- Vr*** **graph for length of main shoot (cm) under 75Kg N/ha**

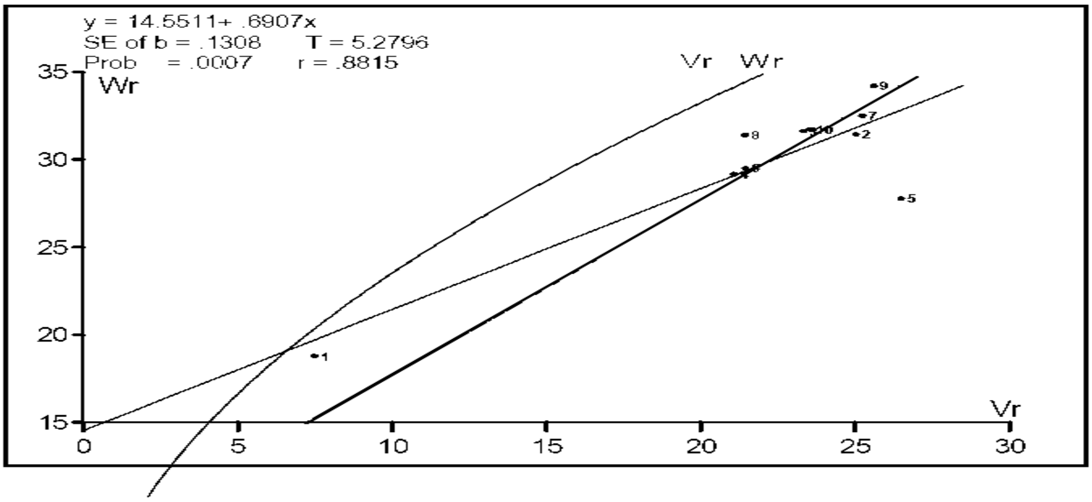


Fig 4.43 ***Wr- Vr*** **graph for length of main shoot (cm) under 150Kg N/ha**

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

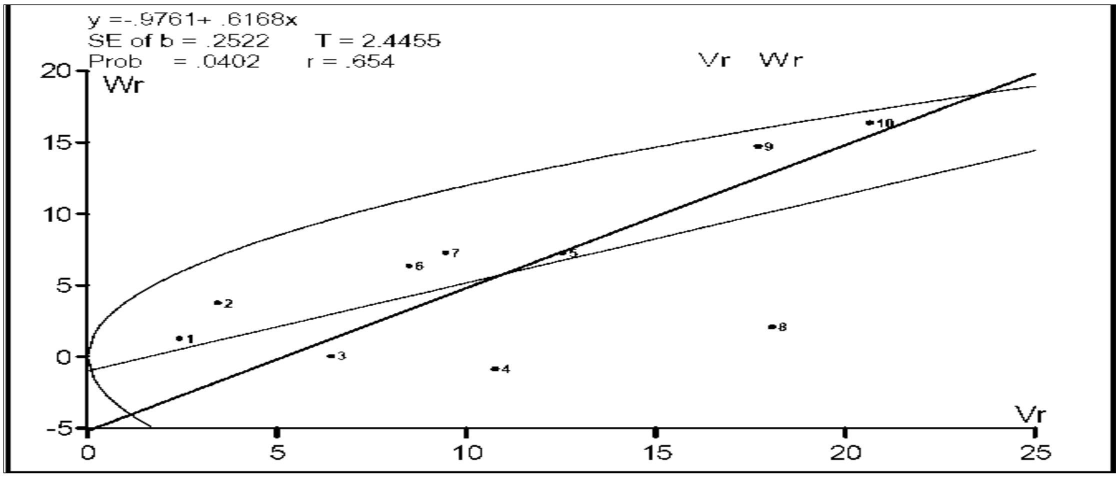


Fig 4.44 *Wr- Vr* graph for number of siliquae on main shoot under control

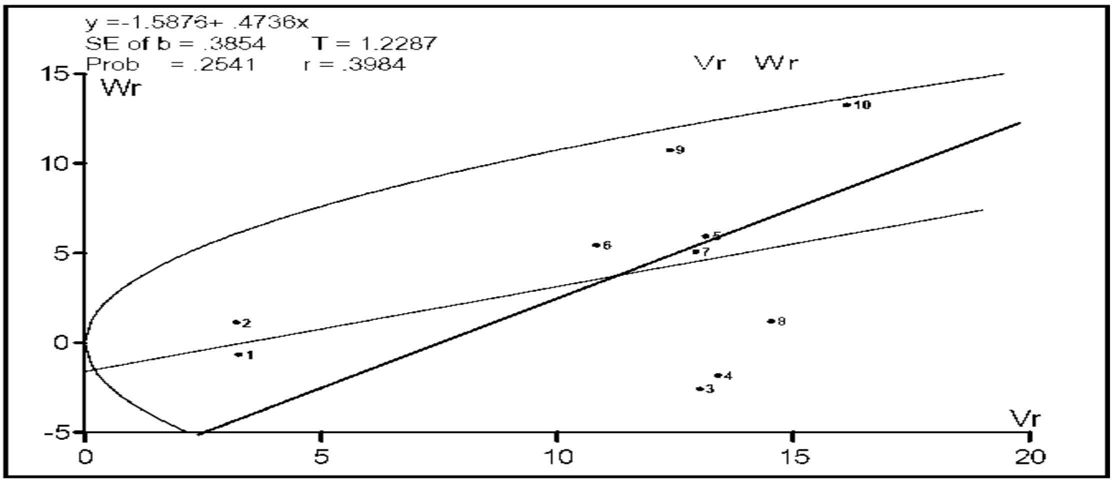


Fig 4.45 *Wr- Vr* graph for number of siliquae on main shoot under 75Kg N/ha

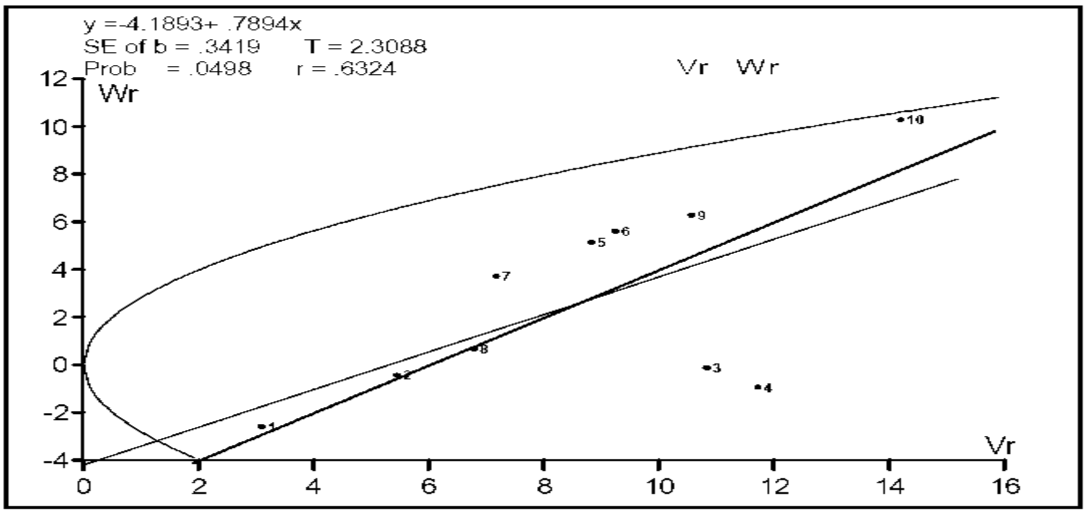


Fig 4.46 *Wr- Vr* graph for number of siliquae on main shoot under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

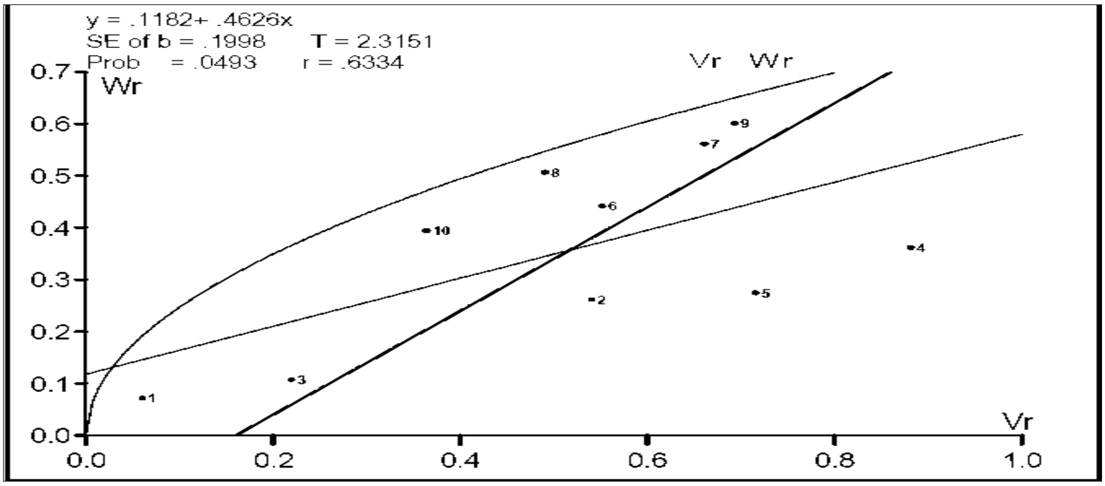


Fig 4.47 *Wr- Vr* graph for siliqua length (cm) under control

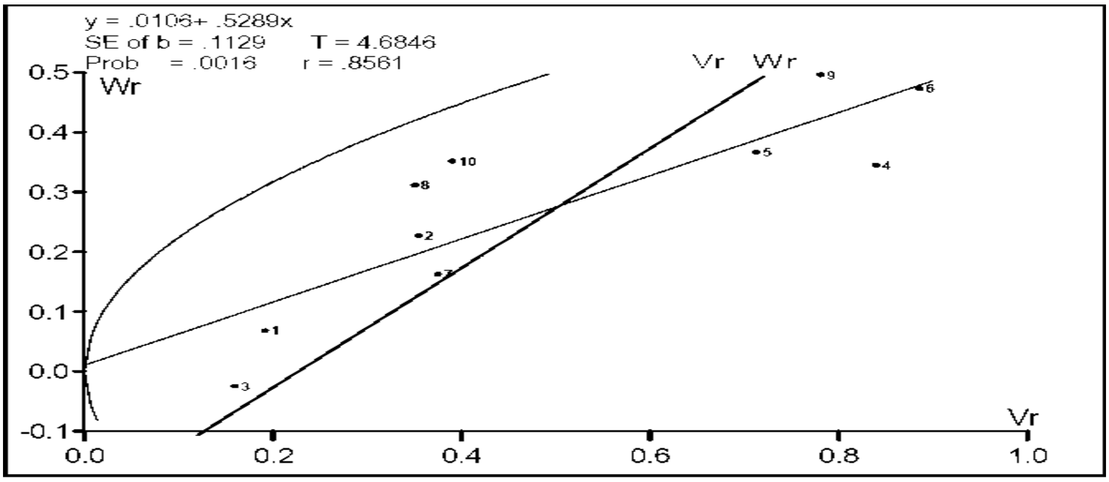


Fig 4.48 *Wr- Vr* graph for siliqua length (cm) under 75Kg N/ha

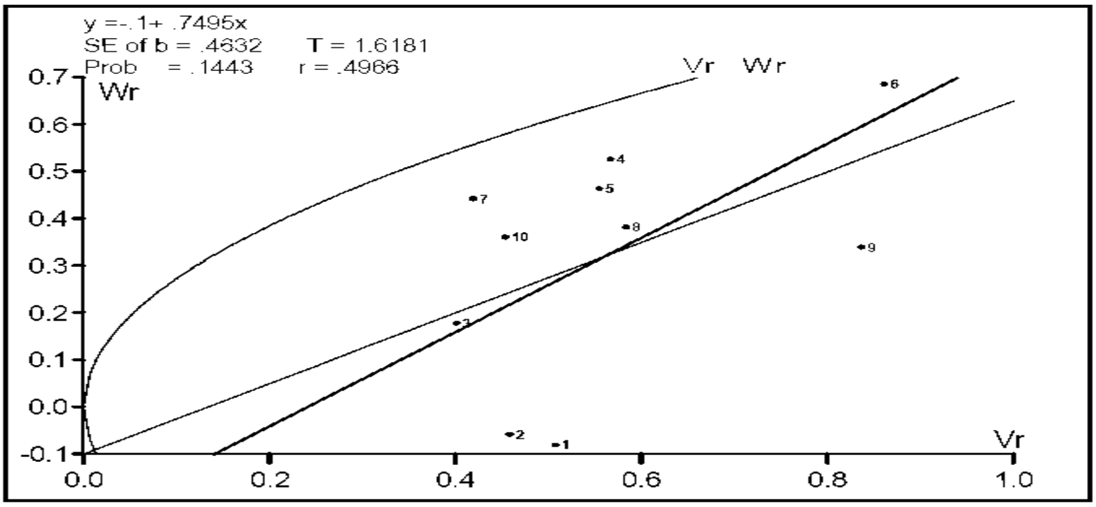


Fig 4.49 *Wr- Vr* graph for siliqua length (cm) under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

Table 4.43 Estimates of components of genetic variance for number of seeds per siliqua, seed & biological yield per plant (g) and Harvest Index (%) under various nitrogen levels

Source of Variations	No. of Seeds per Siliqua	Seed Yield per Plant (g)		Biological Yield per Plant (g)	Harvest Index(%)		
	75 Kg N/ha	75 Kg N/ha	150 Kg N/ha	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
D (Additive Effect)	4.54*	76.86*	73.22*	2677.39*	6.75*	14.65*	11.84*
F (Mean Fr over arrays)	-1.26	0.84	5.54*	173.14*	-7.04	-3.17	-0.23*
H1(Dominannce Effect)	7.35*	143.57*	109.98*	5698.12*	15.21*	14.04*	12.80*
H2	7.10*	120.11*	93.44*	4561.49*	9.90*	10.22*	8.08*
h^2 (Heritabillity)	-0.23	9.09	6.93	476.11	1.12	-0.25	0.00
E (Environ.Comp.)	0.68*	0.92	2.22	70.01	0.79	0.88	0.82
Mean Degree of Dominance	1.27	1.37	1.23	1.46	1.30	0.98	1.04
: : of Genes with +/- Effects in Parents	0.24	0.21	0.21	0.20	0.24	0.18	0.16
: : of Dominant & Recessive Genes in Parents	0.80	1.01	1.06	1.05	0.88	0.80	0.98
Va (Additive Gene Effects)	3.03	49.74	42.11	1820.44	9.56	10.82	8.40
Vd (Dominance Deviations)	1.78	30.03	23.36	1140.37	2.47	2.55	2.02
h2 / H2 (No.of Gene Groups)	-0.03	0.08	0.07	0.10	0.15	-0.03	0.00
h^2(Heritability in Narrow Sense)	0.55	0.62	0.62	0.60	0.75	0.76	0.75

*Significance P ≤0.05; ** Significance P ≤0.01

The ratio of mean degree of dominance was less than one indicating presence of partial dominance. The regression line which intercepted *Wr*-axis above the origin point also indicated presence of partial dominance. The value of H2/4H1 was below 0.25 under this nitrogen level indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles. The narrow sense heritability was high (0.86).

4.6.8 Number of Siliquae on Main Shoot

The additive dominance model was found inadequate in case of control and 75 Kg N/ha condition therefore only graphical analysis was performed whereas under 150 Kg N/ha level additive dominance model was found adequate and thus both graphical and component analysis was performed (Table 4.38).

The regression line intercepted *Wr*-axis below the point of origin in all three nitrogen levels indicating the presence of overdominance for number of siliqua on main shoot (Fig 4.44, 4.45 and 4.46). In case of control the parental genotypes Jumka, RNG-73 and Pusa Mustard-28 were located near to the point of origin indicating the presence of dominant alleles in the genotype for this trait. Four genotypes *viz.*, Gujarat Mustard-3, ZEM-1, DRMR-1 and NRCHB-101 showed equal frequency of dominant and recessive alleles in this condition as depicted from their intermediate position from the point of origin. Three parental genotypes namely, RH-30, TM-4 and KBS-3 were located far from the point of origin which denotes presence of more recessive alleles. Under 75 Kg N/ha level only Jumka and RNG-73 were present near to the origin showing presence of dominant alleles. Remaining parental genotypes were located far from the point of origin depicting more recessive alleles except the genotype DRMR-1 which exhibited relatively equal frequency of dominant and recessive alleles. In case of 150 Kg N/ha level, the genotype Jumka and RNG-73 were located near to the origin showing presence of dominant alleles. Only one genotype i.e KBS-3 exhibited presence of more recessive alleles owing to its far position from origin. Remaining seven parental genotypes showed equal frequency of recessive and dominant alleles based on their position in middle region from the origin.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.42)) indicating role of additive and non-additive component in the genetic expression of this trait under 150 Kg /ha nitrogen level. However the F value was negative and significant denoting existence of recessive alleles in excess to the dominant alleles in parents. The ratio of mean degree of dominance was more than one for this case indicating presence of overdominance. The regression line which intercepted *Wr*-axis below the origin point also indicated presence of overdominance. The value of H2/4H1 was below 0.25 indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles. The narrow sense heritability was moderate (0.44).

4.6.9 Siliqua Length (cm)

The additive dominance model was found inadequate for siliqua length, thus only graphical analysis was carried out for all three nitrogen levels (Table 4.38). The regression line intersected the *Wr* axis below the point of origin under all three nitrogen levels which indicates presence of over dominance for Siliqua length (Fig 4.47, 4.48 & 4.49). In case of control, the genotypes Jumka and Pusa Mustard-28 were present near to the point of origin depicting presence of dominant allele for this trait in the genotypes. Four genotypes *viz.,* RNG-73, DRMR-1, RH-30 and KBS-3 were present in the middle area from the origin indication equal frequency of dominant and recessive alleles. On the other hand, four genotypes namely- Gujarat Mustard-3, ZEM-1, NRCHB-101 and TM-4 were located at far distance from the origin which denoted presence of more recessive alleles.

In case of 75 Kg N/ha condition, the parental genotypes Jumka and Pusa Mustard-28 were located near to the origin suggesting presence of dominant alleles in the genotypes. Four genotypes *viz.,*RNG-73, NRCHB-101, RH-30 and KBS-3 exhibited equal frequency of recessive and dominant alleles based on their position in middle region from the origin. However the genotypes- Gujarat Mustard-3, ZEM-1, DRMR-1 and TM-4 exhibited presence of more recessive alleles as their position was far from the origin.

For condition of 150 Kg N/ha, two genotypes namely DRMR-1 and TM-4 were present far from the origin depicting presence of more recessive alleles. Remaining eight genotypes occupied the middle region from the origin which indicates equal frequency of recessive and dominant alleles. The genotypes were scattered well under all three conditions suggesting diversity for the trait among parents.

4.6.10 Number of Seeds per Siliqua

The additive dominance model was found adequate only under 75 Kg N/ha condition (Table 4.39). Thus component analysis was carried out for this condition along with the graphical analysis.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.43) indicating role of additive and non-additive component in the genetic expression of this trait under 75 Kg N/ha condition. The F value were non significant suggesting equal proportion of the dominant and recessive alleles for number of seeds per siliqua. The ratio of mean degree of dominance was more than one indicating presence of overdominance. The value of H2/4H1 was below 0.25 indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles for this character under 75 Kg N/ha. The narrow sense heritability was moderate (0.55).

The regression line intercepted *Wr*-axis near to origin in case of control and below the origin point in case of 75 Kg and 150 Kg N/ha condition suggesting presence of complete dominance and over dominance, respectively for the trait (Fig 4.50, 4.51 & 4.52). The presence of over dominance in 75 Kg N/ha condition was also suggested by the component analysis. In case of control, the genotype Jumka was located near to the origin suggesting presence of dominant allele whereas the genotype ZEM-1 and DRMR-1 were located far from the origin indicating presence of more recessive allele for the character. Remaining seven genotypes exhibited equal frequency of recessive and dominant alleles for this trait based on their intermediate position from the point of origin.

For 75 Kg N/ha condition, four genotypes *viz.,* Jumka, RNG-73, Pusa Mustard-28 and Gujarat Mustard-3 were near to the point of origin suggesting presence of the dominant alleles in these genotypes for the trait. Five genotypes namely DRMR-1, NRCHB-101, RH-30, TM-4 and KBS-3 were found in the intermediate region from the origin which depicts the presence of equal proportions of dominant and recessive alleles. Only one genotype *i.e.* ZEM-1 showed presence of more recessive alleles as interpreted through its far position from the origin.

The genotypes Jumka and Pusa Mustard-28 exhibited presence of dominant alleles as evident from their near positions from the point of origin under 150 Kg N/ha condition. Six genotypes *viz.,* RNG-73, Gujarat Mustad-3, DRMR-1, RH-30 , TM-4 and KBS-3 were located in the middle region as measured from the point of origin which suggests presence of equal frequencies of recessive and dominant alleles. However two genotypes namely ZEM-1 and NRCHB-101 were situated far from the origin depicting presence of more recessive alleles.

4.6.11 1000 Seed Weight (g)

The additive dominance model did not fit well for 1000 seed weight under all nitrogen levels including control taken up for the study (Table 4.39). Therefore only graphical analysis was performed.

The regression line intercepted the *Wr*-axis under all three nitrogen levels below the origin point which indicates that the over dominance predominates in inheritance of this particular character (Fig 4.53, 4.54 & 4.55).

Under control, the genotypes Jumka and ZEM-1 were present near to the point of origin suggesting the presence of dominant alleles in the genotypes. Three genotypes *viz.,* RNG-73, Pusa Mustard-28 and Gujarat Mustard-3 were present in the middle region from the point of origin which indicates that the genotypes have equal frequency of recessive and dominant alleles. Remaining five genotypes *viz.,* DRMR-1, NRCHB-101, RH-30, TM-4 and KBS-3 were located at the far region from the origin which showed that these genotypes contain more recessive alleles.

In case of 75 Kg N/ha regime, RNG-73 and ZEM-1 were located comparatively near to the origin suggesting preponderance of dominant alleles, while seven genotypes namely Jumka, Pusa Mustard-28, Gujarat Mustard-3, NRCHB-101, RH-30, TM-4 and KBS-3 were found in the intermediate region from the origin which points towards the presence of equal frequency of dominant and recessive alleles.

Only one genotype *i.e.* DRMR-1 was located at the far end from the point of origin showing that the genotype has more recessive alleles for the trait.

For 150 Kg N/ha condition, only genotype namely RNG-73 depicted preponderance of dominant alleles owing to its near position from the point of origin for this trait. Seven genotypes *viz.*, Jumka, Pusa Mustard-28, Gujarat Mustard-3, ZEM-1, NRCHB-101, RH-30 and TM-4 exhibited to contain equal frequencies of dominant and recessive alleles due to their intermediate positions from the point of origin. However, two genotypes namely DRMR-1 and KBS-3 were found at the far region indicating towards the presence of more recessive alleles for 1000 seed weight in these parental genotypes. All parental genotypes were scattered in the graph under all nitrogen regimes indicating diverse nature of parents.

4.6.12 Seed Yield per Plant (g)

The additive dominance model fitted well for seed yield per plant under 75 Kg and 150 Kg N/ha regimes while it was inadequate under control (Table 4.39). Thus in addition to the graphical analysis, component analysis was also performed for 75 Kg and 150 Kg N/ha conditions.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.43)) indicating role of additive and non-additive component in the genetic expression of this trait under 75 Kg and 150 Kg/ha nitrogen levels. However the F value under 150 Kg N/ha condition was positive and significant denoting existence of dominant alleles in excess to the recessive alleles in parents with respect to this character. On the other hand, non significant F values under 75 Kg N/ha suggested equal proportion of the dominant and recessive alleles for this trait. The ratio of mean degree of dominance was more than one for both cases indicating presence of overdominance. The value of H2/4H1 was below 0.25 under both nitrogen levels indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was more than unity indicating preponderance of dominant alleles under both nitrogen levels. The narrow sense heritability under both nitrogen regimes was moderate and equal (0.62).

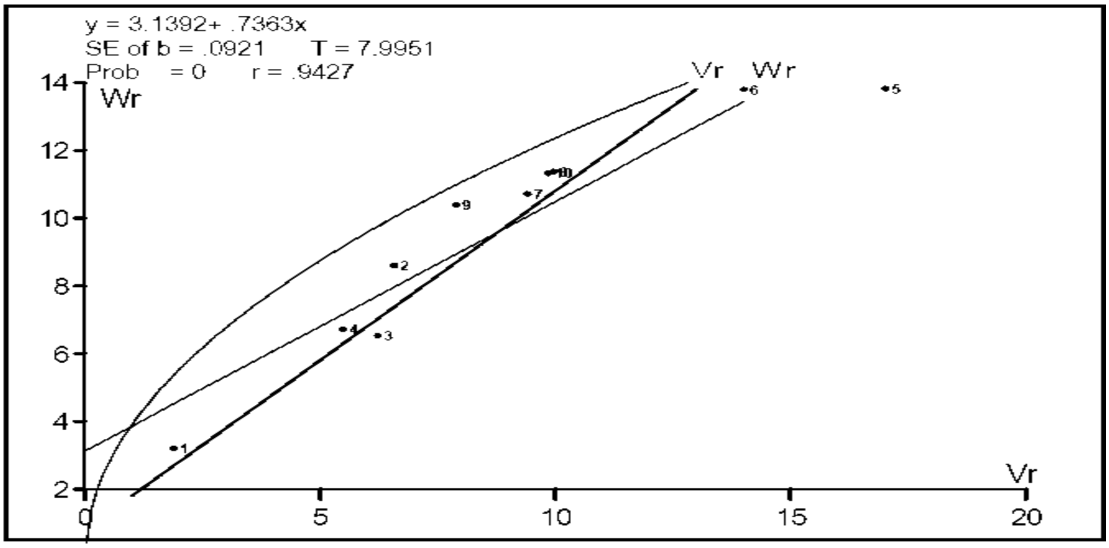


Fig 4.50 ***Wr- Vr*** **graph for no. of seeds per siliqua under control**

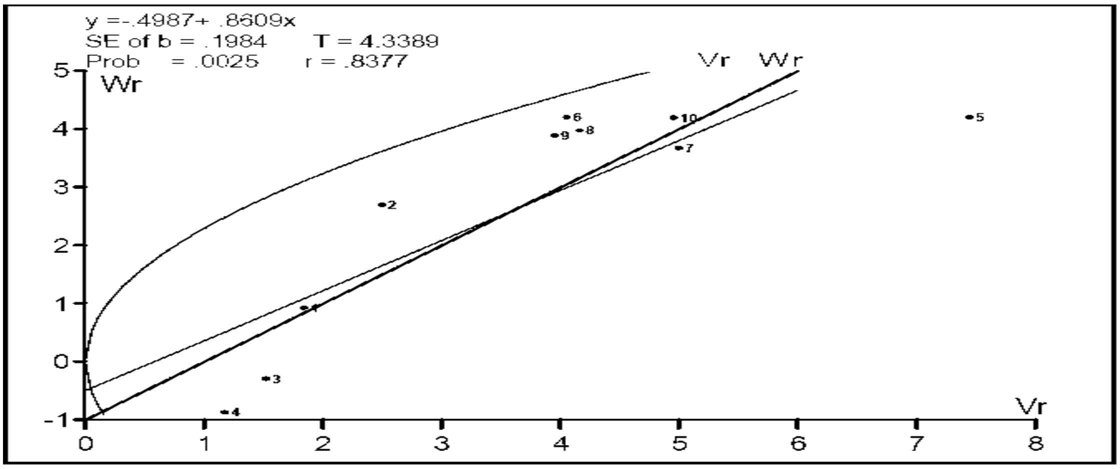


Fig 4.51 ***Wr- Vr*** **graph for no. of seeds per siliqua under 75Kg N/ha**

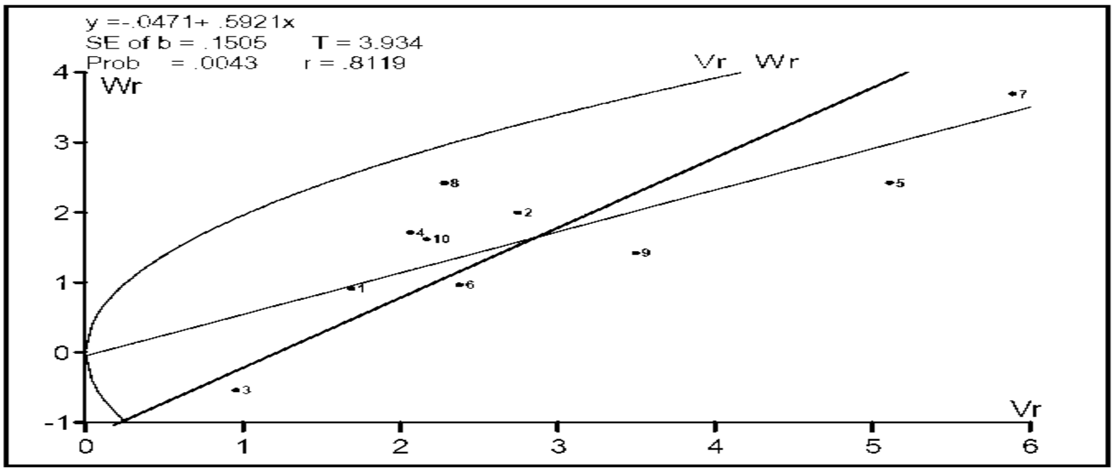


Fig 4.52 ***Wr- Vr*** **graph for no. of seeds per siliqua under 150 Kg N/ha**

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

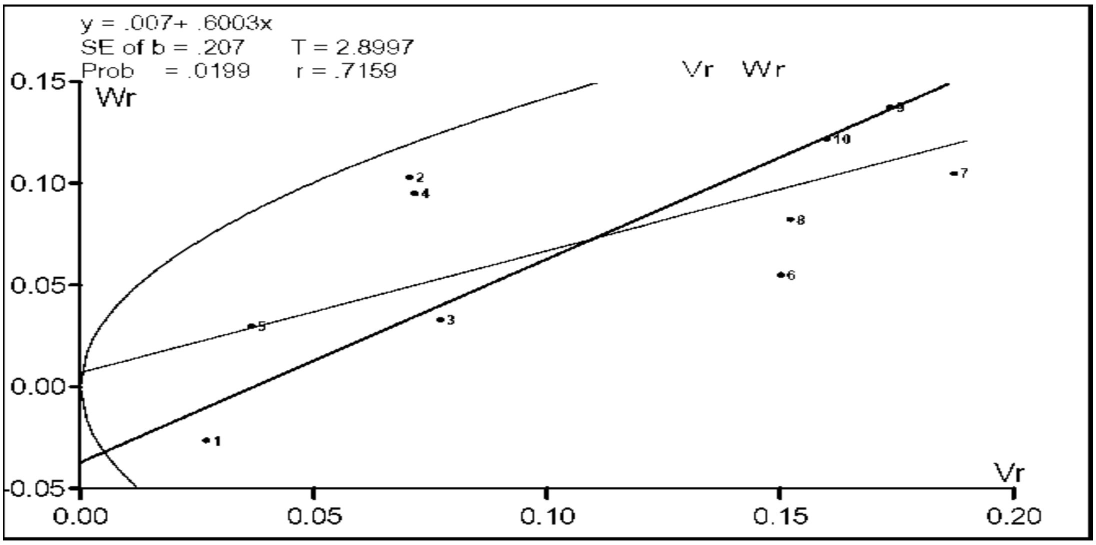


Fig 4.53 *Wr- Vr* graph for 1000 seed weight (g) under control

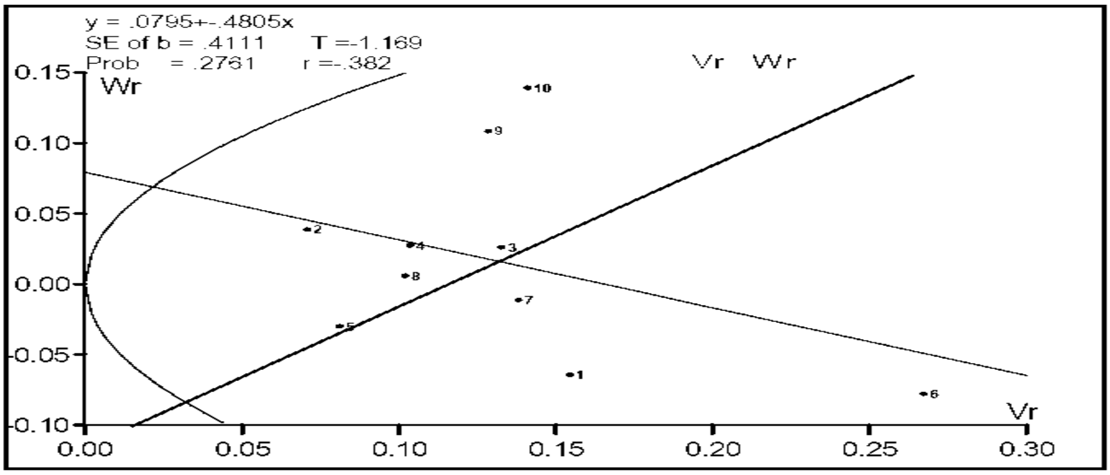


Fig 4.54 *Wr- Vr* graph for 1000 seed weight (g) under 75Kg N/ha

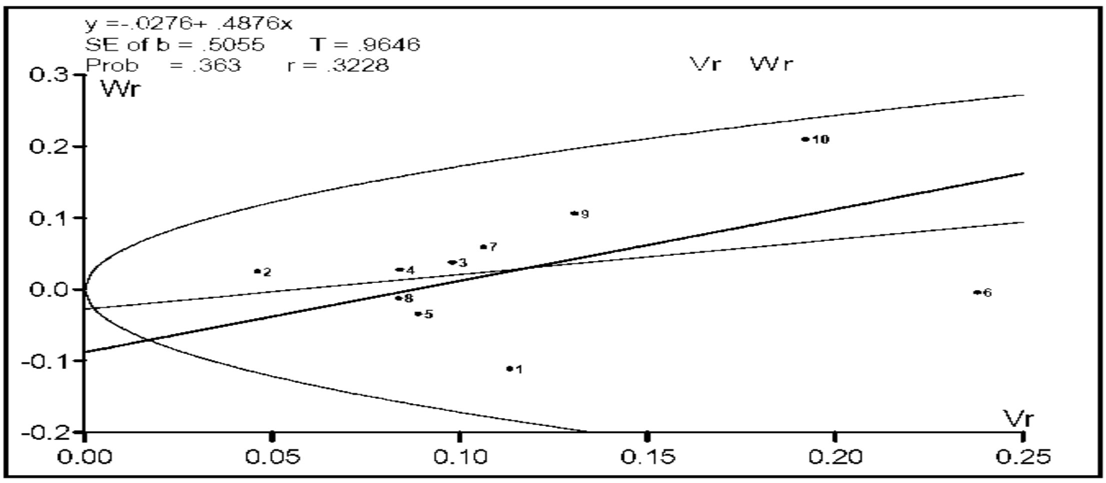


Fig 4.55 *Wr- Vr* graph for 1000 seed weight (g)under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

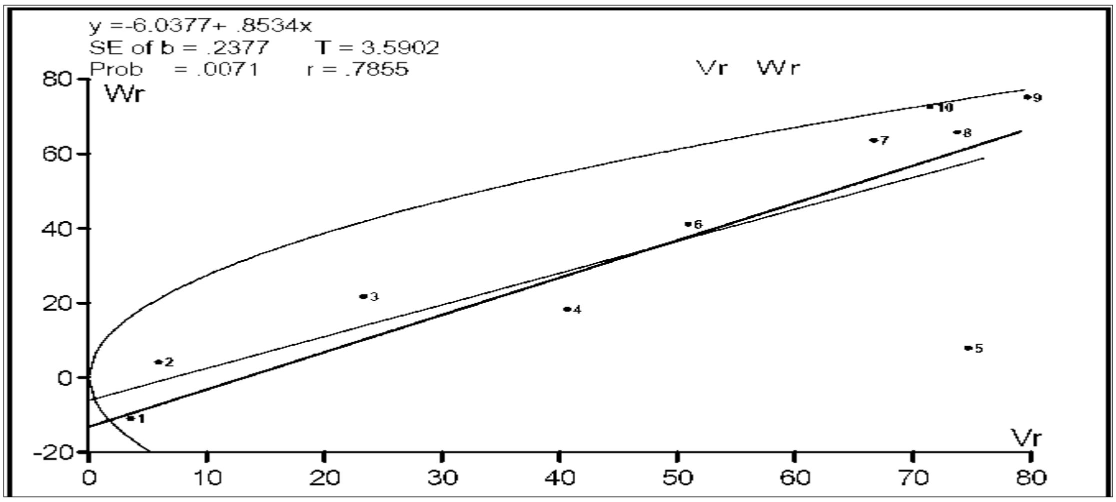


Fig 4.56 ***Wr- Vr*** **graph for seed yield per plant (g) under control**

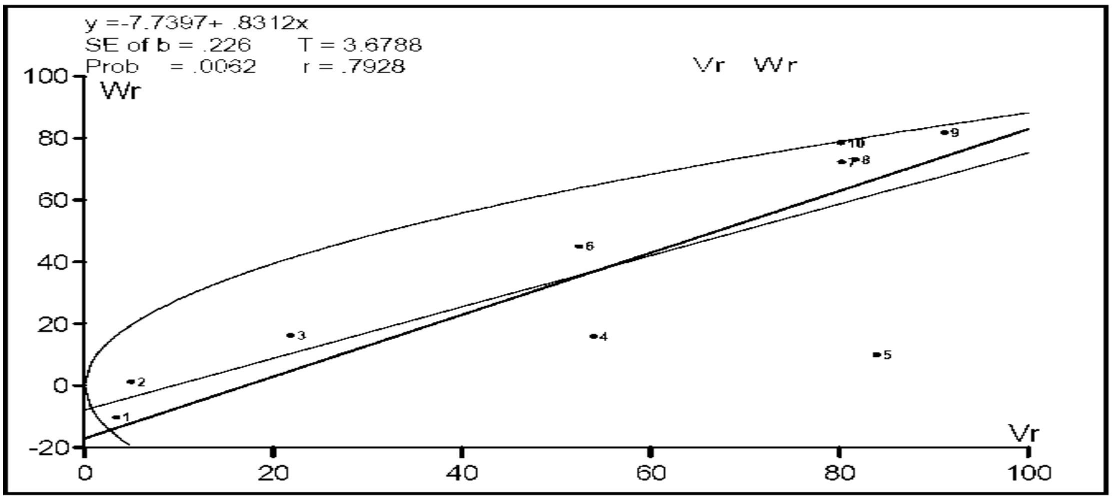


Fig 4.57 ***Wr- Vr*** **graph for seed yield per plant (g) under 75Kg N/ha**

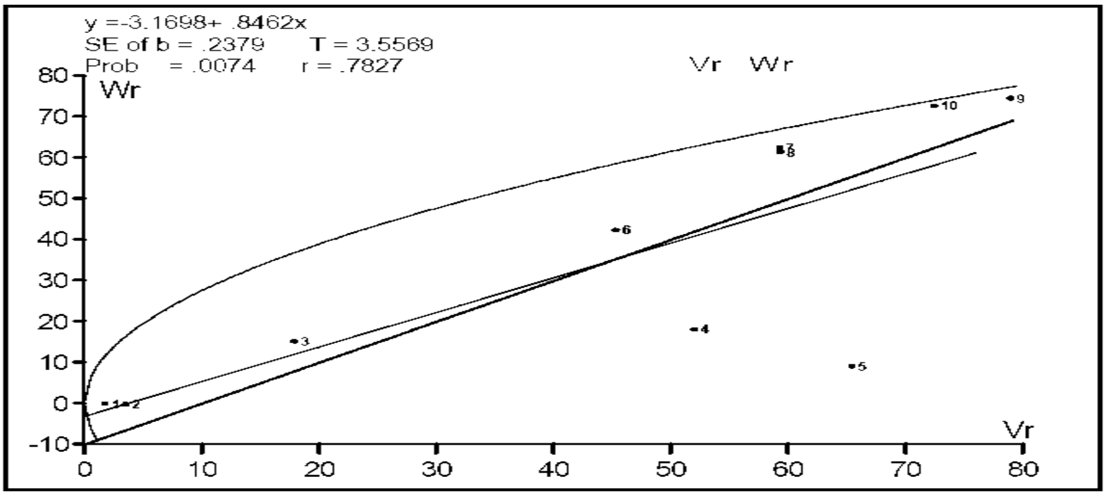


Fig 4.58 ***Wr- Vr*** **graph for seed yield per plant (g) under 150Kg N/ha**

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

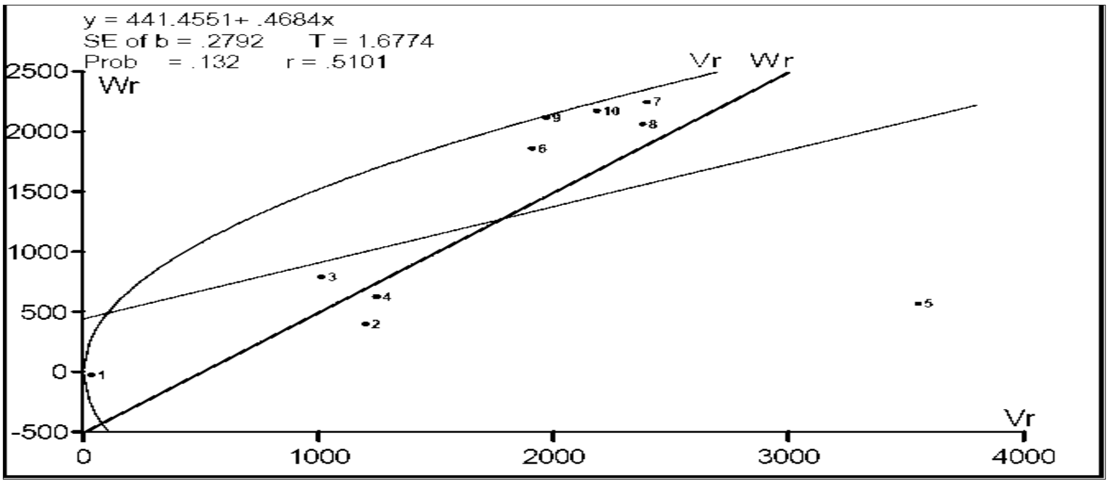


Fig 4.59 *Wr*- *Vr* graph for biological yield per plant (g) under control

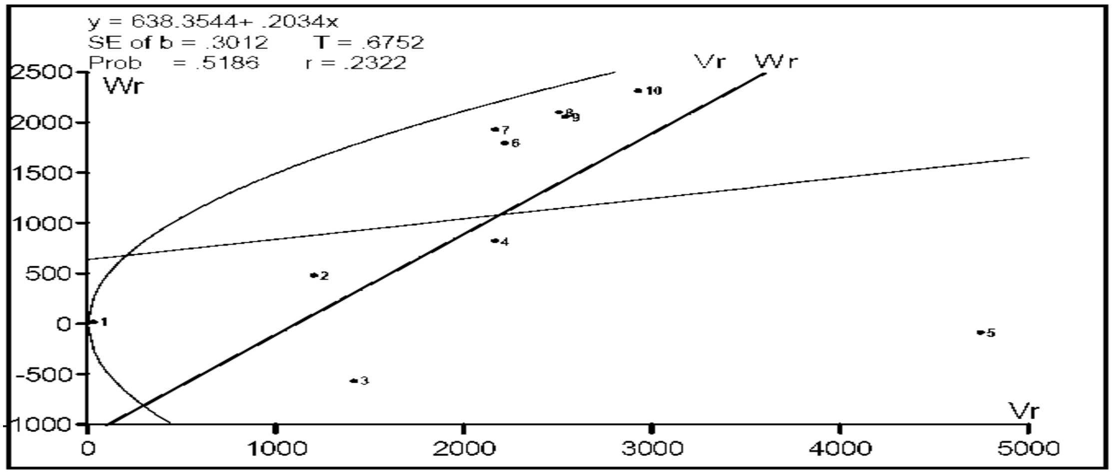


Fig 4.60 *Wr*- *Vr* graph for biological yield per plant (g) under 75Kg N/ha

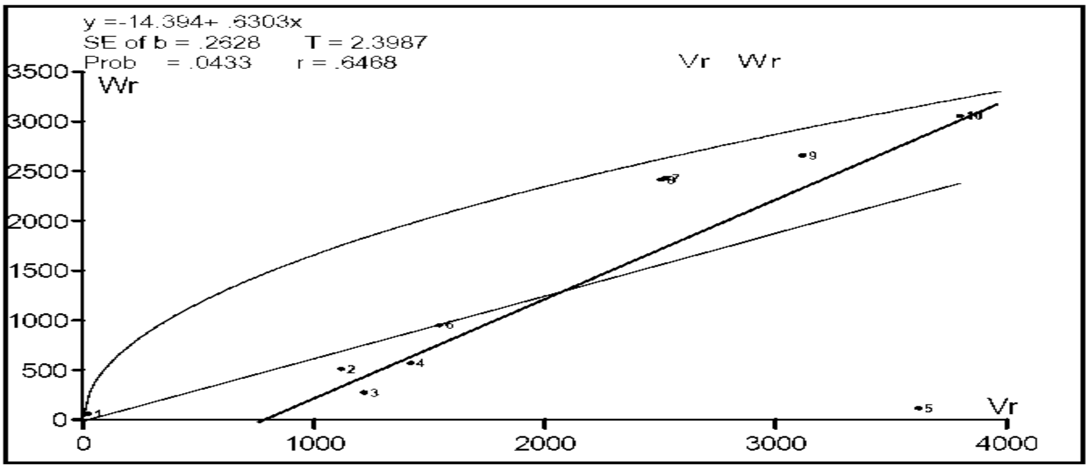


Fig 4.61 *Wr*- *Vr* graph for biological yield per plant (g) under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

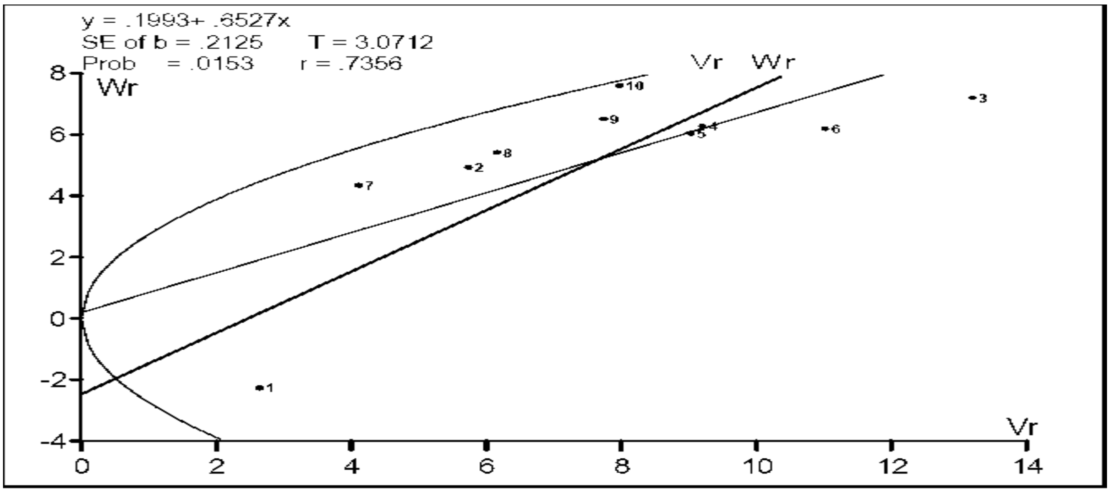


Fig 4.62 *Wr- Vr* graph for Harvest Index (%) under control

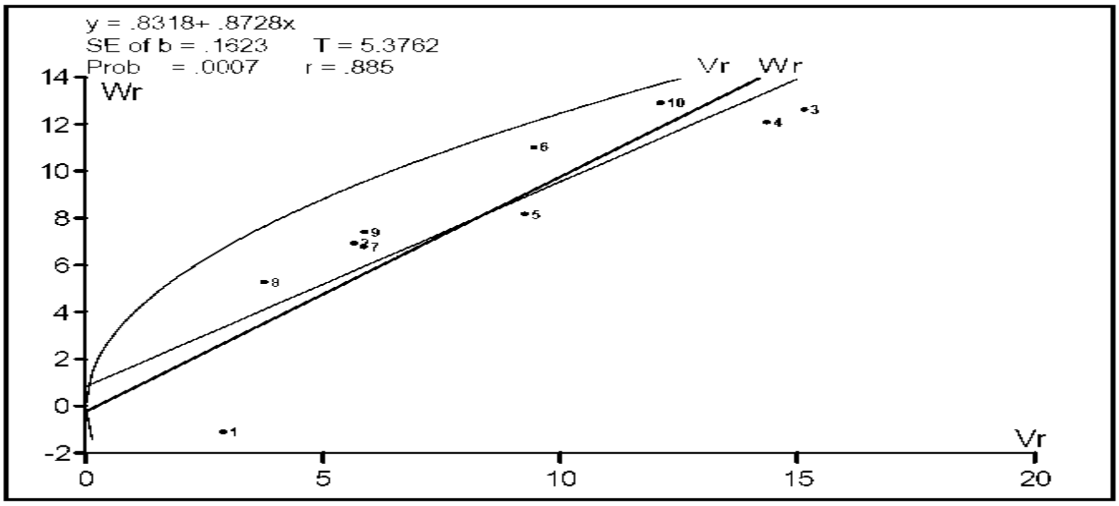


Fig 4.63 *Wr- Vr* graph for Harvest Index (%) under 75 Kg N/ha

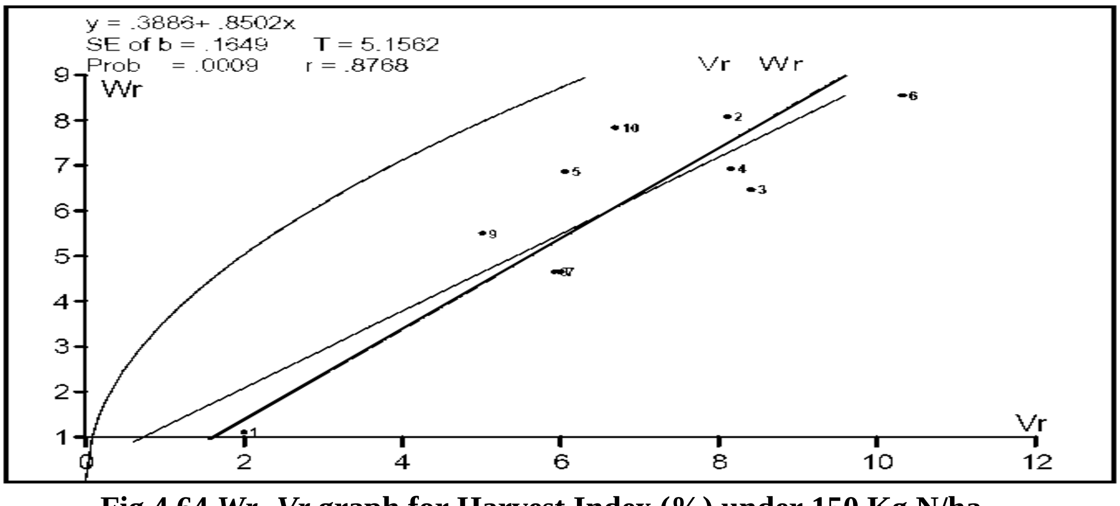


Fig 4.64 *Wr- Vr* graph for Harvest Index (%) under 150 Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

Table 4.44 Estimates of components of genetic variance for seed oil content (%) and chaff nitrogen content (%) under various nitrogen levels

Source of Variations	Seed Oil Content %	Chaff Nitrogen Content (%)		
	150 Kg N/ha	Control	75 Kg N/ha	150 Kg N/ha
D (Additive Effect)	1.43*	0.023*	0.026*	0.026*
F (Mean Fr over arrays)	-1.07*	-0.004	-0.002	-0.001*
H1(Dominannce Effect)	3.46*	0.039*	0.039*	0.037*
H2	3.42*	0.037*	0.037*	0.035*
h^2 (Heritabillity)	0.66	0.006	0.010*	0.010
E (Environ.Comp.)	0.91	0.000	0.000	0.000
Mean Degree of Dominance	1.55	1.296	1.217	1.188
: : of Genes with +/- Effects in Parents	0.25	0.237	0.237	0.236
: : of Dominant & Recessive Genes in Parents	0.61	0.882	0.954	0.954
Va (Additive Gene Effects)	1.27	0.014	0.015	0.015
Vd (Dominance Deviations)	0.86	0.009	0.009	0.009
h2 / H2 (No.of Gene Groups)	0.19	0.152	0.282	0.274
h^2(Heritability in Narrow Sense)	0.42	0.611	0.618	0.629

*Significance $P \leq 0.05$; ** Significance $P \leq 0.01$

The regression line intercepted the *Wr* axis under all three nitrogen levels *viz.,* control, 75 Kg and 150 Kg N/ha below the point of origin which indicated the presence of over dominance for governance of seed yield per plant which was in line with the interpretation of the component analysis (Fig 4.56, 4.57 & 4.58) Under all three nitrogen regimes, three genotypes *viz.,* Jumka, RNG-73 and Pusa Mustard-28 were found in close proximity to the point of origin indicating towards presence of dominant alleles for the character in these genotypes. Two genotypes *i.e.* Gujarat Mustard-3 and DRMR-1 were located in the middle region from the origin suggesting equal frequencies of dominant and recessive alleles in the genotypes for seed yield under all three conditions. Similarly five genotypes namely ZEM-1, NRCHB-101, RH-30, TM-4 and KBS-3 were located in the far region from the point of origin in all three nitrogen regimes which indicates that the genotypes are having more recessive alleles for the character. Also, the genotypes were diverse as depicted through their scattered positions in graphs under all nitrogen levels.

4.6.13 Biological Yield per Plant (g)

The additive dominance model was inadequate for the biological yield per plant except for 150 Kg N/ha condition (Table 4.40). Thus component analysis was only performed for 150 Kg N/ha regime in addition to the graphical analysis.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.43) indicating role of additive and non-additive component in the genetic expression of this trait under 150 Kg N/ha level. However the F value for this condition was positive and significant denoting existence of dominant alleles in excess to the recessive alleles in parents.. The ratio of mean degree of dominance was more than one presence of overdominance for Biological yield.. The value of H2/4H1 was below 0.25 indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was more than unity indicating preponderance of dominant alleles. The narrow sense heritability was moderate (0.60).

In graphical analysis, the regression line intercepted the *Wr*-axis below to the point of origin under all three nitrogen regimes which indicates the presence of over dominance for Biological yield (Fig 4.59, 4.60 & 4.61). Under control, four genotypes *viz.,* Jumka, RNG-73, Pusa Mustard-28 and Gujarat Mustard-3 were located in the near region to the point of origin indicating towards presence of dominant alleles in the genotypes for the trait. Five genotypes *viz.,* DRMR-1, NRCHB-101, RH-30, TM-4 and KBS-3 were located in the middle region from the origin which points towards equal frequencies of recessive and dominant alleles in the genotypes. Only parent ZEM-1 was located at the far end from the point of origin which shows presence of more recessive alleles.

Under 75 Kg N/ha condition, the parents namely Jumka, RNG-73 and Pusa Mustard-28 showed to contain more dominant alleles as evident from their comparatively close position from the point of origin. The genotype ZEM-1 was located far from the origin which indicates presence of more recessive alleles in the parent. Remaining six genotypes occupied in the middle region in the graph which suggests equal frequencies of dominant and recessive alleles in the genotypes.

For 150 Kg N/ha regime, five parents namely Jumka, RNG-73, Pusa Mustard-28, Gujarat Mustard-3 and DRMR-1 were located near to the point of origin showing presence of more dominant alleles. The genotypes NRCHB-101 and RH-30 were located in the intermediate positions as measured from the origin which indicates towards existence of equal frequencies of dominant and recessive alleles. Three genotypes namely ZEM-1, TM-4 and KBS-3 were located far away from the point of origin under this condition which points towards presence of more number of recessive alleles in these genotypes.

4.6.14 Harvest Index (%)

The additive dominance model was found adequate for Harvest Index under all three nitrogen regimes (Table 4.40). Therefore both component analysis and graphical analysis was performed for this trait.

The regression line intercepted *Wr*-axis below the point of origin in case of control and 150 Kg N/ha indicating the overdominance for Harvest Index (Fig 4.62, 4.63 & 4.64). However, the interception was near to the point of origin under 75 Kg N/ha level indicating presence of complete dominance. Under control the genotype Jumka and NRCHB-101 were near to point of origin which shows presence of more dominant alleles in theses parents. Majority of the parents *i.e.* RNG-73, Gujarat Mustard-3, ZEm-1, RH-30, TM-4 and KBS-3 were located in the middle region of the graph indicating equal distribution of recessive and dominant alleles in this genotype. On the other hand two genotypes *i.e.* Pusa Mustard-28 and DRMR-1 exhibited presence of more recessive alleles as evident from their far positions from the origin in the graph.

In case of 75 Kg N/ha regime five parents *viz.*, Jumka, RNG-73, NRCHB-101, RH-30 and TM-4 exhibited presence of dominant alleles owing to their comparatively proximate position to the point of origin. Three parents namely, ZEM-1, DRMR-1 and KBS-3 were located in the middle region of the graph indicating occurrence of equal frequencies of dominant and recessive alleles in these genotypes. On the other hand Pusa Mustard-28 and Gujarat Mustard-3 were located far away from the origin showing presence of more recessive alleles for Harvest Index in them.

For 150 Kg N/ha level, all genotypes lied in the middle region of the graph indicating towards equal distribution of recessive and dominant alleles in the parents except, the parent Jumka and DRMR-1 which showed presence of dominant and recessive alleles, respectively based on their respective near and far positions from the point of origin.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.43) indicating role of additive and non-additive component in the genetic expression of this trait under all three nitrogen levels. However the F value under 150 Kg N/ha condition was negative and significant denoting existence of recessive alleles in excess to the dominant alleles in parents. On the other hand the perusal of F values under control and 75 Kg N/ha suggested equal proportion of the dominant and recessive alleles for Harvest Index. The ratio of mean degree of dominance was more than one for control and 150Kg N/ha level indicating presence of overdominance while the ratio under 75 Kg N/ha condition was less but near to unity suggesting nearly complete dominance for Harvest Index.. The value of H2/4H1 was below 0.25 under all three nitrogen levels indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles under all three nitrogen levels. The narrow sense heritability was high under all three nitrogen levels.

4.6.15 Seed Oil Content (%)

The additive dominance model was inadequate for control and 75 Kg N/ha condition but fitted well for 150 Kg N/ha condition (Table 4.41). Thus component analysis was done for 150 Kg condition along with the graphical approach.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.44) indicating role of additive and non-additive component in the genetic expression of seed oil content under 150 Kg N/ha condition. However the F value condition was negative and significant denoting existence of recessive alleles in excess to the dominant alleles in parents. The ratio of mean degree of dominance was more than one indicating presence of overdominance. The value of H2/4H1 was 0.25 under this nitrogen levels indicating equal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating preponderance of recessive alleles. The narrow sense heritability was moderate (0.42).

The graphical analysis revealed that the regression line under all three conditions intercepted the *Wr*-axis beneath the point of origin suggesting role of overdominance in inheritance of seed oil content (4.65, 4.66 & 4.67). This was also evident from the component analysis for 150 Kg N/ha condition.

In case of control, five genotypes *viz.*, Jumka, RNG-73, Pusa Mustard-28, Gujarat Mustard-3 and NRCHB-101 were near to the point of origin indicating presence of dominant alleles in the genotypes. Three parents namely ZEM-1, DRMR-1 and RH-30 were situated in the central region of the graph indicating the equal distribution of recessive and dominant alleles. On the other hand, only two of the genotypes namely TM-4 and KBS-3 exhibited presence of more recessive alleles owing to their distant positions from the point of origin.

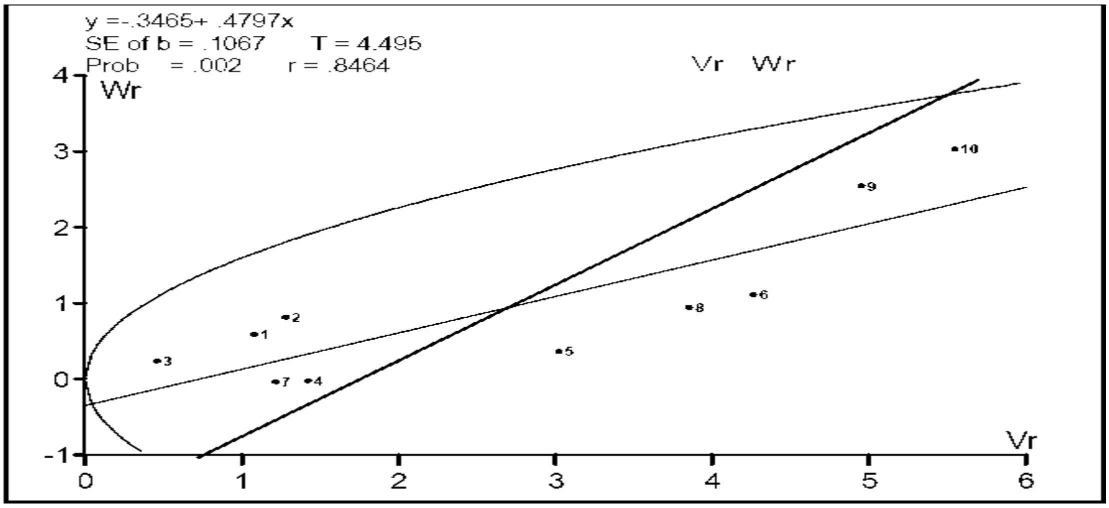


Fig 4.65 *Wr- Vr* graph for seed oil content (%) under control

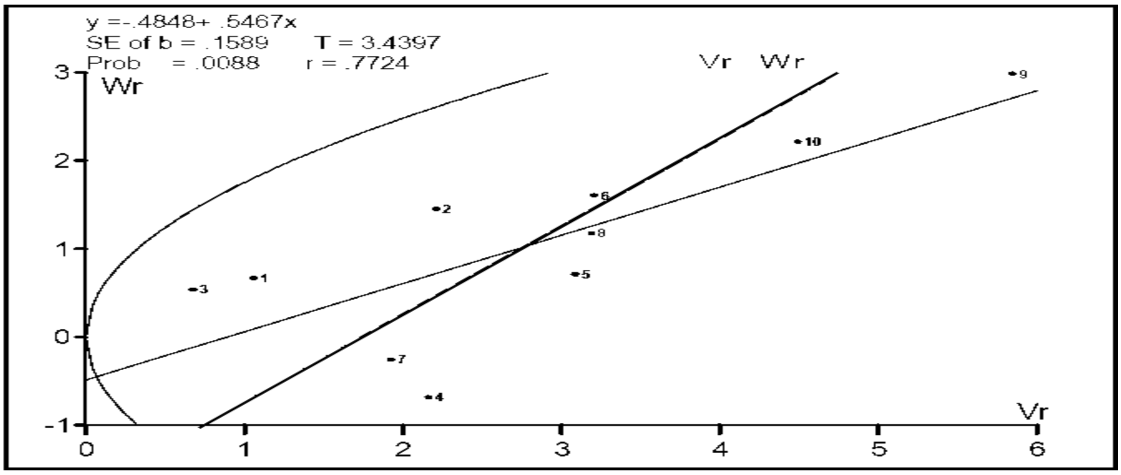


Fig 4.66 *Wr- Vr* graph for seed oil content (%) under 75Kg N/ha

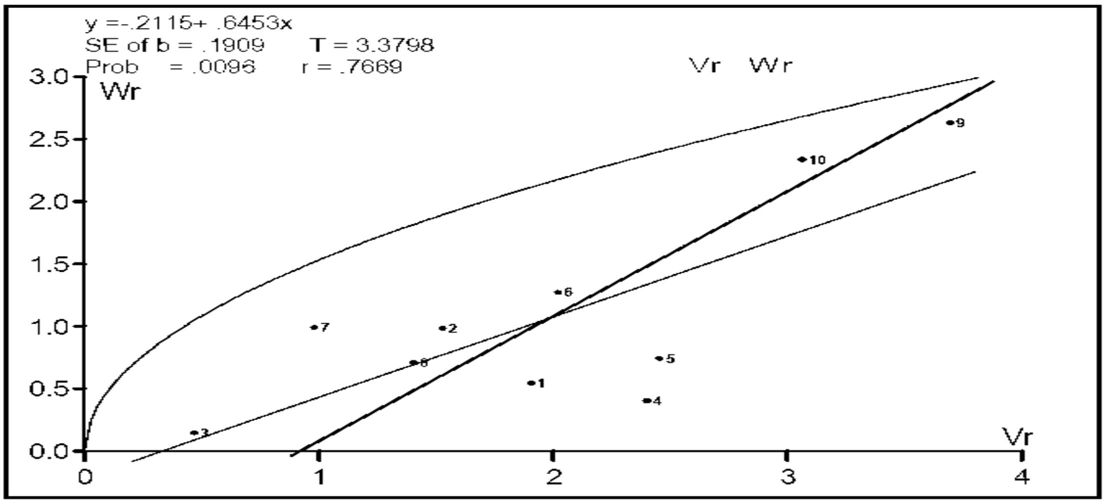


Fig. 4.67 *Wr- Vr* graph for seed oil content (%) under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

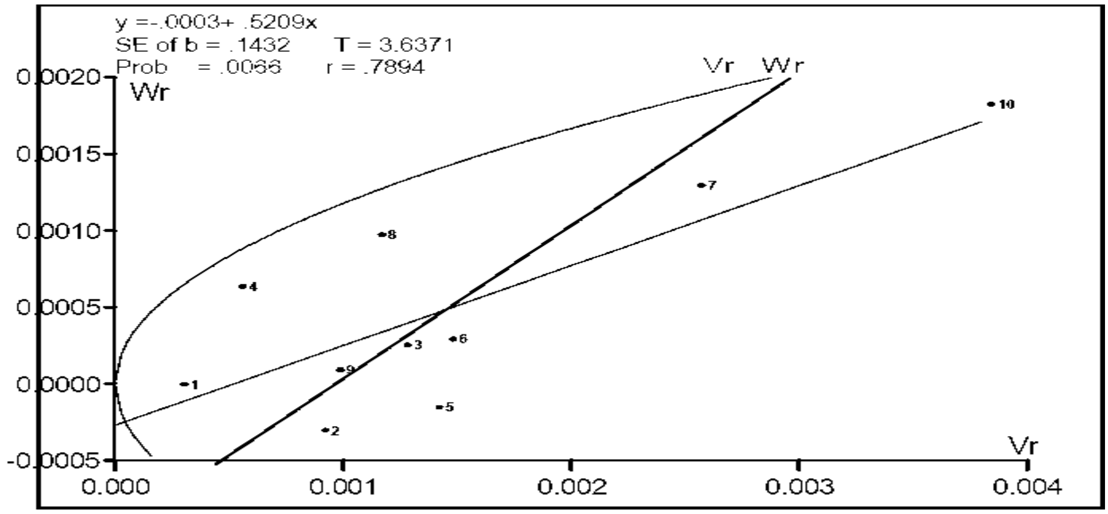


Fig 4.68 *Wr*- *Vr* graph for seed nitrogen content (%) under control

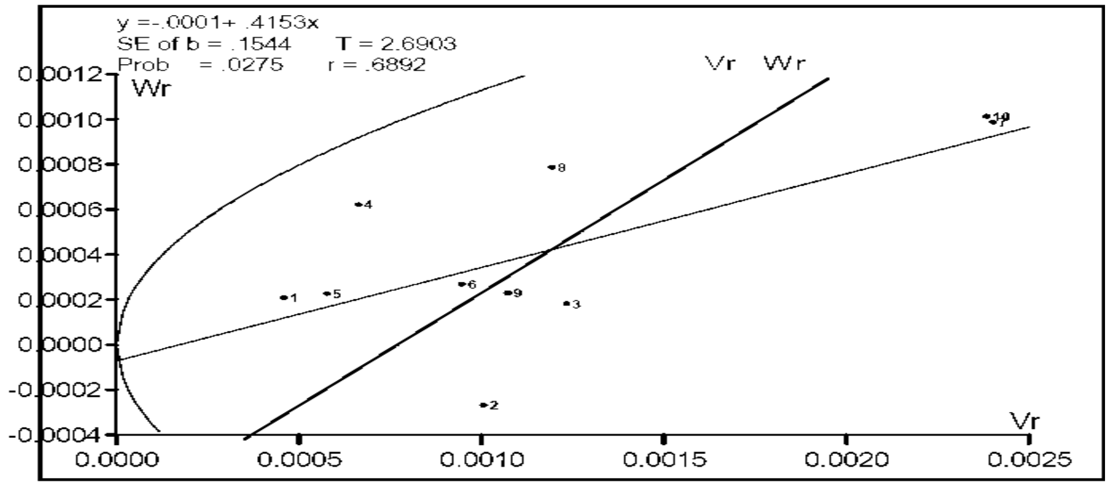


Fig 4.69 *Wr*- *Vr* graph for seed nitrogen content (%) under 75Kg N/ha

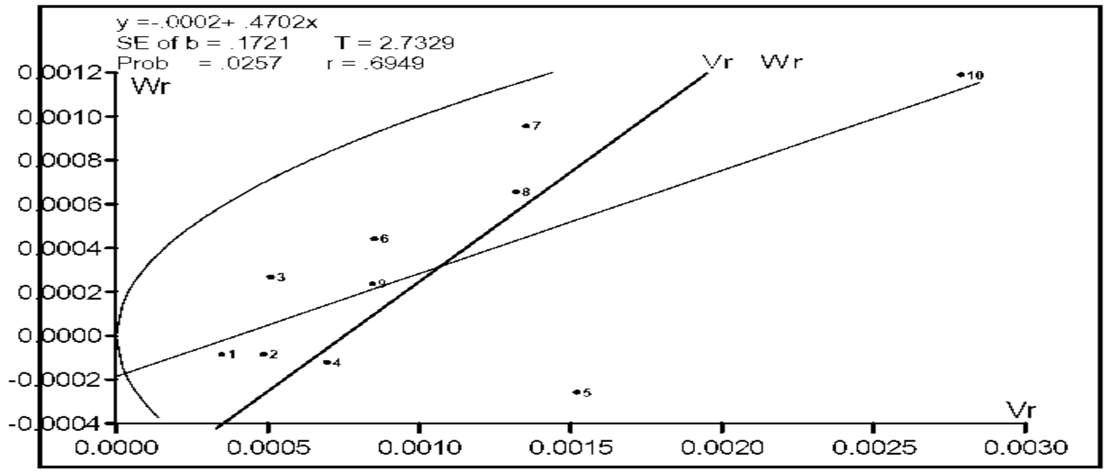


Fig 4.70 *Wr*- *Vr* graph for seed nitrogen content (%) under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

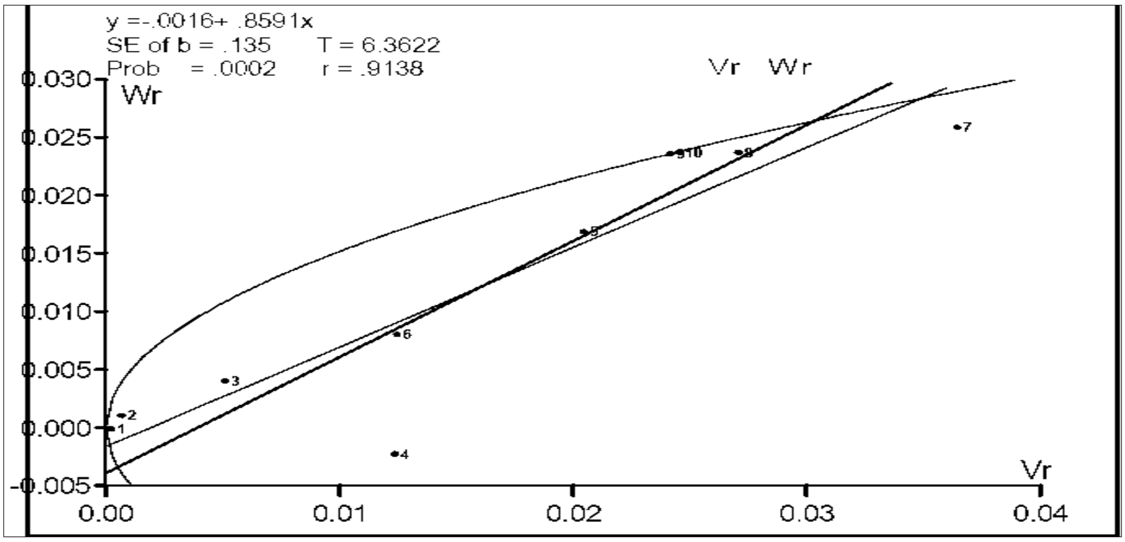


Fig 4.71 *Wr- Vr* graph for chaff nitrogen content (%) under control

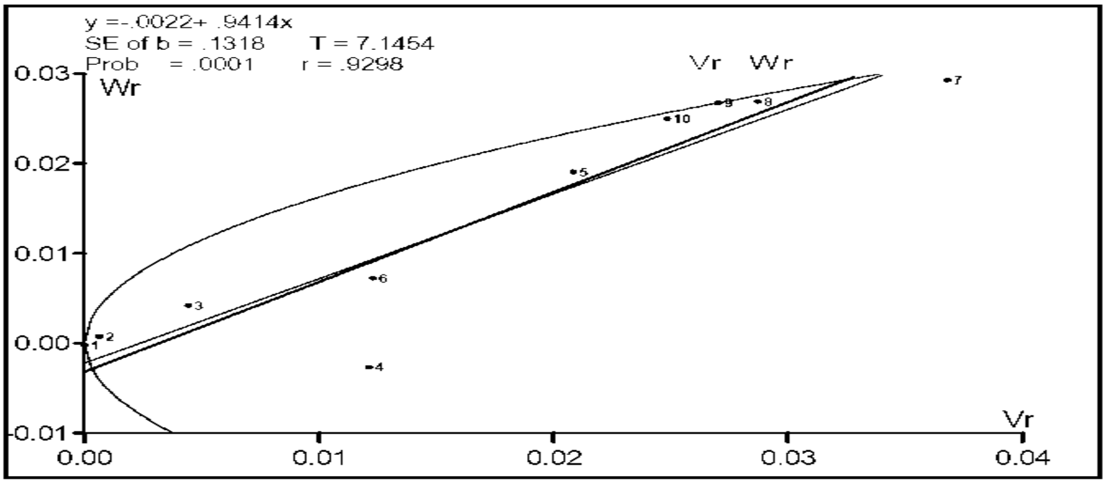


Fig 4.72 *Wr- Vr* graph for chaff nitrogen content (%) under 75Kg N/ha

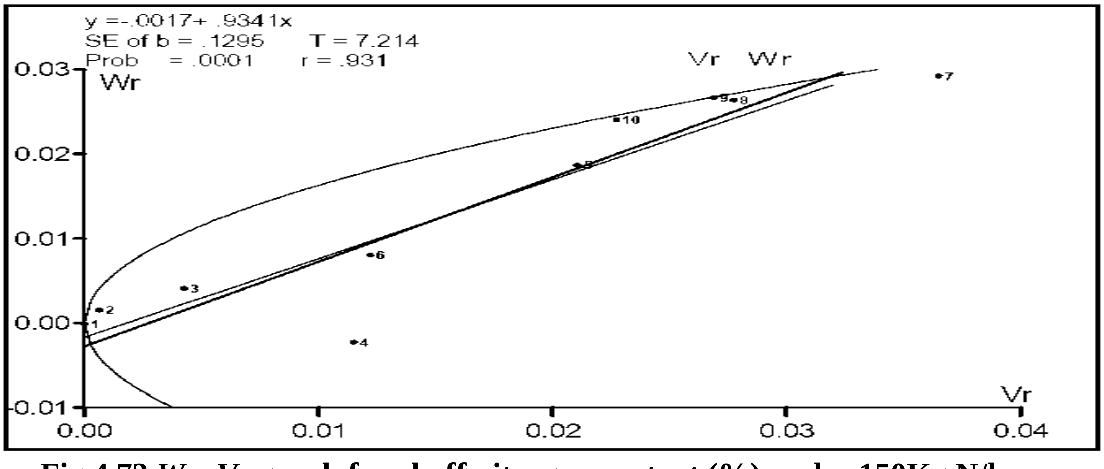


Fig 4.73 *Wr- Vr* graph for chaff nitrogen content (%) under 150Kg N/ha

Array 1= Jumka; 2= RNG-73; 3=Pusa Mustard-28; 4= Gujarat Mustard-3; 5= ZEM-1; 6= DRMR-1; 7= NRCHB-101; 8= Rh-30; 9= TM-4 and 10= KBS-3

Under 75 Kg N/ha condition, only two genotypes *viz.,* Jumka and Pusa Mustard-28 were situated in the close vicinity of the point of origin showing presence of dominant alleles in these genotypes. The genotypes TM-4 and KBS-3 were located at the far end from the origin suggesting presence of more recessive alleles in them. The intermediate positions of the remaining six genotypes i.e RNG-73, Gujarat Mustard-3, ZEM-1, DRMR-1, NRCHB-101 and RH-30 indicated for nearly equal presence of dominant and recessive alleles.

In case of 150 Kg N/ha regime, two genotypes *viz.,* Pusa Mustard-28 and NRCHB-101 were located close to the origin which points towards the presence of dominant alleles in the parents. Six genotypes *viz.,* Jumka, RNG-73, Gujarat Mustard-3, ZEM-1, DRMR-1 and RH-30 were found in the middle region of the graph which suggests equal frequencies of the recessive and dominant alleles. On the other hand two of the genotypes namely TM-4 and KBS-3 were situated at the far end from the origin indicating presence of more recessive alleles. The scattered positions of the parents under all three regimes indicated the diverse nature of parents for the trait under study.

4.6.16 Seed Nitrogen Content (%)

The additive dominance model did not comply with seed nitrogen content under all three conditions of Nitrogen (Table 4.41). Therefore only graphical approach was used for the analysis. The regression line intercepted the *Wr*-axis below the point of origin under all three regimes (Fig 4.68, 4.69 & 4.70) indicating the preponderance of overdominance in the inheritance of seed nitrogen content. Under control, four genotypes namely Jumka, RNG-73, Gujarat Mustard-3 and TM-4 showed presence of dominant alleles as evident from their close positions from the point of origin in the graph. The four genotypes namely Pusa Mustard-28, ZEM-1, DRMR-1 and RH-30 occupied middle positions in the graph depicting equal distribution of dominant and recessive alleles. However the parents NRCHB-101 and KBS-3 were located at the distant end of the graph suggesting more recessive alleles.

In case of 75 Kg N/ ha condition, two parents namely Jumka and ZEM-1 were found near to the origin showing presence of dominant alleles in the genotypes. Six genotypes *viz.*, RNG-73, Pusa Mustard-28, Gujarat Mustard-3, DRMR-1, RH-30 and TM-4 showed equal frequencies of dominant and recessive alleles owing to their intermediate positions in the graph. Two genotypes *viz.*, NRCHB-101 and KBS-3 exhibited presence of more recessive alleles as evident from their far positions in the graph from the point of origin.

Under 150 Kg N/ha condition, four genotypes *viz.*, Jumka, RNG-73, Pusa Mustard-28 and Gujarat Mustard-3 were located in the near area from the point of origin which suggests presence of dominant alleles in these genotypes. Five genotypes *viz.*, ZEM-1, DRMR-1, NRCHB-101, RH-30 and TM-4 exhibited equal frequencies of dominant and recessive alleles owing to their position in middle of graph. However one genotype *i.e.* KBS-3 also exhibited presence of more recessive alleles as evident from its far position from the point of origin.

4.6.17 Chaff Nitrogen Content (%)

The additive dominance model was found adequate for chaff Nitrogen content under all three conditions *viz.*, control, 75 Kg and 150 Kg N/ha (Table 4.41). Therefore analysis was performed by both component and graphical approach.

The component analysis revealed that additive (D) and dominance components (H1 & H2) of genetic variance were significant (Table 4.44) indicating role of additive and non-additive component in the genetic expression of chaff nitrogen content under all three nitrogen regimes. However the F value under 150 Kg N/ha condition was negative and significant denoting existence of recessive alleles in excess to the dominant alleles in parents. On the other hand the perusal of F values under control and 75 Kg N/ha suggested equal proportion of the dominant and recessive alleles for chaff nitrogen content. The ratio of mean degree of dominance was more than one for all Nitrogen levels indicating presence of overdominance. The value of H2/4H1 was below 0.25 under all three nitrogen levels indicating unequal distribution of positive and negative alleles. The ratio of dominant to recessive alleles was less than unity indicating presence of more recessive alleles in the genotypes under all three nitrogen levels for chaff nitrogen content. The narrow sense heritability was moderate under all three nitrogen levels.

The graphical analysis suggested governance of inheritance of chaff nitrogen content by over dominance as evident by the intersection of the regression line below the point of origin in all three conditions (fig 4.71, 4.72 & 4.73). The role of overdominance was also evident from the component analysis. Under all three Nitrogen regimes, three genotypes *viz.,* Jumka, RNG-73 and Pusa Mustard-28 were located near to the point of origin suggesting presence of dominant alleles in the parents for this particular trait. On the other hand, two genotypes *viz.,* Gujarat Mustard-3 and DRMR-1 showed equal frequencies of recessive and dominant alleles due to occupation of the positions in the middle region of the graph. However majority of the parental genotypes namely, ZEM-1, NRCHB-101, RH-30, TM-4 and KBS-3 were located at the far region from the point of origin depicting presence of more recessive alleles in the parents with respect to chaff nitrogen content.

4.7 Heterobeltiosis (%) and Standard Heterosis (%)

Heterobeltiosis (HB) represents the percent increase or decrease of mean value of a F1 Hybrid for a trait over the better parent while the Standard or Economic Heterosis (HE) represents the increase or decrease of mean value of F_1 Hybrid over the standard check. Both these types of heterosis are presented in Tables 4.45 to 4.53.

4.7.1 Days to Flower Initiation

The range of heterobeltiosis for days to flower initiation in control varied from -17.07 (ZEM-1 × DRMR-1) to 6.14% (RNG-73 × Pusa Mustard-28). The desirable and significantly negative heterobeltiosis was exhibited by fourteen crosses *viz.,* ZEM-1 × DRMR-1; Jumka × DRMR-1; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; RNG-73 × DRMR-1; Jumka × RH-30; Jumka × Gujarat Mustard-3; Jumka × Pusa Mustard-28; NRCHB-101 × RH-30; RNG-73 × Gujarat Mustard-3; Pusa Mustard-28 × DRMR-1; ZEM-1 × TM-4; Pusa Mustard- 28 × RH-30 and DRMR-1 × KBS-3.

Only one genotype *i.e.* RNG-73 × Pusa Mustard-28 was associated with significantly positive heterobeltiosis.

In control, the standard heterosis varied from -5.61 (ZEM-1 × NRCHB-101) to 14.95% (DRMR-1 × RH-30). Only two crosses exhibited desirable and significantly negative standard heterosis *viz.,* ZEM-1 × NRCHB-101 and ZEM-1 × DRMR-1, while twenty seven crosses *viz.,* Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × RH-30; RNG-73 × KBS-3; RH-30 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × KBS-3; RH-30 × TM-4; RNG-73 × TM-4; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; RNG-73 × DRMR-1; RNG-73 × RH-30; Jumka × NRCHB-101; RNG-73 × Gujarat Mustard-3; RNG-73 × NRCHB-101; Pusa Mustard- 28 × RH-30; DRMR-1 × RH-30; RNG-73 × Pusa Mustard-28; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × KBS-3; DRMR-1 × NRCHB -101; DRMR-1 × TM-4; Gujarat Mustard-3 × TM-4 and DRMR-1 × KBS-3 were found associated with significantly positive standard heterosis.

For 75 Kg Nitrogen per ha condition, the range varied from -18.40 (ZEM-1 × DRMR-1) to 9.26% (Pusa Mustard-28 × ZEM-1) and -4.81 (ZEM-1 × TM-4) to 18.27% (RNG-73 × Pusa Mustard-28 and Gujarat Mustard-3 × NRCHB-101) for heterobeltiosis and standard heterosis, respectively. Seventeen crosses *viz.,* ZEM-1 × DRMR-1; Jumka × DRMR-1; Pusa Mustard-28 × DRMR-1; Jumka × TM-4; RNG-73 × DRMR-1; RNG- 73 × ZEM-1; Jumka × RNG-73; Jumka × RH-30; ZEM-1 × RH-30; RNG-73 × RH-30; Jumka × Gujarat Mustard-3; ZEM-1 × TM-4; DRMR-1 × KBS-3; ZEM-1 × KBS-3; Jumka × KBS-3; Pusa Mustard- 28 × RH-30 and DRMR-1 × NRCHB -101 exhibited significantly negative and desirable heterobeltiosis while five crosses *viz.,* Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; RH-30 × TM-4 and RNG-73 × Pusa Mustard-28 were also found significantly positive in heterobeltiosis.

Twenty seven crosses *viz.*, RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × KBS-3; Pusa Mustard-28 × DRMR-1; NRCHB-101 × RH-30; Jumka × DRMR-1; Pusa Mustard-28 × KBS-3; Jumka × Gujarat Mustard-3; TM-4 × KBS-3; RNG-73 × Pusa Mustard-28; Gujarat Mustard-3 × NRCHB-101; DRMR-1 × RH-30; DRMR-1 × TM-4; Gujarat Mustard-3 × ZEM-1; DRMR-1 × NRCHB -101; RH-30 × TM-4; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × KBS-3; DRMR-1 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × DRMR-1; Jumka × NRCHB-101; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × RH-30; RH-30 × KBS-3; RNG-73 × Gujarat Mustard-3; RNG-73 × TM-4 and Gujarat Mustard-3 × TM-4 were found associated with significantly positive and undesirable Standard heterosis while none of the crosses came out to be significantly negative for standard heterosis.

In case of 150 Kg Nitrogen per ha condition, the range of heterobeltiosis varied from -13.93 (ZEM-1 × DRMR-1) to 8.18% (Pusa Mustard-28 × TM-4). Significantly negative and desirable heterobeltiosis was exhibited by seventeen crosses *viz.*, ZEM-1 × DRMR-1; RNG-73 × RH-30; ZEM-1 × KBS-3; Jumka × DRMR-1; RNG- 73 × ZEM-1; ZEM-1 × RH-30; Jumka × ZEM-1; Jumka × TM-4; Gujarat Mustard-3 × KBS-3; Jumka × RNG-73; ZEM-1 × TM-4; Jumka × RH-30; RNG-73 × KBS-3; RNG-73 × DRMR-1; Gujarat Mustard-3 × NRCHB-101; ZEM-1 × NRCHB-101 and RNG-73 × TM-4. Only three crosses *viz.*, Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × NRCHB-101 and RH-30 × TM-4 were found associated with significantly positive heterobeltiosis.

Significantly negative and desirable standard heterosis was shown by only two crosses *viz.*, ZEM-1 × KBS-3 and ZEM-1 × TM-4. Twenty four crosses *viz.*, Gujarat Mustard-3 × RH-30; RH-30 × KBS-3; RNG-73 × NRCHB-101; Gujarat Mustard-3 × TM-4; RNG-73 × DRMR-1; Gujarat Mustard-3 × NRCHB-101; RNG-73 × Pusa Mustard-28; Jumka × NRCHB-101; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; NRCHB-101 × RH-30; RNG-73 × TM-4; Pusa Mustard-28 ×

KBS-3; DRMR-1 × RH-30; DRMR-1 × TM-4; Pusa Mustard-28 × DRMR-1; RNG-73 × Gujarat Mustard-3; RH-30 × TM-4; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × DRMR-1; DRMR-1 × NRCHB -101; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4 and DRMR-1 × KBS-3 were found significantly positive and undesirable for standard heterosis.

4.7.2 Days to Fifty Percent Flowering

The range for days to fifty percent flowering in control varied from -22.75 (ZEM-1 × RH-30) to 8.00% (TM-4 × KBS-3) and from 8.4 (ZEM-1 × DRMR-1 and ZEM-1 × RH-30) to 48.74% (Gujarat Mustard-3 × TM-4) for heterobeltiosis and standard heterosis, respectively.

For heterobeltiosis, 29 crosses *viz.*, ZEM-1 × RH-30; ZEM-1 × DRMR-1; RNG-73 × RH-30; RNG-73 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × Gujarat Mustard-3; Jumka × RNG-73; Jumka × Gujarat Mustard-3; RNG-73 × DRMR-1; RNG-73 × Pusa Mustard-28; RNG-73 × TM-4; RNG-73 × KBS-3; ZEM-1 × NRCHB-101; ZEM-1 × TM-4; Jumka × RH-30; Jumka × DRMR-1; Pusa Mustard-28 × RH-30; NRCHB-101 × RH-30; Jumka × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × NRCHB-101; ZEM-1 × KBS-3; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × DRMR-1; RH-30 × TM-4; Gujarat Mustard-3 × NRCHB-101; Jumka × TM-4; RH-30 × KBS-3 and DRMR-1 × RH-30 were found significantly negative and desirable. However only five crosses *viz.*, TM-4 × KBS-3; Pusa Mustard-28 × ZEM-1; DRMR-1 × KBS-3; Pusa Mustard- 28 × TM-4 and DRMR-1 × TM-4 were found significantly positive for heterobeltiosis for this trait which was undesirable.

For Standard heterosis, the entire cross combinations exhibited significantly positive values which were undesirable and none of the crosses exhibited desirable feature for the trait.

Table 4.45 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for days to flower initiation and days to fifty percent flowering under different nitrogen levels

Genotypes		Days to Flower Initiation						Days to Fifty Percent Flowering					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1.	Jumka × RNG-73	-0.89	3.74	-7.69 **	3.85	-5.93 **	2.78	-15.70 **	21.85**	-11.31 **	28.45**	-8.54 **	23.97**
2.	Jumka × Pusa Mustard-28	-6.14 **	0	-3.57	3.85	-3.48	2.78	-8.44 **	18.49**	-8.23 **	25**	-5.81 **	20.66**
3.	Jumka × Gujarat Mustard-3	-6.72 **	3.74	-6.78 **	5.77*	-3.45	3.7	-15.52 **	23.53**	-13.17 **	25**	-13.61 **	20.66**
4.	Jumka × ZEM-1	0.92	2.8	-4.46	2.88	-6.09 **	0	1.42	20.17**	5.76 **	26.72**	6.43 **	23.14**
5.	Jumka × DRMR-1	-10.57 **	2.8	-11.20 **	6.73**	-8.20 **	3.7	-9.94 **	21.85**	-10.00 **	24.14**	-8.18 **	20.66**
6.	Jumka × NRCHB-101	1.82	4.67*	3.57	11.54**	-0.87	5.56**	-6.58 **	19.33**	-9.74 **	19.83**	-9.03 **	16.53**
7.	Jumka × RH-30	-6.84 **	1.87	-7.08 **	0.96	-5.22 **	0.93	-10.78 **	25.21**	-9.76 **	27.59**	-6.29 **	23.14**
8.	Jumka × TM-4	-1.83	0	-8.93 **	-1.92	-6.09 **	0	-3.33 **	21.85**	-3.92 *	26.72**	-5.13 **	22.31**
9.	Jumka × KBS-3	0	1.87	-5.36 *	1.92	-3.48	2.78	-0.71	17.65**	3.62	23.28**	2.14	18.18**
10.	RNG-73 × Pusa Mustard-28	6.14 **	13.08**	5.13 *	18.27**	-2.54	6.48**	-13.95 **	24.37**	-11.90 **	27.59**	-8.54 **	23.97**
11.	RNG-73 × Gujarat Mustard-3	-5.88 **	4.67*	-2.54	10.58**	2.54	12.04**	-16.09 **	22.69**	-14.29 **	24.14**	-13.61 **	20.66**
12.	RNG- 73 × ZEM-1	-0.89	3.74	-8.55 **	2.88	-7.63 **	0.93	-16.28 **	21.01**	-12.50 **	26.72**	-9.15 **	23.14**
13.	RNG-73 × DRMR-1	-8.13 **	5.61**	-8.80 **	9.62**	-4.92 **	7.41**	-15.12 **	22.69**	-11.31 **	28.45**	-7.93 **	24.79**
14.	RNG-73 × NRCHB-101	0	4.67*	-2.56	9.62**	-0.85	8.33**	-18.02 **	18.49**	-16.07 **	21.55**	-12.80 **	18.18**
15.	RNG-73 × RH-30	-3.42	5.61**	-6.84 **	4.81	-9.32 **	-0.93	-18.60 **	17.65**	-13.69 **	25**	-10.37 **	21.49**
16.	RNG-73 × TM-4	1.79	6.54**	-1.71	10.58**	-4.24 *	4.63*	-13.95 **	24.37**	-13.10 **	25.86**	-9.15 **	23.14**
17.	RNG-73 × KBS-3	3.57	8.41**	-2.56	9.62**	-5.08 **	3.7	-13.95 **	24.37**	-12.50 **	26.72**	-9.15 **	23.14**
18.	Pusa Mustard-28 × Gujarat Mustard-3	-3.36	7.48**	-0.85	12.5**	-1.72	5.56**	-8.05 **	34.45**	-1.8	41.38**	-1.78	37.19**
19.	Pusa Mustard-28 × ZEM-1	0	6.54**	9.26 **	13.46**	3.64	5.56**	5.84 **	36.97**	3.80 *	41.38**	7.10 **	37.19**
20.	Pusa Mustard-28 × DRMR-1	-4.88 **	9.35**	-10.40 **	7.69**	0	12.96**	-3.73 **	30.25**	-0.63	37.07**	1.26	33.06**
21.	PusaMustard-28 × NRCHB-101	0	6.54**	7.41 **	11.54**	7.21 **	10.19**	0.65	30.25**	-1.27	34.48**	2.58	31.4**
22.	Pusa Mustard- 28 × RH-30	-4.27 *	4.67*	-5.31 *	2.88	-3.48	2.78	-9.58 **	26.89**	-6.10 **	32.76**	-0.63	30.58**

Genotypes		Days to Flower Initiation						Days to Fifty Percent Flowering					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
23.	Pusa Mustard- 28 × TM-4	0	6.54**	7.41 **	11.54**	8.18 **	10.19**	3.25 **	33.61**	3.16	40.52**	5.13 **	35.54**
24.	Pusa Mustard-28 × KBS-3	0.88	7.48**	2.78	6.73**	2.73	4.63*	0	29.41**	0	36.21**	4.52 **	33.88**
25.	Gujarat Mustard-3 × ZEM-1	1.68	13.08**	0.85	14.42**	3.45	11.11**	-1.72	43.7**	0	43.97**	-0.59	38.84**
26.	Gujarat Mustard-3 × NRCHB-101	-2.44	12.15**	-1.6	18.27**	-4.92 **	7.41**	-3.45 **	41.18**	0	43.97**	-0.59	38.84**
27.	Gujarat Mustard-3 × DRMR-1	1.68	13.08**	-0.85	12.5**	3.45	11.11**	-5.17 **	38.66**	-2.4	40.52**	-2.37	36.36**
28.	Gujarat Mustard-3 × RH-30	-1.68	9.35**	-1.69	11.54**	1.72	9.26**	0.57	47.06**	5.99 **	52.59**	5.33 **	47.11**
29.	Gujarat Mustard-3 × TM-4	-0.84	10.28**	-2.54	10.58**	0.86	8.33**	1.72	48.74**	5.99 **	52.59**	5.92 **	47.93**
30.	Gujarat Mustard-3 × KBS-3	0.84	12.15**	0	13.46**	-6.03 **	0.93	-1.15	44.54**	2.4	47.41**	2.37	42.98**
31.	ZEM-1 × DRMR-1	-17.07 **	-4.67*	-18.40 **	-1.92	-13.93 **	-2.78	-19.88 **	8.4**	-15.63 **	16.38**	-12.58 **	14.88**
32.	ZEM-1 × NRCHB-101	-8.18 **	-5.61**	-4.63	-0.96	-4.50 *	-1.85	-13.16 **	10.92**	-12.99 **	15.52**	-10.32 **	14.88**
33.	ZEM-1 × RH-30	-10.26 **	-1.87	-7.08 **	0.96	-6.96 **	-0.93	-22.75 **	8.4**	-20.12 **	12.93**	-15.09 **	11.57**
34.	ZEM-1 × TM-4	-4.59 *	-2.8	-5.71 *	-4.81	-5.61 **	-6.48**	-11.33 **	11.76**	-15.03 **	12.07**	-15.38 **	9.09**
35.	ZEM-1 × KBS-3	-0.95	-2.8	-5.56 *	-1.92	-8.26 **	-7.41**	-5.76 **	10.08**	-3.6	15.52**	-1.46	11.57**
36.	DRMR-1 × NRCHB -101	-3.25	11.21**	-4.80 *	14.42**	-1.64	11.11**	0	35.29**	1.25	39.66**	2.52	34.71**
37.	DRMR-1 × RH-30	0	14.95**	-3.2	16.35**	0.82	13.89**	-2.40 *	36.97**	0	41.38**	4.40 **	37.19**
38.	DRMR-1 × TM-4	-3.25	11.21**	-4	15.38**	0.82	13.89**	2.48 *	38.66**	3.75 *	43.1**	5.03 **	38.02**
39.	DRMR-1 × KBS-3	-4.07 *	10.28**	-5.60 **	13.46**	-2.46	10.19**	3.73 **	40.34**	5.00 **	44.83**	6.29 **	39.67**
40.	NRCHB-101 × RH-30	-5.98 **	2.8	-0.88	7.69**	-0.87	5.56**	-9.58 **	26.89**	-7.32 **	31.03**	-2.52	28.1**
41.	NRCHB-101 × TM-4	0.91	3.74	-0.93	2.88	-1.8	0.93	1.97	30.25**	0.65	33.62**	0.64	29.75**
42.	NRCHB-101 × KBS-3	0	2.8	0.93	4.81	0	2.78	-1.32	26.05**	-0.65	31.9**	0	28.1**
43.	RH-30 × TM-4	-1.71	7.48**	5.31 *	14.42**	5.22 **	12.04**	-3.59 **	35.29**	-1.22	39.66**	3.14 *	35.54**
44.	RH-30 × KBS-3	-0.85	8.41**	2.65	11.54**	2.61	9.26**	-2.99 **	36.13**	0	41.38**	3.77 **	36.36**
45.	TM-4 × KBS-3	-0.92	0.93	1.85	5.77*	0	0.93	8.00 **	36.13**	7.84 **	42.24**	7.05 **	38.02**

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.46 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for days to maturity and plant height (cm) under different nitrogen levels

	Genotypes	Days to Maturity						Plant Height (cm)					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1.	Jumka × RNG-73	-5.43 **	-2.97**	-5.47 **	-5.82**	-8.54 **	-8.54**	-26.85 **	-8.63**	-25.19 **	-9.26**	-25.00 **	-9.17**
2.	Jumka × Pusa Mustard-28	-2.26 **	-3.35**	-1.92	-6.91**	0.38	-5.34**	-25.00 **	-9.9**	-25.59 **	-12.04**	-25.39 **	-11.93**
3.	Jumka × Gujarat Mustard-3	-6.81 **	-3.35**	-5.78 **	-5.09**	-5.32 **	-4.98**	-22.89 **	-6.39**	-22.60 **	-8.02**	-22.22 **	-7.95**
4.	Jumka × ZEM-1	-8.68 **	-2.23**	-10.49 **	-6.91**	-3.56 **	-3.56**	0	-5.11**	-2.62 *	-8.33**	-1.96 *	-8.26**
5.	Jumka × DRMR-1	-3.33 **	-2.97**	-3.40 **	-6.91**	-3.31 **	-6.41**	-18.03 **	-7.03**	-17.68 **	-8.02**	-17.26 **	-7.65**
6.	Jumka × NRCHB-101	-4.36 **	-2.23**	-6.18 **	-6.18**	-6.79 **	-7.12**	-21.56 **	-7.03**	-20.74 **	-8.02**	-20.58 **	-7.95**
7.	Jumka × RH-30	-3.32 **	-2.6**	-1.12	-4**	-3.72 **	-7.83**	-28.35 **	-11.18**	-27.25 **	-12.65**	-26.09 **	-11.62**
8.	Jumka × TM-4	-0.75	-2.23**	0.76	-3.27**	-1.83 *	-4.63**	-18.80 **	-8.95**	-18.54 **	-10.49**	-18.66 **	-10.7**
9.	Jumka × KBS-3	1.54	-1.86*	3.46 **	-2.18*	3.83 **	-3.56**	-6.73 **	-11.5**	-6.60 **	-12.65**	-6.54 **	-12.54**
10.	RNG-73 × Pusa Mustard-28	-1.09	1.49	-1.82	-2.18*	-6.05 **	-6.05**	-3.84 **	20.13**	-3.31 **	17.28**	-3.03 **	17.43**
11.	RNG-73 × Gujarat Mustard-3	-2.87 **	0.74	-3.61 **	-2.91**	-6.03 **	-5.69**	0	24.92**	-0.51	20.68**	-0.25	20.8**
12.	RNG- 73 × ZEM-1	-7.64 **	-1.12	-5.24 **	-1.45	-4.63 **	-4.63**	0.77	25.88**	1.02	22.53**	0.76	22.02**
13.	RNG-73 × DRMR-1	-1.81 *	0.74	-2.55 **	-2.91**	-7.12 **	-7.12**	-1.28	23.32**	-1.02	20.06**	-1.01	19.88**
14.	RNG-73 × NRCHB-101	-1.45	1.12	-2.55 **	-2.55**	-1.78 *	-1.78*	-0.77	23.96**	-0.51	20.68**	-1.01	19.88**
15.	RNG-73 × RH-30	-1.09	1.49	0	-0.36	-2.49 **	-2.49**	-1.02	23.64**	-0.51	20.68**	-1.01	19.88**
16.	RNG-73 × TM-4	-3.99 **	-1.49	-4.74 **	-5.09**	-6.05 **	-6.05**	-1.79	22.68**	-2.04 *	18.83**	-2.02 **	18.65**
17.	RNG-73 × KBS-3	-1.45	1.12	-2.55 **	-2.91**	-2.85 **	-2.85**	-4.09 **	19.81**	-2.29 *	18.52**	-2.27 **	18.35**
18.	Pusa Mustard-28 × Gujarat Mustard-3	-4.66 **	-1.12	-3.61 **	-2.91**	-4.26 **	-3.91**	-1.84	19.17**	-1.56	16.98**	-1.29	16.82**
19.	Pusa Mustard-28 × ZEM-1	-6.94 **	-0.37	-4.90 **	-1.09	-2.85 **	-2.85**	1.6	22.04**	0.52	18.83**	0.52	18.65**
20.	Pusa Mustard-28 × DRMR-1	-0.74	-0.37	-0.38	-4**	-1.84 *	-4.98**	3.46 **	24.28**	2.09 *	20.68**	1.81 **	20.18**
21.	PusaMustard-28 × NRCHB-101	-2.91 **	-0.74	-2.55 **	-2.55**	-3.57 **	-3.91**	3.72 **	24.6**	3.39 **	22.22**	3.11 **	21.71**
22.	Pusa Mustard- 28 × RH-30	0	0.74	-1.5	-4.36**	-1.49	-5.69**	0.77	24.92**	1.54	21.91**	1.53 *	21.41**

Genotypes		Days to Maturity						Plant Height (cm)					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
23.	Pusa Mustard- 28 × TM-4	1.88 *	0.74	0.38	-3.64**	1.83 *	-1.07	1.6	22.04**	1.57	20.06**	1.3	19.57**
24.	Pusa Mustard-28 × KBS-3	0	-1.12	0	-5.09**	2.26 *	-3.56**	1.33	21.73**	1.04	19.44**	1.04	19.27**
25.	Gujarat Mustard-3 × ZEM-1	-5.21 **	1.49	-4.55 **	-0.73	-3.90 **	-3.56**	-0.53	20.77**	-0.52	18.21**	0	18.35**
26.	Gujarat Mustard-3 × NRCHB-101	-2.87 **	0.74	-0.72	0	-2.84 **	-2.49**	-0.53	20.77**	-0.52	18.21**	0	18.35**
27.	Gujarat Mustard-3 × DRMR-1	-2.51 **	1.12	-3.25 **	-2.55**	-2.13 *	-1.78*	1.32	23**	0.52	19.44**	0.52	18.96**
28.	Gujarat Mustard-3 × RH-30	-3.58 **	0	-3.25 **	-2.55**	-3.90 **	-3.56**	-4.12 **	18.85**	-2.57 **	16.98**	-1.53 *	17.74**
29.	Gujarat Mustard-3 × TM-4	-2.87 **	0.74	-0.72	0	-4.96 **	-4.63**	-2.11	18.85**	-2.60 **	15.74**	-1.29	16.82**
30.	Gujarat Mustard-3 × KBS-3	-3.58 **	0	-1.08	-0.36	-4.61 **	-4.27**	-1.84	19.17**	-2.60 **	15.74**	-2.07 **	15.9**
31.	ZEM-1 × DRMR-1	0	7.06**	3.15 **	7.27**	5.69 **	5.69**	-16.62 **	-5.43**	-16.57 **	-6.79**	-16.44 **	-6.73**
32.	ZEM-1 × NRCHB-101	1.04	8.18**	4.20 **	8.36**	7.12 **	7.12**	-22.91 **	-8.63**	-21.28 **	-8.64**	-21.11 **	-8.56**
33.	ZEM-1 × RH-30	0.69	7.81**	3.15 **	7.27**	5.69 **	5.69**	-24.23 **	-6.07**	-23.39 **	-8.02**	-23.02 **	-7.95**
34.	ZEM-1 × TM-4	1.04	8.18**	1.4	5.45**	3.91 **	3.91**	-17.38 **	-7.35**	-17.70 **	-9.57**	-17.27 **	-9.17**
35.	ZEM-1 × KBS-3	1.39	8.55**	3.15 **	7.27**	6.05 **	6.05**	1.02	-5.43**	-1.31	-7.1**	-0.65	-7.03**
36.	DRMR-1 × NRCHB -101	-2.18 **	0	-0.73	-0.73	-2.14 *	-2.49**	-1.08	17.25**	-0.8	15.12**	-0.79	14.98**
37.	DRMR-1 × RH-30	-1.11	-0.37	1.87	-1.09	0.74	-2.49**	-4.12 **	18.85**	-3.34 **	16.05**	-3.07 **	15.9**
38.	DRMR-1 × TM-4	1.11	1.49	3.77 **	0	1.47	-1.42	4.23 **	18.21**	4.14 **	16.36**	4.11 **	16.21**
39.	DRMR-1 × KBS-3	-0.37	0	2.26 *	-1.45	0	-3.2**	1.97	15.65**	1.93 *	13.89**	1.64 *	13.46**
40.	NRCHB-101 × RH-30	0	2.23**	1.45	1.45	0.36	0	-6.96 **	15.34**	-5.91 **	12.96**	-5.63 **	12.84**
41.	NRCHB-101 × TM-4	-0.73	1.49	0.36	0.36	-0.71	-1.07	-2.70 *	15.34**	-2.13 *	13.58**	-2.11 **	13.46**
42.	NRCHB-101 × KBS-3	-1.82 *	0.37	-0.36	-0.36	-1.43	-1.78*	-2.43 *	15.65**	-1.33	14.51**	-1.58 *	14.07**
43.	RH-30 × TM-4	0.37	1.12	3.75 **	0.73	2.20 *	-0.71	-3.35 **	19.81**	-2.31 *	17.28**	-2.30 **	16.82**
44.	RH-30 × KBS-3	-0.37	0.37	2.25 *	-0.73	1.86 *	-2.49**	-4.12 **	18.85**	-3.86 **	15.43**	-3.58 **	15.29**
45.	TM-4 × KBS-3	-0.75	-2.23**	-0.38	-4.36**	-2.93 **	-5.69**	0	12.14**	-0.56	9.26**	-0.84	8.87**

*Significance P ≤0.05; ** Significance P ≤0.01

Under 75 Kg Nitrogen per ha condition, the range for heterobeltiosis varied from -20.12 (ZEM-1 × RH-30) to 7.84% (TM-4 × KBS-3). Twenty one cross combinations *viz.,* ZEM-1 × RH-30; RNG-73 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × TM-4; RNG-73 × Gujarat Mustard-3; RNG-73 × RH-30; Jumka × Gujarat Mustard-3; RNG-73 × TM-4; ZEM-1 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × KBS-3; RNG-73 × Pusa Mustard-28; Jumka × RNG-73; RNG-73 × DRMR-1; Jumka × DRMR-1; Jumka × RH-30; Jumka × NRCHB-101; Jumka × Pusa Mustard-28; NRCHB-101 × RH-30; Pusa Mustard- 28 × RH-30 and Jumka × TM-4 were found associated with desirable and significantly negative heterobeltiosis.

On the other hand only seven crosses *viz.,* TM-4 × KBS-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; Jumka × ZEM-1; DRMR-1 × KBS-3; Pusa Mustard-28 × ZEM-1 and DRMR-1 × TM-4 exhibited significantly positive heterobeltiosis. In case of Standard heterobeltiosis the range in the same condition varied from 12.07 (ZEM-1 × TM-4) to 52.59% (Gujarat Mustard-3 × RH-30). Here again, all the cross combinations exhibited significantly positive standard heterosis which was undesirable for the trait.

For the condition of 150 Kg Nitrogen per ha, the range of for heterobeltiosis varied from -15.38 (ZEM-1 × TM-4) to 7.10% (Pusa Mustard-28 × ZEM-1). Nineteen crosses *viz.,* ZEM-1 × TM-4; ZEM-1 × RH-30; Jumka × Gujarat Mustard-3; RNG-73 × Gujarat Mustard-3; RNG-73 × NRCHB-101; ZEM-1 × DRMR-1; RNG-73 × RH-30; ZEM-1 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × TM-4; RNG-73 × KBS-3; Jumka × NRCHB-101; Jumka × RNG-73; RNG-73 × Pusa Mustard-28; Jumka × DRMR-1; RNG-73 × DRMR-1; Jumka × RH-30; Jumka × Pusa Mustard-28 and Jumka × TM-4 exhibited significant level of desirable negative heterobeltiosis for the trait.

However twelve cross combinations *viz.,* Pusa Mustard-28 × ZEM-1; TM-4 × KBS-3; Jumka × ZEM-1; DRMR-1 × KBS-3; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × RH-30; Pusa Mustard- 28 × TM-4; DRMR-1 × TM-4; Pusa Mustard-28 × KBS-3; DRMR-1 × RH-30; RH-30 × KBS-3 and RH-30 × TM-4 also exhibited significantly positive heterobeltiosis which was undesirable for the trait. The range for Standard heterosis among the cross combinations was from 9.09 (ZEM-1 × TM-4) to 47.93 (Gujarat Mustard-3 × TM-4). Here again, all the crosses exhibited significant level of positive standard heterosis which was undesirable for the trait.

4.7.3 Days to Maturity

The range of heterobeltiosis for days to maturity in control varied from -8.68 (Jumka × ZEM-1) to 1.88% (Pusa Mustard-28 × TM-4). Twenty two crosses *viz.,* Jumka × ZEM-1; RNG- 73 × ZEM-1; Pusa Mustard-28 × ZEM-1; Jumka × Gujarat Mustard-3; Jumka × RNG-73; Gujarat Mustard-3 × ZEM-1; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × NRCHB-101; RNG-73 × TM-4; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × KBS-3; Jumka × DRMR-1; Jumka × RH-30; Pusa Mustard-28 × NRCHB-101; RNG-73 × Gujarat Mustard-3; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × DRMR-1; Jumka × Pusa Mustard-28; DRMR-1 × NRCHB -101; NRCHB-101 × KBS-3 and RNG-73 × DRMR-1 were associated with significantly negative heterobeltiosis values which are desirable for the trait.

On the other hand, only one cross combination *i.e.* Pusa Mustard-28 × TM-4 exhibited significantly positive heterobeltiosis for this trait. The range varied from -3.35 (Jumka × Pusa Mustard-28 and Jumka × Gujarat Mustard-3) to 8.55% (ZEM-1 × KBS-3) for Standard heterosis in case of control. Six cross combinations *viz.*, ZEM-1 × KBS-3; ZEM-1 × NRCHB-101; ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × DRMR-1 and NRCHB-101 × RH-30 were found significantly positive and undesirable for standard heterosis of the trait. However ten crosses *viz.,* Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × RNG-73; Jumka × DRMR-1; Jumka × RH-30; Jumka × ZEM-1; Jumka × NRCHB-101; Jumka × TM-4; TM-4 × KBS-3 and Jumka × KBS-3 also exhibited significant level of negative standard heterosis which was desirable for the character.

For the condition of 75 Kg Nitrogen per ha, the range for heterobeltiosis varied from -10.49 (Jumka × ZEM-1) to 4.20% (ZEM-1 × NRCHB-101). Seventeen cross combinations *viz.,* Jumka × ZEM-1; Jumka × NRCHB-101; Jumka × Gujarat Mustard-3; Jumka × RNG-73; RNG- 73 × ZEM-1; Pusa Mustard-28 × ZEM-1; RNG-

73 × TM-4; Gujarat Mustard-3 × ZEM-1; RNG-73 × Gujarat Mustard-3; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × DRMR-1; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × KBS-3 and Pusa Mustard-28 × NRCHB-101 exhibited significantly negative and desirable heterobeltiosis for the trait. Significant level of positive heterobeltiosis was also exhibited by nine crosses *viz.*, ZEM-1 × NRCHB-101; DRMR-1 × TM-4; RH-30 × TM-4; Jumka × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × RH-30; ZEM-1 × KBS-3; DRMR-1 × KBS-3 and RH-30 × KBS-3, which was undesirable for the trait.

The range for standard heterosis among the crosses varied from -6.91 (Jumka × Pusa Mustard-28; Jumka × ZEM-1 and Jumka × DRMR-1) to 8.36% (ZEM-1 × NRCHB-101) for days to maturity under this condition. Significant level of negative and desirable standard/economic heterosis was exhibited by twenty four crosses *viz.*, Jumka × Pusa Mustard-28; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RNG-73; Jumka × Gujarat Mustard-3; RNG-73 × TM-4; Pusa Mustard-28 × KBS-3; Pusa Mustard- 28 × RH-30; TM-4 × KBS-3; Jumka × RH-30; Pusa Mustard-28 × DRMR-1; Pusa Mustard- 28 × TM-4; Jumka × TM-4; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; RNG-73 × NRCHB-101; Pusa Mustard-28 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; Jumka × KBS-3 and RNG-73 × Pusa Mustard-28. Five cross combinations *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × RH-30; ZEM-1 × KBS-3 and ZEM-1 × TM-4 were found associated with significantly positive standard heterosis.

Under 150 Kg Nitrogen per ha condition, the range varied from -8.54 (Jumka × RNG-73) to 7.12% (ZEM-1 × NRCHB-101) and -8.54 (Jumka × RNG-73) to 6.05% (ZEM-1 × KBS-3) for heterobeltiosis and standard heterosis, respectively. Twenty seven cross combinations Jumka × RNG-73; RNG-73 × DRMR-1; Jumka × NRCHB-101; RNG-73 × Pusa Mustard-28; RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; Jumka × Gujarat Mustard-3; Gujarat Mustard-3 × TM-4; RNG- 73 × ZEM-1; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × RH-30; Jumka × RH-30; Pusa Mustard-28 × NRCHB-101; Jumka × ZEM-1; Jumka × DRMR-1; TM-4 × KBS-3; RNG-73 × KBS-3; Pusa

Mustard-28 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; RNG-73 × RH-30; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × DRMR-1; Jumka × TM-4 and RNG-73 × NRCHB-101 were found associated with significantly negative and desirable heterobeltiosis.

Similarly, thirty five crosses *viz.*, Jumka × RNG-73; Jumka × RH-30; Jumka × NRCHB-101; RNG-73 × DRMR-1; Jumka × DRMR-1; RNG-73 × Pusa Mustard-28; RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; Pusa Mustard- 28 × RH-30; TM-4 × KBS-3; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × DRMR-1; Jumka × TM-4; RNG- 73 × ZEM-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × NRCHB-101; Jumka × ZEM-1; Jumka × KBS-3; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × RH-30; DRMR-1 × KBS-3; RNG-73 × KBS-3; Pusa Mustard-28 × ZEM-1; RNG-73 × RH-30; Gujarat Mustard-3 × NRCHB-101; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; RH-30 × KBS-3; RNG-73 × NRCHB-101; Gujarat Mustard-3 × DRMR-1 and NRCHB-101 × KBS-3 were found associated with significantly negative and desirable standard heterosis. Significantly positive heterobeltiosis was exhibited by ten crosses *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × RH-30; ZEM-1 × TM-4; Jumka × KBS-3; Pusa Mustard-28 × KBS-3; RH-30 × TM-4; RH-30 × KBS-3 and Pusa Mustard- 28 × TM-4. However, only five cross combinations were associated with significant level of positive standard heterosis *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × RH-30 and ZEM-1 × TM-4.

4.7.4 Plant Height (cm)

In case of control, the range of heterobeltiosis for plant height varied from -28.35 (Jumka × RH-30) to 4.23% (DRMR-1 × TM-4). The desirable and significantly negative heterobeltiosis was exhibited by twenty one crosses *viz.*, Jumka × RH-30; Jumka × RNG-73; Jumka × Pusa Mustard-28; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; Jumka × Gujarat Mustard-3; Jumka × NRCHB-101; Jumka × TM-4; Jumka × DRMR-1; ZEM-1 × TM-4; ZEM-1 × DRMR-1; NRCHB-101 × RH-30; Jumka × KBS-3; Gujarat Mustard-3 × RH-30; DRMR-1 × RH-30; RH-30 × KBS-3; RNG-73 ×

KBS-3; RNG-73 × Pusa Mustard-28; RH-30 × TM-4; NRCHB-101 × TM-4 and NRCHB-101 × KBS-3. However, in this condition only three cross combinations were found associated with significant level of positive heterobeltiosis.

The range of standard heterosis varied from -9.9 (Jumka × Pusa Mustard-28) to 25.88% (RNG-73 × ZEM-1) for plant height in control. Fourteen cross combinations *viz.*, Jumka × Pusa Mustard-28; Jumka × TM-4; Jumka × RNG-73; ZEM-1 × NRCHB-101; ZEM-1 × TM-4; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × Gujarat Mustard-3; ZEM-1 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; Jumka × ZEM-1; Jumka × KBS-3 and Jumka × RH-30 were found associated with significantly negative standard heterosis. Rest of all crosses exhibited significantly positive and undesirable standard heterosis for the trait.

Under 75 Kg Nitrogen per ha condition, the range of heterobeltiosis among cross combinations varied from -27.25 (Jumka × RH-30) to 4.14% (DRMR-1 × TM-4). Twenty four crosses *viz.*, Jumka × RH-30; Jumka × Pusa Mustard-28; Jumka × RNG-73; ZEM-1 × RH-30; Jumka × Gujarat Mustard-3; ZEM-1 × NRCHB-101; Jumka × NRCHB-101; Jumka × TM-4; ZEM-1 × TM-4; Jumka × DRMR-1; ZEM-1 × DRMR-1; Jumka × KBS-3; NRCHB-101 × RH-30; RH-30 × KBS-3; DRMR-1 × RH-30; RNG-73 × Pusa Mustard-28; Jumka × ZEM-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × RH-30; RH-30 × TM-4; RNG-73 × KBS-3; NRCHB-101 × TM-4 and RNG-73 × TM-4 exhibited significantly negative and desirable heterobeltiosis for plant height under this condition. However, only four cross combinations *viz.*, DRMR-1 × TM-4; Pusa Mustard-28 × NRCHB-101; Pusa Mustard-28 × DRMR-1 and DRMR-1 × KBS-3 were found significantly positive for heterobeltiosis under this condition.

The range for standard heterosis in this condition varied from -12.65 (Jumka × RH-30 and Jumka × KBS-3) to 22.53% (RNG-73 × ZEM-1). The desirable and significantly negative standard heterosis was exhibited by fourteen crosses *viz.*, Jumka × RH-30; Jumka × KBS-3; Jumka × Pusa Mustard-28; Jumka × TM-4; ZEM-1 × TM-4; Jumka × RNG-73; ZEM-1 × NRCHB-101; Jumka × ZEM-1; Jumka × Gujarat Mustard-3; Jumka × DRMR-1; Jumka × NRCHB-101; ZEM-1 × RH-30; ZEM-1 ×

KBS-3 and ZEM-1 × DRMR-1. Rest of thirty one cross combinations were found associated with significantly positive standard heterosis in this condition.

For 150 Kg Nitrogen per ha condition, -26.09 (Jumka × RH-30) to 4.11% (DRMR-1 × TM-4) and -12.54 (Jumka × KBS-3) to 22.02% (RNG-73 × ZEM-1) was the range for heterobeltiosis and standard heterosis, respectively. Twenty four cross combinations *viz.,* Jumka × RH-30; Jumka × Pusa Mustard-28; Jumka × RNG-73; ZEM-1 × RH-30; Jumka × Gujarat Mustard-3; ZEM-1 × NRCHB-101; Jumka × NRCHB-101; Jumka × TM-4; ZEM-1 × TM-4; Jumka × DRMR-1; ZEM-1 × DRMR-1; Jumka × KBS-3; NRCHB-101 × RH-30; RH-30 × KBS-3; DRMR-1 × RH-30; RNG-73 × Pusa Mustard-28; RH-30 × TM-4; RNG-73 × KBS-3; NRCHB-101 × TM-4; Gujarat Mustard-3 × KBS-3; RNG-73 × TM-4; Jumka × ZEM-1; NRCHB-101 × KBS-3 and Gujarat Mustard-3 × RH-30 were found significantly negative for heterobeltiosis which was desirable . However, only five crosses *viz.,* DRMR-1 × TM-4; Pusa Mustard-28 × NRCHB-101; Pusa Mustard-28 × DRMR-1; DRMR-1 × KBS-3 and Pusa Mustard- 28 × RH-30 exhibited significantly positive heterobeltiosis for the trait.

Fourteen crosses *viz.,* Jumka × RNG-73; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; Jumka × ZEM-1; Jumka × Gujarat Mustard-3; Jumka × NRCHB-101; ZEM-1 × RH-30; Jumka × DRMR-1; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; Jumka × KBS-3; Jumka × Pusa Mustard-28; Jumka × RH-30 and Jumka × TM-4 were found associated with significantly negative and desirable standard heterosis for the trait. Rest of all cross combinations (Thirty one), were found associated with significantly positive standard heterosis for the trait under this condition.

4.7.5 Number of Primary Branches per Plant

The range of heterobeltiosis for number of primary branches per plant in control varied from -43.48 (ZEM-1 × NRCHB-101) to 11.59% (Pusa Mustard-28 × KBS-3). The desirable and significantly positive heterobeltiosis was exhibited by none of the cross combinations. Only two cross combinations *i.e.* ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1 were associated with significantly negative heterobeltiosis.

Economic heterosis under same condition varied from -45.51 (ZEM-1 × NRCHB-101) to 7.19 (Jumka × NRCHB-101).

Six crosses exhibited significantly negative economic heterosis *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × TM-4; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; Gujarat Mustard-3 × RH-30; ZEM-1 × RH-30, however none of the cross combination was significantly positive for the trait.

Under 75 Kg/ha Nitrogen level the range of heterobeltiosis varied from -38.13 (Pusa Mustard-28 × ZEM-1) to 34.21% (ZEM-1 × KBS-3). Eight cross combinations *viz.,* ZEM-1 × KBS-3; NRCHB-101 × KBS-3; Gujarat Mustard-3 × DRMR-1; NRCHB-101 × RH-30; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × KBS-3; Jumka × NRCHB-101; Pusa Mustard-28 × DRMR-1 were significantly positive for the traits. On the other hand nine cross combinations *viz.*, Pusa Mustard-28 × ZEM-1; RNG-73 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3;Jumka × RNG-73; RNG-73 × Gujarat Mustard-3; Gujarat Mustard-3 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × Pusa Mustard-28; ZEM-1 × TM-4 were found significantly negative for the trait for heterobeltiosis.

Economic heterosis range was varied from -44.69 (Pusa Mustard-28 × ZEM-1) to 5.59% (RNG-73 × TM-4). None of the cross combinations was significantly positive for the trait however, eighteen cross combinations were significantly negative for the trait *viz.,* Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × ZEM-1; RNG-73 × KBS-3; ZEM-1 × TM-4; ZEM-1 × DRMR-1; Jumka × RNG-73; Jumka × Gujarat Mustard-3; RNG-73 × Gujarat Mustard-3; Jumka × TM-4; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; RNG- 73 × ZEM-1; Jumka × RH-30; RNG-73 × Pusa Mustard-28; Gujarat Mustard-3 × RH-30; ZEM-1 × KBS-3.

Under 150 Kg N/ha level the heterobeltiosis range was varied from -44.10 (Jumka × TM-4) to 31.93% (DRMR-1 × TM-4). Two cross combinations *viz.*, DRMR-1 × TM-4; Gujarat Mustard-3 × NRCHB-101 were found significantly positive for the trait and twenty two cross combinations *viz.*, RNG- 73 × ZEM-1; Jumka × TM-4; RNG-73 × TM-4; RNG-73 × NRCHB-101; Jumka × ZEM-1; Jumka

× Gujarat Mustard-3; Jumka × DRMR-1; Jumka × NRCHB-101; RH-30 × KBS-3; Pusa Mustard- 28 × TM-4; RNG-73 × RH-30; ZEM-1 × KBS-3; Jumka × RH-30; RH-30 × TM-4; Gujarat Mustard-3 × RH-30; PusaMustard-28 × NRCHB-101; RNG-73 × Pusa Mustard-28; ZEM-1 × NRCHB-101; Pusa Mustard-28 × KBS-3; RNG-73 × DRMR-1; NRCHB-101 × RH-30; NRCHB-101 × KBS-3 were significantly negative.

On the other hand economic heterosis varied from -50.78 (ZEM-1 × TM-4) to -0.52% (Gujarat Mustard-3 × DRMR-1). None of the cross combination was significantly positive whereas, thirty three cross combinations were found significantly negative *viz.*, ZEM-1 × TM-4; ZEM-1 × DRMR-1; RH-30 × TM-4; RH-30 × KBS-3; Jumka × TM-4; RNG-73 × TM-4; RNG-73 × NRCHB-101; Gujarat Mustard-3 × RH-30; ZEM-1 × KBS-3; ZEM-1 × RH-30; Jumka × ZEM-1; Pusa Mustard- 28 × TM-4; Jumka × Gujarat Mustard-3; Jumka × DRMR-1; PusaMustard-28 × NRCHB-101; Gujarat Mustard-3 × TM-4; Jumka × NRCHB-101; ZEM-1 × NRCHB-101; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × KBS-3; NRCHB-101 × RH-30; NRCHB-101 × KBS-3; RNG-73 × RH-30; Jumka × RH-30; DRMR-1 × RH-30; TM-4 × KBS-3; RNG-73 × Pusa Mustard-28; RNG- 73 × ZEM-1; RNG-73 × DRMR-1; DRMR-1 × TM-4; NRCHB-101 × TM-4; Pusa Mustard-28 × ZEM-1; Pusa Mustard- 28 × RH-30.

4.7.6 Number of Secondary Branches per Plant

Under control, the range of heterobeltiosis varied from -68.73 (Jumka × NRCHB-101) to 14.14% (TM-4 × KBS-3). For heterobeltiosis under control, only two cross combinations were found significantly positive *viz.*, TM-4 × KBS-3; RNG-73 × TM-4 whereas, twenty two cross combinations *viz.*, Jumka × NRCHB-101; Jumka × TM-4; Jumka × DRMR-1; Jumka × RH-30; Jumka × Gujarat Mustard-3; Jumka × Pusa Mustard-28; Jumka × RNG-73; ZEM-1 × RH-30; Jumka × KBS-3; Jumka × ZEM-1; ZEM-1 × DRMR-1; ZEM-1 × NRCHB-101; ZEM-1 × TM-4; Pusa Mustard- 28 × RH-30; Gujarat Mustard-3 × RH-30; Pusa Mustard- 28 × TM-4; RH-30 × KBS-3; DRMR-1 × RH-30; Pusa Mustard-28 × DRMR-1; RH-30 × TM-4; TM-4 × KBS-3; RNG-73 × TM-4 were significantly negative for the trait.

Table 4.47 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for number of primary and secondary branches per plant under different nitrogen levels

	Genotypes	Number of Primary Branches per Plant						Number of Secondary Branches per Plant					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1.	Jumka × RNG-73	-3.39	2.4	-28.95 **	-24.58**	-5.64	-4.66	-52.78 **	-22.73*	-55.88 **	-40**	-40.85 **	-19.23**
2.	Jumka × Pusa Mustard-28	-11.3	-5.99	3.13	-7.82	-11.79	-10.88	-57.78 **	-39.55**	-49.28 **	-30**	-50.31 **	-38.85**
3.	Jumka × Gujarat Mustard-3	-6.78	-1.2	-14.56	-24.58**	-37.95 **	-37.31**	-60.48 **	-44.32**	-58.82 **	-44**	-51.43 **	-34.62**
4.	Jumka × ZEM-1	-10.73	-5.39	8.86	-3.91	-40.00 **	-39.38**	-44.50 **	-49.55**	-33.13 **	-57.2**	-40.45 **	-49.62**
5.	Jumka × DRMR-1	-13.56	-8.38	8.86	-3.91	-37.95 **	-37.31**	-65.74 **	-47.05**	-64.00 **	-53.2**	-60.69 **	-45.58**
6.	Jumka × NRCHB-101	1.13	7.19	18.35 *	4.47	-31.79 **	-31.09**	-68.73 **	-49.55**	-67.01 **	-49.2**	-69.86 **	-58.85**
7.	Jumka × RH-30	-14.69	-9.58	-8.23	-18.99**	-25.64 **	-24.87**	-64.38 **	-35.23**	-58.29 **	-41.6**	-69.19 **	-56.15**
8.	Jumka × TM-4	-7.34	-1.8	-12.03	-22.35**	-44.10 **	-43.52**	-66.55 **	-55.91**	-68.38 **	-57**	-69.86 **	-58.85**
9.	Jumka × KBS-3	-14.12	-8.98	5.06	-7.26	-11.79	-10.88	-48.75 **	-44.09**	-49.07 **	-45**	-55.45 **	-52.88**
10.	RNG-73 × Pusa Mustard-28	0	-2.99	-23.68 **	-18.99**	-23.44 **	-23.83**	9.72	79.55**	14.49 **	58**	1.69	38.85**
11.	RNG-73 × Gujarat Mustard-3	3.7	0.6	-28.95 **	-24.58**	-1.04	-1.55	8.61	77.73**	23.97 **	68.6**	18.31 **	61.54**
12.	RNG- 73 × ZEM-1	-3.09	-5.99	-25.26 **	-20.67**	-18.75 *	-19.17*	0.14	63.86**	20.00 **	63.2**	10.28 *	50.58**
13.	RNG-73 × DRMR-1	-3.7	-6.59	-12.63	-7.26	-18.23 *	-18.65*	9.58	79.32**	21.91 **	65.8**	17.08 **	62.12**
14.	RNG-73 × NRCHB-101	-5.56	-8.38	-11.05	-5.59	-42.71 **	-43.01**	4.58	71.14**	2.47	57.8**	14.93 **	56.92**
15.	RNG-73 × RH-30	4.32	1.2	-3.16	2.79	-27.60 **	-27.98**	-1.88	78.41**	16.43 **	63**	-5.54	34.42**
16.	RNG-73 × TM-4	1.23	-1.8	-0.53	5.59	-43.23 **	-43.52**	12.50 *	84.09**	26.62 **	72.2**	14.79 **	56.73**
17.	RNG-73 × KBS-3	-6.17	-8.98	-36.84 **	-32.96**	-9.38	-9.84	10	80**	21.62 **	65.4**	10.28 *	50.58**
18.	Pusa Mustard-28 × Gujarat Mustard-3	1.31	-7.19	-32.50 **	-39.66**	0	-14.51	1.59	45.45**	-21.74 **	8	-10.14 *	20.96**
19.	Pusa Mustard-28 × ZEM-1	5.8	-12.57	-38.13 **	-44.69**	-3.03	-17.1*	2.22	46.36**	0.14	38.2**	8.75	33.85**
20.	Pusa Mustard-28 × DRMR-1	5.26	-4.19	16.88 *	4.47	7.27	-8.29	-13.82 *	33.18**	-4.78	31.4**	-5.14	31.35**
21.	PusaMustard-28 × NRCHB-101	4.35	0.6	11.88	0	-24.40 **	-34.2**	-5.49	52.5**	-7.53 *	42.4**	1.97	39.23**
22.	Pusa Mustard- 28 × RH-30	1.32	-8.38	10	-1.68	-1.82	-16.06*	-18.88 **	47.5**	-1.71	37.6**	-9.05 *	29.42**

Genotypes	Number of Primary Branches per Plant						Number of Secondary Branches per Plant					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
23. Pusa Mustard- 28 × TM-4	2.1	-12.57	-2.5	-12.85	-27.88 **	-38.34**	-17.62 **	17.95	-6.52	29**	-13.52 **	18.08**
24. Pusa Mustard-28 × KBS-3	11.59	-7.78	5.62	-5.59	-18.79 *	-30.57**	-3.33	38.41**	-2.46	34.6**	7.66	32.5**
25. Gujarat Mustard-3 × ZEM-1	-13.07	-20.36	-12.69	-34.64**	14	-11.4	5	47.95**	2.21	39**	2	37.31**
26. Gujarat Mustard-3 × NRCHB-101	5.23	-3.59	-25.37 **	-44.13**	22.00 *	-5.18	-1.03	52.95**	7.35	46**	-0.69	37.5**
27. Gujarat Mustard-3 × DRMR-1	-1.86	-5.39	29.10 **	-3.35	14.29	-0.52	-10.85	43.86**	-11.30 **	36.6**	-9.01 *	24.23**
28. Gujarat Mustard-3 × RH-30	-18.95	-25.75*	8.96	-18.44*	-24.67 *	-41.45**	-17.75 **	49.55**	-0.43	39.4**	-15.14 **	20.77**
29. Gujarat Mustard-3 × TM-4	-7.84	-15.57	6.54	-8.94	-12.67	-32.12**	3.71	46.14**	2.21	39**	-8.31 *	25.19**
30. Gujarat Mustard-3 × KBS-3	-1.96	-10.18	20.15 *	-10.06	-12.18	-29.02**	-5.32	33.41**	-3.97	30.6**	-12.00 **	18.46**
31. ZEM-1 × DRMR-1	-26.97 *	-33.53**	2.29	-25.14**	-16.13	-46.11**	-36.47 **	-1.82	-25.85 **	-3.6	-25.14 **	3.65
32. ZEM-1 × NRCHB-101	-43.48 **	-45.51**	5.26	-21.79**	-20.83 *	-31.09**	-34.51 **	5.68	-35.06 **	0	-26.90 **	-0.19
33. ZEM-1 × RH-30	-16.56	-24.55*	3.73	-22.35**	-18.88	-39.9**	-50.88 **	-10.68	-41.57 **	-18.2**	-33.11 **	-4.81
34. ZEM-1 × TM-4	-23.78	-34.73**	-16.99 *	-29.05**	-23.39	-50.78**	-30.34 **	-8.18	-43.38 **	-23**	-36.34 **	-13.08*
35. ZEM-1 × KBS-3	-12.78	-30.54**	34.21 **	-14.53*	-26.28 **	-40.41**	-7.92	0.45	-26.30 **	-20.4**	-15.09 **	-10.19
36. DRMR-1 × NRCHB -101	-5.59	-8.98	22.56 *	-8.94	3.57	-9.84	1.55	63.86**	-4.42	47.2**	-8.47 *	26.73**
37. DRMR-1 × RH-30	-3.95	-12.57	17.91	-11.73	2.1	-24.35**	-14.38 **	55.68**	-3.14	35.6**	-5.54	34.42**
38. DRMR-1 × TM-4	-4.61	-13.17	10.46	-5.59	31.93 *	-18.65*	8.97	68.41**	17.35 **	59.6**	3.19	42.88**
39. DRMR-1 × KBS-3	-5.26	-13.77	19.08	-12.85	5.77	-14.51	-4.26	47.95**	6.15	38**	-8.33 *	26.92**
40. NRCHB-101 × RH-30	0.62	-2.99	28.36 **	-3.91	-17.86 *	-28.5**	-9.25	65**	-4.29	47.4**	-13.65 **	22.88**
41. NRCHB-101 × TM-4	-13.66	-16.77	3.92	-11.17	-6.55	-18.65*	2.68	65.68**	-2.21	50.6**	2.11	39.42**
42. NRCHB-101 × KBS-3	3.11	-0.6	33.08 **	-1.12	-17.86 *	-28.5**	1.83	64.32**	0.13	54.2**	6.9	45.96**
43. RH-30 × TM-4	-7.28	-16.17	5.23	-10.06	-25.17 *	-44.56**	-11.12 *	61.59**	7.57	50.6**	-3.92	36.73**
44. RH-30 × KBS-3	-2.65	-11.98	18.66	-11.17	-31.41 **	-44.56**	-15.25 **	54.09**	8.43 *	51.8**	-2.84	38.27**
45. TM-4 × KBS-3	2.1	-12.57	10.46	-5.59	-6.41	-24.35**	14.14 *	50.45**	5.15	43**	-3.1	32.31**

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.48 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for length of main shoot (cm) and number of siliquae on main shoot under different nitrogen levels

	Genotypes	Length of Main Shoot (cm)						Number of Siliquae on Main Shoot					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1.	Jumka × RNG-73	-31.44 **	-30.37**	-26.24 **	-29.4**	-23.59 **	-28.3**	-8.54	-3.85	-8.33	-10.47*	-2.67	-20.65**
2.	Jumka × Pusa Mustard-28	-21.93 **	-27.52**	-19.84 **	-26.9**	-14.98 **	-26.4**	-11.54 *	-11.54*	-15.00 **	-20.93**	-14.67 *	-30.43**
3.	Jumka × Gujarat Mustard-3	-26.08 **	-29.15**	-27.90 **	-31.1**	-22.67 **	-26.64**	-18.75 **	-16.67**	-21.43 **	-23.26**	-21.95 **	-30.43**
4.	Jumka × ZEM-1	-22.70 **	-32.33**	-22.59 **	-32.47**	-16.21 **	-29.33**	-5.8	-16.67**	-8.22	-22.09**	-8.45	-29.35**
5.	Jumka × DRMR-1	-24.15 **	-27.36**	-28.54 **	-31.02**	-23.75 **	-26.4**	-10.39 *	-11.54*	-9.09	-18.6**	-1.47	-27.17**
6.	Jumka × NRCHB-101	-28.92 **	-28.75**	-31.18 **	-31.18**	-28.01 **	-27.67**	-4.41	-16.67**	-4.11	-18.6**	-1.47	-27.17**
7.	Jumka × RH-30	-21.95 **	-27.04**	-27.78 **	-30.29**	-25.02 **	-26.56**	-23.53 **	-16.67**	-19.10 **	-16.28**	-14.29 *	-28.26**
8.	Jumka × TM-4	-18.97 **	-28.01**	-14.90 **	-24.8**	-20.60 **	-26.88**	0	-11.54*	1.37	-13.95**	0	-23.91**
9.	Jumka × KBS-3	-14.70 **	-26.3**	-12.38 **	-26.25**	-19.38 **	-28.3**	0	-12.82**	2.74	-12.79**	8.82	-19.57**
10.	RNG-73 × Pusa Mustard-28	-1.68	-0.16	-0.59	-4.85	2.61	-3.72*	-2.44	2.56	0	-2.33	14.67 *	-6.52
11.	RNG-73 × Gujarat Mustard-3	-5.53 *	-4.07	-2.95	-7.11	0.83	-4.35*	0	5.13	1.19	-1.16	-4.88	-15.22*
12.	RNG- 73 × ZEM-1	-5.29	-3.83	-1.18	-5.41	2.95	-3.4*	-3.66	1.28	-1.19	-3.49	9.33	-10.87
13.	RNG-73 × DRMR-1	-2.09	-0.57	-1.17	-4.6	2.13	-1.42	1.22	6.41	2.38	0	6.67	-13.04*
14.	RNG-73 × NRCHB-101	-5.05	-3.58	-3.15	-3.15	-4.88 **	-4.43**	-9.76 *	-5.13	-8.33	-10.47*	-1.33	-19.57**
15.	RNG-73 × RH-30	-10.10 **	-8.71**	-4.35	-7.67*	-5.97 **	-7.91**	-2.35	6.41	-8.99 *	-5.81	-5.19	-20.65**
16.	RNG-73 × TM-4	-3.21	-1.71	-4.05	-8.16*	5.48 **	-1.03	4.88	10.26*	4.76	2.33	12	-8.7
17.	RNG-73 × KBS-3	-7.30 **	-5.86*	-5.74	-9.77*	1.77	-4.51**	-3.66	1.28	-1.19	-3.49	6.67	-13.04*
18.	Pusa Mustard-28 × Gujarat Mustard-3	-1.19	-5.29	-3.55	-7.84*	-0.17	-5.3**	-1.25	1.28	-1.19	-3.49	-2.44	-13.04*
19.	Pusa Mustard-28 × ZEM-1	6.75 *	-0.9	-0.97	-9.69*	13.70 **	-1.58	6.41	6.41	8.75	1.16	12	-8.7
20.	Pusa Mustard-28 × DRMR-1	-1.11	-5.29	2.01	-1.53	-1.72	-5.14**	12.82 **	12.82**	16.25 **	8.14	14.67 *	-6.52
21.	PusaMustard-28 × NRCHB-101	-1.79	-1.55	-5.74	-5.74	-2.44	-1.98	-1.28	-1.28	15.00 **	6.98	9.33	-10.87
22.	Pusa Mustard- 28 × RH-30	8.54 **	1.47	-0.08	-3.55	-0.32	-2.37	-11.76 **	-3.85	-13.48 **	-10.47*	0	-16.3**

Genotypes		Length of Main Shoot (cm)						Number of Siliquae on Main Shoot					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**
23.	Pusa Mustard- 28 × TM-4	11.84 **	3.83	4.25	-4.93	3.09	-5.06**	3.85	3.85	3.75	-3.49	2.67	-16.3**
24.	Pusa Mustard-28 × KBS-3	4.12	-3.34	4.69	-4.52	8.18 **	-3.79*	5.13	5.13	5	-2.33	9.33	-10.87
25.	Gujarat Mustard-3 × ZEM-1	0.85	-3.34	0.17	-4.28	2.33	-2.92	10.00 *	12.82**	8.33	5.81	0	-10.87
26.	Gujarat Mustard-3 × NRCHB-101	0.34	-3.83	1	-2.5	0.25	-3.24	1.25	3.85	1.19	-1.16	-2.44	-13.04*
27.	Gujarat Mustard-3 × DRMR-1	-5.2	-4.97	-5.01	-5.01	-6.69 **	-6.25**	5	7.69	1.19	-1.16	-3.66	-14.13*
28.	Gujarat Mustard-3 × RH-30	2.21	-2.04	-3.6	-6.95	-2.58	-4.58**	-7.06	1.28	-8.99 *	-5.81	-4.88	-15.22*
29.	Gujarat Mustard-3 × TM-4	3.74	-0.57	-2.7	-7.03	3.75 *	-1.58	11.25 *	14.1**	10.71 *	8.14	6.1	-5.43
30.	Gujarat Mustard-3 × KBS-3	1.1	-3.09	-2.87	-7.19	1.83	-3.4*	1.25	3.85	4.76	2.33	9.76	-2.17
31.	ZEM-1 × DRMR-1	-9.44 **	-13.27**	-8.45 *	-11.63**	-9.58 **	-12.73**	-9.09	-10.26*	-3.9	-13.95**	2.82	-20.65**
32.	ZEM-1 × NRCHB-101	-11.54 **	-11.32**	-10.10 **	-10.1**	-11.17 **	-10.75**	7.25	-5.13	4.11	-11.63**	1.41	-21.74**
33.	ZEM-1 × RH-30	-3.66	-9.93**	-7.95 *	-11.15**	-7.51 **	-9.41**	-15.29 **	-7.69	-16.85 **	-13.95**	-3.9	-19.57**
34.	ZEM-1 × TM-4	-3.94	-14.66**	-5.94	-16.88**	-6.61 **	-13.99**	7.25	-5.13	8.22	-8.14	1.41	-21.74**
35.	ZEM-1 × KBS-3	-2.23	-14.41**	-1.02	-13.65**	-4.18 *	-14.78**	0	-11.54*	1.37	-13.95**	5.63	-18.48**
36.	DRMR-1 × NRCHB -101	-6.50 *	-6.27*	-7.84 *	-7.84*	-11.25 **	-10.83**	1.3	0	7.79	-3.49	13.24	-16.3**
37.	DRMR-1 × RH-30	-1.7	-5.86*	-6.03	-9.29*	-2.42	-4.43**	-10.59 *	-2.56	-8.99 *	-5.81	1.3	-15.22*
38.	DRMR-1 × TM-4	-0.17	-4.4	-0.59	-4.04	-2.05	-5.45**	-3.9	-5.13	5.19	-5.81	12.86	-14.13*
39.	DRMR-1 × KBS-3	-2.04	-6.19*	-9.62 *	-12.76**	-4.67 **	-7.98**	-3.9	-5.13	0	-10.47*	7.46	-21.74**
40.	NRCHB-101 × RH-30	-3.09	-2.85	-2.34	-2.34	-4.33 *	-3.87*	-17.65 **	-10.26*	-17.98 **	-15.12**	-11.69	-26.09**
41.	NRCHB-101 × TM-4	0.49	0.73	-7.19	-7.19	-4.80 **	-4.35*	1.45	-10.26*	2.74	-12.79**	-2.86	-26.09**
42.	NRCHB-101 × KBS-3	-2.68	-2.44	-2.83	-2.83	-4.56 **	-4.11*	0	-15.38**	0	-17.44**	1.47	-25.00**
43.	RH-30 × TM-4	6.88 *	-0.08	1	-2.5	0.08	-1.98	3.53	12.82**	1.12	4.65	6.49	-10.87
44.	RH-30 × KBS-3	-0.17	-6.68*	-1.17	-4.6	-5.17 **	-7.11**	8.24	17.95**	5.62	9.3*	5.19	-11.96*
45.	TM-4 × KBS-3	-1.19	-12.21**	1.92	-9.94*	-6.01 **	-13.44**	-1.45	-12.82**	5.48	-10.47*	8.57	-17.39**

*Significance P ≤0.05; ** Significance P ≤0.01

For economic heterosis under control, range varied from -49.55 (Jumka × ZEM-1 and Jumka × NRCHB-101) to 84.09% (RNG-73 × TM-4). Thirty one cross combinations *viz.*, RNG-73 × TM-4; RNG-73 × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × DRMR-1; RNG-73 × RH-30; RNG-73 × Gujarat Mustard-3; RNG-73 × NRCHB-101; DRMR-1 × TM-4; NRCHB-101 × TM-4; NRCHB-101 × RH-30; NRCHB-101 × KBS-3; RNG- 73 × ZEM-1; DRMR-1 × NRCHB -101; RH-30 × TM-4; Jumka × TM-4; DRMR-1 × RH-30; RH-30 × KBS-3; Gujarat Mustard-3 × NRCHB-101; PusaMustard-28 × NRCHB-101; TM-4 × KBS-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × ZEM-1; DRMR-1 × KBS-3; Pusa Mustard- 28 × RH-30; Pusa Mustard-28 × ZEM-1;Gujarat Mustard-3 × TM-4; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × DRMR-1 showed significantly positive for the trait over the check Varuna. Ten cross combinations *viz.*, Jumka × TM-4; Jumka × ZEM-1; Jumka × NRCHB-101; Jumka × DRMR-1; Jumka × Gujarat Mustard-3; Jumka × KBS-3; Jumka × Pusa Mustard-28; Pusa Mustard-28 × KBS-3; Jumka × RH-30; Jumka × RNG-73 exhibited negative economic heterosis.

Under 75Kg/ha Nitrogen condition the range of heterobeltiosis varied from -68.38 (Jumka × TM-4) to 26.62% (RNG-73 × TM-4). Nine cross combinations *viz.*, RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; RNG-73 × KBS-3; RNG- 73 × ZEM-1; DRMR-1 × TM-4; RNG-73 × RH-30; RNG-73 × Pusa Mustard-28; RH-30 × KBS-3 exhibited significant positive heterobeltiosis. Whereas, seventeen cross combinations *viz.*, Jumka × TM-4; Jumka × NRCHB-101; Jumka × DRMR-1; Jumka × Gujarat Mustard-3; Jumka × RH-30; Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × KBS-3; ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; Jumka × ZEM-1; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × DRMR-1; PusaMustard-28 × NRCHB-101 showed significantly negative for the trait.

Standard heterosis range varied from -57.2 (Jumka × ZEM-1) to 72.2% (RNG-73 × TM-4). Thirty cross combinations *viz.*, RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; RNG-73 × KBS-3; RNG- 73 × ZEM-1; RNG-73 × RH-30; DRMR-1 × TM-4;; RNG-73 × Pusa Mustard-28; RNG-73 × NRCHB-101;

NRCHB-101 × KBS-3; RH-30 × KBS-3; NRCHB-101 × TM-4; RH-30 × TM-4; NRCHB-101 × RH-30; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × NRCHB-101; TM-4 × KBS-3; PusaMustard-28 × NRCHB-101; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; Pusa Mustard-28 × ZEM-1; DRMR-1 × KBS-3; Pusa Mustard- 28 × RH-30; Gujarat Mustard-3 × DRMR-1; DRMR-1 × RH-30; Pusa Mustard-28 × KBS-3; Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × KBS-3; Pusa Mustard- 28 × TM-4 exhibited significantly positive whereas, ten crosses *viz.,* Jumka × RNG-73; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4; Jumka × KBS-3; ZEM-1 × RH-30; ZEM-1 × TM-4; ZEM-1 × KBS-3 showed negative heterosis for the trait.

Under 150Kg/ha Nitrogen level range of heterobeltiosis varied from -69.86 (Jumka × TM-4) to 18.31% (RNG-73 × Gujarat Mustard-3). Six cross combinations *viz.,* RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × TM-4; RNG- 73 × ZEM-1; RNG-73 × KBS-3 exhibited significantly positive heterobeltiosis for the trait whereas, twenty four cross combinations *viz.,* Jumka × RH-30; Jumka × NRCHB-101; Jumka × TM-4; Jumka × DRMR-1; Jumka × KBS-3; Jumka × Gujarat Mustard-3; Jumka × Pusa Mustard-28; Jumka × RNG-73; Jumka × ZEM-1; ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; Gujarat Mustard-3 × RH-30; ZEM-1 × KBS-3; NRCHB-101 × RH-30; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard- 28 × RH-30; Gujarat Mustard-3 × DRMR-1; DRMR-1 × NRCHB -101;DRMR-1 × KBS-3; Gujarat Mustard-3 × TM-4 showed significantly negative heterobeltiosis.

Economic heterosis range was varied from -58.85 (Jumka × NRCHB-101) to 62.1% (RNG-73 × DRMR-1). Thirty one crosses *viz.,* RNG-73 × DRMR-1; RNG-73 × Gujarat Mustard-3; RNG-73 × NRCHB-101; RNG-73 × TM-4; ;RNG- 73 × ZEM-1; RNG-73 × KBS-3; NRCHB-101 × KBS-3; DRMR-1 × TM-4; NRCHB-101 × TM-4; PusaMustard-28 × NRCHB-101; RNG-73 × Pusa Mustard-28; RH-30 × KBS-3; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × ZEM-1; RH-30 × TM-4; RNG-73 × RH-30; DRMR-1 × RH-30; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28

× KBS-3; TM-4 × KBS-3; Pusa Mustard-28 × DRMR-1; Pusa Mustard- 28 × RH-30; DRMR-1 × KBS-3; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × DRMR-1; NRCHB-101 × RH-30; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × KBS-3; Pusa Mustard- 28 × TM-4 exhibited significantly positive results over the check Varuna. On the other hand only three crosses *viz.*, ZEM-1 × TM-4; Jumka × Gujarat Mustard-3; Jumka × RNG-73 showed significantly negative values for the trait over the check.

4.7.7 Length of Main Shoot (cm)

Under control, range of heterobeltiosis varied from -31.44 (Jumka × RNG-73) to 11.84% (Pusa Mustard- 28 × TM-4). Four crosses out of forty five cross *viz.,* Pusa Mustard-28 × ZEM-1; RH-30 × TM-4; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4 exhibited significantly positive heterosis and fifteen crosses *viz.,* RNG-73 × Gujarat Mustard-3; DRMR-1 × NRCHB -101; RNG-73 × KBS-3; ZEM-1 × DRMR-1; RNG-73 × RH-30; ZEM-1 × NRCHB-101; Jumka × KBS-3; Jumka × TM-4; Jumka × Pusa Mustard-28; Jumka × RH-30; Jumka × ZEM-1; Jumka × DRMR-1; Jumka × Gujarat Mustard-3; Jumka × NRCHB-101; Jumka × RNG-73 showed significantly negative heterobeltiosis.

Economic heterosis range varied from -32.33 (Jumka × ZEM-1) to 3.83% (Pusa Mustard- 28 × TM-4). None of the cross exhibited significant superiority over the check Varuna whereas, twenty crosses *viz.*, ZEM-1 × RH-30; RNG-73 × RH-30; RH-30 × KBS-3; DRMR-1 × NRCHB -101; DRMR-1 × KBS-3; RNG-73 × KBS-3; DRMR-1 × RH-30; Jumka × ZEM-1; Jumka × RNG-73; Jumka × Gujarat Mustard-3; Jumka × NRCHB-101; Jumka × TM-4; Jumka × Pusa Mustard-28; Jumka × DRMR-1; Jumka × RH-30; Jumka × KBS-3; ZEM-1 × TM-4; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × NRCHB-101 showed significantly negative values as compared to Varuna.

In case of 75 Kg N/ha level heterobeltiosis was ranged from -31.18 (Jumka × NRCHB-101) to 4.69% (Pusa Mustard-28 × KBS-3). None of the crosses exhibited significant and positive heterobeltiosis. On the other side fourteen crosses *viz.,* Jumka × NRCHB-101; Jumka × DRMR-1; Jumka × Gujarat Mustard-3; Jumka × RH-30;

Jumka × RNG-73; Jumka × ZEM-1; Jumka × Pusa Mustard-28; Jumka × TM-4; Jumka × KBS-3; ZEM-1 × NRCHB-101; DRMR-1 × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × RH-30; DRMR-1 × NRCHB -101 showed significant and negative heterosis.

Standard heterosis range varied from -32.47(Jumka × ZEM-1) to -1.53% (Pusa Mustard-28 × DRMR-1) in 75 Kg N/ha condition.. Here again none of the cross combination exhibited significant superiority over the check Varuna.

Under 150Kg/ha Nitrogen level heterobeltiosis varied from -28.01 (Jumka × NRCHB-101) to 13.70% (Pusa Mustard-28 × ZEM-1). In this condition four crosses *viz.,* Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × KBS-3; RNG-73 × TM-4; Gujarat Mustard-3 × TM-4 exhibited significantly positive heterosis whereas twenty four crosses *viz.,* Jumka × NRCHB-101; Jumka × RH-30; Jumka × DRMR-1; Jumka × RNG-73; Jumka × Gujarat Mustard-3; Jumka × TM-4; Jumka × KBS-3; Jumka × ZEM-1; Jumka × Pusa Mustard-28; DRMR-1 × NRCHB -101; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × RH-30; Gujarat Mustard-3 × DRMR-1; ZEM-1 × TM-4; TM-4 × KBS-3; RNG-73 × RH-30; RH-30 × KBS-3; RNG-73 × NRCHB-101; NRCHB-101 × TM-4; DRMR-1 × KBS-3; NRCHB-101 × KBS-3; NRCHB-101 × RH-30; ZEM-1 × KBS-3 exhibited significantly negative heterosis.

Standard heterosis ranged from -29.33 (Jumka × ZEM-1) to -1.03% (RNG-73 × TM-4) in 150 Kg N/ ha condition. None of the cross showed significant and positive heterosis over the check Varuna.

4.7.8 Number of Siliqua on Main Shoot

Under control heterobeltiosis varied from -23.53 (Jumka × RH-30) to 12.82% (Pusa Mustard-28 × DRMR-1). Three cross combinations *viz.*, Pusa Mustard-28 × DRMR-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × ZEM-1 exhibited significant and positive heterosis and nine crosses *viz.*, Jumka × RH-30; Jumka × Gujarat Mustard-3; NRCHB-101 × RH-30; ZEM-1 × RH-30; Pusa Mustard- 28 × RH-30; Jumka × Pusa Mustard-28; DRMR-1 × RH-30; Jumka × DRMR-1; RNG-73 × NRCHB-101 showed significantly negative heterosis.

Table 4.49 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for siliqua length (cm) and number of seeds per siliqua under different nitrogen levels

	Genotypes	Siliqua Length (cm)						Number Seeds per Siliqua					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1.	Jumka × RNG-73	1.94	30.58**	-1.89	25.81**	-25.95 **	-6.4	-13.46 **	25**	0	0	0	-2.7
2.	Jumka × Pusa Mustard-28	-0.65	27.27**	-7.55	18.55*	-5.06	20	-5.77	36.11**	-5.26	-5.26	-13.89	-16.22
3.	Jumka × Gujarat Mustard-3	-1.29	26.45**	-1.89	25.81**	-8.23	16	-5.77	36.11**	-21.05 **	-21.05**	-19.44	-21.62
4.	Jumka × ZEM-1	-6.45	19.83*	-4.4	22.58*	-6.33	18.4	-11.54 **	27.78**	-18.42 **	-18.42**	-16.67	-18.92
5.	Jumka × DRMR-1	0	28.1**	3.77	33.06**	8.23	36.8**	-1.92	41.67**	-7.89	-7.89	-19.44	-21.62
6.	Jumka × NRCHB-101	0.65	28.93**	-13.21	11.29	-6.33	18.4	-11.54 **	27.78**	-7.89	-7.89	-5.56	-8.11
7.	Jumka × RH-30	-5.81	20.66*	-12.58	12.1	-8.86	15.2	-11.54 **	27.78**	-10.53	-10.53	-11.11	-13.51
8.	Jumka × TM-4	0	28.1**	0	28.23**	3.16	30.4*	-15.38 **	22.22**	-15.79 *	-15.79*	-13.89	-16.22
9.	Jumka × KBS-3	-6.45	19.83*	-3.14	24.19**	-5.06	20	-13.46 **	25**	-7.89	-7.89	-13.89	-16.22
10.	RNG-73 × Pusa Mustard-28	0.79	4.96	-2.16	9.68	-3.68	4.8	-19.44 **	-19.44**	-14.71 *	-23.68**	0	-18.92
11.	RNG-73 × Gujarat Mustard-3	19.33	17.36	14.96	17.74*	9.56	19.2	-5.71	-8.33	-10.81	-13.16*	-13.89	-16.22
12.	RNG- 73 × ZEM-1	9.24	7.44	8.66	11.29	6.62	16	-17.65 **	-22.22**	-12.5	-26.32**	-10.34	-29.73*
13.	RNG-73 × DRMR-1	13.53	24.79*	8.9	28.23**	13.24	23.2*	-11.76	-16.67**	-6.25	-21.05**	6.9	-16.22
14.	RNG-73 × NRCHB-101	-0.74	10.74	0.72	12.1	-8.09	0	-5.88	-11.11	-3.03	-15.79*	3.13	-10.81
15.	RNG-73 × RH-30	-4.96	-4.96	3.15	5.65	-9.56	-1.6	-14.71 *	-19.44**	-9.38	-23.68**	-6.9	-27.03*
16.	RNG-73 × TM-4	4.2	2.48	1.57	4.03	-14.71	-7.2	-5.88	-11.11	-3.03	-15.79*	6.9	-16.22
17.	RNG-73 × KBS-3	-7.2	-4.13	-8.15	0	-9.56	-1.6	-20.59 **	-25**	-15.63 *	-28.95**	-13.79	-32.43*
18.	Pusa Mustard-28 × Gujarat Mustard-3	7.14	11.57	-2.88	8.87	-2.36	-0.8	-5.56	-5.56	-8.11	-10.53	-22.22	-24.32
19.	Pusa Mustard-28 × ZEM-1	5.56	9.92	5.04	17.74*	13.39	1.6	0	0	5.88	-5.26	16.67	-5.41
20.	Pusa Mustard-28 × DRMR-1	-6.77	2.48	-6.85	9.68	15.79	5.6	-2.78	-2.78	2.94	-7.89	-3.33	-21.62
21.	PusaMustard-28 × NRCHB-101	-11.11	-0.83	-13.67	-3.23	14.55	0.8	5.56	5.56	11.76	0	0	-13.51
22.	Pusa Mustard- 28 × RH-30	7.14	11.57	2.88	15.32	32.73 *	16.8	0	0	5.88	-5.26	3.33	-16.22

Genotypes		Siliqua Length (cm)						Number Seeds per Siliqua					
		Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
		HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
23.	Pusa Mustard- 28 × TM-4	4.76	9.09	5.04	17.74*	28.70 *	18.4	2.78	2.78	8.82	-2.63	-3.33	-21.62
24.	Pusa Mustard-28 × KBS-3	0.79	4.96	-1.44	10.48	20.51	12.8	0	0	5.88	-5.26	0	-18.92
25.	Gujarat Mustard-3 × ZEM-1	15.53	-1.65	-2.59	-8.87	-17.32	-16	0	-2.78	-5.41	-7.89	-16.67	-18.92
26.	Gujarat Mustard-3 × NRCHB-101	-15.04	-6.61	-24.66 **	-11.29	-7.09	-5.6	5.71	2.78	0	-2.63	-30.56 *	-32.43*
27.	Gujarat Mustard-3 × DRMR-1	-22.96 *	-14.05	-22.46 **	-13.71	-11.02	-9.6	-5.71	-8.33	-10.81	-13.16*	-13.89	-16.22
28.	Gujarat Mustard-3 × RH-30	-14.88	-14.88	-9.09	-11.29	-10.24	-8.8	2.86	0	-2.7	-5.26	-19.44	-21.62
29.	Gujarat Mustard-3 × TM-4	-15.97	-17.36	-18.03 *	-19.35*	-17.32	-16	2.86	0	-2.7	-5.26	-22.22	-24.32
30.	Gujarat Mustard-3 × KBS-3	-9.6	-6.61	-10.37	-2.42	-7.09	-5.6	-2.86	-5.56	-8.11	-10.53	-22.22	-24.32
31.	ZEM-1 × DRMR-1	-17.29	-9.09	-18.49 *	-4.03	7.89	-1.6	-25.81 **	-36.11**	-20.69 *	-39.47**	-23.08	-45.95**
32.	ZEM-1 × NRCHB-101	-23.70 **	-14.88	-19.57 *	-10.48	3.57	-7.2	-35.29 **	-38.89**	-33.33 **	-42.11**	-31.25 *	-40.54**
33.	ZEM-1 × RH-30	-14.05	-14.05	-9.09	-11.29	-1.79	-12	-14.29	-33.33**	-17.24 *	-36.84**	-17.86	-37.84**
34.	ZEM-1 × TM-4	-20.17 *	-21.49*	-14.75	-16.13	-4.35	-12	-25.81 **	-36.11**	-30.30 **	-39.47**	-11.54	-37.84**
35.	ZEM-1 × KBS-3	-21.60 *	-19.01	-17.78 *	-10.48	-2.56	-8.8	-30.30 **	-36.11**	-23.33 **	-39.47**	-10.34	-29.73*
36.	DRMR-1 × NRCHB -101	0	11.57	-18.49 *	-4.03	7.02	-2.4	-14.71 *	-19.44**	-12.12	-23.68**	-25	-35.14**
37.	DRMR-1 × RH-30	-6.02	3.31	-15.07 *	0	0.88	-8	-3.23	-16.67**	3.45	-21.05**	-10.71	-32.43*
38.	DRMR-1 × TM-4	-7.52	1.65	-19.86 **	-5.65	4.35	-4	-3.23	-16.67**	-9.09	-21.05**	0	-29.73*
39.	DRMR-1 × KBS-3	-9.77	-0.83	-14.38	0.81	9.4	2.4	-12.12	-19.44**	-3.33	-23.68**	-6.9	-27.03*
40.	NRCHB-101 × RH-30	0	11.57	0	11.29	5.88	-13.6	2.94	-2.78	6.06	-7.89	-9.38	-21.62
41.	NRCHB-101 × TM-4	-8.15	2.48	-7.97	2.42	13.04	4	0	-5.56	3.03	-10.53	-34.38 *	-43.24**
42.	NRCHB-101 × KBS-3	-14.81	-4.96	-15.22	-5.65	2.56	-4	5.88	0	9.09	-5.26	-21.88	-32.43*
43.	RH-30 × TM-4	-5.79	-5.79	-2.46	-4.03	0.87	-7.2	-3.23	-16.67**	-9.09	-21.05**	-14.29	-35.14**
44.	RH-30 × KBS-3	-8	-4.96	-11.85	-4.03	-10.26	-16	-18.18 **	-25**	-10	-28.95**	-13.79	-32.43*
45.	TM-4 × KBS-3	-8	-4.96	-11.11	-3.23	-2.56	-8.8	-12.12	-19.44**	-12.12	-23.68**	-27.59	-43.24**

*Significance P ≤0.05; ** Significance P ≤0.01

In control, Standard heterosis range varied from -16.67 (Jumka × Gujarat Mustard-3) to 17.95% (RH-30 × KBS-3). Six crosses *viz.*, RH-30 × KBS-3; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × ZEM-1; RH-30 × TM-4; Pusa Mustard-28 × DRMR-1; RNG-73 × TM-4 showed significantly positive heterosis over the check Varuna.

Under 75Kg/ha Nitrogen level heterobeltiosis was ranged from -21.43 (Jumka × Gujarat Mustard-3) to 16.25% (Pusa Mustard-28 × DRMR-1). Significant and positive heterosis was observed for only three crosses *viz.*, Pusa Mustard-28 × DRMR-1; PusaMustard-28 × NRCHB-101; Gujarat Mustard-3 × TM-4 whereas, nine crosses *viz.*, Jumka × Gujarat Mustard-3; Jumka × RH-30; NRCHB-101 × RH-30; ZEM-1 × RH-30; Jumka × Pusa Mustard-28; Pusa Mustard- 28 × RH-30; RNG-73 × RH-30; Gujarat Mustard-3 × RH-30; DRMR-1 × RH-30 showed significant and negative heterosis.

Standard heterosis range was varied from -23.26 (Jumka × Gujarat Mustard-3) to 9.3% (RH-30 × KBS-3). Significant and positive heterosis over the check was observed for only one cross namely RH-30 × KBS -3 and twenty crosses exhibited significant and negative heterosis over the check *viz.*, Jumka × Gujarat Mustard-3; Jumka × ZEM-1; Jumka × Pusa Mustard-28; Jumka × DRMR-1; Jumka × NRCHB-101; NRCHB-101 × KBS-3; Jumka × RH-30; NRCHB-101 × RH-30; Jumka × TM-4; ZEM-1 × DRMR-1; ZEM-1 × RH-30; ZEM-1 × KBS-3; Jumka × KBS-3; NRCHB-101 × TM-4; ZEM-1 × NRCHB-101; Jumka × RNG-73; RNG-73 × NRCHB-101; Pusa Mustard- 28 × RH-30; DRMR-1 × KBS-3; TM-4 × KBS-3.

In case of 150Kg/ha Nitrogen condition the range of heterobeltiosis varied from -21.95 (Jumka × Gujarat Mustard-3) to 14.67% (RNG-73 × Pusa Mustard-28). In this condition significant and positive heterosis was observed for only two crosses *viz.*, RNG-73 × Pusa Mustard-28; Pusa Mustard-28 × DRMR-1 and three cross combinations *viz.*, Jumka × Gujarat Mustard-3; Jumka × Pusa Mustard-28; Jumka × RH-30 exhibited significant and negative heterosis.

Standard heterosis ranged from -30.43 (Jumka × Pusa Mustard-28) to -2.17% (Gujarat Mustard-3 × KBS-3). None of the cross exhibited significant and positive heterosis over the check Varuna.

4.7.9 Siliqua Length (cm)

The range for heterobeltiosis under control was varied from -23.70 (ZEM-1 × NRCHB-101) to 19.33% (RNG-73 × Gujarat Mustard-3). None of the cross showed significant and positive heterosis and following crosses *viz.*, ZEM-1 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; ZEM-1 × KBS-3; ZEM-1 × TM-4 exhibited significant and negative heterosis.

Standard or economic heterosis was varied from -21.49 (ZEM-1 × TM-4) to 30.58% (Jumka × RNG-73). Ten cross combinations *viz.*, Jumka × RH-30; Jumka × ZEM-1; Jumka × KBS-3; Jumka × RNG-73; Jumka × NRCHB-101; Jumka × DRMR-1; Jumka × TM-4; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; RNG-73 × DRMR-1 exhibited significant and positive heterosis over the check Varuna whereas, only one cross *i.e.* ZEM-1 × TM-4 showed significantly negative heterosis over the check.

Under N 75Kg /ha condition heterobeltiosis ranged from -24.66 (Gujarat Mustard-3 × NRCHB-10) to 14.96% (RNG-73 × Gujarat Mustard-3). In this case none of the cross combination exhibited significant and positive heterosis whereas, nine crosses *viz.*, Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; DRMR-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × TM-4; ZEM-1 × KBS-3; DRMR-1 × RH-30 showed significantly negative heterosis.

Standard heterosis range varied from -19.35 (Gujarat Mustard-3 × TM-4) to 33.06% (Jumka × DRMR-1). Eleven cross combinations *viz.*, Jumka × DRMR-1; Jumka × TM-4; RNG-73 × DRMR-1; Jumka × RNG-73; Jumka × Gujarat Mustard-3; Jumka × KBS-3; Jumka × ZEM-1; Jumka × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; Pusa Mustard- 28 × TM-4 showed significantly positive heterosis over the check, only one cross *i.e.* Gujarat Mustard-3 × TM-4 exhibited significant negative result compared to the check variety.

In case of 150Kg/ha Nitrogen level heterobeltiosis ranged from -25.95 (Jumka × RNG-73) to 32.73% (Pusa Mustard- 28 × RH-30). Two crosses *viz.,* Pusa Mustard-28 × RH-30; Pusa Mustard- 28 × TM-4 exhibited significant and positive heterosis whereas, Only one cross namely, Jumka × RNG-73 showed significant negative heterosis.

Economic heterosis range varied from -16 (RH-30 × KBS-3) to 36.8% (Jumka × DRMR-1). Three cross combinations *viz.,* Jumka × DRMR-1; Jumka × TM-4; RNG-73 × DRMR-1 exhibited significant positive heterosis over the check variety Varuna.

4.7.10 Number of Seeds per Siliqua

Under control heterobeltiosis ranged from -35.29 (ZEM-1 × NRCHB-101) to 5.88% (NRCHB-101 × KBS-3). None of the cross combination exhibited significantly positive heterobeltiosis. Whereas, sixteen cross combinations *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; ZEM-1 × TM-4; RNG-73 × KBS-3; RNG-73 × Pusa Mustard-28; RH-30 × KBS-3; RNG- 73 × ZEM-1; Jumka × TM-4; RNG-73 × RH-30; DRMR-1 × NRCHB -101; Jumka × RNG-73; Jumka × KBS-3; Jumka × ZEM-1; Jumka × NRCHB-101; Jumka × RH-30.

In case of standard heterosis in control, range varied from -38.89 (ZEM-1 × NRCHB-101) to 41.67% (Jumka × DRMR-1). Nine crosses *viz.*, Jumka × DRMR-1; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × RNG-73; Jumka × KBS-3; Jumka × ZEM-1; Jumka × NRCHB-101; Jumka × RH-30; Jumka × TM-4 exhibited significantly positive heterosis over the check Varuna. On the other hand seventeen crosses *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × TM-4; ZEM-1 × KBS-3; ZEM-1 × RH-30; RNG-73 × KBS-3; RH-30 × KBS-3; RNG- 73 × ZEM-1; RNG-73 × Pusa Mustard-28; RNG-73 × RH-30; DRMR-1 × NRCHB -101;

DRMR-1 × KBS-3; TM-4 × KBS-3 RNG-73 × DRMR-1; DRMR-1 × RH-30; DRMR-1 × TM-4 and RH-30 × TM-4.

Under 75Kg/ha nitrogen level heterobeltiosis varied from -24.66 (Gujarat Mustard-3 × NRCHB-101) to 14.96% (RNG-73 × Gujarat Mustard-3). None of the cross exhibited significantly positive heterosis. On the other hand nine crosses *viz.,* Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; DRMR-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; DRMR-1 × NRCHB -101; Gujarat Mustard-3 × TM-4; ZEM-1 × KBS-3; DRMR-1 × RH-30 exhibited significantly negative heterobeltiosis.

Standard heterosis varied from -19.35 (Gujarat Mustard-3 × TM-4) to 33.06% (Jumka × DRMR-1) in 75 Kg N/ ha condition. Eleven crosses *viz.*, Jumka × DRMR-1; Jumka × TM-4; RNG-73 × DRMR-1; Jumka × RNG-73; Jumka × Gujarat Mustard-3; Jumka × KBS-3; Jumka × ZEM-1; Jumka × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1and Pusa Mustard- 28 × TM-4 exhibited significantly positive heterosis over the check Varuna whereas, only one cross *i.e.* Gujarat Mustard-3 × TM-4 showed significantly negative heterosis over the check.

In case of 150Kg/ha nitrogen level heterobeltiosis varied from -34.38 (NRCHB-101 × TM-4) to 16.67% (Pusa Mustard-28 × ZEM-1). Three cross combinations *viz.,* NRCHB-101 × TM-4; ZEM-1 × NRCHB-101 and Gujarat Mustard-3 × NRCHB-101 exhibited significantly negative heterobeltiosis.

Standard heterosis was ranged from -45.95 (ZEM-1 × DRMR-1) to -2.7% (Jumka × RNG-73) in case of 150 Kg/ ha condition . None of the cross combination exhibited significantly positive heterosis over the check Varuna whereas, seventeen crosses *viz.*, ZEM-1 × DRMR-1; NRCHB-101 × TM-4; TM-4 × KBS-3; ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × TM-4; DRMR-1 × NRCHB -101; RH-30 × TM-4; RNG-73 × KBS-3; Gujarat Mustard-3 × NRCHB-101; DRMR-1 × RH-30; NRCHB-101 × KBS-3; RH-30 × KBS-3; RNG- 73 × ZEM-1; ZEM-1 × KBS-3; DRMR-1 × TM-4; RNG-73 × RH-30 and DRMR-1 × KBS-3 exhibited significantly negative heterosis over the check Varuna.

Table 4.50 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for 1000 seed weight (g) and seed yield per plant (g) under different nitrogen levels

Genotypes	1000 Seed Weight (g)						Seed Yield per Plant (g)					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1. Jumka × RNG-73	-14.13	-15.96*	-18.69 **	-10.31	-12.38	-6.12	-14.71 *	16*	-15.49 **	5.26	-10.96	6.56
2. Jumka × Pusa Mustard-28	-8.33	-18.09*	-20.79 **	-17.53**	-17.48 *	-13.27	13.79 *	32**	4.62	19.3**	-4.48	4.92
3. Jumka × Gujarat Mustard-3	-13.83	-13.83	-23.81 **	-17.53**	-17.65 *	-14.29*	3.45	20*	-3.08	10.53*	-4.48	4.92
4. Jumka × ZEM-1	-8.14	-15.96*	-20.39 **	-15.46*	-10.1	-9.18	5.17	22**	-1.54	12.28*	-10.45	-1.64
5. Jumka × DRMR-1	-20.00 **	-19.15**	-31.43 **	-25.77**	-29.63 **	-22.45**	3.45	20*	-4.62	8.77	-5.97	3.28
6. Jumka × NRCHB-101	-24.74 **	-22.34**	-22.55 **	-18.56**	-11.58	-14.29*	-26.76 **	4	-23.61 **	-3.51	-15.94 *	-4.92
7. Jumka × RH-30	-13.33	-17.02*	-14.85 *	-11.34	-3	-1.02	-25.68 **	10	-23.68 **	1.75	-18.92 **	-1.64
8. Jumka × TM-4	5.13	-12.77	-10.89	-7.22	7.95	-3.06	-3.17	22**	-10.29 *	7.02	-10.14	1.64
9. Jumka × KBS-3	12.16	-11.7	-12.87 *	-9.28	10.23	-1.02	-1.72	14	-7.69	5.26	-7.46	1.64
10. RNG-73 × Pusa Mustard-28	0	-2.13	-11.21 *	-2.06	-6.67	0	-4.41	30**	-5.63	17.54**	-6.85	11.48
11. RNG-73 × Gujarat Mustard-3	-2.13	-2.13	-10.28	-1.03	-3.81	3.06	2.94	40**	1.41	26.32**	0	19.67**
12. RNG- 73 × ZEM-1	-4.35	-6.38	-11.21 *	-2.06	-14.29 *	-8.16	-5.88	28**	-7.04	15.79**	-13.70 *	3.28
13. RNG-73 × DRMR-1	-7.37	-6.38	-16.82 **	-8.25	-11.11	-2.04	8.82	48**	7.04	33.33**	1.37	21.31**
14. RNG-73 × NRCHB-101	-6.19	-3.19	-11.21 *	-2.06	-4.76	2.04	4.23	48**	-1.39	24.56**	-6.85	11.48
15. RNG-73 × RH-30	-2.17	-4.26	-13.08 *	-4.12	-8.57	-2.04	-9.46	34**	-7.89 *	22.81**	-12.16 *	6.56
16. RNG-73 × TM-4	-8.7	-10.64	-13.08 *	-4.12	-6.67	0	4.41	42**	2.82	28.07**	-4.11	14.75*
17. RNG-73 × KBS-3	-15.22 *	-17.02*	-14.02 *	-5.15	-7.62	-1.02	2.94	40**	1.41	26.32**	-6.85	11.48
18. Pusa Mustard-28 × Gujarat Mustard-3	-11.7	-11.7	-11.43 *	-4.12	-6.8	-2.04	7.69	-16*	2.33	-22.81**	6.82	-22.95**
19. Pusa Mustard-28 × ZEM-1	-1.16	-9.57	-7.77	-2.06	-2.91	2.04	12.82	-12	11.63	-15.79**	15.91	-16.39*
20. Pusa Mustard-28 × DRMR-1	-17.89 *	-17.02*	-20.00 **	-13.4*	-17.59 **	-9.18	11.11	0	6.38	-12.28*	15.56	-14.75*
21. PusaMustard-28 × NRCHB-101	-11.34	-8.51	-7.84	-3.09	-5.83	-1.02	-30.99 **	-2	-37.50 **	-21.05**	-30.43 **	-21.31**
22. Pusa Mustard- 28 × RH-30	-16.67 *	-20.21**	-18.18 **	-16.49**	-14.56 *	-10.2	-27.03 **	8	-32.89 **	-10.53*	-27.03 **	-11.48

Genotypes	1000 Seed Weight (g)						Seed Yield per Plant (g)					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**
23. Pusa Mustard- 28 × TM-4	-10.71	-20.21**	-18.18 **	-16.49**	-15.53 *	-11.22	-33.33 **	-16*	-33.82 **	-21.05**	-30.43 **	-21.31**
24. Pusa Mustard-28 × KBS-3	1.19	-9.57	-4.04	-2.06	-4.85	0	-20.75 **	-16*	-21.43 **	-22.81**	-30.51 **	-32.79**
25. Gujarat Mustard-3 × ZEM-1	0	0	-6.67	1.03	2.94	7.14	5.88	-28**	2.94	-38.60**	21.21	-34.43**
26. Gujarat Mustard-3 × NRCHB-101	-3.16	-2.13	-9.52	-2.06	-10.19	-1.02	-17.78 *	-26**	-23.40 **	-36.84**	-15.56	-37.7**
27. Gujarat Mustard-3 × DRMR-1	0	3.19	-5.71	2.06	0.98	5.1	-43.66 **	-20*	-61.11 **	-50.88**	-53.62 **	-47.54**
28. Gujarat Mustard-3 × RH-30	-3.19	-3.19	-8.57	-1.03	-3.92	0	-50.00 **	-26**	-52.63 **	-36.84**	-47.30 **	-36.07**
29. Gujarat Mustard-3 × TM-4	-10.64	-10.64	-13.33 *	-6.19	-2.94	1.02	-47.62 **	-34**	-55.88 **	-47.37**	-57.97 **	-52.46**
30. Gujarat Mustard-3 × KBS-3	-6.38	-6.38	-8.57	-1.03	-1.96	2.04	-41.51 **	-38**	-41.07 **	-42.11**	-38.98 **	-40.98**
31. ZEM-1 × DRMR-1	-8.42	-7.45	-13.33 *	-6.19	-15.74 *	-7.14	-57.78 **	-62**	-55.32 **	-63.16**	-46.67 **	-60.66**
32. ZEM-1 × NRCHB-101	-12.37	-9.57	-10.68	-5.15	-4.04	-3.06	-66.20 **	-52**	-63.89 **	-54.39**	-57.97 **	-52.46**
33. ZEM-1 × RH-30	-3.33	-7.45	-9.71	-4.12	-13	-11.22	-72.97 **	-60**	-73.68 **	-64.91**	-67.57 **	-60.66**
34. ZEM-1 × TM-4	0	-8.51	-7.77	-2.06	-2.02	-1.02	-68.25 **	-60**	-72.06 **	-66.67**	-66.67 **	-62.3**
35. ZEM-1 × KBS-3	4.65	-4.26	-2.91	3.09	2.02	3.06	-54.72 **	-52**	-62.50 **	-63.16**	-64.41 **	-65.57**
36. DRMR-1 × NRCHB -101	0	3.19	-1.9	6.19	-4.63	5.1	-36.62 **	-10	-34.72 **	-17.54**	-28.99 **	-19.67**
37. DRMR-1 × RH-30	0	1.06	-5.71	2.06	-3.7	6.12	-33.78 **	-2	-34.21 **	-12.28*	-31.08 **	-16.39*
38. DRMR-1 × TM-4	2.11	3.19	-4.76	3.09	-7.41	2.04	-30.16 **	-12	-33.82 **	-21.05**	-37.68 **	-29.51**
39. DRMR-1 × KBS-3	1.05	2.13	-1.9	6.19	-0.93	9.18	-20.75 **	-16*	-21.43 **	-22.81**	-18.64 *	-21.31**
40. NRCHB-101 × RH-30	3.09	6.38	0	5.15	3	5.1	-14.86 **	26**	-14.47 **	14.04**	-13.51 *	4.92
41. NRCHB-101 × TM-4	4.12	7.45	0.98	6.19	11.58	8.16	-1.41	40**	-1.39	24.56**	-1.45	11.48
42. NRCHB-101 × KBS-3	-8.25	-5.32	-8.82	-4.12	-2.11	-5.1	-4.23	36**	-1.39	24.56**	1.45	14.75*
43. RH-30 × TM-4	-5.56	-9.57	-7.29	-8.25	-6	-4.08	-5.41	40**	-6.58	24.56**	-9.46	9.84
44. RH-30 × KBS-3	6.67	2.13	2.08	1.03	1	3.06	-2.7	44**	-3.95	28.07**	-5.41	14.75*
45. TM-4 × KBS-3	-1.28	-18.09*	-1.19	-14.43*	9.88	-9.18	1.59	28**	-2.94	15.79**	-1.45	11.48

*Significance P ≤0.05; ** Significance P ≤0.01

4.7.11 1000 Seed Weight (g)

The range of heterobeltiosis for 1000 seed weight in control varied from –24.74 (Jumka × NRCHB-101) to 12.16% (Jumka × KBS-3). None of the crosses exhibited significantly positive and desirable heterobeltiosis for the trait among the various cross combinations. However, five crosses *viz.,* Jumka × NRCHB-101; Jumka × DRMR-1; Pusa Mustard-28 × DRMR-1; Pusa Mustard- 28 × RH-30 and RNG-73 × KBS-3 were found associated to significant level of negative heterobeltiosis.

The range in control for standard heterosis varied from -22.34 (Jumka × NRCHB-101) to 7.45% (NRCHB-101 × TM-4). Here again, none of the crosses were found significantly positive for standard heterosis among the cross combinations. However, eleven crosses *viz.,* Jumka × NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; Jumka × DRMR-1; Jumka × Pusa Mustard-28; TM-4 × KBS-3; Jumka × RH-30; RNG-73 × KBS-3; Pusa Mustard-28 × DRMR-1; Jumka × RNG-73 and Jumka × ZEM-1 were found associated with significantly negative standard heterosis in control.

For 75 Kg Nitrogen per ha condition, the range of heterobeltiosis and standard heterosis among various combinations was from -31.43 (Jumka × DRMR-1) to 2.08% (RH-30 × KBS-3) and -25.77 (Jumka × DRMR-1) to 6.19% (DRMR-1 × NRCHB-101), respectively. The significantly positive and desirable heterobeltiosis and standard heterosis were exhibited by none of the crosses for the trait under this condition. Twenty one crosses *viz.,* Jumka × DRMR-1; Jumka × Gujarat Mustard-3; Jumka × NRCHB-101; Jumka × Pusa Mustard-28; Jumka × ZEM-1; Pusa Mustard-28 × DRMR-1; Jumka × RNG-73; Pusa Mustard- 28 × RH-30; Pusa Mustard- 28 × TM-4; RNG-73 × DRMR-1; Jumka × RH-30; RNG-73 × KBS-3; Gujarat Mustard-3 × TM-4; ZEM-1 × DRMR-1; RNG-73 × RH-30; RNG-73 × TM-4; Jumka × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; RNG-73 × Pusa Mustard-28; RNG- 73 × ZEM-1 and RNG-73 × NRCHB-101 were found associated with significantly negative and undesirable heterobeltiosis.

Similarly, nine crosses *viz.,* Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Pusa Mustard- 28 × RH-30; Pusa

Mustard- 28 × TM-4; Jumka × ZEM-1; TM-4 × KBS-3 and Pusa Mustard-28 × DRMR-1 exhibited significantly negative standard heterosis for 1000 seed weight under this condition.

Under 150 Kg Nitrogen per ha condition, -29.63 (Jumka × DRMR-1) to 11.58% (NRCHB-101 × TM-4) and -22.45 (Jumka × DRMR-1) to 9.18% (DRMR-1 × KBS-3) was the range observed for heterobeltiosis and standard heterosis, respectively among the cross combinations. None of the cross combinations exhibited significant level of positive heterobeltiosis along with standard heterosis for 1000 seed weight under this condition. However eight crosses *viz.,* Jumka × DRMR-1; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × DRMR-1; Jumka × Pusa Mustard-28; ZEM-1 × DRMR-1; Pusa Mustard- 28 × TM-4; Pusa Mustard- 28 × RH-30 and RNG-73 × ZEM-1 were found significantly negative for heterobeltiosis for the trait.

Similarly three crosses *viz.,* Jumka × DRMR-1; Jumka × Gujarat Mustard-3 and Jumka × NRCHB-101 exhibited significantly negative standard heterosis under 150 Kg N/ ha condition for 1000 seed weight.

4.7.12 Seed Yield per Plant (g)

In case of control, the range for heterobeltiosis varied from -72.97 (ZEM-1 × RH-30) to 13.79% (Jumka × Pusa Mustard-28). Only one genotype *i.e.* Jumka × Pusa Mustard-28 exhibited significantly positive and desirable heterobeltiosis. However Twenty two crosses *viz.,* ZEM-1 × RH-30; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × KBS-3; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × NRCHB-101; DRMR-1 × TM-4; Pusa Mustard- 28 × RH-30; Jumka × NRCHB-101; Jumka × RH-30; Pusa Mustard-28 × KBS-3; DRMR-1 × KBS-3; Gujarat Mustard-3 × NRCHB-101; NRCHB-101 × RH-30 and Jumka × RNG-73 were found significantly negative in heterobeltiosis for the trait under control.

The range for standard heterosis for seed yield per plant under control varied from -62 (ZEM-1 × DRMR-1) to 48% (RNG-73 × DRMR-1 and RNG-73 × NRCHB-

101). The significantly positive and desirable Standard/ Economic heterosis was associated with twenty crosses *viz.*, RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RH-30 × KBS-3; RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; RNG-73 × KBS-3; NRCHB-101 × TM-4; RH-30 × TM-4; NRCHB-101 × KBS-3; RNG-73 × RH-30; Jumka × Pusa Mustard-28; RNG-73 × Pusa Mustard-28; RNG- 73 × ZEM-1; TM-4 × KBS-3; NRCHB-101 × RH-30; Jumka × ZEM-1; Jumka × TM-4; Jumka × Gujarat Mustard-3; Jumka × DRMR-1 and Jumka × RNG-73. However, Fifteen crosses *viz.*, ZEM-1 × DRMR-1; ZEM-1 × RH-30; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × KBS-3; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × KBS-3 and DRMR-1 × KBS-3 were also found significantly negative for standard heterosis for the character under control.

Under 75 Kg Nitrogen per ha condition, -73.68 (ZEM-1 × RH-30) to 11.63% (Pusa Mustard-28 × ZEM-1) was the range for heterobeltiosis among cross combinations for seed yield per plant. None of the cross combinations were found significantly positive for heterobeltiosis for the trait under this condition. However twenty four crosses *viz.*, ZEM-1 × RH-30; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × KBS-3; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × TM-4; ZEM-1 × DRMR-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × NRCHB-101; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; Pusa Mustard- 28 × TM-4; DRMR-1 × TM-4; Pusa Mustard- 28 × RH-30; Jumka × RH-30; Jumka × NRCHB-101; Gujarat Mustard-3 × NRCHB-101; Pusa Mustard-28 × KBS-3; DRMR-1 × KBS-3; Jumka × RNG-73; NRCHB-101 × RH-30; Jumka × TM-4 and RNG-73 × RH-30 exhibited significant level of negative heterobeltiosis for the trait.

The range of standard heterosis for the trait under this condition varied from -66.67 (ZEM-1 × TM-4) to 33.33% (RNG-73 × DRMR-1). Seventeen crosses *viz.*, RNG-73 × DRMR-1; RNG-73 × TM-4; RH-30 × KBS-3; RNG-73 × Gujarat Mustard-3; RNG-73 × KBS-3; RNG-73 × NRCHB-101; NRCHB-101 × TM-4; NRCHB-101 × KBS-3; RH-30 × TM-4; RNG-73 × RH-30; Jumka × Pusa Mustard-28; RNG-73 × Pusa Mustard-28; RNG- 73 × ZEM-1; TM-4 × KBS-3; NRCHB-101 ×

RH-30; Jumka × ZEM-1 and Jumka × Gujarat Mustard-3 exhibited significantly positive standard heterosis for the trait. On the other hand, twenty two crosses *viz.,* ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × RH-30; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × KBS-3; DRMR-1 × KBS-3; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; DRMR-1 × TM-4; DRMR-1 × NRCHB -101; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × DRMR-1; DRMR-1 × RH-30 and Pusa Mustard- 28 × RH-30 were also found associated with significantly negative and undesirable standard heterosis for the trait under this condition.

Under 150 Kg Nitrogen per ha condition, the range for heterobeltiosis and Standard heterosis varied from -67.57 (ZEM-1 × RH-30) to 21.21% (Gujarat Mustard-3 × ZEM-1) and from -65.57 (ZEM-1 × KBS-3) to 21.31% (RNG-73 × DRMR-1), respectively. None of the crosses were found significantly positive for heterobeltiosis for the trait under this condition. However twenty two crosses *viz.,* ZEM-1 × RH-30; ZEM-1 × TM-4; ZEM-1 × KBS-3; Gujarat Mustard-3 × TM-4; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; ZEM-1 × DRMR-1; Gujarat Mustard-3 × KBS-3; DRMR-1 × TM-4; DRMR-1 × RH-30; Pusa Mustard-28 × KBS-3; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; DRMR-1 × NRCHB -101; Pusa Mustard- 28 × RH-30; Jumka × RH-30; DRMR-1 × KBS-3; Jumka × NRCHB-101; RNG- 73 × ZEM-1; NRCHB-101 × RH-30 and RNG-73 × RH-30 exhibited significantly negative and undesirable heterobeltiosis.

Only five cross combinations *viz.,*RNG-73 × DRMR-1; RNG-73 × Gujarat Mustard-3; RNG-73 × TM-4; NRCHB-101 × KBS-3 and RH-30 × KBS-3 were found associated with significantly positive and desirable standard heterosis for seed yield per plant under 150 Kg Nitrogen per ha condition. On the other hand, twenty one crosses *viz.,* ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × DRMR-1; ZEM-1 × RH-30; Gujarat Mustard-3 × TM-4; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 ×

RH-30; Gujarat Mustard-3 × ZEM-1; Pusa Mustard-28 × KBS-3; DRMR-1 × TM-4; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; DRMR-1 × KBS-3; DRMR-1 × NRCHB -101; Pusa Mustard-28 × ZEM-1; DRMR-1 × RH-30 and Pusa Mustard-28 × DRMR-1 exhibited significantly negative standard heterosis for the trait.

4.7.13 Biological Yield per Plant (g)

In case of control, the range for heterobeltiosis varied from -63.70 (ZEM-1 × NRCHB-101) to 28.80% (Pusa Mustard-28 × ZEM-1). Only three crosses *viz.,* Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × Gujarat Mustard-3 and Pusa Mustard-28 × DRMR-1 exhibited significantly positive heterobeltiosis for biological yield per plant. On the other hand, fourteen crosses *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; ZEM-1 × TM-4; Jumka × RNG-73; Gujarat Mustard-3 × KBS-3; Jumka × NRCHB-101; Gujarat Mustard-3 × RH-30; Jumka × RH-30; Gujarat Mustard-3 × DRMR-1; Jumka × KBS-3; Gujarat Mustard-3 × TM-4 and Jumka × DRMR-1 were found associated with significantly negative and undesirable heterobeltiosis. The range of standard heterosis for the trait under control varied from -43.23 (ZEM-1 × NRCHB-101) to 90.23% (RNG-73 × KBS-3). Twenty six cross combinations *viz.*, RNG-73 × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × NRCHB-101; RNG-73 × TM-4; RNG- 73 × ZEM-1; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; RNG-73 × RH-30; Pusa Mustard- 28 × RH-30; RH-30 × TM-4; NRCHB-101 × RH-30; RH-30 × KBS-3; NRCHB-101 × KBS-3; DRMR-1 × RH-30; NRCHB-101 × TM-4; Pusa Mustard-28 × DRMR-1; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × NRCHB-101; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × KBS-3; TM-4 × KBS-3; ZEM-1 × NRCHB-101; DRMR-1 × NRCHB -101; DRMR-1 × KBS-3; Pusa Mustard- 28 × TM-4; DRMR-1 × TM-4 and Gujarat Mustard-3 × NRCHB-101 exhibited significantly positive and desirable standard heterosis for the trait. Only five cross combinations *viz.*, ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × RH-30; ZEM-1 × TM-4 and ZEM-1 × KBS-3 exhibited significantly negative standard heterosis for the trait.

Table 4.51 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for biological yield per plant (g) and Harvest Index (%) under different nitrogen levels

Genotypes	Biological Yield per Plant (g)						Harvest Index (%)					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1. Jumka × RNG-73	-44.15 **	2.26	-36.36 **	0.72	-40.41 **	-0.69	1.69	13.68*	-7.58	4.68	-5.05	7.25
2. Jumka × Pusa Mustard-28	-7.44	7.52	-20.55 *	4.32	-19.62 **	1.37	9.82	22.78**	0.95	14.33*	-8.29	3.57
3. Jumka × Gujarat Mustard-3	2.9	6.77	-2.38	3.24	3.18	0.34	0.93	12.83	-5.23	7.31	-7.38	4.62
4. Jumka × ZEM-1	6.88	10.9	6.43	7.19	4.59	1.72	-1.52	10.11	-7.45	4.83	-14.25 *	-3.15
5. Jumka × DRMR-1	-22.32 *	0.75	-25.61 **	-0.72	-13.58	-3.78	6.7	19.32**	-3.21	9.61	-4.76	7.58
6. Jumka × NRCHB-101	-30.77 **	8.27	-30.66 **	5.76	-30.54 **	2.41	-14.08 *	-3.94	-19.46 **	-8.78	-17.70 **	-7.07
7. Jumka × RH-30	-28.61 **	13.53	-28.50 **	10.07	-30.41 **	3.78	-13.28 *	-3.03	-18.36 **	-7.56	-16.10 **	-5.25
8. Jumka × TM-4	-15.93	15.04	-15.9	12.23	-17.59 **	7.9	-5.1	6.12	-15.82 **	-4.68	-16.62 **	-5.83
9. Jumka × KBS-3	-26.15 **	8.27	-43.65 **	5.4	-42.83 **	1.37	-5.86	5.27	-11.84 *	-0.15	-11.30 *	0.19
10. RNG-73 × Pusa Mustard-28	1.44	85.71**	14.09	80.58**	4.54	74.23**	-5.76	-29.96**	-17.49 *	-34.91**	-10.9	-36.02**
11. RNG-73 × Gujarat Mustard-3	0	83.08**	11.36	76.26**	1.65	69.42**	3.02	-23.47**	-9.15	-28.33**	-1.61	-29.34**
12. RNG- 73 × ZEM-1	0.62	84.21**	13.18	79.14**	3.3	72.16**	-8.05	-30.49**	-18.11 *	-35.4**	-16.4	-39.98**
13. RNG-73 × DRMR-1	-0.41	82.33**	12.05	77.34**	2.27	70.45**	9.36	-18.73**	-4.7	-24.82**	-0.8	-28.77**
14. RNG-73 × NRCHB-101	1.03	84.96**	14.09	80.58**	4.74	74.57**	-11.91	-19.96**	-16.67 *	-31.01**	-16.67 *	-36.02**
15. RNG-73 × RH-30	-1.44	80.45**	10.45	74.82**	1.03	68.38**	-20.09 **	-25.6**	-18.89 *	-29.74**	-22.29 **	-36.74**
16. RNG-73 × TM-4	0.82	84.59**	12.5	78.06**	1.86	69.76**	-16.41 *	-23.04**	-19.54 **	-28.08**	-21.74 **	-32.4**
17. RNG-73 × KBS-3	3.9	90.23**	-1.54	84.17**	-0.39	76.63**	-0.86	-26.34**	-13.07	-31.4**	-12.14	-36.93**
18. Pusa Mustard-28 × Gujarat Mustard-3	27.83 **	48.5**	32.33 **	73.74**	-18.80 **	2.41	-18.14	-43.21**	-22.65	-55.53**	14.28	-24.62**
19. Pusa Mustard-28 × ZEM-1	28.80 **	49.62**	35.62 **	78.06**	14.99 *	45.02**	-22.19 *	-41.19**	-26.63 *	-52.71**	-11.02	-41.56**
20. Pusa Mustard-28 × DRMR-1	18.55 *	53.76**	4.85	39.93**	-8.72	15.12	-2.36	-32.41**	1.62	-37.25**	13.02	-25.05**
21. PusaMustard-28 × NRCHB-101	-4.33	49.62**	-19.58 *	22.66	-15.85 **	24.05**	-27.90 **	-34.49**	-22.17 **	-35.54**	-17.36 *	-36.55**
22. Pusa Mustard- 28 × RH-30	9.46	74.06**	-13.79	32.73**	-12.90 *	29.9**	-33.30 **	-37.89**	-21.17 **	-31.69**	-15.96 *	-31.59**

Genotypes	Biological Yield per Plant (g)						Harvest Index (%)					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**	**HB**	**HE**
23. Pusa Mustard- 28 × TM-4	-6.59	27.82*	-9.43	20.86	4.72	37.11**	-28.83 **	-34.49**	-26.90 **	-34.67**	-33.52 **	-42.61**
24. Pusa Mustard-28 × KBS-3	1.28	48.5**	-34.62 **	22.3	-47.48 **	-6.87	-21.10 *	-43**	9.71	-36.91**	26.56 *	-27.72**
25. Gujarat Mustard-3 × ZEM-1	22.69	19.92	-0.68	5.04	31.67 **	8.59	-21.07 *	-40.34**	-9.38	-41.59**	-8.58	-39.7**
26. Gujarat Mustard-3 × NRCHB-101	-4.93	23.31*	-24.26 **	1.08	-10.49	-0.34	-13.38	-39.91**	1.14	-37.54**	-5.98	-37.65**
27. Gujarat Mustard-3 × DRMR-1	-26.44 **	15.04	-35.85 **	-2.16	-35.20 **	-4.47	-23.36 **	-30.39**	-39.34 **	-49.78**	-28.02 **	-44.75**
28. Gujarat Mustard-3 × RH-30	-29.79 **	11.65	-39.25 **	-6.47	-34.79 **	-2.75	-28.69 **	-33.63**	-22.01 **	-32.42**	-19.22 *	-34.21**
29. Gujarat Mustard-3 × TM-4	-25.82 **	1.5	-32.61 **	-10.07	-45.14 **	-28.18**	-29.34 **	-34.97**	-34.32 **	-41.3**	-23.37 **	-33.83**
30. Gujarat Mustard-3 × KBS-3	-32.56 **	-1.13	-20.00 **	49.64**	-47.67 **	-7.22	-13.12	-37.2**	-25.14 *	-57.83**	-2.63	-35.79**
31. ZEM-1 × DRMR-1	-52.17 **	-37.97**	-61.46 **	-48.56**	-37.65 **	-30.58**	-18.84 *	-38.64**	11.04	-28.43**	-14.68	-43.42**
32. ZEM-1 × NRCHB-101	-63.70 **	-43.23**	-54.01 **	-29.86*	-53.15 **	-30.93**	-6.94	-15.43*	-21.26 **	-34.81**	-10.34	-31.16**
33. ZEM-1 × RH-30	-59.81 **	-36.09**	-62.85 **	-42.81**	-56.45 **	-35.05**	-32.89 **	-37.52**	-29.16 **	-38.62**	-24.96 **	-38.89**
34. ZEM-1 × TM-4	-51.10 **	-33.08**	-59.57 **	-46.04**	-59.84 **	-47.42**	-34.52 **	-39.7**	-30.50 **	-37.88**	-17.23 *	-28.53**
35. ZEM-1 × KBS-3	-52.05 **	-29.7*	-70.58 **	-44.96**	-72.67 **	-51.55**	-9.78	-31.83**	4.5	-32.62**	8.12	-28.96**
36. DRMR-1 × NRCHB -101	-11.3	38.72**	-27.36 **	10.79	-39.39 **	-10.65	-28.42 **	-34.97**	-10.16	-25.6**	17.09 *	-10.12
37. DRMR-1 × RH-30	-0.47	58.27**	-24.53 **	16.19	-38.94 **	-8.93	-30.50 **	-35.28**	-12.83	-24.48**	12.76	-8.21
38. DRMR-1 × TM-4	-6.59	27.82*	-16.17	11.87	-33.86 **	-13.4	-25.16 **	-31.08**	-21.06 **	-29.45**	-5.85	-18.71**
39. DRMR-1 × KBS-3	-7.44	35.71**	-20.38 **	48.92**	-44.57 **	-1.72	-13.75	-37.68**	-11.29	-45.2**	20.51 *	-20.09**
40. NRCHB-101 × RH-30	2.36	62.78**	-6.54	43.88**	1.84	51.89**	-16.85 *	-22.62**	-7.46	-19.84**	-15.13	-30.92**
41. NRCHB-101 × TM-4	0.24	56.77**	0.47	53.24**	1.17	49.14**	-2.97	-10.7	-9.06	-18.72**	-13.47	-25.29**
42. NRCHB-101 × KBS-3	3.37	61.65**	-16.54 *	56.12**	-14.73 **	51.2**	-7.38	-15.86*	-3.65	-20.23**	-1.14	-24.1**
43. RH-30 × TM-4	2.6	63.16**	3.97	60.07**	2.07	52.23**	-7.77	-14.16*	-12.93	-22.18**	-16.53 *	-27.91**
44. RH-30 × KBS-3	2.36	62.78**	-15.58 *	57.91**	-14.34 **	51.89**	-4.95	-11.5	-6.36	-18.87**	-7.21	-24.43**
45. TM-4 × KBS-3	-1.28	44.74**	-23.85 **	42.45**	-21.71 **	38.83**	-3.92	-11.55	-9.06	-18.72**	-6.96	-19.66**

*Significance P ≤0.05; ** Significance P ≤0.01

Under 75 Kg Nitrogen per ha condition, the range for heterobeltiosis varied from -70.58 (ZEM-1 × KBS-3) to 35.62% (Pusa Mustard-28 × ZEM-1). The significantly positive and desirable heterobeltiosis for biological yield per plant was exhibited by only two crosses *viz.*, Pusa Mustard-28 × ZEM-1 and Pusa Mustard-28 × Gujarat Mustard-3. However twenty four cross combinations *viz.*, ZEM-1 × KBS-3; ZEM-1 × RH-30; ZEM-1 × DRMR-1; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; Jumka × KBS-3; Gujarat Mustard-3 × RH-30; Jumka × RNG-73; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × TM-4; Jumka × NRCHB-101; Jumka × RH-30; DRMR-1 × NRCHB -101; Jumka × DRMR-1; DRMR-1 × RH-30; Gujarat Mustard-3 × NRCHB-101; TM-4 × KBS-3; Jumka × Pusa Mustard-28; DRMR-1 × KBS-3; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × NRCHB-101; NRCHB-101 × KBS-3 and RH-30 × KBS-3 were associated with significantly negative heterobeltiosis for the trait.

The standard heterosis under 75 Kg Nitrogen per ha condition varied from -48.56 (ZEM-1 × DRMR-1) to 84.17% (RNG-73 × KBS-3). Twenty crosses *viz.*, RNG-73 × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × TM-4; Pusa Mustard-28 × ZEM-1; RNG-73 × DRMR-1; RNG-73 × Gujarat Mustard-3; RNG-73 × RH-30; Pusa Mustard-28 × Gujarat Mustard-3; RH-30 × TM-4; RH-30 × KBS-3; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; Gujarat Mustard-3 × KBS-3; DRMR-1 × KBS-3; NRCHB-101 × RH-30; TM-4 × KBS-3; Pusa Mustard-28 × DRMR-1 and Pusa Mustard- 28 × RH-30 exhibited significantly positive and desirable standard heterosis. Significantly negative standard heterosis under this was exhibited by five cross combinations *viz.*, ZEM-1 × DRMR-1; ZEM-1 × TM-4; ZEM-1 × KBS-3; ZEM-1 × RH-30 and ZEM-1 × NRCHB-101.

Under 150 Kg Nitrogen per ha condition, -72.67 (ZEM-1 × KBS-3) to 31.67% (Gujarat Mustard-3 × ZEM-1) and -51.55 (ZEM-1 × KBS-3) to 76.63% (RNG-73 × KBS-3) was the range among various cross combinations for heterobeltiosis and standard heterosis for the trait, respectively. Only two genotype *viz.*, Gujarat Mustard-3 × ZEM-1 and Pusa Mustard-28 × ZEM-1 were found significantly positive and desirable for heterobeltiosis. However, twenty six crosses *viz.*, ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; Gujarat Mustard-3 ×

KBS-3; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × TM-4; DRMR-1 × KBS-3; Jumka × KBS-3; Jumka × RNG-73; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; ZEM-1 × DRMR-1; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; DRMR-1 × TM-4; Jumka × NRCHB-101; Jumka × RH-30; TM-4 × KBS-3; Jumka × Pusa Mustard-28; Pusa Mustard-28 × Gujarat Mustard-3; Jumka × TM-4; Pusa Mustard-28 × NRCHB-101; NRCHB-101 × KBS-3; RH-30 × KBS-3 and Pusa Mustard- 28 × RH-30 were associated with significantly negative heterobeltiosis.

Eighteen crosses *viz.*, RNG-73 × KBS-3; RNG-73 × NRCHB-101; RNG-73 × Pusa Mustard-28; RNG- 73 × ZEM-1; RNG-73 × DRMR-1; RNG-73 × TM-4; RNG-73 × Gujarat Mustard-3; RNG-73 × RH-30; RH-30 × TM-4; NRCHB-101 × RH-30; RH-30 × KBS-3; NRCHB-101 × KBS-3; NRCHB-101 × TM-4; Pusa Mustard-28 × ZEM-1; TM-4 × KBS-3; Pusa Mustard- 28 × TM-4; Pusa Mustard- 28 × RH-30 and Pusa Mustard-28 × NRCHB-101 also exhibited significantly positive standard heterosis. However only six crosses *viz.*, ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1 and Gujarat Mustard-3 × TM-4 were found associated with significantly negative standard heterosis among the cross combinations for biological yield per plant under this condition.

4.7.14 Harvest Index (%)

The range for heterobeltiosis for Harvest Index under control varied from -34.52 (ZEM-1 × TM-4) to 9.82% (Jumka × Pusa Mustard-28) and for standard heterosis, the range varied from -43.21 (Pusa Musta5rd-28 × Gujarat Mustard-3) to 22.78% (Jumka × Pusa Mustard-28). None of the crosses was found associated with significantly positive and desirable heterobeltiosis. However, three cross combinations *viz.*, Jumka × Pusa Mustard-28; Jumka × DRMR-1 and Jumka × RNG-73 exhibited significantly positive standard heterosis for the trait under control.

Twenty crosses *viz.*, ZEM-1 × TM-4; Pusa Mustard- 28 × RH-30; ZEM-1 × RH-30; DRMR-1 × RH-30; Gujarat Mustard-3 × TM-4; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × RH-30; DRMR-1 × NRCHB -101; Pusa Mustard-28 × NRCHB-101; DRMR-1 × TM-4; Gujarat Mustard-3 × DRMR-1; Pusa Mustard-28 × ZEM-1; Pusa Mustard-28 × KBS-3; Gujarat Mustard-3 × ZEM-1; RNG-73 × RH-30; ZEM-1

× DRMR-1; NRCHB-101 × RH-30; RNG-73 × TM-4; Jumka × NRCHB-101 and Jumka × RH-30 exhibited significantly negative heterobeltiosis. Similarly, significantly negative standard heterosis was exhibited by thirty three crosses *viz.,* Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × KBS-3; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; ZEM-1 × TM-4; ZEM-1 × DRMR-1; Pusa Mustard- 28 × RH-30; DRMR-1 × KBS-3; ZEM-1 × RH-30; Gujarat Mustard-3 × KBS-3; DRMR-1 × RH-30; Gujarat Mustard-3 × TM-4; DRMR-1 × NRCHB -101; Pusa Mustard-28 × NRCHB-101; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × RH-30; Pusa Mustard-28 × DRMR-1; ZEM-1 × KBS-3; DRMR-1 × TM-4; RNG- 73 × ZEM-1; Gujarat Mustard-3 × DRMR-1; RNG-73 × Pusa Mustard-28; RNG-73 × KBS-3; RNG-73 × RH-30; RNG-73 × Gujarat Mustard-3; RNG-73 × TM-4; NRCHB-101 × RH-30; RNG-73 × NRCHB-101; RNG-73 × DRMR-1; NRCHB-101 × KBS-3; ZEM-1 × NRCHB-101 and RH-30 × TM-4 for Harvest Index under control.

Under 75 Kg Nitrogen per ha condition, -39.34 (Gujarat Mustard-3 × DRMR-1) to 11.04% (ZEM-1 × DRMR-1) was the range for heterobeltiosis among the cross combinations for Harvest Index. The range of standard heterosis varied from -57.83 (Gujarat Mustard-3 × KBS-3) to 14.33% (Jumka × Pusa Mustard-28). None of the crosses exhibited significantly positive and desirable heterobeltiosis for the trait. Only one genotype *i.e.* Jumka × Pusa Mustard-28 was found significantly positive for standard heterosis.

Twenty one cross combinations *viz.,* Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × TM-4; ZEM-1 × TM-4; ZEM-1 × RH-30; Pusa Mustard- 28 × TM-4; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × NRCHB-101; Gujarat Mustard-3 × RH-30; ZEM-1 × NRCHB-101; Pusa Mustard- 28 × RH-30; DRMR-1 × TM-4; RNG-73 × TM-4; Jumka × NRCHB-101; RNG-73 × RH-30; Jumka × RH-30; RNG- 73 × ZEM-1; RNG-73 × Pusa Mustard-28; RNG-73 × NRCHB-101; Jumka × TM-4 and Jumka × KBS-3 were found significantly negative for heterobeltiosis. On the other hand significantly negative and undesirable standard heterosis for Harvest Index under this condition was exhibited by thirty six crosses *viz.,* Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × Gujarat Mustard-3; Pusa

Mustard-28 × ZEM-1; Gujarat Mustard-3 × DRMR-1; DRMR-1 × KBS-3; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; ZEM-1 × RH-30; ZEM-1 × TM-4; Gujarat Mustard-3 × NRCHB-101; Pusa Mustard-28 × DRMR-1; Pusa Mustard-28 × KBS-3; Pusa Mustard-28 × NRCHB-101; RNG- 73 × ZEM-1; RNG-73 × Pusa Mustard-28; ZEM-1 × NRCHB-101; Pusa Mustard- 28 × TM-4; ZEM-1 × KBS-3; Gujarat Mustard-3 × RH-30; Pusa Mustard- 28 × RH-30; RNG-73 × KBS-3; RNG-73 × NRCHB-101; RNG-73 × RH-30; DRMR-1 × TM-4; ZEM-1 × DRMR-1; RNG-73 × Gujarat Mustard-3; RNG-73 × TM-4; DRMR-1 × NRCHB -101; RNG-73 × DRMR-1; DRMR-1 × RH-30; RH-30 × TM-4; NRCHB-101 × KBS-3; NRCHB-101 × RH-30; RH-30 × KBS-3; NRCHB-101 × TM-4 and TM-4 × KBS-3.

For 150 Kg Nitrogen per ha condition the range for heterobeltiosis for Harvest Index varied from -33.52 (Pusa Mustard-28 × TM-4) to 26.56% (Pusa Mustard-28 × KBS-3). Significantly positive heterobeltiosis was exhibited by only three cross combinations *viz.*, Pusa Mustard-28 × KBS-3; DRMR-1 × KBS-3 and DRMR-1 × NRCHB -101. Seventeen crosses *viz.*, Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × DRMR-1; ZEM-1 × RH-30; Gujarat Mustard-3 × TM-4; RNG-73 × RH-30; RNG-73 × TM-4; Gujarat Mustard-3 × RH-30; Jumka × NRCHB-101; Pusa Mustard-28 × NRCHB-101; ZEM-1 × TM-4; RNG-73 × NRCHB-101; Jumka × TM-4; RH-30 × TM-4; Jumka × RH-30; Pusa Mustard- 28 × RH-30; Jumka × ZEM-1 and Jumka × KBS-3 were found associated with significantly negative heterobeltiosis.

The range of standard heterosis under this condition varied from -44.75 (Gujarat Mustard-3 × DRMR-1) to 7.58% (Jumka × DRMR-1). None of the crosses were found associated with significantly positive standard heterosis. However, thirty four crosses *viz.*, Gujarat Mustard-3 × DRMR-1; ZEM-1 × DRMR-1; Pusa Mustard-28 × TM-4; Pusa Mustard-28 × ZEM-1; RNG- 73 × ZEM-1; Gujarat Mustard-3 × ZEM-1; ZEM-1 × RH-30; Gujarat Mustard-3 × NRCHB-101; RNG-73 × KBS-3; RNG-73 × RH-30; Pusa Mustard-28 × NRCHB-101; RNG-73 × Pusa Mustard-28; RNG-73 × NRCHB-101; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; RNG-73 × TM-4; Pusa Mustard- 28 × RH-30; ZEM-1 × NRCHB-101; NRCHB-101 × RH-30; RNG-73 × Gujarat Mustard-3; ZEM-1 × KBS-3; ZEM-1 × TM-4; RH-30 × TM-4; Pusa Mustard-28 × KBS-3; NRCHB-101 × TM-

4; Pusa Mustard-28 × DRMR-1; Pusa Mustard-28 × Gujarat Mustard-3; RH-30 × KBS-3; NRCHB-101 × KBS-3; DRMR-1 × KBS-3; TM-4 × KBS-3; DRMR-1 × TM-4 and RNG-73 × DRMR-1 exhibited significantly negative and undesirable standard heterosis for the trait under this condition.

4.7.15 Seed Oil Content (%)

The range among cross combinations under control for heterobeltiosis for seed oil content varied from -12.05 (Jumka × RH-30) to 7.09% (DRMR-1 × TM-4). Only four crosses *viz.,* DRMR-1 × TM-4; NRCHB-101 × KBS-3; Gujarat Mustard-3 × TM-4 and ZEM-1 × DRMR-1 were found associated with significantly positive and desirable heterobeltiosis for the trait under control. On the other hand, fifteen crosses *viz.,* Jumka × RH-30; Pusa Mustard- 28 × RH-30; NRCHB-101 × RH-30; Jumka × DRMR-1; Gujarat Mustard-3 × ZEM-1; RNG-73 × RH-30; Jumka × RNG-73; Gujarat Mustard-3 × RH-30; Jumka × KBS-3; Jumka × Gujarat Mustard-3; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; Jumka × TM-4; Pusa Mustard-28 × DRMR-1 and RNG-73 × DRMR-1 were found associated with significantly negative heterobeltiosis for the trait.

The range for standard heterosis for oil content under control varied from -15.54 (Jumka × KBS-3) to 2.94% (ZEM-1 × DRMR-1 and RH-30 × KBS-3). None of the crosses were found associated with significantly positive standard heterosis in this case. However significantly negative standard heterosis under control was associated with thirty five crosses *viz.,* TM-4 × KBS-3; Jumka × NRCHB-101; RNG-73 × TM-4; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × ZEM-1; NRCHB-101 × RH-30; Pusa Mustard- 28 × TM-4; Gujarat Mustard-3 × KBS-3; Pusa Mustard-28 × ZEM-1; Jumka × ZEM-1; RNG-73 × RH-30; Gujarat Mustard-3 × RH-30; NRCHB-101 × TM-4; DRMR-1 × KBS-3; Gujarat Mustard-3 × NRCHB-101; RNG-73 × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; ZEM-1 × NRCHB-101; Gujarat Mustard-3 × DRMR-1; DRMR-1 × NRCHB -101; RH-30 × TM-4; Jumka × KBS-3; Jumka × TM-4; Jumka × Gujarat Mustard-3; Jumka × RNG-73; Jumka × DRMR-1; Jumka × RH-30; Pusa Mustard-28 × KBS-3; RNG-73 × NRCHB-101; Pusa Mustard-28 ×

NRCHB-101; Pusa Mustard- 28 × RH-30; Pusa Mustard-28 × DRMR-1; Jumka × Pusa Mustard-28; RNG-73 × DRMR-1 and RNG-73 × KBS-3.

For 75 Kg Nitrogen per ha condition, -11.48 (Jumka × RH-30) to 8.23% (Gujarat Mustard-3 × TM-4) and -16.2 (Jumka × KBS-3) to 2.58% (ZEM-1 × TM-4) was the range for heterobeltiosis and standard heterosis among cross combinations. Only two crosses *i.e.* Gujarat Mustard-3 × TM-4 and NRCHB-101 × KBS-3 were found significantly positive for heterobeltiosis which was desirable. None of the crosses exhibited significantly positive standard heterosis under this condition.

Seventeen crosses *viz.,* Jumka × RH-30; NRCHB-101 × RH-30; Jumka × DRMR-1; Jumka × KBS-3; Gujarat Mustard-3 × ZEM-1; Pusa Mustard- 28 × RH-30; RNG-73 × TM-4; Jumka × ZEM-1; Pusa Mustard-28 × ZEM-1; RNG-73 × RH-30; Gujarat Mustard-3 × RH-30; Jumka × Gujarat Mustard-3; Gujarat Mustard-3 × NRCHB-101; RNG-73 × DRMR-1; Pusa Mustard-28 × DRMR-1; DRMR-1 × KBS-3 and ZEM-1 × NRCHB-101 were found associated with significantly negative heterobeltiosis. On the other hand, significantly negative standard heterosis for oil content under this condition was associated with thirty two crosses *viz.,* RNG-73 × NRCHB-101; Pusa Mustard-28 × NRCHB-101; NRCHB-101 × RH-30; Gujarat Mustard-3 × ZEM-1; Jumka × ZEM-1; Jumka × Pusa Mustard-28; Pusa Mustard-28 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; TM-4 × KBS-3; RNG-73 × DRMR-1; Pusa Mustard-28 × DRMR-1; Pusa Mustard- 28 × RH-30; DRMR-1 × KBS-3; NRCHB-101 × TM-4; RNG-73 × RH-30; Pusa Mustard-28 × Gujarat Mustard-3; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × KBS-3; ZEM-1 × NRCHB-101; RNG-73 × Gujarat Mustard-3; RNG-73 × Pusa Mustard-28; Jumka × KBS-3; Jumka × Gujarat Mustard-3; RNG-73 × TM-4; Jumka × TM-4; Pusa Mustard-28 × KBS-3; Jumka × DRMR-1; Jumka × RH-30; RNG-73 × KBS-3; Jumka × RNG-73; Jumka × NRCHB-101 and Pusa Mustard- 28 × TM-4.

Under 150 Kg Nitrogen per ha condition, the range for heterobeltiosis and standard heterosis was from -9.83 (Jumka × Gujarat Mustard-3) to 5.05% (Gujarat Mustard-3 × TM-4) and -17.3 (Jumka × Gujarat Mustard-3) to 1.1% (ZEM-1 ×

DRMR-1), respectively. None of the cross combinations exhibited significantly positive heterobeltiosis and standard heterosis for oil content under this condition.

Only two crosses *viz.,* Jumka × Gujarat Mustard-3 and Pusa Mustard-28 × ZEM-1 were found associated with significantly negative heterobeltiosis. In addition, twenty six crosses *viz.,* Pusa Mustard-28 × DRMR-1; Jumka × NRCHB-101; Jumka × TM-4; Pusa Mustard-28 × Gujarat Mustard-3; Pusa Mustard-28 × KBS-3; NRCHB-101 × TM-4; Gujarat Mustard-3 × RH-30; Pusa Mustard- 28 × TM-4; Jumka × ZEM-1; Pusa Mustard-28 × NRCHB-101; Gujarat Mustard-3 × NRCHB-101; Jumka × Pusa Mustard-28; Jumka × RNG-73; Jumka × RH-30; RNG-73 × RH-30; TM-4 × KBS-3; RNG-73 × Pusa Mustard-28; RNG-73 × DRMR-1 ZEM-1 × NRCHB-101; Pusa Mustard- 28 × RH-30; Jumka × Gujarat Mustard-3; Jumka × KBS-3; RNG-73 × TM-4; RNG-73 × NRCHB-101; RNG-73 × KBS-3 and Pusa Mustard-28 × ZEM-1 exhibited significantly negative standard heterosis for oil content under this condition.

4.7.16 Seed Nitrogen Content (%)

The range for seed nitrogen under control for heterobeltiosis and standard heterosis varied from -11.55 (ZEM-1 × KBS-3) to 4.48% (NRCHB-101 × TM-4) and -10.26 (ZEM-1 × KBS-3) to 4.76% (NRCHB-101 × KBS-3), respectively. None of the crosses exhibited significantly positive heterobeltiosis under control for seed nitrogen. However, only one cross combination *i.e.* NRCHB-101 × KBS-3 exhibited significantly positive and desirable standard heterosis for the trait. Eleven crosses *viz.,* ZEM-1 × KBS-3; RNG-73 × KBS-3; DRMR-1 × KBS-3; TM-4 × KBS-3 Jumka × KBS-3; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; RNG-73 × RH-30; ZEM-1 × RH-30; Gujarat Mustard-3 × KBS-3 and Jumka × Pusa Mustard-28 were found significantly negative for heterobeltiosis for seed nitrogen in this condition. In addition, significantly negative standard heterosis for seed nitrogen in control was exhibited by sixteen cross combinations *viz.,* RNG-73 × DRMR-1; Jumka × Pusa Mustard-28; RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × KBS-3; Gujarat Mustard-3 × NRCHB-101; ZEM-1 × RH-30; DRMR-1 × KBS-3; ZEM-1 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Jumka × Gujarat Mustard-3; Jumka × DRMR-1; Jumka × NRCHB-101; Jumka × TM-4; TM-4 × KBS-3 and ZEM-1 × KBS-3.

Table 4.52 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for seed oil content (%) and seed nitrogen content (%) under different nitrogen levels

Genotypes	Seed Oil Content (%)						Seed Nitrogen Content (%)					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
1. Jumka × RNG-73	-6.71 **	-13.22**	-4.34	-10.8**	4.12	-7.67*	0	-3.66	-0.37	-3.23	2.55	-1.06
2. Jumka × Pusa Mustard-28	-0.54	-10.04**	-0.8	-8.83**	3.85	-7.92*	-4.91 *	-7.69**	-4.44 *	-7.53**	-2.16	-4.23*
3. Jumka × Gujarat Mustard-3	-6.43 **	-14.44**	-7.08 **	-14.6**	-9.83 **	-17.3**	0	-5.13*	-0.38	-5.02**	2.57	-1.76
4. Jumka × ZEM-1	-6.25 **	-8.2**	-8.07 **	-9.2**	-5.15	-8.04*	1.54	-3.66	0.75	-3.94*	2.21	-2.46
5. Jumka × DRMR-1	-7.99 **	-12.61**	-9.62 **	-11.29**	-1.79	-6.33	0.39	-4.76*	-1.13	-5.73**	-0.37	-4.93**
6. Jumka × NRCHB-101	-0.54	-9.79**	-3.57	-10.43**	-3.01	-9.87**	-2.99	-4.76*	-1.47	-3.94*	-0.72	-3.52*
7. Jumka × RH-30	-12.05 **	-12.48**	-11.48 **	-11.04**	-5.6	-7.67*	-1.12	-2.93	1.11	-1.79	0	-2.11
8. Jumka × TM-4	-5.95 *	-14.93**	-4.41	-12.15**	1.92	-9.5**	-1.89	-4.76*	-1.84	-4.3*	-1.43	-2.82
9. Jumka × KBS-3	-6.63 **	-15.54**	-8.81 **	-16.2**	-4.71	-13.76**	-5.78 *	-4.4	-4.61 **	-3.58*	-5.23 **	-4.23*
10. RNG-73 × Pusa Mustard-28	1.05	-6**	2.5	-4.42*	4.96	-7.19*	0.75	-2.2	1.11	-1.79	0.36	-1.76
11. RNG-73 × Gujarat Mustard-3	1.05	-6**	1.45	-5.4*	2.12	-6.33	0	-3.66	-0.37	-3.23	0.36	-3.17
12. RNG- 73 × ZEM-1	-2.12	-4.16	-0.75	-1.96	0.13	-2.92	-0.38	-4.03	-1.85	-4.66**	-0.36	-3.87*
13. RNG-73 × DRMR-1	-5.28 *	-10.04**	-6.50 **	-8.22**	-2.68	-7.19*	-5.70 *	-9.16**	-5.17 **	-7.89**	-1.46	-4.93**
14. RNG-73 × NRCHB-101	-4.34	-11.02**	-3.42	-9.94**	-5.24	-11.94**	-5.22 *	-6.96**	-4.78 **	-7.17**	-2.9	-5.63**
15. RNG-73 × RH-30	-7.13 **	-7.59**	-7.45 **	-6.99**	-5.35	-7.43*	-5.22 *	-6.96**	-4.43 *	-7.17**	-2.88	-4.93**
16. RNG-73 × TM-4	-2.89	-9.67**	-8.16 **	-14.36**	-1.23	-12.3**	-0.75	-3.66	-0.74	-3.23	-0.71	-2.11
17. RNG-73 × KBS-3	-3.29	-10.04**	-4.61	-11.04**	-1.35	-10.72**	-8.30 **	-6.96**	-8.16 **	-7.17**	-5.92 **	-4.93**
18. Pusa Mustard-28 × Gujarat Mustard-3	-1.07	-9.55**	2.15	-6.87**	-1.33	-9.5**	0.75	-2.2	1.48	-1.79	0.72	-1.41
19. Pusa Mustard-28 × ZEM-1	-6.37 **	-8.32**	-7.58 **	-8.71**	-7.54 *	-10.35**	1.51	-1.47	0.74	-2.51	0.72	-1.41
20. Pusa Mustard-28 × DRMR-1	-5.41 *	-10.16**	-6.13 **	-7.85**	-5.62	-9.99**	3.77	0.73	2.96	-0.36	2.52	0.35
21. PusaMustard-28 × NRCHB-101	-1.75	-10.89**	-3.04	-9.94**	-1.05	-8.04*	4.1	2.2	4.41 *	1.79	3.24	1.06
22. Pusa Mustard- 28 × RH-30	-10.21 **	-10.65**	-8.18 **	-7.73**	-4.61	-6.7*	0	-1.83	1.11	-1.79	1.8	-0.35

Genotypes	Seed Oil Content (%)						Seed Nitrogen Content (%)					
	Control		75 Kg N/ha		150 Kg N/ha		Control		75 Kg N/ha		150 Kg N/ha	
	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE	HB	HE
23. Pusa Mustard- 28 × TM-4	0.54	-9.42**	-1.62	-10.31**	3.02	-8.53*	3.02	0	3.31	0.72	2.14	0.7
24. Pusa Mustard-28 × KBS-3	-2.58	-12.24**	-3.23	-11.78**	0	-9.5**	-2.89	-1.47	-3.55 *	-2.51	-1.05	0
25. Gujarat Mustard-3 × ZEM-1	-7.62 **	-9.55**	-8.20 **	-9.33**	-2.89	-5.85	0.39	-5.86*	1.54	-5.73**	0	-4.23*
26. Gujarat Mustard-3 × NRCHB-101	-1.93	-6.85**	-7.00 **	-8.71**	-3.58	-8.04*	-1.17	-6.96**	-0.76	-6.45**	-1.84	-5.99**
27. Gujarat Mustard-3 × DRMR-1	3.08	-5.75**	4.36	-3.07	0.92	-6.21	0	-1.83	0.74	-1.79	0.72	-2.11
28. Gujarat Mustard-3 × RH-30	-6.64 **	-7.1**	-7.20 **	-6.75**	-6.6	-8.65*	-1.12	-2.93	-0.74	-3.58*	0	-2.11
29. Gujarat Mustard-3 × TM-4	5.22 *	-3.79	8.23 **	-1.6	5.05	-3.65	-1.51	-4.4	-2.57	-5.02**	-2.14	-3.52*
30. Gujarat Mustard-3 × KBS-3	-0.67	-9.18**	2.56	-6.75**	3.72	-4.87	-5.05 *	-3.66	-4.61 **	-3.58*	-8.01 **	-7.04**
31. ZEM-1 × DRMR-1	5.13 *	2.94	1.61	0.37	4.27	1.1	-0.78	-6.59**	-0.76	-6.45**	-2.96	-7.75**
32. ZEM-1 × NRCHB-101	-4	-6**	-5.34 *	-6.5**	-4.15	-7.06*	-2.61	-4.4	-1.84	-4.3*	-1.81	-4.58**
33. ZEM-1 × RH-30	-3.2	-3.67	-2.08	-1.6	-1.62	-3.78	-5.22 *	-6.96**	-4.06 *	-6.81**	-7.55 **	-9.51**
34. ZEM-1 × TM-4	2.88	0.73	3.85	2.58	2.64	-0.49	1.13	-1.83	-0.37	-2.87	-4.29 *	-5.63**
35. ZEM-1 × KBS-3	2.38	0.24	-0.75	-1.96	3.77	0.61	-11.55 **	-10.26**	-7.45 **	-6.45**	-10.10 **	-9.15**
36. DRMR-1 × NRCHB -101	0.64	-4.41*	-0.5	-2.33	0.89	-3.78	-1.87	-3.66	-2.57	-5.02**	-0.72	-3.52*
37. DRMR-1 × RH-30	-2.09	-2.57	-0.37	0.12	-0.12	-2.31	-2.24	-4.03	-2.21	-5.02**	-2.52	-4.58**
38. DRMR-1 × TM-4	7.09 **	1.71	1.75	-0.12	4.6	-0.24	0.75	-2.2	0.37	-2.15	-2.86	-4.23*
39. DRMR-1 × KBS-3	-2.06	-6.98**	-5.87 *	-7.61**	-0.38	-4.99	-8.30 **	-6.96**	-6.74 **	-5.73**	-5.92 **	-4.93**
40. NRCHB-101 × RH-30	-9.10 **	-9.55**	-10.01 **	-9.57**	-3.49	-5.6	1.49	-0.37	1.1	-1.43	0.36	-1.76
41. NRCHB-101 × TM-4	2.43	-7.1**	0	-7.12**	-1.97	-8.89**	4.48	2.56	5.15 **	2.51	1.07	-0.35
42. NRCHB-101 × KBS-3	6.21 *	-3.67	6.21 *	-1.35	2.1	-5.12	3.25	4.76*	2.48	3.58*	1.74	2.82
43. RH-30 × TM-4	-3.94	-4.41*	-2.2	-1.72	1.99	-0.24	-0.37	-2.2	1.1	-1.43	-2.86	-4.23*
44. RH-30 × KBS-3	3.44	2.94	-0.49	0	-0.12	-2.31	-0.72	0.73	-0.71	0.36	-3.83 *	-2.82
45. TM-4 × KBS-3	1.38	-9.91**	2.61	-8.47**	2.29	-7.43*	-6.14 *	-4.76*	-5.32 **	-4.3*	-5.92 **	-4.93**

*Significance P ≤0.05; ** Significance P ≤0.01

Table 4.53 Estimates of heterobeltiosis (HB%) and standard heterosis (HE%) for chaff nitrogen content (%) under different nitrogen levels

Genotypes	Chaff Nitrogen					
	Control		75 Kg N/ha		150 Kg N/ha	
	HB	HE	HB	HE	HB	HE
1. Jumka × RNG-73	-15.02 **	-29.72**	-14.15 **	-29.26**	-14.38 **	-28.8**
2. Jumka × Pusa Mustard-28	-33.78 **	-33.73**	-31.01 **	-30.66**	-29.72 **	-29.5**
3. Jumka × Gujarat Mustard-3	5.49 **	-26.02**	1.11	-29.26**	-0.22	-29.43**
4. Jumka × ZEM-1	-35.93 **	-27.52**	-36.99 **	-28.64**	-36.64 **	-28.18**
5. Jumka × DRMR-1	-2.2	-30.03**	-1.09	-29.34**	0.44	-28.96**
6. Jumka × NRCHB-101	-45.33 **	-30.11**	-45.12 **	-30.51**	-45.49 **	-30.12**
7. Jumka × RH-30	-36.30 **	-25.08**	-40.79 **	-29.49**	-39.86 **	-29.11**
8. Jumka × TM-4	-28.57 **	-30.03**	-41.45 **	-30.74**	-40.86 **	-30.43**
9. Jumka × KBS-3	-28.51 **	-30.03**	-27.56 **	-28.17**	-26.56 **	-27.64**
10. RNG-73 × Pusa Mustard-28	-16.42 **	-16.35**	-17.05 **	-17.35**	-17.41 **	-17.16**
11. RNG-73 × Gujarat Mustard-3	1.62	-15.96**	1.89 *	-16.03**	1.12	-15.92**
12. RNG- 73 × ZEM-1	-25.64 **	-15.88**	-26.03 **	-16.5**	-26.23 **	-16.38**
13. RNG-73 × DRMR-1	0.29	-17.06**	1.89 *	-15.8**	-7.10 **	-22.75**
14. RNG-73 × NRCHB-101	-35.79 **	-17.92**	-35.98 **	-18.05**	-35.98 **	-17.93**
15. RNG-73 × RH-30	-29.81 **	-17.45**	-30.26 **	-17.9**	-30.24 **	-17.78**
16. RNG-73 × TM-4	-16.45 **	-18.16**	-31.58 **	-19.3**	-30.30 **	-18.01**
17. RNG-73 × KBS-3	-15.90 **	-17.69**	-16.54 **	-17.59**	-16.08 **	-17.31**
18. Pusa Mustard-28 × Gujarat Mustard-3	-0.39	-0.31	-0.78	-0.62	-1.01	-0.7
19. Pusa Mustard-28 × ZEM-1	-11.40 **	0.24	-12.33 **	-0.16	-11.78 **	0
20. Pusa Mustard-28 × DRMR-1	0.08	0.16	-0.78	-0.47	-0.46	-0.16
21. PusaMustard-28 × NRCHB-101	-23.12 **	-1.73	-23.17 **	-2.1**	-23.32 **	-1.71
22. Pusa Mustard- 28 × RH-30	-15.17 **	-0.24	-15.79 **	-0.23	-15.22 **	-0.08
23. Pusa Mustard- 28 × TM-4	-0.47	-0.39	-16.45 **	-0.78	-15.51 **	-0.62
24. Pusa Mustard-28 × KBS-3	0.16	0.24	0	0.08	-0.15	0.16
25. Gujarat Mustard-3 × ZEM-1	-54.07 **	-48.03**	-54.11 **	-48.17**	-54.04 **	-47.9**
26. Gujarat Mustard-3 × NRCHB-101	-27.80 **	-48.35**	-27.17 **	-48.25**	-24.72 **	-47.75**
27. Gujarat Mustard-3 × DRMR-1	-60.02 **	-48.9**	-59.76 **	-48.33**	-59.42 **	-47.98**
28. Gujarat Mustard-3 × RH-30	-56.02 **	-48.27**	-55.92 **	-47.7**	-55.27 **	-47.28**
29. Gujarat Mustard-3 × TM-4	-46.23 **	-47.33**	-54.61 **	-46.77**	-53.80 **	-45.65**
30. Gujarat Mustard-3 × KBS-3	-45.62 **	-46.78**	-46.46 **	-47.16**	-40.66 **	-41.54**
31. ZEM-1 × DRMR-1	0.42	13.6**	-0.68	13.07**	-0.41	12.89**
32. ZEM-1 × NRCHB-101	-10.64 **	14.23**	-10.37 **	14.55**	-10.66 **	14.52**
33. ZEM-1 × RH-30	-2.81 *	14.31**	-3.95 **	13.31**	-3.69 *	13.51**
34. ZEM-1 × TM-4	1.67	15.02**	-2.63 **	15.18**	-1.85	15.45**
35. ZEM-1 × KBS-3	2.36	15.8**	1.37 *	15.56**	1.99	15.61**
36. DRMR-1 × NRCHB -101	-43.73 **	-28.07**	-43.90 **	-28.17**	-43.61 **	-27.72**
37. DRMR-1 × RH-30	-39.51 **	-28.85**	-40.13 **	-29.18**	-39.53 **	-28.73**
38. DRMR-1 × TM-4	-28.01 **	-29.48**	-40.13 **	-29.34**	-39.47 **	-28.8**
39. DRMR-1 × KBS-3	-28.11 **	-29.64**	-29.13 **	-29.88**	-28.84 **	-29.89**
40. NRCHB-101 × RH-30	0.74	28.77**	0.61	27.7**	-0.79	27.17**
41. NRCHB-101 × TM-4	1.78	30.11**	1.22 *	29.57**	2	30.75**
42. NRCHB-101 × KBS-3	2.89 *	31.53**	3.05 **	31.28**	1.88	30.59**
43. RH-30 × TM-4	0.4	18.08**	0.66	19.22**	0.07	17.93**
44. RH-30 × KBS-3	0.13	17.77**	-0.66	17.12**	0.07	17.93**
45. TM-4 × KBS-3	0.96	-1.1	-14.47 **	1.56*	-12.48 **	2.95

*Significance P ≤0.05; ** Significance P ≤0.01

In case of 75 Kg Nitrogen per ha condition, the range for heterobeltiosis and standard heterosis for seed nitrogen, varied from -8.16 (RNG-73 × KBS-3) to 3.31% (Pusa Mustard-28 × TM-4) and -7.89 (RNG-73 × DRMR-1) to 3.58% (NRCHB-101 × KBS-3), respectively. Two crosses *viz.*, NRCHB-101 × TM-4 and Pusa Mustard-28 × NRCHB-101 were found associated with significantly positive and desirable heterobeltiosis. Only one genotype *i.e.* NRCHB-101 × KBS-3, exhibited significantly positive standard heterosis.

Twelve cross combinations *viz.,* RNG-73 × KBS-3; ZEM-1 × KBS-3; DRMR-1 × KBS-3; TM-4 × KBS-3; RNG-73 × DRMR-1; RNG-73 × NRCHB-101; Jumka × KBS-3; Gujarat Mustard-3 × KBS-3; Jumka × Pusa Mustard-28; RNG-73 × RH-30; ZEM-1 × RH-30 and Pusa Mustard-28 × KBS-3 were found associated with significantly negative heterobeltiosis in condition of 75 Kg Nitrogen per ha. In addition, Twenty five crosses *viz.*, RNG-73 × DRMR-1; Jumka × Pusa Mustard-28; RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × KBS-3; ZEM-1 × RH-30; Gujarat Mustard-3 × NRCHB-101; ZEM-1 × DRMR-1; ZEM-1 × KBS-3; Jumka × DRMR-1; Gujarat Mustard-3 × ZEM-1; DRMR-1 × KBS-3; Jumka × Gujarat Mustard-3; Gujarat Mustard-3 × TM-4; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; RNG- 73 × ZEM-1; Jumka × TM-4; ZEM-1 × NRCHB-101; TM-4 × KBS-3; Jumka × ZEM-1; Jumka × NRCHB-101; Jumka × KBS-3; Gujarat Mustard-3 × RH-30 and Gujarat Mustard-3 × KBS-3 exhibited significantly negative standard heterosis for seed nitrogen under this condition.

Under 150 Kg Nitrogen per ha condition, the range for heterobeltiosis varied from -10.10 (ZEM-1 × KBS-3) to 3.24% (Pusa Mustard-28 × NRCHB-101). None of the cross combinations exhibited significantly positive heterobeltiosis for seed nitrogen under this condition. However, nine crosses *viz.*, ZEM-1 × KBS-3; Gujarat Mustard-3 × KBS-3; ZEM-1 × RH-30; RNG-73 × KBS-3; DRMR-1 × KBS-3; TM-4 × KBS-3; Jumka × KBS-3; ZEM-1 × TM-4 and RH-30 × KBS-3 were found associated with significantly negative heterobeltiosis for the trait.

The range of standard heterosis for seed nitrogen content under 150 Kg Nitrogen per ha condition varied from -9.51 (ZEM-1 × RH-30) to 2.82% (NRCHB-

101 × KBS-3). None of the cross combinations exhibited significantly positive standard heterosis. In addition, significantly negative standard heterosis for seed nitrogen under this condition, was exhibited by twenty four crosses *viz.,* ZEM-1 × RH-30; ZEM-1 × KBS-3; ZEM-1 × DRMR-1; Gujarat Mustard-3 × KBS-3; Gujarat Mustard-3 × NRCHB-101; RNG-73 × NRCHB-101; ZEM-1 × TM-4; Jumka × DRMR-1; RNG-73 × DRMR-1; RNG-73 × RH-30; RNG-73 × KBS-3; DRMR-1 × KBS-3; TM-4 × KBS-3; ZEM-1 × NRCHB-101; DRMR-1 × RH-30; Jumka × Pusa Mustard-28; Jumka × KBS-3; Gujarat Mustard-3 × ZEM-1; DRMR-1 × TM-4; RH-30 × TM-4; RNG- 73 × ZEM-1; Jumka × NRCHB-101; Gujarat Mustard-3 × TM-4 and DRMR-1 × NRCHB -101.

4.7.17 Chaff Nitrogen Content (%)

In case of control the range of heterobeltiosis varied from-60.02 (Gujarat Mustard-3 × DRMR-1) to 5.49% (Jumka × Gujarat Mustard-3). For heterobeltiosis significant and positive heterobeltiosis was observed for only two cross combinations *viz.,* Jumka × Gujarat Mustard-3 and NRCHB-101 × KBS-3 whereas, twenty crosses *viz.,* Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Jumka × NRCHB-101; DRMR-1 × NRCHB -101; DRMR-1 × RH-30; Jumka × RH-30; Jumka × ZEM-1; RNG-73 × NRCHB-101; Jumka × Pusa Mustard-28; RNG-73 × RH-30; Jumka × TM-4; Jumka × KBS-3; DRMR-1 × KBS-3; DRMR-1 × TM-4; Gujarat Mustard-3 × NRCHB-101; RNG- 73 × ZEM-1 and PusaMustard-28 × NRCHB-101 exhibited significant and negative heterosis.

Standard heterosis was varied from -48.9 (Gujarat Mustard-3 × DRMR-1) to 31.53% (NRCHB-101 × KBS-3) under control. Nine cross combinations *viz.,* NRCHB-101 × TM-4; NRCHB-101 × RH-30; RH-30 × TM-4; RH-30 × KBS-3; ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × RH-30; ZEM-1 × NRCHB-101; ZEM-1 × DRMR-1 exhibited significantly positive heterosis over the check Varuna. On the other side thirty crosses *viz.,* Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Jumka × Pusa Mustard-28;

NRCHB-101 × KBS-3; Jumka × NRCHB-101; Jumka × DRMR-1; Jumka × TM-4; Jumka × KBS-3; Jumka × RNG-73; DRMR-1 × KBS-3; DRMR-1 × TM-4; DRMR-1 × RH-30; DRMR-1 × NRCHB -101; Jumka × ZEM-1; Jumka × Gujarat Mustard-3; Jumka × RH-30; RNG-73 × TM-4; RNG-73 × NRCHB-101; RNG-73 × KBS-3; RNG-73 × RH-30; RNG-73 × DRMR-1; RNG-73 × Pusa Mustard-28; RNG-73 × Gujarat Mustard-3; RNG- 73 × ZEM-1 showed significantly negative heterosis over the check.

Under 75 Kg N/ha Heterobeltiosis varied from -59.76 (Gujarat Mustard-3 × DRMR-1) to 3.05% (NRCHB-101 × KBS-3). Significantly positive heterobeltiosis was observed by five crosses *viz.*, NRCHB-101 × KBS-3; RNG-73 × Gujarat Mustard-3; RNG-73 × DRMR-1; ZEM-1 × KBS-3; NRCHB-101 × TM-4. Whereas, thirty one cross combinations Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × KBS-3; Jumka × NRCHB-101; DRMR-1 × NRCHB -101; Jumka × TM-4; Jumka × RH-30; DRMR-1 × RH-30; DRMR-1 × TM-4; Jumka × ZEM-1; RNG-73 × NRCHB-101; RNG-73 × TM-4; Jumka × Pusa Mustard-28; RNG-73 × RH-30; DRMR-1 × KBS-3; Jumka × KBS-3; Gujarat Mustard-3 × NRCHB-101; RNG- 73 × ZEM-1; PusaMustard-28 × NRCHB-101; RNG-73 × Pusa Mustard-28; RNG-73 × KBS-3; Pusa Mustard- 28 × TM-4; Pusa Mustard- 28 × RH-30; TM-4 × KBS-3; Jumka × RNG-73; Pusa Mustard-28 × ZEM-1; ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × TM-4 exhibited significantly negative heterosis.

Standard heterosis varied from -48.33 (Gujarat Mustard-3 × DRMR-1) to 15.56% (ZEM-1 × KBS-3) under 75 Kg Nitrogen per ha condition. Significantly positive heterosis over check Varuna was observed by eleven cross combinations *viz.*, NRCHB-101 × KBS-3; NRCHB-101 × TM-4; NRCHB-101 × RH-30; RH-30 × TM-4; RH-30 × KBS-3; ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × RH-30; ZEM-1 × DRMR-1; TM-4 × KBS-3, remaining crosses showed significantly negative heterosis over the check.

Under 150 Kg Nitrogen per ha condition, the range of heterobeltiosis varied from -59.42 (Gujarat Mustard-3 × DRMR-1) to 2% (NRCHB-101 × TM-4). None of the crosses exhibited significantly positive heterobeltiosis for chaff nitrogen under this condition. However, significantly negative and undesirable heterobeltiosis for the trait was exhibited by thirty one cross combinations *viz.*, Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × TM-4; Jumka × NRCHB-101; DRMR-1 × NRCHB -101; Jumka × TM-4; Gujarat Mustard-3 × KBS-3; Jumka × RH-30; DRMR-1 × RH-30; DRMR-1 × TM-4; Jumka × ZEM-1; RNG-73 × NRCHB-101; RNG-73 × TM-4; RNG-73 × RH-30; Jumka × Pusa Mustard-28; DRMR-1 × KBS-3; Jumka × KBS-3; RNG- 73 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; PusaMustard-28 × NRCHB-101; RNG-73 × Pusa Mustard-28; RNG-73 × KBS-3; Pusa Mustard- 28 × TM-4; Pusa Mustard- 28 × RH-30; Jumka × RNG-73; TM-4 × KBS-3; Pusa Mustard-28 × ZEM-1; ZEM-1 × NRCHB-101; RNG-73 × DRMR-1 and ZEM-1 × RH-30.

The range of standard heterosis among the cross combinations under 150 Kg Nitrogen per ha condition varied from -47.98 (Gujarat Mustard-3 × DRMR-1) to 30.75% (NRCHB-101 × TM-4). Significantly positive and desirable standard heterosis for the trait under this condition was associated with ten crosses *viz.*, NRCHB-101 × TM-4; NRCHB-101 × KBS-3; NRCHB-101 × RH-30; RH-30 × TM-4; RH-30 × KBS-3; ZEM-1 × KBS-3; ZEM-1 × TM-4; ZEM-1 × NRCHB-101; ZEM-1 × RH-30 and ZEM-1 × DRMR-1. On the other side, twenty seven crosses *viz.*, Gujarat Mustard-3 × DRMR-1; Gujarat Mustard-3 × ZEM-1; Gujarat Mustard-3 × NRCHB-101; Gujarat Mustard-3 × RH-30; Gujarat Mustard-3 × TM-4; Gujarat Mustard-3 × KBS-3; Jumka × TM-4; Jumka × NRCHB-101; DRMR-1 × KBS-3; Jumka × Pusa Mustard-28; Jumka × Gujarat Mustard-3; Jumka × RH-30; Jumka × DRMR-1; Jumka × RNG-73; DRMR-1 × TM-4; DRMR-1 × RH-30; Jumka × ZEM-1; DRMR-1 × NRCHB -101; Jumka × KBS-3; RNG-73 × DRMR-1; RNG-73 × TM-4; RNG-73 × NRCHB-101; RNG-73 × RH-30; RNG-73 × KBS-3; RNG-73 × Pusa Mustard-28; RNG- 73 × ZEM-1 and RNG-73 × Gujarat Mustard-3 exhibited significantly negative standard heterosis for chaff nitrogen under this condition.

The contribution of various parameters including number of primary and secondary branches, number of siliqua per plant and Harvest Index towards heterosis has also been established by Pradhan *et al.* (1993). The desirable and superior cross combinations based on the positive heterosis for various characters including seed yield, biological yield, Harvest Index and oil content have been identified by Kumar *et al.* (1990); Patel *et al.* (1999); Gami and Chauhan (2007); Nigam and Richa (2009); Chaudhary *et al.* (2010); Chaudhari *et al.* (2015); Tomar and Singh (2016); Mohan *et al.* (2017); Chaurasia *et al.* (2018) and Yadav *et al.* (2020). The negative heterosis value have been used to identify the desirable cross combinations for various characters including earliness for flowering and maturity by Turi *et al.* (2006) and Gupta *et al.* (2010). High level of standard heterosis for seed yield in Indian mustard have been obtained in the studies by Verma *et al.* (2011) upto (80.97) percent and Kumar *et al.* (2013) upto (43.90) % in the Indian Mustard. Adhikari *et al.* (2017) also observed three types of heterosis *viz.*, mid, better and standard for most of the traits except plant height.

In the present study relatively lesser number of combinations showing standard heterosis for various characters were found as compared to heterobeltiosis which was in line with studies of Katiyar *et al.* (2000 & 2005). Dahiya *et al.* (2017) also found twenty crosses out of total forty five crosses exhibiting heterobeltiosis in Indian mustard but, only twelve were found associated with economic heterosis for seed yield. In the present study, only few cross combinations exhibited heterobeltiosis with respect to few characters, but none of them exhibited economic heterosis for the respective character. Such results were also found by Kumar and Srivastva (2007) for seed yield and oil content in their study on Indian mustard.

SUMMARY AND CONCLUSION

The present study entitled "Evaluation of heterotic combinations for seed yield and quality parameters under various nitrogen levels in Indian mustard [*Brassica juncea* L. Czern.& Coss.]" was undertaken with a view to examine the mean performance, magnitude of heterosis and combining ability of parental lines and their hybrids under different regimes of nitrogen levels. The experimental material comprised of 10 parents, their 45 cross combinations produced through diallel crossing (without reciprocals) and one check Varuna. The experiment was laid out in a alpha lattice design with two replications at School of Agriculture research farm Jalandhar Punjab during 2017 and 2018.

The data were observed and recorded for seventeen characters including seed yield per plant under three different nitrogen levels including control. The summary of the results obtained from the present research endeavour are give below:

The analysis of variance for yield and its contributing characters revealed that the mean squares due to genotypes were highly significant for most of the characters studied under various nitrogen levels *viz.,* 75Kg N/ha & 150Kg N/ha and control. The analysis of variance also depicted significant differences for all the characters among parents and hybrids under all three conditions. The significant mean sum of squares differences for the characters studied among parents showed that material used for present study had sufficient variability for different traits.

Based on mean values of parents, two parental genotypes *viz.,* Jumka and ZEM-1 performed best under all three conditions *viz.,* control, 75 Kg N/ha and 150 Kg N/ha for different characters including seed yield per plant. The cross combinations *viz.,* RH-30 × KBS-3; NRCHB-101 × KBS-3; RH-30 × TM-4; RNG-73 × DRMR-1 and RNG-73 × Gujarat Mustard-3 were found promising in general for all seventeen traits including the resulting oil yield under all three nitrogen levels. The cross combination RNG-73 × DRMR-1 was found most responsive for nitrogen based on overall performance. In addition, high mean values for seed yield per plant were exhibited by two cross combinations *viz.,* RNG-73 × DRMR-1 and RH-30 × KBS-3. These cross combinations can be utilized in future breeding programmes.

The seed nitrogen uptake and the stover nitrogen uptake seem to significantly increase in general with increase in nitrogen levels. The other traits *viz.,* days to flower initiation, days to fifty percent flowering, days to maturity, plant height, number of secondary branches per plant, siliqua length, 1000-seed weight, seed yield per plant, Harvest Index, oil content, seed nitrogen and chaff nitrogen were found to increase with increase in nitrogen level. However, the variation was non-significant in majority of cases. A declining trend was observed for number of seeds per siliqua on increase of nitrogen levels. The traits *viz.,* number of primary branches per plant, length of main shoot, number of siliqua on main shoot and biological yield seems to be unaffected across the nitrogen levels under study.

The pooled GGE analysis of variance revealed that the mean squares due to genotypes and environment were significant for majority of the characters. The G × E interaction was insignificant for majority of the traits except for siliqua length and seed nitrogen where it was highly significant. IPCA-I was found significant for majority of the traits. However, IPCA-II was significant for all traits except for plant height, siliqua length, test weight, seed yield per plant, seed oil content and seed & chaff nitrogen content. On overall basis, the condition of 75 Kg N/ha was established as the most discriminating environment for majority of the characters. However the condition of 150 Kg N/ha and control were found discriminating for seed yield per plant. In addition, the condition of 75 Kg N/ha was also found representative majority of the traits. In maximum cases all three environments *viz.,* control, 75 Kg N/ha and 150 Kg N/ha were confined into the same sector of GGE biplot which depicts close correlation between them.

Analysis of variance for combining ability under various nitrogen levels *viz.,* Control, 75KgN/ha and 150KgN/ha showed significant *gca* differences for all the traits and significant *sca* differences for most of the traits barring few cases across the nitrogen levels. The ANOVA indicated importance of both additive and dominant gene actions for the expression of various traits. The lower potence ratio

($\sigma 2gca/\sigma 2sca$) indicated higher role of dominance gene actions in the inheritance of the traits.

General combining ability estimates showed parent RNG-73: RH-30 and Gujarat Mustard-3 as desirable general combiners for various traits including seed yield and oil content under all three nitrogen levels *viz.*, Control, 75Kg/ha and 150Kg/ha.

Based on the specific combining ability estimates, none of the cross exhibited desirable *sca* effects for the traits under study. However, the cross combination RH-30 × KBS-3 appeared most promising for seed yield including some related traits and oil content across various nitrogen levels. The other cross combinations *viz.*, Jumka × ZEM-1, Pusa Mustard-28 × ZEM-1 and RNG-73 × Gujarat Mustard-3 also exhibited desirable *sca* effects in general under three nitrogen levels.

The additive dominance model was found adequate for plant height, Harvest Index and chaff nitrogen under all three nitrogen levels *viz.*, Control, 75 Kg and 150 Kg N/ha. The model was also fitted for number of secondary branches per plant (under control & 150 Kg N/ha), length of main shoot (75 Kg N/ha), number of siliquae on main shoot (150 Kg N/ha), number of seeds per siliqua (75 Kg N/ha), seed yield per plant (75 Kg and 150 Kg N/ha), biological yield per plant (150 Kg N/ha) and seed oil content (150 Kg N/ha). The overdominance was found predominantly responsible for inheritance of most of the traits under all three Nitrogen levels. However the graphical and component analysis depicted predominance of complete dominance in case of length of main shoot (Under control), number of seeds per siliqua (Control) and Harvest Index (75 Kg N/ha). The partial dominance was depicted to control inheritance of length of main shoot under 75 Kg N/ha condition only. The wide scattering of parental array points for all the characters indicated the existence of considerable genetic diversity among the parents. On over all basis, the parents Jumka, RNG-73 and Pusa Mustard-28 possessed more dominant genes.

The heterobeltiosis estimates indicated that only few cross combinations were significantly desirable for the various traits under three nitrogen levels *viz.*, Control, 75Kg/ha and 150Kg/ha. In addition the cross combinations *viz.*, Pusa Mustard-28 ×

ZEM-1; Pusa Mustard-28 × DRMR-1; Jumka × Pusa Mustard-28; RNG-73 × DRMR-1 and RNG-73 × Gujarat Mustard-3 exhibited desirable values for most of the characters including seed yield per plant.

The estimates of the standard or economic heterosis indicated the superiority of cross combinations *viz.*, RNG-73 × DRMR-1, RNG-73 × Gujarat Mustard-3; RNG-73 × TM-4; RNG-73 × KBS-3 and Jumka × Pusa Mustard-28 for the various characters under all three nitrogen levels including the economic traits of seed yield. However, most of the cross combinations were found less responsive for standard heterosis at higher nitrogen dose of 150Kg/ha for all seventeen traits.

The perusal of *per se* performance, combining ability analysis including general & specific combining ability effects along with the estimates of heterosis (heterobeltiosis and standard heterosis) indicated that the hybrids RNG-73 × DRMR-1; RNG-73 × Gujarat Mustard-3 ; RH-30 × KBS-3 and NRCHB-101 × KBS-3 can be exploited for desirable results for seed/oil yield and other related traits in breeding programmes. These cross combinations can further be evaluated at large scale for future utilization.

REFERENCES

Acharya NN and Swain D. 2004. Combining ability analysis of seed yield and its components in Indian mustard *(Brassica juncea* L.). *Indian Journal of Agricultural Research* 38 (1): 40 – 44

Adhikari S, Pathak S, Joshi D, Pant U, Singh AK and Bhajan R. 2017. Heterosis analysis for seed yield and other component traits in Indian Mustard [*Brassica juncea* (L.) Czern. and Coss.]. *International Journal of Current Microbiology and Applied Sciences 6*(10): 1157-1162

Aher CD, Chinchane VN, Shelke LT, Borgaonkar, SB. and Gaikwad AR. 2009. Genetic study in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.]. *International Journal of Plant Science* 4(1): 83-85

Akbar M, Babar MA and Hussain M. 2008. Combining ability studies in rapeseed (*Brassica napus*). *International Journal of Agriculture and Biology* 10(2): 205–208

Allard RW. 1960. Principles of Plant Breeding. *John Wiley and Sons, Inc-New York*

Arifullah M, Munir M, Mahmood A, Khan S, Ajmal and Shabbir G. 2012. Combining ability analysis of some yield attributes in Indian mustard *(Brassica juncea* L*) Pakistan. Journal of Agriculture Research.* 25(2): 104-109

Arora A, Singh V and Das RR. 1994. Yield and oil quality of mustard as affected by rates of nitrogen and sulphur in inceptisols. *Journal of Oilseeds Research* 11: 273-76

Azizinia, S. 2012. Combining Ability Analysis of Yield Component Parameters in Winter Rapeseed Genotypes (*Brassica napus* L.). *Journal of Agriculture Science* 4(4): 87-94

Balint T, Rengel Z and Allen D. 2008. Australian canola germplasm differs in nitrogen and sulphur efficiency. *Australian Journal of Agricultural Research* 59**:** 167-74

Barupal HL, Sharma AK, Shekhawat HS, Kumar P and Kumar M. 2017. Heterosis Studies in Indian Mustard (*Brassica juncea*). *International Journal of Agriculture Innovations and Research* 5: 1468-1473

Bhari NR, Siag RK and Mann PS. 2000. Response of Indian mustard (*Brassica juncea*) to N and P on Torripsamments of north-western Rajasthan. *Indian Journal of Agronomy* 45: 746-51

Chaudhari NH, Patel M, Gami RA and Shah SK. 2015. Study of combining ability and heterosis for seed yield and seed quality traits in rapeseed [*Brassica rapa* L.]. *The Bioscan* 10 (4): 1985-1989

Chaudhary PG and Lal SK. 2010. Heterosis and combining ability analysis for yield and its components in Indian mustard (*Brassica juncea* L. Czern. & Coss). *Frontiers of Agriculture in China* 4 (3): 299-307

Chaudhary PK, Patel PT, Prajapati KP, Patel JR, Patel PJ and Patel BK. 2019. Combining ability analysis for seed yield and its contributing traits in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. *International Journal of Agriculture, Environment and Biotechnology* 12(2): 368-372

Chaudhary SPS, Sharma SN and Singh AK. 1997. Line × Tester analysis in Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Indian Journal of Genetics Plant Breeding* 57(2): 168-173

Chaurasiya JP, Singh M, Yadav RK and Singh L. 2018. Heterosis and combining ability analysis in Indian mustard (*Brassica juncea* (L.) Czern. and Coss.) *Journal of Pharmacognosy and Phytochemistry* 2: 604-609

DAC&FW. 2019. Rapeseed- mustard area and production data. *https://eands.dacnet.nic.in* 07 August, 2021

Dahiya N, Bhajan R, Rashmi and Pant U. 2018. Heterosis and combining ability for different traits in local germplasm and varietal crosses in *Brassica juncea* (L.). *International Journal of Chemical Studies* 6 (1): 1884-1887

Deekshitulu V*VR*, Subbaiah G, Viah R*VR* and Singh M. 1998. Effect of nitrogen and sulphur on seed yield, oil content and oil yield of Indian mustard. *Journal of Oilseeds Research* 15**:** 355-56

Deekshitulu V*VR*, Subbaiah G, Viah R*VR* and Singh M. 1998. Effect of nitrogen and sulphur on seed yield, oil content and oil yield of Indian mustard. *Journal of Oilseeds Research* 15: 355-56

Dholu VK, Sasidharan N, Suthar K, Bhusan B and Patel JN. 2014. Heterosis and combining ability analysis in Indian mustard, *Brassica juncea* (L.) Czern. & Coss. *International Journal of Agricultural Sciences* 10: 102-107

Ding M, Tier B, Yan W, Powell MB, Mcrae TA and Wu HX. 2008. Application of GGE biplot analysis to evaluate Genotype (G), Environment (E) and G × E interaction on *Pinus radiata*: a case study. *New Zealand Journal of Forestry Science* 38(1): 132- 142

Dixit S, Kumar K and Chauhan YS. 2005. Heterosis in Indian mustard (*Brassica juncea* L. Czern. and Coss.). *Agriculture Science Digest* 25(1): 19-22

Donald CM and Hamblin J. 1976. The biological yield and Harvest Index of cereals as agronomic and plant breeding criteria. *Advances in. Agronomy* **28:**361-405

Dongarkar KP, Pawar WS, Khawale *VS*, Khutate NG and Gudadhe NN. 2005. Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea* L.). *Journal of Soils and Crops* 15: 163-67

DRMR. 2019. Rapeseed-mustard area and production data. *https://www.drmr.res.in* 07 August, 2021

Duan YH, Zhang YL, Ye T, Fan xR, xu GH and Shen QR. 2007. Responses of rice cultivars with different nitrogen use efficiency to partial nitrate nutrition. *Annals of Botany* 99: 1153-60

East EM. 1936. Heterosis. *Genetics* 26 : 375-397

Fonseca S and Patterson P. 1968. Hybrid vigor in a seven parent diallel cross in common winter wheat. *Crop Science* 8: 85-88

Frasat S, Muhammad HNT, Shehzad AG, and Saeed M. 2013. Heterosis and combining ability for seed yield and its components in *Brassica juncea* L. *Albanian journal of Agriculture Science 12 (2): 203 -208*

Gallais A and Coque M. 2005. Genetic variation and selection for nitrogen use efficiency in maize a synthesis. *Maydica* 50: 531-37

Gami RA and Chauhan RM. 2013. Heterosis and combining ability analysis for seed yield and its attributes in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. *Indian Jounal of Agricultural Research* 47 (6) : 535 – 539

Garnayak LM, Singh NP, Singh S and Paikaray RK. 2000. Influence of irrigation and nitrogen on growth, yield and nutrient uptake by late sown *Brassica* oilseeds. *Indian Journal of Agronomy* 45: 371-78

Ghosh SK, Gulati SC and Rajani R. 2002. Combining ability and heterosis for seed yield and its components in Indian mustard (*Brassica juncea* (L.) Czern. & Coss). *Indian Journal of Genetics and Plant Breeding* 62(1): 29-33

Goswami PK and Behl RK. 2005. Exploitation of heterosis and selection of superior combiners in Indian mustard. *Annals of Agriculture Research* 26(1): 56-58

Gouis L, Beghin D, Heumez E and Pluchard P. 2000. Genetic differences for nitrogen uptake and nitrogen utilization efficiencies in winter wheat. *European Journal of Agronomy* 12**:** 163-73

Grami B and Lacroix LJ. 1977. Cultivar variation in total nitrogen uptake in rape. *Canadian Journal of Plant Science* 57**:** 619-24

Griffing B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. *Australian Journal of Biological Science* 9: 463-493

Gul S, Uddin R, Khan NU, Arif M , Goher R and Zakaria M. 2018. Inheritance studies through combining ability for morphological and yield traits in F_1 populations of *Brassica napus*. *The Journal of Animal & Plant Sciences* 28(4): 1094-1102

Gupta P, Chaudhary HB and Lal SK. 2010. Heterosis and combining ability analysis for yield and its components in Indian mustard (*Brassica juncea* L. Czern. & Coss). *Frontiers of Agriculture in China* 4 (3): 299–307

Gupta P. 2009. Heterosis and correlation analysis for yield and its components in Indian Mustard [(*Brassica juncea* L.). *Souvenir of National Seminar on "Designing Crops for the changing climate* 68: 205-210

Gupta VP, Sekhon MS and Satija DR. 1991. Studies on genetic diversity, heterosis and combining ability in Indian mustard (*Brassica juncea* L. (Czern. & Coss)). *Indian Journal of Genetics and Plant Breeding* 51 (4): 448-453

Hayes HK, Immer FR and Smith DC. 1955. Methods of plant breeding. *Mc Graw Hill Book Company, Inc., New York*. PP. 432

Hayman BI. 1954. The theory and analysis of diallel crosses. *Genetics* 39 : 789-809

Henderson CR. 1952. Specific and general combining ability. *In heterosis (Gowen, J.W. ed.), Iowa State College Press, Ames Iowa.* PP 352-371.

Hirel B and Lemaire G. 2005. From agronomy and ecophysiology to molecular genetics for improving nitrogen use efficiency in crops. *Journal of Crop Improvement* 15: 369-420

Hirel B, Bertin P, Quillere I, Bourdoncle W, Attagnat C, Dellay C, Gouy A, Cadiou S, Retailliau C, Falque M and Gallais A. 2001. Towards a better understanding of the genetic and physiological basis for nitrogen use efficiency in maize. *Plant Physiology* 125**:** 1258-70

Jinks JL. 1956. The F2 and backcross generations from set of diallel crosses. *Heredity* 10 : 1-30

Jones DF. 1917. Dominance of linked factors as a means of accounting for heterosis. *Genetics* 2: 466-479

Kandpal BK. 2001. Integrated nutrient management in relation to growth, yield and quality of *Brassica carinata* and its residual effect on succeeding rice. *Ph.D. Thesis, GB PUAT, Pant Nagar, Uttrakhand PP-203*

Katiyar RK, Chamola R, Banerjee PK and Singh HB. 2005. Assessment of heterosis and combining ability for seed yield in Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Brassica* 7(1/2): 33-37

Katiyar RK, Chamola, R. and Chopra VL. 2000. Heterosis and combining ability in Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Indian Journal of Genetics and Plant Breeding* 4: 557-559

Kaur S, Kumar R, Kaur R, Singh I, Singh H and Kumar V. 2019. Heterosis and combining ability analysis in Indian mustard (*Brassica juncea* L.). *Journal of oilseed Brassica* 10(1) : 38-46

Keivanrad S and Zandi P. 2014. Effect of nitrogen levels on growth, yield and oil quality of indian mustard grown under different plant densities. *Cercetari Agronomice in Moldova* 1 (157) : 28-35

Khulbe RK, Pant DP and Rawat RS. 1998. Combining ability analysis for yield and its components in Indian mustard. *Journal of Oilseeds Research* 15 (2): 219-226

Koutroubas SD and Ntanos DA. 2003. Genotypic differences for grain yield and nitrogen utilization in *Indica* and *Japonica* rice under Mediterranean conditions. *Field Crops Research* 83: 251-60

Kumar A and Kumar S. 2008. Crop growth rate and developmental characteristics of Indian mustard var Vardan to varying levels of nitrogen and sulphur. *Indian Journal of Agriculture Research* 42: 112-15

Kumar A and Srivastava S. 2000. Combining ability of mustard genotypes. *Journal of Applied Biology* 10 (1): 12-17

Kumar A and Srivastava S. 2007. Heterosis in quantitative characters of mustard (*Brassica juncea* (L.) Czern. & amp; Coss). *Journal of Applied Biology* 17: 25-28

Kumar A, Singh M, Yadav RK, Singh P, and Lallu. 2018 . Study on combining ability for growth, yield and quality characters of Indian mustard. *The Pharma Innovation Journal* 7(1): 417-424

Kumar D, Singh S, Sharma SN and Shivay YS. 2000. Relative efficiency of urea and dicyandiamide-blended urea on mustard (*Brassica juncea*) varieties. *Indian Journal of Agronomy* 45: 179-83

Kumar P, Lamba A, Yadav RK, Singh L and Singh M. 2013. Analysis of yield and its components based on heterosis and combining ability in Indian mustard *[Brassica juncea* (L.) Czern. & Coss.]. *The Bioscan* 8(4): 1497-1502

Kumar PR, Arora RK, Singh NP, Yadav RC and Kumar P. 1990. A study of heterosis in Indian mustard (*Brassica juncea* L. Coss. And Czern.). *Acta-Agronomica-Hungarica* 39: 137-143

Kumbhalkar HB, Dawande VB and Nair B. 1999. Combining ability studies in Indian mustard *(Brassica juncea* L.). *Journal of Soils and Crops* 2: 247-249

Kumbhare M D, Khawale *VS*, Rajput GR, Datey CP and Idapuganti KG. 2007. Effect of nitrogen levels and chlormequat on mustard (*Brassica juncea* L.). *Journal of Soils and Crops* 17: 394-97

Ladha JK, Kirk GJD, Bennet J, Peng S, Reddy CK, Reddy PM and Singh U. 1998. Opportunities for increased nitrogen use efficiency from improved low land rice germplasm. *Field Crops Research* 56**:** 41-71

Laine P, Ourry A, Macduff J, Boucaud J and Salette J. 1993. Kinetic parameters of nitrate uptake by different catch crop species-effects of low temperatures or previous nitrate starvation. *Physiolology* 88**:** 85-92

Lal D, Kumar R, Kumar A, Singh SK, Kumar D and Kumar S. 2018. Estimation of specific combining ability in Indian mustard (*Brassica juncea* L). *Journal of Pharmacognosy and Phytochemistry* 7 (5): 901-905

Mahto JL and Haider ZA. 2004. Heterosis and combining ability study in *Brassica juncea*. *Journal of Research Birsa Agricultural University* 2: 239-248

Malagoli P, Laine P, Rossato L and Ourry A. 2005. Dynamics of nitrogen uptake and mobilization in field grown winter oilseed rape (*Brassica napus*) from stem extension to harvest. *Annals of Botany* 95**:** 853-61

Malviya N, Kumar K and Upadhyay DK. 2019. Combining ability and heterosis for seed yield, its component traits and oil content in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. *Journal of Pharmacognosy and Phytochemistry* 8 (3): 696-699

Malviya N, Kumar K, Umesh B and Verma, O P. 2012. Heterosis for seed yield, oil content and yield Components in Indian mustard [*Brassica juncea* (l.) Czern. & Coss.]. *Plant Archives* 12 (1) : 279-281

Mather K and Jinks JL. 1982. The study of continuous variation. Biometrical Genetics, *Chapman and Hall*, London, XII, 382

Matzinger DF and Kempthorne O. 1956. The modified diallel table with partial inbreeding and interactions with environment. *Genetics* 41: 822-833

Meena BS, Tanwar SPS and Sharma GL. 2001. Effect of nitrogen, irrigation and interculture on yield, nutrient content and uptake in mustard (*Brassica juncea* L. Czern. & Coss). *Journal of Soils and Crops* 11: 184-87

Meredith WR and Bridge RR. 1972. Heterosis and gene action in cotton. *Crop Science* 12**:** 304-310

Mi GH, Chen FJ and Zhang FS. 2007. Physiological and genetic mechanisms for nitrogen use efficiency in maize. *Journal of Crop Science and Biotechnology* 10: 57-63

Mohan S, Yadav RK, Tomar A and Singh M. 2017. Studies on heterosis over economic parents for seed yield and its contributing traits in Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Journal of Pharmacognosy and Phytochemistry* 6(5): 909-911

Monalisa P, Singh NB, Singh NG and Laishram JM. 2005. Genetic divergence and combining ability in relation to heterosis in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] for seed yield, its attributes and oil yield. *Indian Journal of Genetics and Plant Breeding* (4): 302-304

Nair B, Kalamkar V and Bansod S. 2005. Combining ability analysis in mustard *[Brassica juncea]*. *Journal of Soils and Crops* 15(2): 415-418

Nair B, Kalamkar V, Budhanwar PD and Suryapujary SM. 2007. Studies on heterosis in mustard (*Brassica juncea* L.). *Journal of Phytological Research* 20(2): 287-291

Nassimi AW, Ali R, Hassan S and Ali N. 2006. Combining ability analysis for maturity and other traits in Rapeseed (*Brassica napus* L.). *Journal of Agronomy 5* (3): 523-526

Nigam A and Richa. 2009. Heterotic response of seed yield and its components in Indian mustard [*Brassica juncea* (L.) Czern. and Coss]. *Indian Journal of Genetics* 4: (1) 41-43

Ofori A and Becker HC. 2008. Breeding of *Brassica rapa* for biogas production: heterosis and combining ability of biomass yield. *Bioenergy Research* 1: 98–104

Pasricha NS and Tandon HLS. 1993. Fertilizer management in oilseeds. *Fertilizer Management in Commercial Crops*. *HLS Tandon (Ed). FDC, New Delhi*. PP. 98

Patel AM, Prajapati B and Patel DG. 2012. Heterosis and combining ability studies in Indian mustard (*Brassica juncea* L.). *Indian Journal of Science Research and Technology* 1: 38-40

Patel R, Ram B and Verma OP. 1999. Heterosis *vis-a-vis gca* of parents in mustard [*Brassica juncea* (L). Czern. & Coss.]. *Cruciferae-Newsletter* (21): 101

Pradhan AK, Sodhi YS, Mukhopadhyay A and Pental D. 1993. Heterosis breeding in Indian mustard [*Brassica juncea (*L). Czern. & Coss.] and analysis of component characters contributing to heterosis for yield. *Euphytica* 69: 219-229

Raghuvanshi N, Kumar V and Dev J. 2018. Study on nitrogen levels and varieties on yield contributing characters, quality and economics of mustard (*Brassica juncea* Czern. & Coss.) varieties under late sown condition. *International Journal of Current Microbiology and Applied Sciences* (7): 3152-3161

Rahimizadeh M, Kashani A, Zare A, Koocheki AR, Nassiri M. 2010. Nitrogen use efficiency of wheat as affected by preceding crop, application rate of nitrogen and crop residues. *Australian Journal of Crop Science* 4: 363-368

Rai SK, Verma A and Pandey DD. 2005. Analysis of combining ability in Indian mustard (*Brassica juncea* L. Czern. and Coss*)* . *Plant Archives* 5(1): 69-75.

Ramesh V. 2012. Combining ability analysis of plant height and yield components in spring type of rapeseed varieties (*Brassica napus* L.) using line × tester analysis. *International Journal of Agriculture and Forestry* 2(1): 58-62

Rana KS and Rana DS. 2003. Response of mustard (*Brassica juncea*) to nitrogen and sulphur under dryland conditions. *Indian Journal of Agronomy* 48: 217-19

Rao NV and Gulati SC. 2002. Combining ability effects *vis-a-vis per se* performance in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.]. *Agricultural Science Digest* 22(4): 287-288

Rathke GW, Behrens T and Diepenbrock W. 2006. Integrated nitrogen management strategies to improve seed yield, oil content and nitrogen efficiency of winter oilseed rape (*Brassic napus* L.). *Agriulture, Ecosystem and Environment* 117**:** 80-108

Reddy CS and Reddy PR. 1998. Performance of mustard varieties on alfisols of Rayalaseema region of Andhra Pradesh. *Journal of Oilseeds Research* 15: 379-80

Saeed F, Tahir MHN, Kang SA., Riaz M, Farooq J and Saeed M. 2013. Heterosis and combining ability for seed yield and its components in *Brassica juncea* (L.) Czern & Coss. *Albanian Journal of Agricultural Sciences* 12 (2) : 203-208

Sah D, Bohra JS and Shukla DN. 2006. Effect of nitrogen, phosphorus and sulphur on growth attributes and nutrient uptake by Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Crop Research* 31: 52-55

Sandhu PS. 2010. Nitrogen and spacing requirements of promising hybrids of Indian mustard (*Brassica juncea* L. Czern. & Coss.). *M.Sc Thesis, Punjab Agricultural University, Ludhaina*

Sarkar B and Singh JN. 2001. Combining ability analysis and reciprocal cross effects in Indian mustard (*Brassica juncea). Indian Journal of Agricultural Sciences* 71(7): 493-496

Sheikh IA And Singh JN. 1998. Combining ability analysis of seed yield and oil content in *Brassica juncea* (L.) Czern. & Coss.. *Indian Journal of Genetics and Plant Breeding* 58(4): 507-511

Shull GH. 1909. A pure line method of corn breeding. *American Breeders Association Report* 5 : 51-59

Shweta, Ranjeet, Singh P and Dixit RK. 2005. Combining ability and heterosis for seed yield, its components and oil content in Indian mustard. *Farm Science Journal* 14(1): 44-48

Singh A and Meena NL. 2003. Effect of nitrogen and sulphur levels on the oil and protein yield of mustard (*Brassica juncea*). *Annals of Agricultural Research* 24: 368-71

Singh B, Singh SK, Singh A and Singh A. 2018. Studies on combining ability effect on seed yield and it's components in Indian mustard (*Brassica juncea* L.). *Journal of Pharmacognosy and Phytochemistry* 7(1): 879-882

Singh F, Sinsinwar BS, Kumar PR and Premi OP. 2002. Effect of different levels of irrigation and nitrogen on yield and oil content of Indian mustard (*Brassica juncea*). *Journal of Oilseeds Research.* 19: 62-63

Singh GK and Prasad K. 2003. Effect of row spacing and doses of nitrogen on nutrient uptake and oil yield in mustard. *Crop Research* 25: 431-35

Singh H, Kumar R, Kaur S, Singh I and Kaur R. 2019. Genetic analysis of Indian Mustard for Yield by calculating heterosis and combining ability. *Journal of Agriculture Science* 10: 1-12

Singh K and Verma OP. 1998. Genetic behaviour of yield and its components in Indian mustard (*Brassica juncea* (L.) Czern. & Coss). *Journal of Oilseeds Research* 15(2): 343-344.

Singh M and Lallu. 2004. Heterosis in relation to combining ability for seed yield and its contributing traits in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.] *Journal of Oilseeds Research* 21(1): 140-142

Singh M, Dixit RK and Vijendra V. 2007b. Studies on heterosis in relation to seed yield in Indian mustard (*Brassica juncea* L.). *Souvenir of National Seminar* on *"Changing Global Vegetable Oils Scenario* 6: 106

Singh M, Lallu, Srivastava RL and Dixit RK. 2002. Combining ability studies for seed yield its component characters and oil content in Indian mustard (*Brassica juncea* (L.) Czern. and Coss). *Journal of Progressive Agriculture* 2(2): 125-128

Singh R, Singh JN and Meena PKP. 2004. Combining ability studies for Harvest Index and other yield contributing characters in Indian mustard (*Brassica juncea* L. Czern. And Coss.). *Annals of Agricultural Research* 25(4): 512-516

Singh R, Singh JN and Meena PKP. 2005b. Combining ability studies for Harvest Index and other yield contributing characters in Indian mustard (*Brassica juncea* L. Czern. And Coss.). *Annals of Agricultural Research* 26(2): 281-285

Singh RA and Rathi KS. 1984. Studies on nitrogen requirement of mustard (*Brassica juncea*). *Indian Journal of Agronomy* 29: 231-33

Singh RK and Dixit P. 2007. Heterosis and combining ability studies for seed yield, Its attributes and oil content in Indian mustard *[Brassica juncea* (L.) Czern. & Coss.]. *Crop Improvement* 34 (2): 192-196

Singh SK, Haider ZA and Ram S. 2005a. Combining ability and heterosis for seed yield and its components in Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Sciences* 75(4): 228-229

Singh SP and Singh V. 2005. Effect of nitrogen, sulphur and zinc on Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Science* 75: 828-30

Singh T and Brar JS. 1999. Effect of nitrogen and phosphorus application on seed yield of Indian mustard (*Brassica juncea* L. Czern. & Coss). *Annals of Biology* 15: 123-24

Singh V, Bhajan R and Kumar K. 2007a. Genetic diversity in Indian mustard (*Brassica juncea* L. Czern. and Coss.). *Journal of Progressive Agriculture* 7(1/2): 105-109

Singh Y, Singh T, Singh UN and Rajput PK. 2010. Effect of nutrient management on yield, quality and economics of irrigated Indian mustard (*Brassica juncea*). *Indian Journal of Agricultural Science* 80: 691-94

Sood OP, Sood VK and Thakur HL. 2000. Combining ability and heterosis for seed yield traits involving natural and synthetic Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Indian Journal of Genetics and Plant Breeding* 60(4): 561-563

Sprague GF and Tatum LA. 1942. General *vs* specific combining ability in single crosses of Corn. *Journal of American Society of Agronomy* 34: 923-932

Subbiah BV and Asija GL.1956. A rapid procedure for estimation of available nitrogen in soils. *Current Science* 25: 259-66

Swarnkar GB, Singh M, Prasad L and Dixit RK. 2002. Combining ability for seed yield and its contributing characters in Indian mustard [*Brassica juncea* (L.) Czern. and Coss.]. *Plant Archives* 2(1): 5-14

Tak GM and Khan MN. 2000. Combining ability for seed yield and its attributes in Indian mustard (*Brassica juncea* L. Czern. and Coss.). *Advances in plant Sciences*. 13(2): 423-426

Thakur KS, Kumar A and Manjula S. 2005. Performance of promising varieties of gobhi sarson (*Brassica napus*) at different nitrogen levels. *Indian Journal of Agronomy* 50: 67-69

Tomar A and Singh M. 2017. Selection of best germplasm & crosses based on heterotic response and combining ability parameters in Indian mustard (*Brassica juncea* L. Czern. & Coss). *Journal of Pharmacognosy and Phytochemistry* 6(1): 345-349

Tomar TS, Singh S, Kumar S and Tomar S. 1997. Response of Indian mustard (*Brassica juncea*) to nitrogen, phosphorus and sulphur fertilization. *Indian Journal of Agronomy* 42**:** 148-51

Turi NA, Raziuddin , Khan, N. U., Hassan, G., Bhakt, J., Khan, S. And Shafi, M. (2011). Combining ability for yield related traits in *Brassica juncea* L. *Pakistan Journal of Botany* 43(2): 1241-1248

Turi NA., Raziuddin, S and Ali S. 2006. Estimation of heterosis for some important traits in mustard (*Brassica juncea* L.). *Journal of Agricultural and Biological Sciences* 1(4): 6-10

Turi, NA, Raziuddin S, Khan F, Munir NU, Shah I, and Khan S. 2010. Combining ability analysis in *Brassica juncea* L. for oil quality traits. *African Journal. of Biotechnology* 9(26): 3998-4002

Turner JH. 1953. A study of heterosis in upland cotton, combining ability and inbreeding effects. *Agronomy Journal 45***:** 478-490

Vaghela PO, Bhadauria HS, Patel JB and Sutariya DA. 2013. Heterosis breeding in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. *Agres 3: 307-312*

Vaghela PO, Thakkar DA, Bhadauria HS, Sutariya DA, Parmar SK and Prajapati, DV. 2011. Heterosis and combining ability for yield and its component traits in Indian mustard [*Brassica juncea* (L.)]. *Journal of Oilseed Brassica* 2(1): 39-43

Verma OP, Yadav R, Kumar K, Singh R, Maurya KN and Ranjana. 2011. Combining ability and heterosis for seed yield & its components in Indian mustard (*Brassica juncea* L. Czern. & Coss.). *Plant Archives* 11 (2): 863-865

Verma RP. 2000. Combining ability analysis of yield and its Components through diallel crosses in Indian mustard *(Brassica juncea L. Czern.* & *Coss*). *Indian Journal of Agricultural Research* 34(2): 91-96

Verma, OP and Kushwaha GD. 1999. Heterosis and combining ability for seed quality traits in Indian mustard (*Brassica juncea* L. Czern. & Coss). *Cruciferae-Newsletter* 21: 107-108

Yadav IS and Kumar S. 1999. Analysis of combining ability for oil content in Indian mustard. *Cruciferae-Newsletter* (21): 139-140

Yadav RB, Singh RK and Singh H. 2007. Response of Indian mustard (*Brassica juncea* L.) to nitrogen and sulphur in mid-western plain zone of Uttar Pradesh. *Indian Journal of Crop Sciences* 2: 243-44

Yadav VN, Singh M, Yadav RK, Singh HC, Maurya AK, Singh AK and Singh SG. 2020. Genetics of seed yield in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] under late sown environment. *Journal of Pharmacognosy and Phytochemistry* (4): 249-254

Yan W and Hunt LA. 2002. Biplot analysis of diallel data. *Crop Science* 42: 21-30

Yan W and Tinker NA. 2006. Biplot analysis of multi-environment trial data: Principles and applications. *Canadian Journal of Plant Science* 86 (3): 623-645

Yan W, Hunt LA, Sheng Q and Szlavnics Z. 2000. Cultivar evaluation and mega-environment investigation based on the GGE biplot. *Crop Science* 40: 597-605

Yan W, Kang MS, Ma B, Woods S and Cornelius PL. 2007. GGE Biplot *vs*. AMMI Analysis of Genotype-by-Environment data. *Crop Science* 47: 643-653.

Yates F .1936. A new method of arranging variety trails involving a large number of varieties. *Journal of Agriculture Science* 26: 424-455

Yau SK and Thurling N. 1987. Genetic variation in nitrogen uptake and utilization in spring rape (*Brassica napus*) and its exploitation thorough selection. *Plant Breeding* 98: 330-38

LIST OF PUBLICATIONS

RESEARCH PAPERS

Kumar Manoj and Janeja Harmeet Singh. 2021. Response of Yield and its Attributing Traits for various Nitrogen Regimes in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. *Plant Archives* Accepted (Ref. PA/April-21/303)

Kumar Manoj and Kumari Vedna. 2019. Variability and correlation studies in Indian mustard [*Brassica juncea* (L.) Czern. & Coss.]. Jornal of Plant Development Sciences 11 (10): 589-594

A Premkumar , **Kumar Manoj** and Chauhan Ruchi. 2020. Improvement of rice variety for biotic and abiotic stress resistance using techniques of allele mining. *Journal of Pharmacognosy and Phytochemistry* 9(5): 1888-1893

A Premkumar and **Kumar Manoj**. 2017. Application of molecular markers for bacterial blight resistant varieties in rice (*Oryza sativa*). *Journal of Applied and Natural Science* 9(4): 2309-2314

Kumari Vedna, **Kumar Manoj** and Kumar Vinod. 2020. Assessment of drought tolerance using drought tolerance indices and their inter relationship in mustard [*Brassica juncea* (L.)]. *Journal of oilseed Brassica* 11(2): 134- 138

ORAL AND POSTER PRESENTATIONS IN CONFERENCES

Kumar Manoj and Janeja Harmeet Singh. Genetic analysis in Indian mustard (*Brassica juncea* L.) by calculating Combining Ability under various Nitrogen level. Oral presentation in *International conference of International academy of Physical Science on Recent Advances in Biotechnology, Bioinformatics and Biochemistry*, 18-20 December, 2020, Prayagraj

Kumar Manoj and Janeja Harmeet Singh. Heterosis analysis in Indian mustard (*Brassica juncea* L.) under various Nitrogen level. Oral presentation in *International conference of International academy of Physical Science on Recent Advances in Biotechnology, Bioinformatics and Biochemistry,* 18-20 December, 2020, Prayagraj

Kumar Vinod, Kumari Vedna and **Kumar Manoj.** Model plant type in Ethiopian mustard (*Brassica carinata* A. Braun) . Poster presentation in *Third National Brassica Conference on Enhancing Oilseed Brassica production* through climate smart technologies, 16-18 February, 2017, IARI, New Delhi

`