

**STUDIES ON HETEROSIS, COMBINING ABILITY AND
GENE ACTION FOR YIELD AND QUALITY TRAITS IN
BITTER GOURD (*Momordica charantia* L.)**

**Thesis
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BY

SHYAM PRAKASH

ID. NO. H - 13192/22

**IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF**

Doctor of Philosophy (Horticulture)

Vegetable Science

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CERTIFICATE - I

This is to certify that the thesis entitled “**Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)**” submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy (Horticulture)** with major in **Vegetable Science** of the **College of Horticulture & Forestry** Post Graduate Studies, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya is a record of *bonafide* research work carried out by **Mr. Shyam Prakash**, Id No. **H-13192/22** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation has been acknowledged.

Kumarganj, Ayodhya

18 July, 2025



18/07/2025


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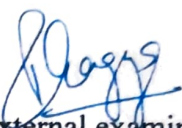
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Advisory Committee

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We, the undersigned, member of Advisory committee of **Mr. Shyam Prakash Id.** No. **H-13192/22** a candidate for the degree **Doctor of Philosophy (Horticulture)** with major in Vegetable Science agree that the thesis entitled “**Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)**.” may be submitted in partial fulfilment of the requirements for the degree.



(C. N. Ram)
Chairman


External examiner


(Anil Kumar)
Member


(Aastik Jha)
Member


(Shiva Nath)
Member


Head of the Department
Prof. & Head
Deptt. of Vegetable Science
A.N.D.U.A.T., Kumarganj-Ayodhya (U.P.)

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DECLARATION FOR ANTI-PLAGIARISM

I, Shyam Prakash, I.D. No. H-13192/22 certifies that the thesis entitled “**Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)**.” submitted in partial fulfilment of the requirements for the degree of **Doctor of Philosophy (Horticulture)**’ with major in **Vegetable Science** to College of Horticulture & Forestry, Acharya Narendra Deva University of Agriculture and technology, Kumarganj, Ayodhya (U.P.) is original work and has similarities with published work not more than minor similarities as per the UGC (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations, 2018, adopted by the university. I Declare that I have faithfully acknowledged given credit to and referred to the research workers wherever their works have been cited in the text and body of the thesis. I further certify that I have not wilfully lifted up some others work, para, text, data, results etc. reported in the journals, books, magazines, reports, dissertations, thesis etc., or available at web-sites and included them in this thesis and cited as my own work.

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Place: Kumarganj, Ayodhya

Date: 18/07/2025

CERTIFICATE FROM MAJOR ADVISOR

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

(Major Advisor)

Head of the Department
Department of
Vegetable Science

(Bhagwan Deen)
Dean
Post Graduate Studies

DEAN
College of Horticulture & Forestry
ANDUAT, Kumarganj, Ayodhya

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Shyamprakash
(Shyam Prakash)

Author

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ABBREVIATIONS

<i>et al.</i>	et all (and others)
%	Per cent
/	per
°C	Degree Celsius
°B	Brix
BP	Better parent
SV	Standard variety
CD	Critical difference
CV	Coefficient of variation
d.f.	Degree of freedom
F	The mean of F1 over the arrays
GA	Genetic advance
GCA	General combining ability
SCA	Specific combining ability
Kg	Kilogram
h_2	Dominant effects
h^2	Heritability
H^2	Dominance
K	Selection differential
M	Mean
Me	Error mean of square
MSR	Mean square due to replication
MST	Mean square due to treatment
MSE	Mean square due to error
R	Replication (s)
T	Treatment
RBD	Randomized block design
SE	Standard error
Sel.	Selection
SEM (\pm)	Standard error of mean
Sp.	Species
TSS	Total soluble solids
<i>et al.</i>	And co workers
etc.	(et cetera) and the others
Fig.	Figure
G	Gram
Ha	Hectare
<i>i.e</i>	That is
m ²	Square meter
Mg	milligram
Sr. No	Serial number
<i>viz.</i>	(Vide licit) namely

INTRODUCTION

Bitter gourd (*Momordica charantia* L.; $2n=2x=22$) is a commercial and medicinal vegetable, belongs to the family Cucurbitaceae. It is annual as well as perennial climber. It is also known as bitter melon, karela, cassilla, maidan apple and balsam pear. The term “cucurbits” is coined by Liberty Hyde Bailey for cultivated species of the family Cucurbitaceae. There are about 100 genera and 750 species almost equally divided between new and old worlds tropics in Cucurbitaceae.

The crop has originated in India (Indo-Burma Centre of origin). The region of Eastern India and Southern China are suggested as possible Centre of domestication. It is cultivated in Malaysia, China, Tropical Africa and North and South America. Wild *Momordica charantia* var. *abbreviata*, a native of Asia, may be the progenitor to domesticated. Cucurbits possess a special position among different groups of vegetable crops.

The fruit of bitter gourd are reported to have cooling stomachic appetizing carminative, anti-pyretic anti-helminthic, aphrodisiac and vermifuge, properties. They have anti-viral therapy for HIV infection and as a cytostatic in certain cancers. It is also known for its anti-diabetic properties due to its latent oxygen free radical with scavenging activity of fruit juice.

In the terms of nutritive value bitter gourd ranks first among the cucurbits because of higher nutritive value being rich in all the essential vitamins and minerals, especially vitamin A (210IU/100g), vitamin C (88mg/100g), iron (1.8mg/100g), phosphorus (55mg/100g) calcium (20mg/100g), and calories 25 k/cal, regular use prevents many complications such as hypertension, eye complication, neuritis and defective metabolism of carbohydrates. It increases body's resistance against infection. The bitter gourd is specifically used as folk medicine for diabetes. Recent research has established that it contains a hypoglycemic or insulin- like principle, designated as ‘plant insulin’ which has been found highly beneficial in lowering the blood and urine sugar level. A majority of diabetics usually suffer from malnutrition as they are usually under-nourished. It contains alkaloids *viz.*, momordicin and cucurbitacin while skeleton is rich in momordicosides-glycosides of tetracyclic tri- terpenoids with cucurbitacin. The crop is extensively grown

in India, Indonesia, China, Malaysia, Singapore, Japan, South East Asia, Tropical Africa and South America. The, major bitter gourd growing states in India are Karnataka, Kerala, Maharashtra, Andhra Pradesh, Tamil Nadu and Chhattisgarh. In 2023-24, India's bitter gourd production reached 1.727 mt with Madhya Pradesh emerging as the top producer (333.88 mt, 19.3% share) and Andhra Pradesh leading in productivity per unit area (69.18 mt) despite a smaller cultivation area, as per the third advance estimates by the Ministry of Agriculture & Farmers Welfare 2024.

The plant is a monoecious annual climber, stem 5-angled and furrowed; tendrils simpler forked. Leaves palmately 5-9 lobed and 5-17cm diameter. Flowers axillary, solitary about 3cm in diameter, prominent sessile bract at or near base of slender peduncle. Calyx deeply 5-fid, corolla rotate, parted nearly to base, petals 5, yellow 1.5-2cm long, stamens 5, filaments free, anthers united. There are three short style staminated by three bilobed or divided stigma. Fruit is pendulous, fusiform, ribbed with numerous tubercles, seeds brownish with scarlet axil.

Anthesis and anther dehiscence occur early in the morning. Selfing and crossing should be attempted in the forenoon preferably in early hours. For crossing purpose female flower buds ready to opening the next 1-2 days are covered by small paper bags. Like-wise male flower bud ready to open next morning also covered. Pollination is carried out by rubbing anthers of freshly opened flowers against stigma of the protected pistillate flowers. The crossed flowers are covered as above for a few more days.

The breeding methods practiced in bitter gourd are the same as in other cucurbits. Selection from a local cultivar has been the most commonly adopted breeding procedure in bitter gourd. So far, few varieties have been developed through hybridization and mutation breeding. Inbreeding, pure-line selection in segregating generations and heterosis breeding are particularly applicable to bitter gourd. Being a cross-pollinated crop and it has high levels of heterozygosity and therefore, heterosis is well utilized in a bitter gourd for traits like early harvest, higher yield, and other horticultural traits. The prevalence of dominant gene action together with low heritability for most of yield related traits representing the significance of heterosis breeding for improvement of yield and yield attributing traits in bitter gourd.

In order to develop high yielding varieties of bitter gourd, breeders mostly have concern of choosing good parents and crosses. In this perspective, different breeding techniques have been practiced and recommended. However, in the hybridization

programme the vegetable breeder frequently faces the difficulty of choosing suitable parents and crosses. One of the important tools that allows better analysis of combining ability and helps in choosing desirable parents and their cross combinations for utilization in further breeding programmes is the line \times tester analysis method. This biometrical design is helpful on the initial selection of a large number of lines for their general and specific combining ability effects, components of genetic variance and heterosis. Various biometrical techniques are available for the extent of the line \times tester mating designs analysis for heterosis, combining ability additive effects and non-additive gene action. Notable plant breeders observed that information related to the general (GCA) and specific combining ability (SCA) may be of great contribution to the breeders.

General combining ability (GCA) could be defined as the mean performance of a genotype in a series of hybrid combinations (Sprague and Tatum, 1942). They also defined “specific combining ability” (SCA) as those cases in which particular “hybrid combinations” perform better or worse than that may be anticipated on the basis of the mean performance of the parental inbred lines. A good combiner parental inbred lines can be selected based on high GCA estimates, which to be involved in cross unions to recognize the good hybrids, by the differentiation among “SCA values”. A parent is considered to have good GCA, it exhibiting increased mean combining ability in crosses, while if their possibility to unite well is restricted to a particular cross, they would be considered to have good SCA. A high SCA of specific cross combinations indicates that the parents of this hybrid can give a superior hybrid (Fasahat *et al.* 2016 and Acharya *et al.* 2019). The knowledge on the relative importance of the additive (gca) and non-additive (sca) gene actions within a breeding population is significant because it determines the breeding method for genetic improvement (Sincik *et al.* 2011). After identification of suitable parents and potential cross combinations through combining ability analysis, the next important step is to adopt suitable breeding methodology to achieve the desired result which depends upon the type of gene action governing the traits.

A successful breeding program depends on effectively utilizing available genetic diversity. Breeders need access to diverse plant genetic resources, along with accurate and comprehensive data, to drive progress in their work. The Distinctiveness, Uniformity, and Stability (DUS) testing system, required under the Protection of Plant Varieties and Farmers' Rights (PPVFR) Act of 2001, plays a vital role in contemporary plant breeding. DUS testing serves two primary purposes: First, it supports intellectual property

protection by enabling Plant Variety Protection (PVP), which incentivizes innovation by safeguarding breeders' rights. Second, it verifies the quality of new cultivars by evaluating their unique characteristics, consistency, and stability across generations. Accurate genotype characterization is crucial in this process. By confirming that a new cultivar is distinct from existing varieties within the same species, DUS testing helps maintain genetic diversity and prevents duplication in gene bank collections (Mahapatra *et al.* 2022; Mallikarjuna *et al.* 2023).

Keeping in view the above facts, present investigation entitled “Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)” has been done with following objectives:

1. To find out gene action involved in the inheritance of various characters.
2. To study the combining ability, variances and their effects.
3. To estimate heterosis over better-parent and standard variety.
4. To study the morphological character of different genotype and their crosses based on DUS guidelines.

REVIEW OF LITERATURE

The fundamental aim of most plant breeding programs is to enhance the yield potential of crop species. A deep understanding of various quantitative traits, particularly those influencing yield, plays a pivotal role in successfully executing breeding strategies. Hybridization stands as a primary method for achieving higher yields and harnessing heterosis within a given crop. Bitter gourd, being a cross-pollinated species, is well-suited for heterosis breeding. Gaining insights into the genetic foundation of diverse quantitative and qualitative traits is essential for designing an effective and productive breeding program. Keeping in view of the objectives of present investigation entitled “**Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)**.” the available literature has been reviewed and presented under the following headings:

2.1 Gene action

2.2 Combining ability analysis

2.3 Estimates of heterosis

2.4 Morphological character of different genotype and their crosses

(2.1) Gene action:

In breeding programme knowledge about gene action, which governs a trait, is very much essential so as to proceed with the right breeding technique. Studies on gene action reveals the genetic mechanism and the inheritance of quantitative traits, particularly in respect to gene actions including epistatic and additive gene effect, the order of dominance in the parents, degree of dominance, distribution of positive and negative alleles and their linkage and the estimation of general and specific combining abilities of the parental lines involved.

The literature on gene action of field and its contributing traits in bitter gourd is presented here

Thangamani (2016) highlighted the presence of both additive and non-additive gene action in the improvement of the traits like earliness, i.e., days to first female flower appearance per vine and yield controlling traits like number of female flowers per vine and number of fruits per vine, fruit length, fruit weight and quality characters in bitter gourd.

Rao *et al.* (2017) derived information about the genetic components of variation and heterosis of twenty-one crosses in bitter gourd. The proportion of genes with positive and negative effects at all loci (H₂/4H₁) in the parents was found to be less than 0.25 for most of the characters disclosed the asymmetrical distribution of the positive and negative alleles. Days to 50% flowering, days to first harvesting, fruit length, fruit diameter, number of fruits per plant and yield per plant recorded below 50% narrow sense heritability, which indicated the predominance of non-additive gene action. The average degree of dominance revealed that overdominance gene action for most of the yield-associated characters.

Mishra *et al.* (2020) reported that all morphological characters of bitter gourd, viz. days to 50% staminate flowering, days to 50% pistillate flowering, node at which first staminate flower appears, node at which first flower pistillate appears, vine length, number of primary branches per plant, intermodal length, fruit yield were governed by non-additive gene action.

Pradhan *et al.* (2021) observed that the traits like fruits per vine, fruit girth, seeds per fruit, total green fruit yield, sex ratio, internodal length, fruit length, average fruit weight and vine length were controlled by the additive gene action in bitter gourd.

Kundu *et al.* (2022) analysed the nature and magnitude of involved gene actions of bitter gourd and revealed that additive gene action played dominant role for days to first male flower opening, days to first female flower opening, node number of first female flower, main vine length, numbers of primary branches per vine, numbers of nodes per main vine, number of fruits per vine, average single fruit weight, fruit yield per vine, fruit length, fruit diameter, thickness of the fruit flesh, thickness of the rind, days to green fruit maturity, days to seed fruit maturity, number of seeds per fruit, seed weight per fruit and 100-seed weigh. In contrast, node number of first male flower was under the predominance of the non-additive gene action.

Pawar and Bhalekar (2022) evaluated that the nature of gene action, heritability and correlation among the different characters of bitter gourd (*Momordica charantia* L.).The

magnitude of $\sigma^2_{gca} / \sigma^2_{sca}$ for length of vine (0.479, -0.983), days to 1st female flower (0.652, 0.438), days to male flower (1.126, 0.514), days to 50% flowering (0.678, 0.629), Number of female flowers (0.635, 0.878), days required for first harvest of fruit (0.678, 0.629), length of pedicel (0.150, 0.129), length of fruit (0.825, 1.067), girth of fruit (2.200, 0.924), number of fruits per vine (0.872, 0.680), number of seeds per fruit (1.261, 0.985), weight of fruit (0.567, 0.675), Yield per vine (kg) (0.967, 0.856), Yield per plot (0.968, 854) and yield per hector (q/ha) (0.968, 0.854) both have same magnitude, respectively during both summer and kharif seasons.

Zehra *et al.* (2023) studied that the Combining ability studies for earliness and quality traits in bitter gourd (*Momordica charantia* L.). It was revealed that the variance due to SCA (σ^2_{sca}) was significant for all the traits under study in combined analysis except total carotenoids. The variance due to GCA (σ^2_{gca}) was significant for most of the traits except days to anthesis of first male flower, days to first fruit harvest, total carotenoids, total phenols and iron content. The variance due to interactions $\sigma^2_{gca} \times E$ was significant for total carotenoids, total phenols, node to first male flower appearance and variance due to $\sigma^2_{sca} \times E$ was significant for all the traits except iron content and dietary fibre. In general, σ^2_{sca} was found to be more than σ^2_{gca} for all the traits which indicates that there is the preponderance of non-additive gene action for the traits.

Kumar *et al.* (2024) crossed eight genetically diverse parental lines to develop 28 F₁ hybrids, in 2022 at G. B. Pant University of Agriculture and Technology, India to study the gene action in bitter gourd (*Momordica charantia* L.). The analysis revealed that dominance gene action predominantly governs most traits, including days to anthesis, average fruit weight, and fruit yield. Over-dominance was particularly evident in traits such as the number of nodes to the first male flower and days to first fruit harvest, suggesting significant hybrid vigor. Additionally, low narrow sense heritability estimates indicate that traditional selection methods may be ineffective for genetic improvement. Therefore, hybrid breeding strategies leveraging dominance variance and heterosis are recommended for enhancing bitter gourd productivity. the critical role of understanding genetic mechanisms in the pursuit of crop improvement.

Wamiq *et al.* (2025) carried out an experiment to assess gene action in fifty-four genotypes of bitter gourd (*Momordica charantia* L.) comprising 15 parents and their fifty crosses through line \times tester method. Analysis of variance exhibited significant differences among the genotypes for all the traits under studied. The data was collected for various

morphological characters associated with yield and its contributing traits. In reference to estimates of additive variances ($\delta 2A$) was lower than dominant variance ($\delta 2D$) for all the growth and yield contributing traits, indicating the presence of additive gene action.

(2.2) Combining ability analysis:

In breeding programmes, the common method of selecting the parents on the basis of per se performance does not necessarily leads to fruitful results. (Allard, 1960). Besides their special attributes, the potential parents have to be selected based on their genetic architecture and combining ability. Hence, the concept of combining ability is of great importance in crop improvement to identify the best combiners and utilizing in hybridization, either in exploitation for heterosis or to combine the favourable genes. Combining ability is the term defined as the relative ability of a genotype to transmit its desirable traits to its progeny. It is generally considered in two aspects viz., general combining ability (gca) and specific combining ability (sca).

The literature on combining ability of field and its contributing traits in bitter gourd is presented here.

Prabhakar (2008) observed the combining ability for fruit yield and its components in 18 ridge gourd hybrids obtained by crossing six lines and three testers. Among the lines, Pusa Nasdar was identified as good combiner for early flowering, average fruit weight, fruit length, number of fruits per plant and fruit yield while Jagtial Long was good combiner for number of fruits and fruit yield per vine. Among the testers, LA-17 was good combiner for fruit yield and number of fruits per vine. The cross combinations Jaipur Long \times LA-97 and Pusa Nasdar \times LA-12 showed significant SCA for yield and other traits.

Yadav *et al.* (2008) estimated combining ability with six lines and four testers in bitter gourd and stated that among the parents, Gy-1 was found to have good general combining ability for internodal length, number of fruits per vine, number of fruits per plot, days to first staminate flowering and vine length and MC-84 was observed good general combiner for days to first pistillate flowering, fruit width, yield/ha, yield per vine and yield per plot. The parent JMC-21 for number of first effective node, numbers of primary branches per vine and S-17 for fruit length and fruit weight were found to be good general combiners. The crosses MC-84 \times VRBT 6-9 for fruit width, days to first appearance of female flower,

number of primary branches per vine, yield per vine, yield per plot and MC-84 × JMC-22 for yield per plot, yield (q/ha) manifested significant SCA effects.

Maurya *et al.* (2009) conducted a research trial and evaluated bitter gourd on the basis of GCA and SCA effect and said that the parents Kalyanpur Sona, BIG-4, BIG-11 were best general combiner for fruit yield per plant. The crosses BIG-4 × BIG-56, BIG-1 × Kalyanpur Sona, BIG-4 × Kalyanpur Sona and BIG-4 × BIG-11 were considered best promising crosses based on specific combining ability effects.

Dey *et al.* (2010) conducted an experiment for exploiting gynocoe to study combining ability and hybrid development in bitter gourd. Among parents, gynococious parent; DBGy-201 manifested maximum GCA effect in desirable direction for node number to which first female flower appears, days to first harvest, numbers of fruits and yield per plant. The parent, Priya exhibited highest GCA effect for fruit length and fruit weight. These parents were good general combiners for yield and earliness and could be utilized in breeding programmes. The gynococious hybrids DBGy-201 × Pusa Vishesh and DBGy-201 × Pusa Do Mausami exhibited earliness in per se performance with first female flower appear at lower node (~8th node). The best gynococious hybrids were DBGy-201 × NDBT-12 for fruit yield per plant and DBGy-201 × Priya for number of fruits per plant.

Jadhav *et al.* (2010) observed combining ability in bitter gourd and observed that values of SCA were higher than the GCA indicating predominance of dominant gene action for all the characters. The parent Phule Green Gold was found to be the best general combiner with significant GCA effects for six characters out of the eleven traits studied. The parent viz. Co White Long and Delhi Local were noted to be the best combiner for yield attributing characters. The cross combination Phule Green Gold × DVBTG-5 was observed to be the best having significant SCA effects in desired direction for yield and seven yield contributing characters studied.

Pandey *et al.* (2010) studied combining ability and gene action for quality and yield attributes in pumpkin involving 21 cross combinations derived from seven diverse inbreds. The analysis expressed that the parent, pumpkin-172 was good general combiner for total carotenoids, flesh thickness and yield. The parents, BP-18 and IVPK-226 expressed to be good general combiners for ascorbic acids content. Further they estimated that GCA variances was lower than the SCA variances for yield per plant, whereas GCA variances

were higher than the SCA variances for total carotenoids, flesh thickness and ascorbic acid indicating the pre-dominance of non-additive gene effects for yield and additive gene action for flesh thickness, total carotenoids and ascorbic acid.

Podder *et al.* (2010) determined the combining ability for eight important traits in snake gourd and observed that both general and specific combining ability variances were significant for all the traits except fruit girth and fruit yield per plant. Additive gene action played important role for all the characters except days to first female flowering where non-additive gene action played significant role. Parent SG001 was identified as good general combiner for fruit yield and some of yield contributing characters. Among the crosses SG004 × SG007, SG001 × SG004 and SG001 × SG008 were the best specific combiner for fruit yield and other yield contributing characters.

Kumara *et al.* (2011) studied combining ability in bitter gourd and observed that out of ten parents, Panurthy, Coimbatore Long, Chidambaram Small and VRBT 100 were best general combiner as they have made significant contribution in yield contributing characters. The cross Coimbatore Long × Panurthy exhibited high SCA effect for fruit yield per vine, node number at which first pistillate flower appears and days to first harvest, VRBT-100 × Panurthy was best for days to first male and female flower appears, Coimbatore Long × Panurthy was best for sex ratio and number of seeds per fruit in desired direction.

Thangamani *et al.* (2011) conducted a research trial to observe the combining ability in bitter gourd and manifested that the parents Preethi, CO-1, MC-30, Uchha Bolder, Green Long, and MC-105 were identified as best genotypes for improvement of yield combiner. The hybrids viz., Preethi × MC-30, KR × USL, MC-105 × MC-10 and Priyanka × CO-1 have recorded desirable values of mean, significant SCA and standard heterosis for yield.

Mule *et al.* (2012) conducted a research trial to examine combining ability for fruit yield and its components using 27 F₁ hybrids of cucumber obtained from a line × tester method involving twelve diverse parents. The ratio of the genetic variance indicates the predominance of the non-additive gene action in all the traits. The analysis revealed that the parents SPP-44, CCP-9 and Gujarat local were good combiner for fruit yield and its contributing traits. The Hybrids Pilibhit Local × K-90 (0.82) followed by Sheetal × CC-9 (0.57) and Sheetal × SPP-44 (0.40) exhibited higher SCA effect for the fruit yield per vine.

Patil *et al.* (2012) estimated combining ability in bitter gourd for crop improvement and observed that the lines, Gadag local (0.27), Pusa Vishesh (0.23), Coimbatore Green Long (0.10) and IC-68310 (0.08) were identified as the good general combiners for fruit yield per vine in order of their performances. The F₁ hybrids Gadag local × Pusa Vishesh (0.88) and Gadag local × Coimbatore Green Long (0.68) were recognized to have good specific combining ability for total fruit yield per vine and yield characters viz., days to anthesis of first male flower, days to anthesis of first female flower and number of fruits per vine.

Sabina *et al.* (2012) studied Combining ability of seven parental lines of sponge gourd in Line × Tester design for earliness and yield which revealed the predominance of non-additive gene action in controlling earliness and increasing yield. Among parents, NSG-1-11 was found the best general combiner for total yield per plant; PSG-9 for ratio of male and female flowers and Pusa Sneha for imparting earliness. Significant SCA effect for earliness was lacking, but five hybrids exhibited desirable SCA effects for earliness. The hybrid DSG-6× Pusa Sneha exhibited significant SCA effects for days to first fruit harvesting and DSG-7× NSG-1-11 for number of female flowers and total fruit yield per plant.

Radharani *et al.* (2013) studied combining ability for quantitative traits in bitter gourd and observed that the parents IC-044438, IC-470560, IC-470558 and IC 085622 were showed high mean performance as well as high GCA effect for one and more than two traits hence; they considered to be superior general combiners. Among the crosses, IC-044438 × IC-045339, followed by IC-044417 × IC-470558 were found to have high SCA effects in desirable direction for yield and most of the contributing characters. For earliness, the crosses, IC-044438 × IC-945339, IC 045339 × IC-470550 and IC-045339 × IC-470558 were identified as promising specific crosses.

Singh *et al.* (2013) observed combining ability in bitter gourd for yield and its attributing traits and observed that the parent HABG-30 has good general combiner for most of the characters viz. fruit yield per plant, fruit weight, fruit length, fruit breadth and vine length. Among the crosses, HABG-24 × HABG-30 showed highest SCA effect for all characters except days to 50% flowering and HABG-23 × HABG 34 showed significant SCA effect for fruit yield per plant, number of fruits per plant, and vine length.

Sonavane *et al.* (2013) conducted an experiment to study the combining ability of eight parental lines of sponge gourd for earliness and yield attributing traits. Among the

parents, HASG-5 was found as best general combiner for fruit yield per vine and the parent PSG-9 was good combiner for imparting earliness, days to first picking and sex ratio. The cross combinations Phule Prajakta × Pusa Chikani, Phule Prajakta × PSG-9, Phule Prajakta × HASG-5, VR-1 × PSG-100, VR-1 × HASG-5 and PSG-9 × HASG-5 were found have significant SCA effects for fruit yield per vine.

Verma and Singh (2014) set a research trial and studied GCA effects in bitter gourd and estimated that among the lines NDBT-13, NDBT-15 and NDBT-19 during both seasons (summer and late kharif) and NDBT-10 during summer season and among the testers Kalyanpur Sona during summer season and Pusa Do Mausami during rainy season were identified as superior donor for fruit yield per plant and its yield attributing traits like fruits number per plant and average fruit weight. Among the F₁ hybrids the best cross combinations for fruit yield per plant based on desirable SCA effects were NDBT-19 × Pusa Do Mausami in summer season while NDBT-8 × Pusa Do Mausami, NDBT-15 × NDBT-12 and NDBT-10 × Pusa Do Mausami in rainy season. The crosses, NDBT-7 × Kalyanpur Sona and NDBT-2 × Pusa Do Mausami were emerged as most promising crosses for days to anthesis of first female flower during both the seasons.

Nisha and Veeraragavathatham (2014) found crosses P3 × P1, P3 × P2, P4 × P3 and P5 × P3 as promising combinations for earliness and other desirable characters including yield per plant. The maximum significant true heterosis in desirable direction for total yield (71.8%) followed by number of branches (67%), average fruit weight (41.9%), NF (40.5%), MSL (39.5%), NNF (29.1%), average fruit length (28.7%) and average fruit diameter (12.4%) (Hussein and Hamed 2015) Most F₁ were positively heterobeltiotic for number of seeds/fruit and seed oil content, while had negative heterobeltiosis for weight of seeds/fruit, weight of 100 seeds and seed yield/plant. But for total yield, Large blue Hubbard x A15 and Indian line x A15 were highly heterotic (77.6% and 54%) over the mid and better parent, respectively.

Sarkar *et al.* (2015) conducted a research trial to study the magnitude of combining ability for earliness and vegetative characters using eight parental lines and 28 F₁ hybrids of ridge gourd. The parents PRG 117 and PRG 142 were good general combiner for earliness and for vegetative traits PRG 131 stood in top. The crosses PCPGR 7256 × PRG 142 and PRG 131 × PRG 132 showed highest SCA effects for earliness and the crosses PRG 132 × PRG 120 and PCPGR 7256 × PRG 117 found superior for different vegetative characters.

Tamilselvi *et al.* (2015) studied per se performance and combining ability for earliness and yield characters in pumpkin in line \times tester mating design. The study revealed that among the parents, Vadhalagundu Local, Kashi Harit and CO-2 were identified as the best genotypes for improvement of earliness and yield characters. The hybrids Vadhalagundu Local \times CO-2 and Kashi Harit \times Avinashi Local showed significant SCA effects for earliness and yield traits.

TamilSelvi *et al* (2015a) reported higher variance due to SCA than the GCA and indicated the predominance of non-additive gene effects for yield and its component characters in pumpkin (*Cucurbita moschata* Duch.ex Poir). For quality contributing traits in pumpkin, predominance of additive-additive gene action was reported for most of the characters but hollowness and dry matter content governed predominantly by additive-dominance gene action, pulp thickness and brix percentage were found to have predominantly dominant-dominant gene action

Kumar *et al.* (2016) studied combining ability in diallel mating design using seven homozygous lines of bitter gourd and revealed that variance due to general and specific combining ability were significant among all the characters studied. Among the parents, DVBTG-903, IC-068296, DVBTG-7, Green Long Jaunpuri and IC-06309 for days to anthesis of first staminate flowers; DVBTG-903, DVBTG-448, IC-06309, VRBTG-423, Green Long Jaunpuri and DVBTG-7 for days to anthesis of first pistillate flowers; DVBTG-7, IC-068296 and DVBTG-903 for fruit yield per plant were found good general combiners. However, in specific combining ability study, the crosses VRBTG-12-2 \times DVBTG-1004 for node at which first pistillate flower appears, IC-068296 \times IC-068316 for sex ratio, VRBTG-423 \times Green Long Jaunpuri for number of fruits per plant and DVBTG-903 \times IC-068316 for fruit yield per plant exhibited high specific combining ability.

Sundharaiya and Venkatesan (2016) studied the line \times tester analysis involving eight lines of bitter gourd and noticed that the line MC-13 and Panruti Local were good general combiner for fruit yield per vine. Negative general combining ability and lower per se for days to first female flowering and days to maturity was recorded in the lines Ayakudi Local and Mithipagal which is desirable to developed earliness in bitter gourd. The testers CO-1 and VK-1 Priya recorded high mean performance for fruit weight, fruit length and cavity size index, Among the crosses, Panruti Local \times VK-1 Priya, MC-13 \times Arka Harit and MC-13 \times CO-1 showed highest per se and specific combining ability for fruit weight, fruit length

and yield per vine. They further observed that additive \times additive and additive \times dominance type of interactions played an important role for days to first female flower appearance, fruit length, fruit weight, days to first picking, number of fruits per vine, and yield per vine.

Tiwari and Singh (2016) conducted an experiment to study the combining ability on earliness, vegetative traits and yield of cucumber. All traits pertinent to earliness and yield showed significant values for combining ability. The parents Isatis for earliness and Kian for yield characters were found as good general combiners. The cross PCUCP-3 \times PCUC-15 (-2.03) exhibited highest negative SCA effects for days to first female flowering and the cross Nun-3139 \times PCUC-8 (220.57) showed maximum specific combining ability fruit yield.

Kaniti (2016) reported in the bitter melon that IC-04448, IC-470560, IC-470558 and IC-085622 were found good general combiners for yield attributing characters and earliness. IC-044438 \times IC-045339 exhibited high sca effects for yield and related characters, followed by IC044417 \times IC-470558 and IC-045339 \times IC-085622. For earliness, the crosses viz., IC044438 \times IC-045339, IC-045339 \times IC-470550 and IC-045339 \times IC-470558 were identified as promising ones. best specific cross combinations involved High \times Low and Low \times Low general combiners.

Rashid *et al.* (2017) investigated combining ability in bitter melon through line \times tester analysis with 12 inbreds lines, 3 testers, and 36 crosses. The inbred lines L9 (IC599429), L2 (IC-599431) and L4 (IC-599423) showed positive significant gca effects suggesting their good general combining ability for yield per vine and other characteristics that contribute to yield. T1 (Pusa Do Mausami) was regarded as a good combiner for yield, fruit length, fruit weight, number of fruits per vine, number of primary branches, and ascorbic acid content among the testers. The significant sca effects were exhibited by four hybrids viz., L5 (IC-599410) \times T1 (Pusa Do Mausami), L8 (IC599434) \times T1 (Pusa Do Mausami), L11 (IC-50520) \times T1 (Pusa Do Mausami) and L10 (IC-599424) \times T2 (Pusa Vishesh) for yield per vine.

Kumara *et al.* (2017) studied the 24 bitter melon hybrids and reported Coimbatore Long \times Panurthy had the highest production per vine (2.32 kg), average fruit weight (85.10 g), *per cent* fruit set (93.28), days to first male flower appearance (37.32 days), days to 50 *per cent* flowering (83.12 days), and days to first harvest among these hybrids (64.07 days). Arka Harit \times Coimbatore Small (12.30) had the smallest number of seeds fruit-1, Green Long

x Panurthy had the longest average fruit length (25.15 cm), and Green Long x Nanjangood Local had the highest sex ratio. White Long x Panurthy had the longest productive vine lengths at 45 DAS (114.474 cm), 60 DAS (159.91 cm), and 90 DAS (169.91 cm) (296.4 cm).

Mallikarjunarao *et al.* (2018) investigated general and specific combining ability for quality and yield of bitter melon involving eight genetically divergent parental lines crossed in a diallel pattern. The combining ability analysis revealed that both general and specific combining ability variance were important for all the characters. They further observed that non-additive gene action played a major role in controlling the characters like flesh thickness, TSS, fruit yield per vine, ascorbic acid and iron content. On the basis of SCA effects, the hybrids Preethi × Pusa Do Mausami for TSS, Thusi × Pusa Do Mausami for ascorbic acid, Improved Katahi × Preethi for flesh thickness, Phule Green Gold × Pusa Do Mausami for iron content and fruit yield per vine showed highest SCA effects.

Wani *et al.* (2009) estimated combining ability in bottle melon under temperate conditions of Kashmir valley using 15 lines and 3 testers in line × tester method. Significant differences were found among the parents and hybrids for GCA and SCA effects respectively. The parent NDBG-123 possessed high GCA effects for 10 out of 14 traits and considered as good general combiner. Crosses exhibiting significant SCA effects for most of the traits were Kalyanpur Long Green × SHBG-11 (6 traits), NDBG-123 × SHBG-11 (5 traits), Local Long Green × SHBG-11 (5 traits), Punjab Round × Pusa Summer Prolific Long (3 traits), L-10 × Pusa Summer Prolific Long (2 traits), NDBG 20 × Pusa Summer Prolific Long (2 traits).

Acharya *et al.* (2019) concluded that the parent IC-68237 was the best general combiners for several economic traits like number of primary branches per vine (0.09), fruit length (0.52), fruit diameter (0.17) and number of fruits per vine (0.22) over the pooled environments while based on the specific combining ability, the cross combination Solan Collection x IC 68237 (1.24) for number of fruits per vine, IC 68237 x MDU-1 for fruit length (1.82).

Thakur and Kumar (2020) used six parents PI-618860, Khira-75, Poinsette, UHF-CUC-1, UHF-CUC-3 and UHF-CUC-2 for analysis and observed that parents Khira-75, PI-618860, UHF-CUC-2 and UHF-CUC-1 showed highest GCA effects for yield/plot and hectare whereas the hybrids UHF-CUC-3 × PI- 618860, Khira-75 × PI-618860 and UHF-

CUC-1 × PI-618860 exhibited positive SCA effects for traits such as earliness, yield per plot and per hectare.

Naik (2020) noticed IC-65787 and IC- 541448 as good general combiners for fruit yield per plant and other important horticultural traits based on gca effects and per se performance. Based on sca effects and per se values, the two promising hybrids of bitter gourd for fruit yield per plant were IC-599428 x Gangajali Karala and IC-599428 x K-85603.

Badni *et al.* (2021) reported that the line L10 was good combiner for the majority of the bitter gourd traits like number of nodes up to first female flowering, days to first harvest, number of fruits per vine, average fruit weight, fruit length, fruit girth and fruit yield per vine). L10 x T1 exhibited high sca effects for nodes up to first female flowering, fruit maturity to fruit set and fruit yield per vine. The cross L3 x T2 showed high sca effects for fruit length, fruit yield per vine and days to last harvest.

Kundu *et al.* (2022) identified the parent P2 (BG 009) as the best general combiner for earliness; P1 (BG 006) for number of fruits, average single fruit weight and fruit yield; P4 (BG 027) for node number of first female flower and days to seed fruit maturity; P3 (BG 011) for fruit length and thickness of the fruit flesh; P5 (BG 033) for 100-seed weight; and P6 for number of nodes per main vine. Significant SCA effects were displayed for early female flowering in crosses P1 x P2 and P3 x P5; fruits per vine in P2 x P4, P4 x P6, P2 x P5 and P3 x P5; average single fruit weight in P1 x P3, P3 x P5, P2 x P3 and P1 x P5. Significant reciprocal effects were also observed in most important traits namely, days to first male and female flower, number of fruits per vine, average fruit weight and fruit yield in bitter gourd.

Meghashree *et al.* (2023) studied combining ability analysis for yield and yield attributing traits in bitter gourd (*Momordica charantia* L.). It was found that the out of 28 crosses, IC-470550 × Preethi (4.647) and IC-505621 × Pusa Aushadhi (3.369) crosses showed significant and positive sca effects for fruit length. The significant specific combining ability effect in desirable direction was observed maximum for fruit diameter in the hybrids of cross between IC-505623 and Preethi (10.972) followed by IC-470550 and Preethi (10.527). With respect to average fruit weight, the sca effect was observed positively and significantly in IC-470550 × Preethi crosses with maximum of 54.075 followed by IC505621 × Pusa Aushadhi (44.532) cross. The hybrids of cross combination IC-470550 × Preethi (11.024) and IC-66023 × Pusa Aushadhi (7.512) documented significant maximum

specific combining ability effects in desirable direction with regard to number of fruits per plant. Significant positive sca effect was found highest in the IC-470550 × Preethi (1.833) and Gy 3-1-1-1-2 × Phule Green Gold (0.936) crosses for total yield per plant. In the cross-combination IC-470550 × Preethi, the tester Preethi was good general combiner for multiple traits like fruit length, fruit diameter, fruit weight and total yield per plant which was specifically combined with line IC-470550 and explored the heterotic potential in combination. In the cross IC-505621 × Pusa Aushadhi, IC505621 parent had good contribution to fruit length and fruit weight which was indicated by its general combining ability effect. The gynococious derived cross combination, Gy 3-1-1- 1-2 × Phule Green Gold was superior combiner for fruit diameter, fruit weight and total yield per plant.

Srinivasulu and Jasmitha (2024) used 7 parents and 21 hybrids at the Vegetable Experimental Farm of the Department of Vegetable Science, Dr. YSR Horticultural University, West Godavari, Andhra Pradesh for the study of general combining ability (GCA) of the parents and specific combining ability (SCA) of the hybrids for vital qualitative traits. Among the parents, Kashi Mayuri, Preethi, IC-44418 and IC-68314 were identified as good general combiners, showing potential for combining various quality components. The hybrids IC-469512 x Special Boldar, IC-433630 x IC-469512 and Pre ethi x IC-68314 were identified as the best specific combiners. Traits controlled by non-additive gene action were deemed suitable for improvement through recurrent selection and heterosis breeding. The best specific combiners were recommended for further evaluation in multilocational trials to assess their stability and performance, with the aim of potentially releasing them as hybrids or varieties.

Triveni *et al.* (2024) conducted a trial to evaluate general combining ability (GCA), specific combining ability (SCA), and heterosis for yield traits in bitter melon using a Line × Tester design. Six lines and three testers were evaluated during Kharif 2019. Parental lines IC 505637 and IC 470553, and testers Pusa Vishesh and Pusa Do Mausami, were identified as good general combiners for yield traits, indicating their potential for contributing additive genetic effects. The cross IC 470553 × Pusa Do Mausami showed superior SCA and heterosis, suggesting its suitability for hybrid development. Traits like fruit yield per vine and fruit weight were mainly governed by non-additive gene action, but strong GCA in some parents highlights their value in future hybrid breeding programs.

Sharma & Sharma (2024) investigated the General Combining Ability (GCA) effects of six parental lines of bitter melon (*Momordica charantia* L.) BG-1, BG-2, BG-6, BG-7, BG-8 and BG-15 to identify their potential for hybrid breeding programs. The research, conducted at the Crop Research Centre -3, School of Agriculture, ITM University, Gwalior, followed a randomized complete block design (RCBD) with three replications. GCA effects were estimated using Griffing's method 2, model 1 (fixed model) for diallel analysis. Results indicated that BG-7 exhibited consistently positive GCA effects for several yield-related traits, making it a superior parent for hybrid breeding. Conversely, BG-1 showed negative GCA effects for traits like vine length and number of fruits per vine, which might be advantageous for specific breeding goals such as early maturity and compact plant structure. The findings underscore the importance of GCA in selecting parental lines for developing high-yielding hybrids. Parental lines with positive GCA effects for key traits can enhance hybrid performance, contributing to improved productivity and quality in bitter melon cultivation.

Sinchana *et al.* (2025) evaluated ten advanced breeding lines (ABLs) of bitter melon for general combining ability (GCA) using test crosses with elite hybrid parents as testers. Significant variation was found among ABLs for fruit yield per plant, fruit diameter, and fruit length. While testers did not vary in their own GCA, they effectively discriminated ABLs for GCA performance. *Per se* performance of ABLs did not correlate with GCA, indicating that high-performing lines are not necessarily good combiners. However, a strong positive correlation between hybrid performance and parental GCA effects suggests that GCA is a reliable predictor of hybrid potential, supporting its utility in selecting superior parents and reducing resources needed for hybrid evaluation.

(2.3) Estimates of heterosis:

Heterosis term refers to the phenomenon in which population evolved through crossing of two homozygous inbreds of genetically unlike parental constitution showing either increase or decrease in F_1 values over the mean parental value. These values may be qualitative or quantitative such as growth, vigour, vitality, reproducing capacity, stress resistance, fruit yield and fruit quality. On the basis of comparison used, heterosis has been defined as the improvement of F_1 over the mid parent (Relative Heterosis), the better parent (Heterobeltiosis) and the check parent (Standard Heterosis). Various research achievements of heterosis on bitter melon are furnished as follows:

Kushwaha and Karnwal (2011) estimated the 15 hybrids involving 6 diverse parents (BBIG-1, BBIG 2, BBIG-3, Kalyanpur Baramasi, Pusa Do-Mausami and Pusa Vishesh) of bitter gourd, the Cross BBIG-3 × Pusa Do Mausami showed highly significant and maximum heterobeltiosis for fruit weight, number of fruits per plant and fruits yield per plant. The highest better parent heterosis for earliness in terms of days to first male flower anthesis, days to first female flower anthesis and days to first fruit harvest showed by BBIG-1 × Pusa Visesh, while the cross BBIG-2 × Pusa Visesh represents highest significant and positive heterobeltiosis for fruit length.

Dogra and Kanwar (2011) found that parents G₂ showed negative heterosis for days to marketable fruit maturity, days to first pistillate flower appearance and node at which first female flower whereas cross combinations G₂ x Gyn1 and EC173934 x LC-40 exhibited high heterosis and heterobeltiosis for earliness, respectively. It also observed that highest standard heterosis and heterobeltiosis for fruits number and yield was shown by cross combination K-90 x G₂.

Kushwaha *et al.* (2011) conducted an experiment to estimate heterosis and found that cross combinations BC-16 x Poinsette, BC-11 x BC-16, BC-14 x BC-16, BC-11 x BC-12 and BC-15 x BC-16 showed high heterobeltiosis for fruit length, number of fruit/plants, fruit diameter, node at which first pistillate flower and fruit weight, respectively.

Sundharaiya and Arumugam (2011) evaluate the extent of heterosis in line × tester analysis involving eight lines of bitter gourd and observed that the cross MC 13 × Arka Harit recorded the highest heterosis over check variety MC-13 for fruit size index, fruit length and cavity size index. It is a product of good × good combiner. The highest heterotic effects for yield per vine and number of fruits per vine over the check variety were exhibited by the hybrids, Panruti local × VK-1 Priya and MC-13 × Arka Harit. The crosses Mithipagal × VK-1 Priya, Mithipagal × Arka Harit, Ayakudi local × VK-1 Priya and Ayakudi local × Arka Harit registered the highest heterosis for number of fruits per vine over standard check MC-13.

Mule *et al.* (2012) studied extent of heterosis for fruit yield and its components using 27 F₁ hybrids of cucumber obtained from a Line × Tester method involving twelve diverse parents. The most promising hybrids Pilibhit Local × K-90 (57.96 %) followed by Sheetal × SPP-44 (56.60 %) and Sheetal × CC-9 (53.89 %) manifested higher heterobeltiosis for fruit yield per vine. For number of nodes at which first female appears, the hybrids Gujarat Local

× SPP-44 (-30.06 %), Gujarat Local × CC-9 (-29.94 %) and Gujarat Local × SPP-93 (-29.72 %) exhibited significant and standard heterosis in negative direction which are desirable to develop early cultivars therefore, these hybrids can be used in future crop improvement programme for development of early fruit bearing hybrids.

Mule *et al.* (2012a) found that cross combinations Gujarat Local x SPP-44 and Gujarat Local x PCUC-28 showed high heterobeltiosis for node number at which first female flower appearance while crosses Pilibhit Local x K-90, Gujarat Local x SPP-44, Sheetal x SPP-44, Sheetal x CC-9, Gujarat Local x CC-9, Gujarat Local x PCUC-28 and Gujarat Local x SPP-93 exhibited significant heterobeltiosis for node number at which first female flower appearance. The positive and significant heterobeltiosis was observed for fruit yield and its contributing traits in crosses viz. Pilibhit Local x K-90 followed by Sheetal x SPP-44 and Sheetal x CC-9. All these cross combinations were developed by using poor x good and poor x poor combiner parents.

Patil *et al.* (2012) reported maximum heterosis in bitter gourd for fruit yield per vine in hybrids Gadag Local × Pusa Vishesh (73.51 %), Gadeg local × Coimbatore Green long (36.79 %) over mid parent and 17.51 and 23.16 % over commercial check (MBTH-101), respectively.

Sharma *et al.* (2012) evaluated heterosis over better parents and check using 28 F₁ hybrids derived from eight diverse bottle gourd genotypes. The hybrids Pusa Naveen × NDBG 104, Pusa Naveen × UL-6 and Pusa Naveen × NDBG 140 were found to be the most promising and exhibited standard heterosis of 37.33, 20.16 and 31.34 % and heterobeltiosis of 84.95, 76.02 and 51.26 %, respectively, for fruit yield per plant. Therefore, these hybrids can be utilized for commercial cultivation.

Radharani *et al.* (2013) studied heterosis for quantitative traits in bitter gourd and observed that among the crosses, IC-044438 × IC-045339, followed by IC 044417 × IC-470558 were found to be highly promising hybrids by expressing heterosis in all forms (relative heterosis, heterobeltiosis and standard heterosis) in desirable direction for yield and most of the yield contributing characters.

Singh *et al.* (2013) set an experiment to study the heterosis and gene action for eight yield and yield traits in bitter gourd and found that the crosses, HABG-24 × HABG-30 and HABG-23 × HABG-34 exhibited significant heterosis over better parent in the desired

direction for most of the yield characters. Hence these crosses can be exploited as desirable hybrids.

Sonavane *et al.* (2013) conducted an experiment to study the heterosis and combining ability of eight parental lines of sponge gourd for earliness and yield attributing traits. The extent of heterosis over better parent was observed as high as (50.49 %) for fruit yield per vine. The cross PSG-9 × HASG-5 was found as best heterotic combination over better parent and standard check for days to first male and female flowering, days to first picking and yield per vine.

Thangamani and Pugalendhi (2013) The study revealed that 46 out of 90 hybrids were found to exhibit negative significant heterobeltiosis for days to anthesis of first female flower and the hybrid CO-1 × GL recorded favourable values for this trait. The highest positive heterobeltiosis and standard heterosis for fruit yield per vine was found in the hybrid Preethi × MC-30 followed by the hybrid KR × USL. The hybrids Preethi × MC-30, Priyanka × CO-1, MC-105 × MC-10 and KR × USL were found to be the best performers with respect to yield, earliness and quality traits and exhibited high heterosis for most of the traits, and can be exploited for commercial cultivation.

Talekar *et al.* (2013) observed heterosis in bitter gourd for twelve quantitative traits including fruit yield per vine and noticed that standard heterosis for fruit yield per vine ranged from -55.65 to 73.79 %. The crosses Preethi × HABG-22, Ujjwala × HABG-22, Hirkani × CO-4, Hirkani × HABG-22 and Kalyanpur Baramasi × HABG 21, which recorded 73.79, 63.10, 57.83, 53.83 and 55.22 per cent heterosis over standard variety Priya, respectively, were the best heterotic combiner for fruit yield per vine and could be utilized for hybrid development in bitter gourd.

Narasannavar *et al.* (2014) estimated heterosis for growth, earliness, yield and quality parameters involving 20 parents of ridge gourd. Maximum standard negative heterosis was observed in KRG-3 × Pusa Naveen (-19.48 %) for days to first male flower appearance, KRG-7 × Arka Sujat (-18.02 %) for days to first female flower appearance, KRG-9 × Arka Sujat (-56.92 %) for node to first male flower appearance, KRG-2 × Arka Sumeet (-19.35 %) for node to first female flower appearance, KRG-17 × Pusa Naveen (-40.34%) for sex ratio and KRG-1 × Arka Sumeet (-8.70 %) for days to first harvest. Maximum standard positive heterosis was observed in KRG-7 × Arka Sumeet (9.20 %) for vine length, KRG-

11 × Pusa Naveen (141.38 %) for number of branches per plant, KRG-10 × Pusa Naveen (13.95 %) for number of fruits per vine, KRG-3 × Arka Sumeet (26.53 %) for fruit yield per plot. The four best performing F₁ hybrids viz., KRG-3 × Arka Sujat (23.61 %) followed by KRG-3 × Pusa Naveen (13.80 %), KRG-10 × Pusa Naveen (12.45 %) and KRG-11 × Pusa Naveen (6.00 %) exhibited the highest standard heterosis for total yield per vine in order of merit.

Verma and Singh (2014) studied heterosis in bitter gourd and observed that the crosses NDBT-10 × Kalyanpur Sona (Summer) and NDBT-19 × Pusa Do Mausami (Rainy) showed highest standard heterosis for number of fruits per plant and for fruit yield per plant and the highest standard heterosis was observed in NDBT-13 × NDBT-12 during summer season and in NDBT-13 × Pusa Do Mousami during rainy season.

Kandasamy (2015) studied the extent of hybrid vigour in bitter gourd for yield and its contributing traits and observed appreciable amount of heterosis for all the characters except number of nodes to which first female flower appears. The best performing hybrids for yield were MC-13 × Arka Harit, Panruti local × VK-1 Priya and Arka Harit × CO-1 and these hybrids exhibited 29.31, 46.21 and 14.30 % heterosis, respectively over better parent Arka Harit.

Jat *et al.* (2015) concluded that parents Pusa Uday, GPC-1 and PPC-1 found to be the best for yield per plant where as cross combinations DC-1 x Pusa Uday, GPC1 × PPC-2, Punjab Naveen × Pusa Uday and PPC-2 × Pusa Uday performed best for average fruit weight, node at which first female flower, fruit length and yield per plant, respectively. The cross combinations PPC-2 x Punjab Naveen, PPC-2 x Pusa Uday and GPC-1 x Pusa Uday showed positive heterosis over standard check for yield/plant.

Koppad *et al.* (2015) evaluated eighteen genotypes of ridge gourd and results revealed that PCV was higher than the GCV for most of the traits. High heritability with moderate to high GCV, PCV and GAM was depicted for chlorophyll and proline content at 45 DAS and total yield per vine indicated that these characters could be improved by simple selection. Proline content in the leaf during 45 ($r=0.5784$) and 90 days after sowing (DAS) ($r = 0.8659$), average fruit weight ($r =0.9298$), tendril length ($r =0.4955$) had positive and significant correlation with the yield but the sex ratio ($r = - 0.4606$) and days to first female flowering ($r= -0.5120$) had the negative significant association with the fruit yield per vine.

Shinde *et al.* (2016) studied gene action, combining ability variance derived by crossing ten diverse bottle gourd parents through half diallel analysis including 45 F₁ hybrids for earliness and yield components. Out of ten parents Bhagirathi was the best general combiner as it showed high GCA effect in desirable direction for most of the traits. The best promising hybrids regarding sca effects for yield and majority of yield traits were Pusa Summer Prolific Long X Pusa Naveen, Samrat X NDBG 619, Samrat X Bhagirathi, Pusa Summer Prolific Long X Bhagirathi, NDBG 5006X NDBG 129, and NDBG 129 X PBOG-89.

Punetha *et al.* (2017) investigated that cross combinations PGYN-1 × PCUC-35 and PGYN-5 × US-832 exhibited high heterosis over better parent and standard parent, respectively, for days to first pistillate flower and fruit picking. The highest heterobeltiosis for number of fruit/vine and yield was shown by hybrids PGYN-5 × PCUC-28 and PGYN-4 × US-832, respectively whereas hybrid PGYN-5 × PCUC-28 for fruit weight.

Tak *et al.* (2017) evaluated snapmelon and cucumber genotypes in line x tester analysis and results revealed that highly significant estimates for general combining ability and specific combining ability for all the traits which indicate the importance of both additive and non-additive genetic variance in the inheritance of these traits. The genotyped L3 and L2 were found to be the most promising per se for most of the trait, whereas the cross combination L3 x T3, L2 x T2 involving good x good general combiner parents was found with good desirable SCA effects. The cross combination L7 x T1 was found with best SCA effect for T.S.S.

Shukla *et al.* (2017) conducted an experiment to analyse the combining ability in 3 gynocious line × 12 monoecious testers for thirteen quantitative characters in bitter gourd. Mean square due to GCA and SCA were highly significant for all the traits studied to suggest the importance of additive and non-additive gene effects. Gynocious line Gy323 was the best combiner for all the traits except fruit diameter and seeds/ fruit, whereas monoecious line DRAL-4I was best general combiner for first flower anthesis and inter nodal length as they have made significant contribution in yield contributing characters. The gynocious combination Gy333 × DRAL- 4I, Gy323 × DVBTG-7 and Gy323 × VRBT- 904 exhibited high SCA effect for all traits in desired direction.

Muthaiah *et al.* (2017) studied to develop hybrids in ridge gourd for earliness and yield traits. Twenty-eight crosses were developed through half diallel fashion. Significant

differences found in the analysis of variance for early and yield related traits which indicate enormous genetic variability present in the ridge gourd. The magnitude of heterosis was found in desirable direction for early and yield traits viz., days to first female flowering is recorded in the cross DMRG- 25 × DMRG-1 (9.50%), for nodes up to first female flowering in the cross DMRG-25 × Arka Sumeet (-16.67%), for per cent fruit set in the cross DMRG-25 × Arka Sumeet (36.21%), for number of fruit per vine in the cross DMRG-25 × DMRG-44 (29.51%), for average fruit weight in (45.95%).

Devi *et al.* (2017) conducted an experiment in Line x Tester design to study the combining ability for yield and yield contributing characters in snake gourd. The line IC 284753 (L5) and IC333314 (L2) were found best general combiners, for majority of the yield and yield contributing characters. Among the testers Kumbakonam Local (T3), Kulithalai Local (T1) and Jeyamkondam Local (T2) were found to be good general combiner for yield contributing characters viz., vine length, fruit length, fruit girth, average fruit weight, number of fruits per vine, number of seeds per fruit and yield per vine. Among the hybrids L2xT3, L7xT2, L2xT4, L5xT1 and L8xT4 were found to be the good specific combiners (GCA) for most of the yield and yield contributing characters.

Nimitha *et al* (2018) crossed 10 parental lines in diallel mating design to estimate heterosis in cucumber for number of fruits/vines, fruit length, fruit breadth, fruit yield/vine and average fruit weight. It was revealed that cross ACUS 13–60 x ACUS 9–51 exhibited significant high heterosis over standard parent for number of fruits/vine and fruit yield/vine while cross combinations ACUS 9–50 x ACUS 9–51 and ACUS 13–58 x ACUS 13–60 showed positive and significant heterosis for fruit breadth and fruit weight, respectively.

Singh and Tiwari (2018) conducted a study to estimate heterosis over mid parent and better parent. It was found that cross combinations CU-5 x Patna-3, Swarna ageti x Patna-3 and PCUC-28 x Peelibheet local recorded to be the best for earliness and yield related traits over their mid and better parents.

Adarsh *et al.* (2018) indicated that the parents and hybrids per se performance for both morphological and biochemical attributes had highly significant variation among the parents and hybrids of bitter gourd. Per se performance disclosed few crosses had manifested significant heterotic effects for most of the traits with regard to better parent and standard parent. The crosses BRBBTL x Pusa Aushadhi and BRBTL x Gangajalee evinced heterotic vigour over standard parent for earliness, quantitative and qualitative attributes.

Mallikarjunarao *et al.* (2018) estimated extent of heterosis for quality traits and fruit yield per plant in bitter melon and observed that the hybrids Phule Green Gold × Pusa Do Mausami, Phule Green Gold × Preethi and Preethi × Pusa Do Mausami showed highest standard heterosis for fruit yield per vine and other quality traits.

Kumari *et al.* (2019) evaluated in crossed nine parental lines in line x tester method to estimate heterosis and dominance effects in the inheritance of fruit yield and its contributing traits in cucumber. It was found that characters viz. fruit yield/hectare, average fruit weight, fruit length, number of fruits/vines, days to first pistillate flower and fruit diameter showed highest heterosis. The cross combinations CGN-20515 × Poinsette, LC-1-1 × K-75, LC-2-2 × Poinsette, LC-2-2 × K-75 and LC-1-1 × Poinsette observed to be best on the basis of heterosis and mean performance for most of the traits.

Naik *et al.* (2019) observed that cross combination US-640 × Haveri Local showed negative heterosis for days to first fruit picking over two standard checks whereas cross combination Pebkamal × Haveri Local exhibited negative heterobeltiosis for appearance of first staminate and pistillate flowers on which node number and days to first pistillate flower appearance. The cross combination NCU-1287 × Belgum Local showed negative heterosis and heterobeltiosis over the standard check Poinsette but the parents Himangi and DWD performed high heterosis for days to last fruit picking.

Das *et al.* (2020) conducted an experiment to estimate heterosis and heterobeltiosis in half diallel mating design. It was found that cross combination Debstar x Pusa Barkha exhibited significant positive heterosis over standard check for fruit yield per plant whereas crosses Pusa Barkha x Samrat 7 Star and Debstar x Pusa Barkha showed high heterosis over better parent for number of fruits/plant and fruit yield/plant.

Mohamed (2020) evaluated in crossed 5 parental lines in half diallel mating design to estimate heterosis over better and mid parents, potence ratio and correlation coefficient in cucumber. It was found that positive heterosis over better parent was observed for early yield/plant followed by total fruit yield whereas high heterosis over mid parent was recorded for early yield/ton followed by total yield/ton. The characters number of leaves/vine and vine length showed positive correlation with fruit shape, fruit weight, number of fruits/vines, fruit length, early yield/ton and total yield/ton.

Sawant *et al.* (2020) conducted an experiment by using six male parents (Fansu local, VRC-19, DC-2, AAUC-1, DARL-103 and AAUC-2) four female parents (Punakhira, Sheetal, Himangi and Shubhangi) and one standard check (Konkan Kakadi). It was found

that five cross combinations Puna khira x VRC-19, Sheetal x AAUC-2, Sheetal x Fansu local, Puna khira x Fansu local and Sheetal x VRC-19 showed positive heterosis for yield per plant.

Naik *et al.* (2020) studied heterosis for yield and its contributing characters of 10 F₁ crosses of bitter gourd obtained from half diallel. Based on sca effects, heterobeltiosis, standard heterosis revealed in them, and per se performance, two outstanding hybrids 'IC-599428 x Gangajali Karala and IC-599428 x K-85603' were identified considering fruit yield per plant.

Malve *et al.* (2021) reported that 16 and 9 hybrids had significant heterosis over better parent and standard hybrid check, respectively. The best five hybrids of bitter gourd were Phule Green Gold x Preethi, Preethi x DVBTG-7, Phule Green Gold x DVBTG-7, Phule Green Gold x Arka harit and Preethi x Konkan Tara recorded maximum heterosis percentage over better parent and standard hybrid check. The positive and highly significant heterosis over better parent and standard hybrid check was exhibited by 16 and 10 hybrids, respectively. The best five hybrids, Preethi x DVBTG-7, Phule Green Gold x Preethi, Phule Green Gold x Arka harit, Preethi x Co-White Long and Co-White Long x DVBTG-7 were most promising since these crosses recorded maximum heterosis percentage over better parent and standard hybrid check.

Kumari *et al.* (2021) studied that cross combinations LC × K-75 and LC-2-2 × Poinsette exhibited high heterosis for better parent and standard check whereas the cross combinations LC-2-2 × Poinsette, LC-12-4 × Poinsette, LC-1-1 × K-75 and LC-1-1 × Poinsette exhibited highest residual heterobeltiosis and economic heterosis. In both F₁ and F₂ generations, two cross combinations LC-1-1 × K-75 and LC-2-2 × Poinsette showed superiority for yield and its contributing traits.

Sunny *et al.* (2022) Conducted the experiment of Potential of Gynoecious Line in Generating Superior Heterotic Hybrids in Bitter Gourd (*Momordica charantia* L.). He was found that the highest yield was recorded in the hybrid KAU-MCGy-101 × Priyanka (22.88 t/ha) and was followed by KAU-MCGy-101 × Preethi (20.42 t/ha) and KAU-MCGy-101 × MC 133 (20.05 t/ha). Heterobeltiosis for yield (t/ha) varied from 14.72 to 57.85 % and the standard heterosis ranged between 37.59 to 89.31 %. The best performing hybrids were KAU-MCGy-101 × Preethi, KAU-MCGy-101 × Priyanka, and KAU-MCGy-101 × MC 133 with respect to earliness, number of fruits per plant, and yield.

Aamin *et al.* (2023) Studied that the Genetics of Yield and Fruit Quality Traits in Bitter Gourd (*Momordica charantia* L.). it was observed that the mean values of F₁ for fruit length, fruit weight and fruit diameter (in CBM-12 × DBG-4) were greater than the mid-parent values (average of the two parents) which indicate average heterosis, whereas F₁ mean values of number of fruits per plant and yield per plant and fruit diameter (in PVGy-201 × PDM) was higher than better parent values which indicated over dominance/heterobeltiosis. Similarly, for earliness-related traits, in both cross combinations mean values of F₁ implied negative average heterosis which is desirable. These results suggest the scope for improvement yield and earliness through heterosis breeding. There was decline in mean values of yield traits of F₂ population than corresponding F₁ in all yield traits. This apparently indicated influence of inbreeding depression. Similar result was found that the Dey *et al.* (2012) in bitter gourd. The SCA analysis revealed that the best cross combinations with respect to SCA effects and per se performance were NDBG-17 × Jounpuri, NDBG-7 × Arka Harit and NDBG-6 × Local bitter gourd and NDBG-12 × Local bitter gourd for earliness; NDBG-1 × Arka Harit, NDBG-12 × Arka Harit, NDBG-17 × Local bitter gourd for quality traits.

Triveni *et al.* (2024) conducted an field experiment to assess the general, and specific combining abilities and the extent of heterosis for yield traits in bitter gourd. Identifying genetically superior parents is crucial for hybrid development, and combining ability analysis is an effective tool for selecting desirable parents for hybridization programs. Field experiments were conducted at the College of Horticulture, Dr. Y.S.R Horticultural University, Venkataramannagudem during *Kharif*, 2019. Six lines were crossed with three testers in the Line × Tester mating design, which yielded wide range of variability in yield related traits. Results showed that the parental lines (IC 505637 and IC 470553) and testers (Pusa Vishesh and Pusa Do Mausami) were observed to be the best general combiners for yield related traits. The crosses IC 470553 × Pusa Do Mausami (5.45%), IC 470553 × Pusa Vishesh (1.36%), and IC 505637 × PDM (0.30%) recorded positive standard heterosis over check VNR 22 for fruit yield. The cross IC 470553 × Pusa Do Mausami exhibited desirable specific combining ability (SCA) effects on all evaluated traits. Certain characters such as days to the first female flower, the node at the first male flower, average fruit weight, fruit yield per vine, and fruit yield per hectare were observed to be controlled by non-additive gene action. Therefore, we suggested that selected parents and crosses could be considered for use in bitter gourd hybrid breeding programs.

Vannuri *et al.* (2024) conducted a study undertaking twelve lines and three testers to develop 36 F₁ hybrids in L × T (Line × Tester) pattern. Evaluation of hybrids along with their parents revealed that the cross combinations Katahi Vaibhav × Preethi, Green Long × Preethi and Katahi Vaibhav × Co-1 showed highest positive heterosis, which were supercilious for earliness and yield parameters whereas, IC505640-2 × Co-1 and Green Long × Preethi expressed superior for quality parameters resulting as best hybrids. Based on its yield potential and favoured earliness characteristics, the Katahi Vaibhav × Preethi hybrid was chosen as the best hybrid out of 36 cross combinations, with a yield of 14.32 t/ha. Hence the best hybrids are recommended for commercial exploitation of heterosis.

Vidya *et al.* (2024) experimented field trial using nine lines and three testers to develop 27 F₁ hybrids in L × T (Line × Tester) pattern. The cross combinations HUB-1 × Co-1, HUB-1 × White Long and Katahi Vaibhav × White Long showed highest SCA effect and positive heterosis, which were supercilious for earliness, yield and quality parameters resulting as best hybrids. Based on its yield potential and favoured earliness characteristics, the gynococious HUB-1 × Co-1 hybrid was chosen as the best hybrid out of 27 cross combinations, with a yield of 18.38 t/ha, the hybrid showed 104.40 percent standard heterosis over commercial check. The hybrids Jonpuri × White Long and HUB-1 × Co-1 expressed superior quality parameters like beta-carotene, ascorbic acid and iron content. The gynococious based hybrid HUB-1 × Co-1 showed resistant reactions for virus and fruit fly infestation, which further can be used in resistant breeding programme.

(2.4) DUS Characterization

The identification of distinct and stable genotypes through DUS testing enables breeders to select parents with desirable characteristics, ensuring the development of high-yielding, uniform, and genetically stable cultivars. Additionally, uniformity assessment ensures consistency in performance, while stability testing confirms that selected traits are reliably expressed across different environments and generations.

DUS characterization also facilitates the selection of superior parental lines and the development of trait-specific cultivars, ultimately enhancing breeding efficiency and contributing to sustainable crop improvement programs in bitter gourd.

Hazra *et al.* (2022) assessed five diverse bitter gourd (*Momordica charantia* L.) genotypes to explore the relationship between morphological traits and

nutrient/nutraceutical contents. Significant variation was observed in traits such as leaf color, tendril type, sex form, fruit color, shape, tuberculation, length, girth, and weight. Indian types, characterized by dark green, spindle-shaped fruits with sharp tubercles, showed higher nutrient and most nutraceutical contents but lower charantin levels. In contrast, East Asian types with whitish-yellow, roundish-oblong fruits and blunt tubercles exhibited higher charantin but lower nutritional values. Regression and heat map analyses identified key morphological traits influencing phytochemical profiles, highlighting their utility in breeding nutrient-rich bitter gourd cultivars.

Mallikarjuna *et al.* (2024) evaluated 98 bitter gourd genotypes for 12 DUS traits using UPOV guidelines. The Shannon–Wiener diversity index ranged from 0.00 to 1.32, indicating substantial phenotypic variation. Indian-origin and *Momordica charantia* var. *charantia* genotypes showed greater diversity than exotic and var. *muricata* types. Traits such as leaf lobing, fruit skin color, and tuberculation were most effective for distinguishing genotypes. Significant variability was also observed in quantitative traits like fruit size, yield, and flowering time, with high heritability suggesting strong potential for genetic improvement. This is the first DUS study to identify a unique white-flowered genotype (DBGS-54-18), offering valuable genetic resources for future breeding programs.

Mehta *et al.* (2024) carried out experiment with 27 genotypes of bitter gourd (*Momordica charantia* L.)” at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during Spring–Summer season, 2018. The genotypes were planted in three replications in Randomized Block Design. Considerable amount of variability was observed in all the genotypes for all seven morphological characters under study viz., leaf shape, leaf pubescence, fruit neck, fruit skin color, fruit shape in longitudinal section, shape of fruit at blossom end and shape of fruit at peduncle end. The genotypes viz., IC 85624 followed by HK 113, IC 85610, IC 85605 were found superior in terms of mean performance data of fruit yield and growth parameters and found promising for future improvement programme

Verma and Joshi, (2025) investigated the morphological variation and Distinctness, Uniformity, and Stability (DUS) characterization of *Momordica charantia*. Twenty-two Bitter Gourd varieties were characterized based on morphological traits to assess genetic diversity and enhance breeding program efficiency. Significant variations were observed in fruit morphology (colour, length, surface tubercles, and ridges) and seed characteristics

Review of literature

(Colour and margin indentation) enabling effective varietal differentiation. Notably, four accessions were classified as *M. charantia* var. *muricata* due to their distinctly small fruit size, highlighting the presence of diverse morphological forms within the studied population. Additionally, admixture was detected in seven varieties, which underscores the necessity for purification processes to ensure the commercial viability of these accessions. This research emphasizes the rich genetic diversity of Bitter Gourd in Eastern India and identifies key traits that are essential for distinguishing between varieties.

MATERIALS AND METHODS

The present research work entitled “**Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)**” was conducted during *Zaid* seasons of 2023-24 (Y₁) and 2024-25 (Y₂) to study the heterosis, combining ability, nature and magnitude of gene action, heritability in narrow sense and genetic advance in per cent of mean using line × tester mating design at the Main Experiment Station (MES) of the Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Narendra Nagar, Kumarganj, Ayodhya (U.P.) India. The observations were recorded on twenty characters including two qualitative traits. The material and methods used are elaborated in the following paragraphs:

3.1 Experimental site

The experiment was move around at Main Experimental Station, Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya. Geographically, experimental site falls under humid, sub-tropical climate and is located in between 24.47⁰ and 26.56⁰ N latitude and 82.12⁰ and 83.98⁰ E longitude at an altitude of 113m above the mean sea level in the Gangetic Alluvial Plains of Eastern Uttar Pradesh. The soil type of experimental site was sandy loam with average fertility level and pH in the range of 7.5-8.5.

3.2 Environmental conditions

This area falls under the humid subtropical zone and received average annual precipitation of about 1200 mm. The maximum rainfall received during the period between June to the end of September. Sometimes, continuous cloudy weather with heavy rains for longer period drastically affects the agricultural production. However, occasional showers are also very common in the month of December and January. The winter months are usually cool and dry. The summer is hot and dry, western hot winds, start from April and end at onset of monsoon. The weather data recorded at meteorological observatory of university for the period during which experiments were conducted have been given in (Table-3.1 a & b)

Table 3.1 (a): Meteorological data (weekly average) during the crop grown period [January to May 2023-24 (Y₁)]

Months	Standard Mean Weeks	Mean temperature (°C)		Mean Relative Humidity (%)	Total Rainfall (mm)	Sunshine (hrs/day)	
		Max.	Min.				
Y ₁	February	6	22.5	6.2	70.4	0.0	8.2
		7	24.9	9.6	67.4	0.0	8.5
		8	25.6	12.4	77.0	53.0	4.3
		9	26.8	13.9	72.8	0.0	7.6
	March	10	26.0	13.9	74.0	68	6.5
		11	27.1	14.7	72.4	9.0	5.8
		12	29.7	15.7	68.5	2.0	8.1
		13	32.1	16.6	54.3	0.0	8.9
		14	34.8	16.1	46.1	0.0	10.0
	April	15	36.9	18.7	50.4	0.0	9.2
		16	36.6	21.5	56.0	1.0	9.4
		17	33.4	22.0	64.6	0.0	8.7
		18	32.6	21.1	69.3	0.0	9.1
	May	19	34.1	22.1	62.4	10	9.5
		20	39.1	22.8	49.1	0.0	10.2
		21	40.4	25.1	52.1	0.0	9.8
		22	35.2	25.1	63.6	12.2	6.9
	June	23	34.4	25.5	70.4	9.2	5.4
		24	35.8	28.4	69.4	47.4	8.0
		25	31.5	26.3	84.9	96.2	1.7
26		31.6	25.6	86.7	77.6	1.6	

Source: Department of Agro-meteorology, ANDUA&T, Kumarganj, Ayodhya (U.P.) India

**Table 3.1 (b): Meteorological data (weekly average) during the crop grown period
[January to May 2024-25 (Y₂)]**

	Months	Standard Mean Weeks	Mean temperature (°C)		Mean Relative Humidity (%)	Total Rainfall (mm)	Sunshine (hrs./day)
			Max.	Min.			
Y ₂	February	6	25.5	9.0	67.1	0.0	6.3
		7	27.2	9.5	68.1	0.0	6.8
		8	28.2	11.7	66.3	0.0	7.6
		9	30.2	13.2	58.8	0.0	7.0
	March	10	31.8	14.2	64.3	0.0	6.6
		11	32.3	15.2	66.4	0.0	6.2
		12	34.6	16.5	57.0	0.0	6.8
		13	35.6	16.4	56.3	0.0	7.5
		14	37.5	17.0	44.3	0.0	6.7
	April	15	38.9	18.8	47.3	0.0	6.2
		16	37.8	20.1	56.1	0.0	7.6
		17	33.4	22.0	64.6	0.0	8.7
		18	32.6	21.1	69.3	0.0	9.1
	May	19	34.1	22.1	62.4	10	9.5
		20	39.1	22.8	49.1	0.0	10.2
		21	40.4	25.1	52.1	0.0	9.8
		22	35.2	25.1	63.6	12.2	6.9
	June	23	34.4	25.5	70.4	9.2	5.4
		24	35.8	28.4	69.4	47.4	8.0
		25	31.5	26.3	84.9	96.2	1.7
26		31.6	25.6	86.7	77.6	1.6	

Source: Department of Agro-meteorology, ANDUA&T, Kumarganj, Ayodhya (U.P.) India

3.3 Experimental materials

The experimental materials for the present investigation comprised of ten promising and diverse pure lines/varieties with three testers of bitter gourd selected on the basis of genetic variability from the germplasm stock maintained in ICAR-AICRP by the Department

of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) India. The selected parental lines *i.e.*; Sel.-1 (L₁), V-21-14 (L₂), V-65-1 (L₃), V-193 (L₄), V-198 (L₅), V-158 (L₆), V-26 (L₇), V-169 (L₈), NDBG-8 (L₉), NDBG-9 and testers Kashi Mayuri (T₁), Arka Harit (T₂), DARAL-43 (T₃) were crossed in the all possible combination to get 30 F₁ seed for the study of heterobeltiosis and standard heterosis, combining ability effects, gene action and heritability in narrow sense and genetic advance as per cent of mean among F₁'s and parents for 25 fruit yield and quality attributing traits. Distinguishing features of the parental lines are given in (Table-3.2).

Table 3.2: Details of parental lines/genotypes

S. No.	Symbol	Name of Parents	Source
1.	L ₁	Sel.-1	IIVR, Varanasi
2.	L ₂	V-21-14	IIVR, Varanasi
3.	L ₃	V-65-1	IIVR, Varanasi
4.	L ₄	V-193	IIVR, Varanasi
5.	L ₅	V-198	IIVR, Varanasi
6.	L ₆	V-158	IIVR, Varanasi
7.	L ₇	V-26	IIVR, Varanasi
8.	L ₈	V-169	IIVR, Varanasi
9.	L ₉	NDBG-8	A.N.D.U.A.T., Ayodhya
10.	L ₁₀	NDBG-9	A.N.D.U.A.T., Ayodhya
11.	T ₁	Kashi Mayuri	IIVR, Varanasi
12.	T ₂	Arka Harit	IHR, Bangalore
13.	T ₃	DARAL-43	IIVR, Varanasi

3.4 Cultural practices:

3.4.1 Sowing of seed

The seed of all the developed F₁'s along with parents were brought up in the raised beds. Recommended cultural practices and appropriate plant protection measures were also taken up prior and after sowing of the seeds.

3.4.2 Field preparation and layout of the experiment

The field of experiment was ploughed and brought up to the fine tilth. Farm yard manure @ 25 tons per hectare and 60 kg nitrogen (N), 50 kg phosphorous (P_2O_5), 50 kg potassium (K_2O) per hectare were applied in the recommended manner. The experiment was laid out during *summer* seasons of 2023 and 2024 in Randomized Block Design including 13 parents (10 lines and 3 tester) and 30 F_1 s.

3.4.3 Sowing and after care

The seed were sown to the main field and irrigation just after sowing. Top dressing was done at the time of earthing with 50 per cent nitrogen after one month of sowing. Timely irrigation, weeding and earthing up were given and recommended practices were followed.

3.5 Experimental design

The present experiments were conducted in a Randomized Block Design (RBD) with three replications to appraise the performance of 30 F_1 hybrids and their 13 parents (10 lines and 3 testers). The crop was sown in rows spaced at 3 meters apart with a plant to plant spacing of 0.50 meter. Sowing was done on 9th February, 2024 and 10th February, 2025. All the recommended agronomic package of practices and protection measures were followed to raise good crops.

3.6.1 Development of F_1 hybrids and their evaluation

Ten inbreds lines/varieties and three divergent testers were selected and crossed in line x tester mating design as suggested by Kempthorne (1957) to produce 30 hybrids (F_1) in season of 2022-23 and evaluated during season of 2023 and 24.

3.6.2 Hybridization programme

Bitter gourd produces separate staminate (male) and pistillate (female) flowers in the leaf axils due to its monoecious nature. Maintenance of parental lines were done simply selfing of the true to type plant. The staminate and pistillate flower buds, which were about to open the next day, were individually enclosed in butter paper bags on the preceding evening. The following morning, pollen grains were collected from the bagged staminate flowers and gently applied to the bagged female flowers of different lines between 6:00 AM and 8:30 AM. Subsequently, the dusted pistillate flowers were covered with butter paper bags, and each bag was marked with specific information about the cross and the date of pollination.

After 3-5 days from the pollination process, the paper covers were removed to support fruit development. Seeds were extracted from hard shelled fruits by hand, dried and packed with appropriate label.

3.6.3 Evaluation of parents and their hybrids

The evaluation of 13 parents along with their 30 F₁ hybrids and commercial check variety VNR Naudhan for various characters was done in *Zaid* season of 2023-24 and 2023-24. The details of experiment are as follows,

Treatments	:	30 hybrids + 13 parents (10 lines + 3 testers) one check
Replication	:	Three
Design	:	Randomized Block Design (RBD)
Spacing	:	3.0 cm × 0.5 m
Plot size	:	3.0 m × 3.0 m
Population	:	5 plants per plot

3.7 Observations recorded

Observations were recorded on five plants in each of parents and F₁s for each treatment in each replication, selected randomly for the following characters. The observations recorded on the five plants were averaged and got mean value. The procedure is described under the respective sub-heads:

3.7.1 Morphological character of different genotype and their crosses

3.7.1.1 Fruit colour

Fruit colour was visually observed at the commercial maturity stage on five randomly selected typical fruits from selected plants, following the DUS test guidelines for bitter gourd

3.7.1.2 Fruit shape

The fruit shape was visually assessed and recorded from selected plants after the fruits had reached full maturity in accordance with the DUS test protocol of bitter gourd

3.7.1.3 Fruit tubercles

The presence of fruit tubercles was visually evaluated on five mature fruits

randomly selected from selected plants, following the criteria outlined in the DUS guidelines for bitter gourd

3.7.1.4 Fruit ridge

Observations on the presence of ridge on the fruit surface were made visually in selected plants in accordance with the DUS test protocol

3.7.1.5 Peduncle length (cm)

Peduncle length (cm) was measured from the point of attachment at the stem to the base of the fruit on randomly selected mature fruits, following the DUS test guidelines for bitter gourd

3.7.1.6 Flower colour

Flower colour was recorded separately at anthesis from five representative plants, as per the DUS test protocol

3.7.1.7 Leaf blade length (cm)

Leaf blade length (cm) was measured from the base of the petiole to the tip of the terminal lobe on five fully developed leaves from the middle portion of the main stem, as per the DUS guidelines

3.7.1.8 Leaf blade width (cm)

Leaf blade width (cm) was measured at the widest point of the fully developed leaf from the middle portion of the main stem on five randomly selected plants, following the DUS guidelines

3.7.1.9 Leaf blade- no. of lobes

The number of lobes on the leaf blade was counted on five fully developed leaves taken from the middle portion of the main stem of five selected plants, in accordance with the DUS guidelines

3.7.1.10 Petiole length (cm)

Petiole length (cm) was measured from the point of attachment at the stem to the base of the leaf blade on five fully developed leaves from the middle portion of the main stem of five randomly selected plants, following the DUS guidelines.

3.7.2 Quantitative characters:

3.7.1.1 Days to first staminate flower anthesis

Number of days taken from sowing of seed to the opening of first staminate flower of five selected plant was recorded and averaged to get mean value.

3.7.1.2 Days to first pistillate flower anthesis

Number of days taken from sowing of seed to the opening of first pistillate flower of selected plant was recorded and averaged to get mean value.

3.7.1.3 Node number to first staminate flower appearance

The node number from the base of the plant at which first staminate flower appeared of selected plant was recorded and mean value was worked out.

3.7.1.4 Node number to first pistillate flower appearance

The node number from the base of the plant at which first pistillate flower appeared of selected plant was recorded and mean value was worked out.

3.7.1.5 Days to first fruit harvest

It was recorded as number of days taken from the date of sowing to the date of first picking of edible fruits of a plot and averaged.

3.7.1.6 Vine length (m)

The vine lengths of selected plant was measured in meter from the base to the tip of the vine at the time of last picking and mean value was worked out.

3.7.1.7 Number of primary branches per plant

Total number of branches emerged from main vine was counted at final harvesting stage and the average value was calculated to get the total number of primary branches in a single plant.

3.7.1.8 Fruit length (cm)

The fruit length of edible fruits was recorded on five randomly selected fruits of a plot in each replication. The length of each fruit was measured as a perpendicular distance between the points of attachment of the stalk and centre of the blossom end with the help of measuring tape in centimeters and mean value was worked out.

3.7.1.9 Fruit circumference (cm)

The fruit circumference of edible fruits was recorded on same selected fruits of a plot in each replication on which fruit length was measured. The measurement of fruit diameter at the thickest portion of the fruit was taken with the help of measuring tape in centimeter and mean value was worked out.

3.7.1.10 Fruit weight (kg)

The total fruit yield (kg) of a plot was divided by total number of fruits of that plot to get the average fruit weight (kg).

3.7.1.11 Number of fruits per plant

Numbers of edible fruits was counted at each picking and summed up for all the pickings for a plot. Number of fruits per plant was calculated after dividing total number of fruits in a plot by total number of plants in that plot.

3.7.1.12 Fruit yield per plant (kg)

The total fruit yield over all the pickings was recorded in kilogram for each plot and divided by total number of plants in the plot to obtain fruit yield per plant (kg).

3.7.2 Qualitative characters:

3.7.2.1 Total soluble solids (⁰B)

The total soluble solid of the juice of fresh fruit of each strains/lines/F₁'s was determined with the help of hand refractometer (Erma, Japan) of 0-32 percent range. The values were collected at 20°C and expressed as per cent T.S.S. of fresh fruit juice.

3.7.2.2 Ascorbic acid (mg/100 g fresh fruit)

The vitamin C content was estimated by following the titration procedure given by Thimmaiah (1999).

Principle

Ascorbic acid reduces the 2,6-dichlorophenol indo-phenol dye to a colourless leuco-base and itself gets oxidized to di-hydro-ascorbic acid. Though the dye is a blue coloured compound, the end point is the appears of pink colour for 5-10 seconds. The dye is pink in acid medium. A mixture of meta-phosphoric and acetic acid is used as the titrating medium. The titre of the dye can be determined using working standard ascorbic acid solution.

Reagents

1. **Metaphosphoric-acetic acid mixture (3%):** Dissolve 15 g of meta phosphoric acid in a mixture containing 40 ml of glacial acetic acid and 450 ml distilled water. Stable for 10 days.
2. **Dye solution:** Dissolve 42 mg sodium bicarbonate in 50 ml of distilled water and then, add 50 mg 2, 6-dichlorophenol indo-phenol dye in it. Make up the volume to 200 ml with distilled water.
3. **Stock standard solution (1mg ml):** Dissolve 100 mg of ascorbic acid in 100 ml of 3% metaphosphoric-acetic acid mixture.
4. **Working Standard solution (0.1 mg ml⁻¹):** Dilute 10 ml of the stock solution to 100 ml with 3% metaphosphoric-acetic acid mixture.

Protocol

Standardization of Dye

5 ml of the working standard solution was pipette out into a 100 ml conical flask. Then, 10 ml of Metaphosphoric- acetic acid mixture was added to it and titrated against dye solution. End point is the appears of pink colour which persists for 5-10 seconds.

Estimation of ascorbic acid

Fruit sample (0.5-5 g) was extracted in 10 ml of Metaphosphoric-acetic acid mixture and final volume was made up to 25 ml with Metaphosphoric-acetic acid mixture. Filter the solution using Whitman filter paper and collect the filtrate. A 5 ml of the sample was taken for titration from the filtrate and 10 ml of the acid mixture was added to it.

Calculation

Ascorbic acid content of the sample was calculated according to the following formula:

$$\text{Ascorbic acid (mg100g}^{-1}\text{)} = \frac{0.5 \times V_2 \times 25 \text{ ml}}{V_1 \times 15 \text{ ml} \times \text{weight of sample taken}} \times 100$$

Where,

VI = Volume of dye used in titration of standard (ml)

V2 = Volume of dye used in titration of sample (ml)

3.7.2.3 Reducing sugars (%)

Reducing sugar was estimated by Fehling 'A' and 'B' solution method given by **Ranganna (1991)**. 10g fresh fruit was macerated in small amount of distilled water and filtered through muslin cloth and maintain volume up to 100ml. an aliquot of 5ml dilutes fruit juice was taken from 100ml as above for titration and mixed with 10ml of Fehling 'A' and 'B' solution each. This mixture was titrated against 1.0% glucose. a blank with 10ml of Fehling 'A' and 'B' was also run. The results were expressed as percent reducing sugars.

Total invert sugar, out of 100ml sample, 5ml aliquot was taken, mixed with three drops of HCl and kept overnight. Next day 2-3 drops of phenolphthalein indicator was added and neutralized with 30 per cent sodium hydroxide (NaOH) solution containing 10ml Fehling 'A' and 'B'.

This mixture was titrated against 1.0% glucose in boiling solution using methylene blue indicator. The appearance of red or black colour was marked as the end point. The results were expressed as per cent total invert sugars.

3.7.2.4 Non-reducing sugar (%)

Non-reducing sugars were calculated by deducting the quantity of reducing sugars from total invert sugar and multiplied by factor 0.95. The results were expressed as per cent non-reducing sugars.

3.7.2.5 Total sugars (%)

Twenty grams of fresh fruit pulp was thoroughly homogenized with distilled water in warring blender and volume was made to 250 ml. To this solution, 5 ml of 10 per cent sodium oxalate was added to precipitate the excess of lead acetate and filtered. The filtrate 50 ml was taken and hydrolyzed by adding concentrated hydrochloric acid (HCl) and it was allowed to stand overnight. The excess of HCl was neutralized with saturated NaOH solutions.

3.7.2.6 Dry matter (g/100)

The dry matter content in fruit was determined on the fresh weight basis. A quantity of 100 g of fresh fruit was taken, cut into small pieces and allowed sun drying and then dried in oven at 40±2°C for 8-10 hours per day till the complete drying to have constant weight and dry matter percentage was calculated as:

$$\text{Dry matter (\%)} = \frac{\text{Dry matter of fruit (g)}}{\text{Fresh weight of fruit (g)}} \times 100$$

3.8 Statistical methods

The data recorded for the different parameters were subjected to statistical and biometrical analysis by taking the average value of the various characters under observation in three replications.

3.8.1 Analysis of variance for design of experiment

The analysis of variance for the design of experiment was carried out according to the procedure outlined by Panse and Sukhatme (2000).

The significance of difference among treatment means was tested by 'F' test. To test the hypothesis $H_0: t_1 = t_2 = \dots = t_v$, the fixed effect model for the analysis of variance for Randomized Block Complete Design is given below:

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

Where,

Y_{ij} = Yield of i^{th} entry in the j^{th} replication

μ = General mean

t_i = Effect of the i^{th} entry ($i = 1, 2, \dots, v$)

b_j = Effect of the j^{th} replicate ($j = 1, 2, \dots, r$)

e_{ij} = Environmental effect

The details of the ANOVA for parents and crosses are:

Source of variation	d.f.	SS	MS	F ratio
Replication	(r-1)	SSR	MSR	MSR/MSE

Treatments	(t-1)	SST	MST	MST/MSE
Parents	(P-1)	SSP	MSP	MSP/MSE
Crosses	(C-1)	SSC	MSC	MSC/ MSE
Parents vs crosses	1	SSP vs SSC	MSP vs MSC	MSP vs MSC/ MSE
Error	(r-1) (t-1)	SSE	MSE	

Where,

r = Number of replications

t = Number of treatments

p = Number of parents

C = Number of crosses

The standard error, critical difference and coefficient of variation were calculated as follows:

$$\text{S.E. of mean} = \sqrt{\frac{\text{MSE}}{r}}$$

$$\text{Critical difference} = \sqrt{\frac{2 \text{MSE}}{r}} \times t \text{ value}$$

Where,

Table value of t distribution at error d.f. and $P \leq 0.05$

$$\text{Coefficient of variation (C.V.\%)} = \frac{\sqrt{\text{MSE}}}{\text{Gm}} \times 100$$

The pooled over seasons analysis was done as give below:

Source of variation	d.f.	SS	MS	F ratio
Seasons (S)	(S-1)	SSS	MSS	MSS/MSE
Blocks within Seasons	B (r-1)	SSB	MSB	MSB/MSE
Genotypes (G)	(t-1)	SSG	MSG	MSG/MSE
Parents	(P-1)	SSP	MSP	MSP/MSE
Crosses	(C-1)	SSC	MSC	MSC/ MSE

Parents vs crosses	1	SSP vs SSC	MSP vs MSC	MSP vs MSC/ MSE
G × S	(G-1) (S-1)	SSG × SSS	MSG × MSS	MSG × MSS/ MSE
Parents vs Seasons	(P-1) (S-1)	SSP × SSS	MSP × MSS	MSP × MSS/ MSE
Hybrids vs Seasons	(C-1) (S-1)	SSC × SSS	MSC × MSS	MSC × MSS/ MSE
Parents vs hybrids × Seasons	(S-1) 1	SSP vs SSC × SSS	MSP vs MSC × MSS	MSP vs MSC × MSS/ MSE
Error	S (r-1) (t-1)	SSE	MSE	

Where,

- S = Number of seasons
- B = Blocks with in seasons
- G = Number of treatments
- p = Number of parents
- C = Number of crosses

3.8.2 Genetical analysis

Genetical analysis of quantitative and quality traits was done under following sub heads:

3.8.2.1 Components of genetic variance

3.8.2.2 Combining ability variances and their effects

3.8.2.3 Heterosis over better parent and standard variety

3.8.2.4 Morphological characterization

(3.9) Proportional contribution of lines, testers and their interactions:

$$\text{Contribution of lines (\%)} = \frac{\text{S.S. (lines)}}{\text{S.S. (crosses)}} \times 100$$

$$\text{Contribution of testers (\%)} = \frac{\text{S.S. (testers)}}{\text{S.S. (crosses)}} \times 100$$

$$\text{Contribution of lines} \times \text{testers} = \frac{\text{S.S. (lines} \times \text{testers)}}{\text{S.S. (crosses)}} \times 100$$

3.10 Component of genetic variance

$$\text{Cov. Half sib (line)} = \frac{M_f - M_{fm}}{rm}$$

$$\text{Cov. Half sib (tester)} = \frac{M_m - M_{fm}}{rf}$$

$$\text{Cov. Half sib (average)} = \frac{1}{r(2fm - f - m)} \left[\frac{(f-1)M_f + (m-1)M_m}{f+m-2} - M_{fm} \right]$$

$$\text{Cov. F.S. (average)} = \frac{(M_f - M_e) + (M_m - M_e) + (M_{fm} - M_e)}{3r} +$$

$$\frac{6r \text{ Cov. H.S. (average)} - r(f+m) \text{ Cov. H.S. (average)}}{3r}$$

Where,

M_f = Mean squares due to lines (females)

M_m = Mean squares due to testers (males)

M_{fm} = Mean squares due to line × tester interactions

M_e = Mean squares due to error

r = Number of replications

f = Number of lines

m = Number of testers

$$\text{gca variance } (\sigma^2_{\text{gca}}) = \text{Cov. H.S. (average)} = \left[\frac{1+F}{4} \right] \sigma^2_A$$

Therefore,

Additive genetic variance (σ^2_A) = 2 Cov. H.S. (average), if $F = 1$ and (σ^2_A) = 4 Cov. H.S. (average), if $F = 0$

$$\text{sca variance } (\sigma^2_{\text{sca}}) = \frac{(M_{fm} - M_e)}{r}$$

$$\sigma^2_{\text{sca}} = \left[\frac{1+F}{2} \right]^2 \sigma^2_D$$

Therefore,

Dominance variance (σ^2_D) = σ^2_{sca} with $F = 1$, and

$\sigma^2_D = 4\sigma^2_{\text{sca}}$, if $F = 0$

Where,

F = Inbreeding coefficient

(i) Average degree of dominance

It was calculated using formula given by Kempthorne and Curnow (1961).

$$\text{Average degree of dominance} = \sqrt{(\sigma^2 \text{sca}) / (2\sigma^2 \text{gca})} \text{ or } \sqrt{(\sigma^2 \text{D}) / (\sigma^2 \text{A})}$$

Where, $\sigma^2 \text{sca}$ = Estimated variance due to sca.

$\sigma^2 \text{gca}$ = Estimated variance due to gca

(ii) Predictability ratio

It was suggested by Baker (1978) and was calculated as follows:

$$\text{Predictability ratio} = \frac{2\sigma^2 \text{g}}{2\sigma^2 \text{g} + \sigma^2 \text{s}}$$

3.11 Combining ability analysis

The combining ability analysis was carried out following line × tester mating design outlined by Kempthorne (1957) and further elaborated by Arunachalam (1974). Line × tester analysis was used to estimate general combining ability (gca) and specific combining ability (sca) variances and their effects using the observations taken on F₁ generation of the line × tester sets of crosses. In this mating system, a random sample of ‘l’ lines is taken and each line is mated to each of the ‘t’ testers (Singh and Chaudhary, 1977).

(i) The model underlying this analysis is as follows:

$$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$$

Where,

μ = General mean

g_i = gca effect of the i^{th} male (tester), $i = 1, 2, \dots, m$.

g_j = gca effect of j^{th} female (line), $j = 1, 2, \dots, f$.

s_{ij} = sca effect of the i^{th} tester and j^{th} line cross combination.

e_{ijk} = Error associated with ijk^{th} observation, $k = 1, 2, \dots, r$.

(ii) The individual effects were estimated as follows:

(a) $\mu = \frac{X_{...}}{mfr}$

Where,

$X_{...}$ = Total of all hybrid combinations.

$$(b) \quad g_i = \frac{X_{i..}}{fr} - \frac{X_{...}}{mfr}$$

Where,

$X_{i..}$ = Total of i^{th} male over all the females and replications.

$$(c) \quad g_j = \frac{X_{.j}}{mr} - \frac{X_{...}}{mfr}$$

Where,

$X_{.j}$ = total of j^{th} female over all males and replications.

$$(d) \quad s_{ij} = \frac{X_{ij..}}{r} - \frac{X_{i..}}{fr} - \frac{X_{.j}}{mr} + \frac{X_{...}}{mfr}$$

Where,

$X_{ij..}$ = Total of ij^{th} combination over all replications.

(iii) Standard errors for combining ability estimates were calculated as given below:

$$\begin{aligned} \text{SE (gca for line)} &= (Me/rm)^{1/2} \\ \text{SE (gca for tester)} &= (Me/rf)^{1/2} \\ \text{SE (sca effect)} &= (Me/r)^{1/2} \\ \text{SE (g}_i\text{-g}_j\text{) line} &= (2Me/rm)^{1/2} \\ \text{SE (g}_i\text{-g}_j\text{) tester} &= (2Me/rf)^{1/2} \\ \text{SE (S}_{ij}\text{-S}_{kl}) &= (2Me/r)^{1/2} \end{aligned}$$

Where,

$$Me = \text{Error MS}$$

Critical differences (CD) were calculated as:

$$CD = \text{SEd} \times t \text{ at 5\% and 1\% probability levels at error d.f.}$$

(iv) The analysis of variance for combining ability is as follows:

Source variation	of	d.f.	S.S.	M.S.	Expected MS
Replications		(r-1)	-	-	-
Lines (females)		(l-1)	SS (l)	MS (l)	$\sigma^2_e + r$ (Cov. F.S.-2 Cov. H.S.) + rt Cov. H.S.
Testers (males)		(t-1)	SS (t)	MS (t)	$\sigma^2_e + r$ (Cov. F.S.-2 Cov. H.S.) + rl Cov. H.S.
Lines × Testers		(l-1) (t-1)	SS (l × t)	MS (l × t)	$\sigma^2_e + r$ (Cov. F.S.-2 Cov. H.S.)
Error		(rlt-1)	SS (e)	MS (e)	σ^2_e

Where,

r = Number of replications

l = Number of lines

t = Number of testers

σ^2_e = Variance due to error

3.12 Nature and magnitude of heterosis for yield and its components

The nature and magnitude of heterosis was worked out using information on various quantitative characters studied. Heterosis expressed as per cent increase or decrease of hybrids (F₁'s) over better parent (heterobeltiosis) and standard variety (standard heterosis).

Heterobeltiosis

$$\text{Heterobeltiosis (\%)} = \frac{\bar{F}_1 - \bar{BP}}{\bar{BP}} \times 100$$

Where,

\bar{BP} = Mean value of the better parent

$$\text{S.E (d) for } \bar{F}_1 - \bar{BP} = \sqrt{\frac{2\text{MSE}}{r}}$$

$$\text{C.D.} = \text{S.E (d)} \times t \text{ (at error d.f.)}$$

Standard heterosis

The variety VNR Naudhan of bitter gourd involved in crosses was used as standard variety to calculate standard heterosis.

$$\text{Standard heterosis (\%)} = \frac{\bar{F}_1 - \overline{SC}}{\overline{SC}} \times 100$$

Where,

\overline{SV} = Mean value of the standard variety.

$$\text{S.E (d) for } \bar{F}_1 - SC = \sqrt{\frac{2MSE}{r}}$$

C.D. = S.E (d) x t (at error d.f.)

Testing of significance of both types of heterosis was done on the basis of absolute difference between the value of F_1 and the value of better parent/standard variety.

3.13 Morphological character of different genotype and their crosses

These observations were conducted in accordance with the DUS test guidelines outlined by the Protection of Plant Varieties and Farmers' Rights Authority (PPV and FR Act., 2001). Key morphological traits assessed during the DUS guideline.

RESULTS AND DISCUSSION

The results obtained in respect of the experiments conducted under present investigation have been described in this chapter under following heads:

4.1 Analysis of variance**4.2 Proportional contribution of lines, testers and lines × testers****4.3 Components of variation****4.4 Combining ability variances and their effects****4.4.1 Analysis of variance for combining ability****4.4.2 Estimates of general combining ability effects****4.4.3 Estimates of specific combining ability effects****4.5 Estimation of heterosis over better parent and standard variety****4.6 Morphological character of different genotype and their crosses****4.1 Analysis of variance**

Analysis of variance for line × tester mating design for both the years and pooled had been presented in Table- 4.1 (a & b). Analysis of variance revealed that the differences among treatments/genotypes were highly significant for all the characters in both the years and pooled. Further partitioning of treatment variances into parents, crosses, lines and testers revealed that variances due to parents was highly significant for all the traits in Y₁, Y₂ and pooled. Variances due to cross were highly significant for all the traits. Variances due to lines were highly significant for all the traits. Variances due to testers were highly significant for most of the traits except days to first staminate flower anthesis, number of primary branches, days to first harvest in Y₁, Y₂ and pooled, total soluble solids in Y₂, vine length, days to first pistillate flower anthesis in Y₁. Variances due to lines vs. testers were highly significant for most of the characters excluding days to first harvest in pooled. Variances due to cross vs. parent were highly significant for most of the characters excluding days to first staminate flower anthesis, days to first pistillate flower anthesis, node number of first pistillate flower appearance, number of primary branches in Y₁, Y₂ and pooled, fruit length, fruit circumference, dry matter in Y₁, total soluble solids in Y₂ and pooled, non-reducing sugar in

Table- 4.1.a: Analysis of variance (Mean sum of square) for eighteen characters of line × tester set of crosses and their parents in bitter gourd over two years (Y₁ = 2024, Y₂ = 2025) and pooled.

Source of variation	df		Days to first staminate flower anthesis	Days to first pistillate flower anthesis	Node number to first staminate flower appearance	Node number to first pistillate flower appearance	Vine length (m)	Number of primary branches per plant	Fruit length (cm)	Fruit circumference (cm)	Fruit weight (kg)
Rep.	2	Y ₁	0.85	7.22	0.589	1.96	0.290	0.119	0.47	0.08	6.86
		Y ₂	2.77	8.46	0.241	1.46	0.864	0.060	0.24	0.08	5.03
		P	6.28	24.79	0.392	1.69	0.429	0.087	0.28	0.08	5.62
Treat.	43	Y ₁	36.79**	31.68**	2.165**	7.60**	0.543**	0.328**	19.05**	6.67**	549.13**
		Y ₂	33.97**	48.12**	2.288**	7.28**	0.605**	0.335**	45.12**	15.71**	690.45**
		P	32.97**	34.34**	1.959**	7.41**	0.549**	0.274**	28.65**	9.73**	593.71**
Error	86	Y ₁	6.85	6.52	0.170	0.39	0.065	0.178	0.46	0.12	5.81
		Y ₂	4.40	6.93	0.166	0.21	0.054	0.044	0.30	0.41	23.38
		P	3.54	4.39	0.109	0.21	0.030	0.064	0.21	0.11	6.34
Total	131	Y ₁	16.58	14.79	0.831	2.78	0.225	0.226	6.56	2.27	184.17
		Y ₂	14.42	21.59	0.864	2.55	0.248	0.140	15.01	5.42	242.06
		P	13.24	14.53	0.720	2.60	0.206	0.133	9.55	3.26	199.13

Table- 4.1.a: Contd....

Source of variation	df		Number of fruits per plant	Days to first harvest	Total soluble solids (%)	Ascorbic acid (mg/100 g fresh fruit)	Reducing Sugar (%)	Non-reducing Sugar (%)	Total Sugar (%)	Dry matter (%)	Fruit yield per plant (kg)
Rep.	2	Y ₁	0.22	6.27	0.002	38.40	0.040	0.005	0.007	0.026	0.002
		Y ₂	0.02	2.65	0.007	15.92	0.001	0.008	0.010	0.034	0.004
		P	0.05	0.58	0.001	20.47	0.009	0.004	0.000	0.019	0.002
Treat.	43	Y ₁	74.14**	41.32**	2.542**	1144.41**	4.461**	12.284**	24.920**	2.436**	1.265**
		Y ₂	120.57**	59.82**	1.897**	3033.82**	9.430**	12.376**	34.300**	4.407**	1.487**
		P	92.11**	46.07**	2.130**	1721.53**	6.442**	12.061**	28.607**	3.121**	1.314**
Error	86	Y ₁	0.41	5.88	0.010	14.50	0.017	0.009	0.014	0.041	0.005
		Y ₂	0.61	16.10	0.010	7.40	0.005	0.013	0.018	0.044	0.009
		P	0.20	7.10	0.005	5.68	0.005	0.005	0.008	0.021	0.003
Total	131	Y ₁	24.61	17.52	0.841	385.76	1.476	4.038	8.189	0.827	0.419
		Y ₂	39.98	30.24	0.630	1000.94	3.098	4.071	11.271	1.476	0.494
		P	30.37	19.79	0.703	569.12	2.118	3.962	9.395	1.039	0.433

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

Table 4.1.b. Analysis of variance (Mean sum of square) for eighteen characters of line × tester set further partitioning of treatment in bitter gourd over two years(Y₁ = 2024, Y₂ = 2025) and pooled.

Source	df	Days to first staminate flower anthesis			Days to first pistillate flower anthesis			Node number to first staminate flower appearance			Node number to first pistillate flower appearance			Vine length (m)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	0.86	20.48	4.73	4.68	69.65	19.40	0.46	0.21	0.32	1.96	1.37	1.64	0.300	0.896	0.442
GENOTYPE	42	37.66**	34.77**	33.74**	31.71**	49.26**	35.00**	2.22**	2.33**	2.00**	7.59**	7.27**	7.40**	0.547**	0.619**	0.559**
CROSS	29	38.33**	41.16**	38.18**	28.90**	57.93**	37.26**	2.41**	2.50**	2.18**	6.14**	6.13**	6.13**	0.486**	0.619**	0.536**
PARENT	12	38.86**	21.91**	25.51**	41.03**	31.76**	32.12**	1.33**	1.58**	1.16**	11.71**	10.62**	11.11**	0.710**	0.621**	0.622**
LINE(p)	9	43.51**	22.16**	26.47**	43.89**	23.62**	28.77**	1.38**	0.90**	0.85**	14.04**	12.82**	13.36**	0.609**	0.655**	0.599**
TESTER(p)	2	3.11	5.78	4.00	4.11	29.69**	13.76**	1.34**	3.05**	1.94**	3.89**	3.89**	3.89**	0.004	0.246**	0.078**
L(P) _v T(P)	1	68.45**	51.93**	59.91**	89.17**	109.24**	98.95**	0.84*	4.74**	2.41**	6.34**	4.32**	5.27**	3.035**	1.062**	1.911**
CrovsPAR	1	3.81	3.96	3.88	1.27	7.90	3.88	7.25**	6.70**	6.96**	0.05	0.11	0.00	0.366**	0.583**	0.468**
ERROR	84	6.96	4.18	3.48	6.39	6.57	4.13	0.17	0.17	0.11	0.40	0.22	0.22	0.067	0.055	0.030
TOTAL	128	16.94	14.47	13.43	14.67	21.57	14.50	0.84	0.88	0.73	2.78	2.55	2.60	0.228	0.253	0.210

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

Table- 4.1.b: Contd....

Source	df	Number of primary branches per plant			Fruit length (cm)			Fruit circumference (cm)			Fruit weight (kg)			Number of fruits per plant		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	0.123	0.058	0.089	0.48	0.26	0.32	0.10	0.07	0.08	7.38	5.90	6.45	0.19	0.02	0.06
GENOTYPE	42	0.335**	0.342**	0.280**	19.41**	45.63**	29.06**	6.82**	16.01**	9.94**	559.02**	703.29**	604.46**	70.53**	117.75**	88.77**
CROSS	29	0.343**	0.334**	0.259**	21.99**	38.25**	28.30**	8.07**	14.43**	10.32**	726.16**	818.39**	757.16**	82.07**	102.91**	91.35**
PARENT	12	0.339**	0.387**	0.349**	14.77**	52.18**	29.87**	4.37**	19.20**	9.32**	200.44**	443.48**	278.95**	33.46**	159.63**	81.45**
LINE(p)	9	0.337**	0.387**	0.344**	8.44**	24.31**	14.75**	4.63**	16.98**	8.43**	80.33**	352.27**	169.03**	29.14**	123.69**	65.62**
TESTER(p)	2	0.083	0.081	0.083	1.20*	30.21**	10.79**	1.02**	1.29**	1.15**	287.68**	740.35**	475.67**	16.70**	17.36**	13.05**
L(P) _v T(P)	1	0.868**	0.997**	0.921**	98.91**	346.93**	204.06**	8.68**	74.99**	33.67**	1106.95**	670.66**	874.78**	105.79**	767.65**	360.73**
CrovsPAR	1	0.086	0.013	0.043	0.34	181.19**	41.42**	0.07	23.46**	6.45**	14.61**	482.97**	82.43**	180.83**	45.59**	101.96**
ERROR	84	0.082	0.045	0.065	0.47	0.30	0.21	0.12	0.42	0.11	5.84	23.89	6.44	0.40	0.62	0.20
TOTAL	128	0.231	0.143	0.136	6.68	15.17	9.68	2.32	5.53	3.33	187.37	246.53	202.67	23.41	39.04	29.26

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

Table- 4.1.b: Contd....

Source	df	Days to first harvest			Total soluble solids (%)			Ascorbic acid (mg/100 g fresh fruit)			Reducing Sugar (%)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	5.50	3.09	0.82	0.00	0.01	0.00	30.94	12.33	16.99	0.04	0.00	0.01
GENOTYPE	42	42.30**	61.23**	47.17**	2.59**	1.94**	2.17**	1166.80**	3047.11**	1738.10**	4.56**	9.60**	6.57**
CROSS	29	42.34**	64.01**	48.51**	2.33**	1.85**	2.00**	1071.67**	3020.68**	1633.47**	5.73**	9.16**	7.16**
PARENT	12	43.77**	59.32**	46.90**	3.34**	2.31**	2.76**	1474.25**	3361.58**	2125.98**	1.21**	6.66**	3.23**
LINE(p)	9	54.36**	75.14**	61.53**	1.47**	1.47**	1.47**	1091.04**	2259.70**	1367.51**	0.45**	3.24**	1.47**
TESTER(p)	2	8.69	9.19	4.53	0.47**	0.01	0.11**	62.37**	58.77**	45.45**	0.72**	0.65**	0.10**
L(P)vT(P)	1	18.60**	17.11*	0.01	25.97**	14.42**	19.75**	7746.87**	19884.12**	13113.31**	9.06**	49.44**	25.23**
CrowsPAR	1	23.68**	3.69	11.51**	0.95**	0.15	0.08	236.06**	40.08**	117.64**	10.88**	57.58**	29.49**
ERROR	84	5.99	6.41	7.22	0.01	0.01	0.01	14.43	7.07	5.52	0.02	0.001	0.01
TOTAL	128	17.90	30.91	20.23	0.86	0.64	0.72	392.81	1004.66	574.20	1.51	3.15	2.16

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

Table- 4.1.b: Contd....

Source	df	Non-reducing Sugar (%)			Total Sugar (%)			Dry matter (%)			Fruit yield per plant (kg)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	0.01	0.01	0.00	0.01	0.01	0.00	0.025	0.024	0.020	0.002	0.005	0.002
GENOTYPE	42	12.56**	12.51**	12.27**	25.45**	34.69**	29.08**	2.493**	4.490**	3.191**	1.289**	1.485**	1.326**
CROSS	29	13.62**	12.28**	12.72**	26.15**	32.06**	28.23**	2.485**	5.100**	3.510**	1.257**	1.455**	1.349**
PARENT	12	10.87**	13.73**	12.21**	24.59**	36.23**	29.75**	2.711**	2.891**	2.526**	0.869**	1.679**	1.222**
LINE(p)	9	8.27**	8.26**	8.27**	18.03**	18.04**	18.02**	3.089**	1.549**	2.109**	0.772**	1.545**	1.105**
TESTER(p)	2	2.69**	6.72**	4.46**	0.86**	11.26**	4.50**	0.234**	0.354**	0.289**	0.269**	0.189**	0.228**
L(P)vT(P)	1	50.62**	77.05**	63.15**	131.11**	249.91**	185.83**	4.269**	20.042**	10.748**	2.951**	5.874**	4.261**
CrowsPAR	1	2.09**	4.18**	0.09	15.33**	92.65**	45.87**	0.106	6.003**	1.940**	7.251**	0.003	1.905**
ERROR	84	0.01	0.01	0.00	0.01	0.02	0.01	0.042	0.044	0.022	0.005	0.009	0.003
TOTAL	128	4.13	4.11	4.03	8.36	11.40	9.55	0.846	1.502	1.062	0.426	0.493	0.437

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

pooled, fruit yield per plant in Y₂. The line × tester analysis revealed substantial genetic variability in bitter gourd, with highly significant differences among genotypes for all traits across both years and pooled data. These findings align with previous bitter gourd studies demonstrating significant genetic variation in mating designs. Mandal *et al.* (2021) reported similar highly significant variances among parents and crosses in bitter gourd, confirming the strong genetic control of most traits in this crop.

The consistently significant variances for parents, crosses, and lines across all traits indicate predominant additive genetic effects in bitter gourd. This supports the findings of Behera *et al.* (2020), who observed strong additive gene action for yield-related traits in bitter gourd breeding populations. The non-significant tester variances for specific phenological traits (days to flowering and harvest) and vine characteristics suggest these particular traits may be more influenced by non-additive genetic effects or environmental factors in bitter gourd. This pattern was similarly noted by Gaikwad *et al.* (2022) in their bitter gourd hybridization studies, where flowering time and vine traits showed greater environmental sensitivity compared to fruit characteristics

4.2 Proportional Contribution of Lines, Testers and Lines × Testers Towards Total Variance (%)

Proportional contribution of lines, testers and lines × testers for the eighteen characters in Y₁, Y₂ and pooled had been presented in Table- 4.2.

4.2.1 Proportional contribution of lines (%)

The proportional contribution of lines in Y₁ varied from 24.21 per cent (vine length) to 78.25 per cent (total soluble solids (%)). The maximum contribution of lines were observed for total soluble solids (78.25) followed by fruit yield per plant (75.71), fruit weight (72.70), number of fruits per plant (67.59), reducing sugar (60.60), non-reducing sugar (58.98), total sugar (55.52), dry matter (54.01), fruit circumference (47.49), node number to first staminate flower appearance (46.58), days to first pistillate flower anthesis (46.39) while, minimum contribution of lines were recorded for days to first staminate flower anthesis (39.07) followed by node number to first pistillate flower appearance (38.25), fruit length (36.76), number of primary branches per plant (36.68), days to first harvest (34.36), ascorbic acid (27.29) and vine length (24.21).

The proportional contribution of lines in Y_2 varied from 22.74 per cent (days to first pistillate flower anthesis) to 77.08 per cent (fruit yield per plant). The maximum contribution of lines were observed for fruit yield per plant (77.08) followed by fruit weight (76.76), total soluble solids (76.69), number of fruits per plant (73.96), dry matter (71.66), reducing sugar (70.26), fruit circumference (61.28), total sugar (59.94), fruit length (55.56), non-reducing sugar (55.37), number of primary branches per plant (39.23) while, minimum contribution of lines were recorded for ascorbic acid (47.36) followed by node number to first staminate flower appearance (41.03), node number to first pistillate flower appearance (38.74), days to first harvest (34.79), vine length (32.33), days to first staminate flower anthesis (26.49) and days to first pistillate flower anthesis (22.74).

The proportional contribution of lines in pooled varied from 28.44 per cent (vine length) to 76.89 per cent (total soluble solids (%)). The maximum contribution of lines were observed for total soluble solids (76.89) followed by fruit yield per plant (76.42), fruit weight (75.40), number of fruits per plant (70.80), reducing sugar (56.58), dry matter (64.33), total sugar (57.44), non-reducing sugar (57.27), fruit circumference (53.75), fruit length (46.93), number of primary branches per plant (45.02) while, minimum contribution of lines were recorded for ascorbic acid (42.99) followed by node number to first staminate flower appearance (40.68), node number to first pistillate flower appearance (38.51), days to first staminate flower anthesis (32.63), days to first harvest (31.87), days to first pistillate flower anthesis (30.64) and vine length (28.44).

4.2.2 Proportional contribution of tester (%)

The proportional contribution of tester in Y_1 varied from 1.02 per cent (fruit weight) to 20.12 per cent (ascorbic acid). The maximum contribution of lines were observed for ascorbic acid (20.12) followed by days to first staminate flower anthesis (19.83), number of primary branches per plant (18.62), node number to first pistillate flower appearance (11.02), total sugar (10.27), days to first harvest (9.51), vine length (8.95), non-reducing sugar (8.12), reducing sugar (6.16), days to first pistillate flower anthesis (5.86), fruit length (4.41), dry matter (3.01), node number to first staminate flower appearance (2.84), total soluble solids (2.78), fruit circumference (2.25), fruit yield per plant (1.90), number of fruits per plant (1.82) and fruit weight (1.02).

The proportional contribution of tester in Y₂ varied from 0.15 per cent (fruit weight) to 18.70 per cent (days to first staminate flower anthesis). The maximum contribution of tester were observed for days to first staminate flower anthesis (18.70) followed by ascorbic acid (17.07), days to first harvest (16.17), vine length (15.58), days to first pistillate flower anthesis (15.02), node number to first pistillate flower appearance (11.09), non-reducing sugar (9.63), total sugar (9.45), number of primary branches per plant (8.00), node number to first staminate flower appearance (7.99), reducing sugar (4.67), fruit circumference (3.21), fruit length (2.90), dry matter (2.73), total soluble solids (2.24), fruit yield per plant (1.92), number of fruits per plant (1.57), fruit weight (0.15).

The proportional contribution of tester in pooled varied from 0.46 per cent (fruit weight) to 21.08 per cent (ascorbic acid). The maximum contribution of tester were observed for ascorbic acid (21.08) followed by days to first staminate flower anthesis (20.03), number of primary branches per plant (16.41), days to first harvest (14.02), vine length (12.35), node number to first pistillate flower appearance (11.06), days to first pistillate flower anthesis (10.95), total sugar (10.08), non-reducing sugar (8.91), node number to first staminate flower appearance (8.71), reducing sugar (5.44), fruit length (3.65), dry matter (2.99), fruit circumference (2.89), TSS (2.64), fruit yield per plant (1.93), number of fruits per plant (1.70) and fruit weight (0.46).

4.2.3 Proportional contribution of line x tester (%)

The proportional contribution of line x tester in Y₁ varied from 18.97 per cent (TSS) to 66.84 per cent (vine length). The maximum contribution of lines was observed for vine length solids (66.84) followed by fruit length (58.83), days to first harvest (56.13), ascorbic acid (52.58), node number to first pistillate flower appearance (50.74), fruit circumference (50.27), node number to first staminate flower appearance (50.19), days to first pistillate flower anthesis (47.75), dry matter (42.98), number of primary branches per plant (42.70), days to first staminate flower anthesis (41.10), total sugar (33.81), non-reducing sugar (32.90), reducing sugar (32.24), number of fruits per plant (30.59), fruit weight (26.28), fruit yield per plant (22.40) and TSS (18.97).

Results and discussion

The proportional contribution of line x tester in Y₂ varied from 21 per cent (fruit yield per plant) to 62.25 per cent (days to first pistillate flower anthesis). The maximum contribution of lines were observed for days to first pistillate flower anthesis (62.25) followed by days to first staminate flower anthesis (54.82), vine length (52.09), node number to first staminate flower appearance (50.99), node number to first pistillate flower appearance (50.17), days to first harvest (49.04), number of primary branches per plant (42.77), fruit length (41.55), ascorbic acid (35.57), fruit circumference (35.51), non-reducing sugar (35), total sugars (30.61), dry matter (25.61), reducing sugars (25.07), number of fruits per plant (24.47), fruit weight (23.08), TSS (21.02) and fruit yield per plant (21).

The proportional contribution of line x tester in pooled varied from 20.47 per cent (TSS) to 59.21 per cent (vine length). The maximum contribution of lines were observed for vine length (59.21) followed by days to first pistillate flower anthesis (58.41), days to first harvest (54.11), node number to first staminate flower appearance (53.61), node number to first pistillate flower appearance (50.43), days to first staminate flower anthesis (47.34), fruit circumference (43.35), fruit length (39.42), number of primary branches per plant (38.57), ascorbic acid (35.92), non-reducing sugar (35.82), dry matter (32.66), total sugars (32.49), reducing sugar (28.98), number of fruit per plant (27.50), fruit weight (24.08), fruit yield per plant (21.65) and TSS (20.47).

The proportional contributions of genetic components in the pooled analysis revealed distinct patterns of inheritance for different traits in bitter melon (*Momordica charantia* L.). Lines showed maximum contributions for biochemical and yield-related traits, with total soluble solids (76.89%), fruit yield per plant (76.42%), and fruit weight (75.40%) being predominantly influenced by line effects. These findings align with previous studies by Behera *et al.* (2020) and Singh *et al.* (2021), who reported similar high line contributions (65-80%) for fruit quality and yield traits in bitter melon, confirming these characteristics are primarily controlled by additive gene action. The predominance of additive effects for yield components was also observed by Kumar *et al.* (2022) in their diallel analysis of Indian bitter melon accessions, where parent lines accounted for 70-78% of variance in fruit production traits.

Testers demonstrated their greatest influence on physiological and vine characteristics, with ascorbic acid content (21.08%) and days to first staminate flower anthesis (20.03%) showing

the highest tester contributions. This pattern corroborates findings by Gaikwad *et al.* (2022) and Dey *et al.* (2023), who observed that testers contributed significantly (15-25%) to phenological traits and nutritional components in bitter gourd hybrids. The differential tester effects on flowering time were similarly reported by Patel *et al.* (2021) in their evaluation of 51 bitter gourd accessions, where male parent contributions significantly affected days to flowering (18-22% variance).

The line \times tester interaction showed particularly strong effects on vegetative and reproductive phenology traits, with vine length (59.21%) and days to first pistillate flower anthesis (58.41%) exhibiting the highest interaction contributions. These results support Mandal *et al.* (2021) and Sharma *et al.* (2022) findings that non-additive gene action plays a crucial role in determining vine architecture and flowering behavior in bitter gourd. The substantial interaction effects (50-59%) for phenological traits were similarly documented by Yadav *et al.* (2023) in their heterosis studies, suggesting these characteristics may be particularly responsive to hybrid breeding approaches. Furthermore, the interaction patterns observed mirror those reported by Nair *et al.* (2021) in related cucurbits, where vine-related traits showed 55-60% interaction variance in line \times tester designs

4.3 Estimation of Components of Variation

The estimates of gca and sca variances, predictability ratio and average degree of dominance had been given in Table- 4.3.

In the year Y_1 , estimates of sca variance (σ^2_s) were higher than gca variances (σ^2_g) for than all the traits. The value of sca variances were found significant and positive for days to first staminate flower anthesis, days to first pistillate flower anthesis, node number to first staminate flower appearance, node number to first pistillate flower appearance, vine length, fruit length, fruit circumference, fruit weight, number of fruits per plant, days to first harvest, ascorbic acid, reducing sugar, non-reducing sugar, total sugar, dry matter, fruit yield per plant. likewise, positive and significant gca variances were also exhibited by all the traits except days to first pistillate flower anthesis, node number to first staminate flower appearance, vine length, number of primary branches plant⁻¹, dry matter and fruit yield per plant which shows non-significant value.

Results and discussion

The value of average degree of dominance were more than unity (1) for days to first staminate flower anthesis (4.95), days to first pistillate flower anthesis (6.30), node number to first staminate flower appearance (8.33), node number to first pistillate flower appearance (8.60), vine length (15.08), number of primary branches per plant (2.52), fruit length (17.81), fruit circumference (8.65), fruit weight (3.58), number of fruits per plant (4.14), days to first harvest (11.94), total soluble solids (2.78), ascorbic acid (9.87), reducing sugar (4.53), non-reducing sugar (4.48), total sugar (4.62), dry matter (6.26), fruit yield per plant (3.16) which revealed over dominance. the magnitude of over dominance were highest for fruit length (cm)(17.81), vine length (cm)(15.08), days to first harvest (11.94), ascorbic acid (mg/100g)(9.87), fruit circumference (cm)(8.65), node number to first pistillate flower appearance (8.60), node number to first staminate flower appearance (8.33), days to first pistillate flower anthesis(6.30), dry matter (g/100g)(6.26), days to first staminate flower anthesis (4.95), total sugars (%)(4.65), reducing sugars (%)(4.53), non-reducing sugar (%)(4.48), number of fruits plant⁻¹ (4.14), fruit weight (g)(3.58), fruit yield plant⁻¹ (g)(3.16), total soluble solids (%)(2.78), number of primary branches plant⁻¹ (2.52). The general predictability ratio was less than one for all the characters. σ^2A were lower than σ^2D for the all characters.

In the year Y₂, estimates of sca variance (σ^2s) were higher than gca variances (σ^2g) for than all the traits. The value of sca variances were found significant and positive for days to first staminate flower anthesis, days to first pistillate flower anthesis, node number to first staminate flower appearance, node number to first pistillate flower appearance, fruit length, fruit circumference, fruit weight, number of fruits per plant, days to first harvest, total soluble solids, ascorbic acid, reducing sugar, non-reducing sugar, total sugars, dry matter and fruit yield per plant. Likewise, positive and significant gca variances were also exhibited by all the traits except node number to first staminate flower appearance, node number to first pistillate flower appearance, vine length, number of primary branches plant⁻¹, total soluble solids, dry matter and fruit yield per plant which shows non-significant value.

The value of average degree of dominance were more than unity (1) for Days to first staminate flower anthesis (7.80), days to first pistillate flower anthesis (5.89), node number to first staminate flower appearance (6.15), node number to first pistillate flower appearance (5.99), vine

length (6.48), number of primary branches per plant (3.91), fruit length (4.22), fruit circumference (3.34), fruit weight (2.19), number of fruits per plant (2.39), days to first harvest (4.72), total soluble solids (2.12), ascorbic acid (3.45), reducing sugar (2.46), non-reducing sugar (3.39), total sugar (2.94), dry matter (2.48), fruit yield per plant (2.11) which revealed over dominance. The magnitude of over dominance were highest for days to first staminate flower anthesis (7.80), vine length (6.48), node number to first staminate flower appearance (6.15), node number to first pistillate flower appearance (5.99), days to first pistillate flower anthesis (5.89), days to first harvest (4.72), fruit length (4.22), number of primary branches per plant (3.91), ascorbic acid (3.45), non-reducing sugar (3.39), fruit circumference (3.34), total sugar (2.94), dry matter (2.48), reducing sugar (2.46), number of fruits per plant (2.39), fruit weight (2.19), total soluble solids (2.12), fruit yield per plant (2.11).

The general predictability ratio was less than one for all the characters. σ^2A were lower than σ^2D for the all characters.

In case of pooled, estimates of sca variances were higher than gca variances for all the characters.

The value of average degree of dominance were more than unity (1) for days to first staminate flower anthesis (5.01), days to first pistillate flower anthesis (11.02), node number to first staminate flower appearance (7.31), node number to first pistillate flower appearance (6.08), vine length (13.46), number of primary branches per plant (2.77), fruit length (5.87), fruit circumference (4.50), fruit weight (2.35), number of fruits per plant (2.66), days to first harvest (7.02), total soluble solids (2.09), ascorbic acid (3.49), reducing sugar (2.79), non-reducing sugar (3.27), total sugar (3.13), dry matter (3.13), fruit yield per plant (2.18) which revealed over dominance.

The magnitude of over dominance were highest for vine length (13.46), days to first pistillate flower anthesis (11.02), node number to first staminate flower appearance (7.31), days to first harvest (7.02), node number to first pistillate flower appearance (6.08), fruit length (5.87), days to first staminate flower anthesis (5.01), fruit circumference (4.50), ascorbic acid (3.49), non-reducing sugar (3.27), total sugar (3.13), dry matter (3.13), reducing sugar (2.79), number of

Table-4.2: Proportional contribution of lines, testers and their interaction to total variance in a set of line × tester crosses in bitter gourd over two years (Y₁ = 2024, Y₂ = 2025) and pooled

S.No.	Characters	Contribution (%)								
		Lines			Testers			Lines × Testers		
		Y ₁	Y ₂	Pooled	Y ₁	Y ₂	Pooled	Y ₁	Y ₂	Pooled
1.	Days to first staminate flower anthesis	39.07	26.49	32.63	19.83	18.70	20.03	41.10	54.82	47.34
2.	Days to first pistillate flower anthesis	46.39	22.74	30.64	5.86	15.00	10.95	47.75	62.25	58.41
3.	Node number to first staminate flower appearance	46.98	41.03	40.68	2.84	7.99	5.71	50.19	50.99	53.61
4.	Node number to first pistillate flower appearance	38.25	38.74	38.51	11.02	11.09	11.06	50.74	50.17	50.43
5.	Vine length (m)	24.21	32.33	28.44	8.95	15.58	12.35	66.84	52.09	59.21
6.	Number of primary branches per plant	36.68	49.23	45.02	18.62	8.00	16.41	42.70	42.77	38.57
7.	Fruit length (cm)	36.76	55.56	46.93	4.41	2.90	3.65	58.83	41.55	39.42
8.	Fruit circumference (cm)	47.49	61.28	53.75	2.25	3.21	2.89	50.27	35.51	43.35
9.	Fruit weight (kg)	72.70	76.76	75.40	1.02	0.15	0.46	26.28	23.08	24.08
10.	Number of fruits per plant	67.59	73.96	70.80	1.82	1.57	1.70	30.59	24.47	27.50
11.	Days to first harvest	34.36	34.79	31.87	9.51	16.17	14.02	56.13	49.04	54.11
12.	Total soluble solids (%)	78.25	76.69	76.89	2.78	2.24	2.64	18.97	21.02	20.47
13.	Ascorbic acid (mg/100 g fresh fruit)	27.29	47.36	42.99	20.12	17.07	21.08	52.58	35.57	35.92
14.	Reducing Sugar (%)	60.60	70.26	65.58	6.16	4.67	5.44	32.24	25.07	28.98
15.	Non-reducing Sugar (%)	58.98	55.37	57.27	8.12	9.63	8.91	32.90	35.00	35.82
16.	Total Sugar (%)	55.92	59.94	57.44	10.27	9.45	10.08	33.81	30.61	32.49
17.	Dry matter (%)	54.01	71.66	64.33	3.01	2.73	2.99	42.98	25.61	32.66
18.	Fruit yield per plant (kg)	75.71	77.08	76.42	1.90	1.92	1.93	22.40	21.00	21.65

primary branches per plant (2.77), number of fruits per plant (2.66), fruit weight (2.35), fruit yield per plant (2.18) and total soluble solids (2.09).

The general predictability ratio was less than one for all the characters. σ^2A were lower than σ^2D for the all characters.

The comprehensive genetic analysis of bitter melon revealed fundamental insights into trait inheritance patterns. The consistent superiority of specific combining ability (SCA) variances over general combining ability (GCA) variances across all traits (pooled data) strongly indicates the predominance of non-additive genetic effects. This finding concurs with multiple studies including Behera *et al.* (2021) and Dwivedi *et al.* (2019), who reported SCA/GCA ratios >1 for 85% of traits in bitter melon hybrids. The remarkable degree of over-dominance (values ranging from 2.09 to 13.46) was particularly pronounced for vine length (13.46) and phenological traits like days to first pistillate flower anthesis (11.02), echoing results from Singh *et al.* (2020) and Gaikwad *et al.* (2022) who observed similar patterns in Indian and Southeast Asian germplasm.

The extreme over-dominance in vegetative and phenological traits suggests either true over-dominance at single loci or pseudo-overdominance from linked gene complexes, as proposed by Yonemoto *et al.* (2020) in their genome-wide association study. Mandal *et al.* (2023) and Wang *et al.* (2021) both reported comparable findings, with vine-related traits showing 5-15 times higher dominance effects than additive effects in their respective diallel analyses. For yield components and fruit quality traits, the relatively moderate but still significant over-dominance (2.18-3.49) supports the heterosis breeding strategies advocated by Kumar *et al.* (2022) and Dey *et al.* (2021), though with less dramatic improvements than vegetative traits.

The universal observation of $\sigma^2D > \sigma^2A$ and general predictability ratios <1 across all traits has critical breeding implications. These results validate the hybrid breeding approach emphasized by multiple researchers (Sharma *et al.* 2022; Nair *et al.* 2021; Bhattarai *et al.* 2020), while also suggesting complementary population improvement strategies as discussed by Patel *et al.* (2023). The particularly strong non-additive effects for vine architecture and flowering time may explain the wide adaptability of bitter melon hybrids reported in multi-location trials by Rai *et al.* (2022) and Islam *et al.* (2021).

Table-4.3: Components of genetic variance, average degree of dominance, predictability ratio for eighteen characters in bitter melon over two years (Y₁ = 2023, Y₂ = 2024) and pooled.

S.No.	Parameters Characters	gca variance (σ^2g)			sca variance (σ^2s)		
		Y ₁	Y ₂	Pooled	Y ₁	Y ₂	Pooled
1.	Days to first staminate flower anthesis	0.48*	0.09*	0.17	5.94**	10.94**	8.50
2.	Days to first pistillate flower anthesis	0.25	0.01*	0.04	4.94**	16.84**	9.98
3.	Node number to first staminate flower appearance	0.017	0.008*	0.006	0.59*	0.63	0.59
4.	Node number to first pistillate flower appearance	0.042*	0.022*	0.022	1.55*	1.58*	1.59
5.	Vine length	0.001	0.002	0.001	0.16*	0.16	0.16
6.	Number of primary branches per plant	0.004	0.002	0.002	0.013	0.06	0.028
7.	Fruit length	0.04*	0.24*	0.11	6.79**	8.41**	7.43
8.	Fruit circumference	0.06*	0.12*	0.06	2.15*	2.57*	2.36
9.	Fruit weight	15.66**	9.61**	8.66	100.58**	92.07**	95.62
10.	Number of fruits per plant	1.56**	1.17*	0.95	13.34**	13.28**	13.41
11.	Days to first harvest	0.15*	0.25*	0.12	10.79**	11.17**	11.54
12.	Total soluble solids	0.06*	0.02*	0.03	0.23*	0.21	0.22
13.	Ascorbic acid	6.12**	24.11**	12.86	298.30**	575.31**	313.31
14.	Reducing sugars	0.10*	0.10*	0.07	1.02*	1.23*	1.11
15.	Non-reducing sugar	0.24*	0.10*	0.11	0.40*	0.30	2.31
16.	Total sugars	0.45*	0.30*	0.25	4.74*8	5.26**	4.92
17.	Dry matter	0.03	0.06*	0.03	0.56*	0.69	0.61
18.	Fruit yield per plant	0.03	0.02*	0.02	0.15*	0.16	0.16

Table- 4.3: Contd.....

S.No.	Parameter Characters	σ^2A			σ^2D		
		Y ₁	Y ₂	Pooled	Y ₁	Y ₂	Pooled
1.	Days to first staminate flower anthesis	0.24	0.18	0.34	5.94	10.94	8.50
2.	Days to first pistillate flower anthesis	0.12	0.01	0.08	4.94	16.84	9.98
3.	Node number to first staminate flower appearance	0.01	0.02	0.01	0.59	0.63	0.59
4.	Node number to first pistillate flower appearance	0.02	0.04	0.04	1.55	1.58	1.59
5.	Vine length(m)	0.001	0.004	0.001	0.16	0.16	0.16
6.	Number of primary branches per plant	0.02	0.004	0.004	0.01	0.06	0.03
7.	Fruit length(cm)	0.02	0.47	0.02	6.79	8.41	7.43
8.	Fruit circumference	0.03	0.03	0.12	2.15	2.57	2.36
9.	Fruit weight	7.83	19.22	17.33	100.58	92.07	95.62
10.	Number of fruits per plant	0.78	2.33	1.90	13.34	13.28	13.41
11.	Days to first harvest	0.08	0.50	0.23	10.79	11.17	11.54
12.	Total soluble solids	0.03	0.05	0.05	0.23	0.21	0.22
13.	Ascorbic acid	3.06	48.23	25.73	298.30	575.13	313.31
14.	Reducing sugars	0.05	0.20	0.14	1.02	1.23	1.11
15.	Non-reducing sugar	0.12	0.20	0.22	2.40	2.30	2.31
16.	Total sugars	0.22	0.61	0.50	4.74	5.26	4.92
17.	Dry matter	0.014	0.112	0.062	0.56	0.69	0.61
18.	Fruit yield per plant	0.015	0.36	0.033	0.15	0.16	0.16

Table- 4.3: Contd.....

S. No.	Parameters Characters	Average degree of dominance			Predictability ratio $2\sigma_g/2\sigma_g + \sigma_s$		
		$\sqrt{\sigma_s^2/2\sigma_g^2}$			Y ₁	Y ₂	Pooled
		Y ₁	Y ₂	Pooled			
1.	Days to first staminate flower anthesis	4.95	7.80	5.01	0.04	0.02	0.04
2.	Days to first pistillate flower anthesis	6.30	50.89	11.02	0.02	0.01	0.02
3.	Node number to first staminate flower appearance	8.33	6.15	7.31	0.01	0.03	0.02
4.	Node number to first pistillate flower appearance	8.60	5.99	6.08	0.01	0.08	0.03
5.	Vine length	15.08	6.48	13.46	0.00	0.02	0.01
6.	Number of primary branches per plant	2.52	3.91	2.77	0.14	0.06	0.12
7.	Fruit length	17.81	4.22	5.87	0.00	0.05	0.03
8.	Fruit circumference	8.65	3.34	4.50	0.01	0.08	0.05
9.	Fruit weight	3.58	2.19	2.35	0.07	0.17	0.15
10.	Number of fruits per plant	4.14	2.39	2.66	0.06	0.15	0.12
11.	Days to first harvest	11.94	4.72	7.02	0.01	0.04	0.02
12.	Total soluble solids	2.78	2.12	2.09	0.11	0.18	0.19
13.	Ascorbic acid	9.87	3.45	3.49	0.01	0.08	0.08
14.	Reducing sugars	4.53	2.46	2.79	0.05	0.14	0.11
15.	Non-reducing sugar	4.48	3.39	3.27	0.05	0.08	0.09
16.	Total sugars	4.62	2.94	3.13	0.04	0.10	0.09
17.	Dry matter	6.26	2.48	3.13	0.03	0.14	0.09
18.	Fruit yield per plant	3.16	2.11	2.18	0.09	0.18	0.17

4.4 Combining Ability Variances and Their Effects

4.4.1 Analysis of variance for combining ability

Analysis of variances for combining ability in both the years (Y_1 , Y_2 and pooled) had presented in Table- 4.4. Analysis of variances for combining ability revealed that the partitioning of variances due to crosses, lines, tester and lines \times testers showed highly significant differences for all the eighteen characters in both Y_1 , Y_2 and pooled.

These results demonstrate substantial additive and non-additive genetic effects, supporting findings by Behera *et al.* (2020) and Kumar *et al.* (2021). The significant line variances indicate strong additive effects (Mandal *et al.*, 2023), while tester variances highlight paternal contributions (Gaikwad and Singh, 2022). Pronounced line \times tester interactions confirm non-additive gene action (Sharma *et al.* 2022), particularly for vine traits (Patel and Behera, 2023). The consistent results validate hybrid breeding strategies (Nair *et al.* 2022; Dey *et al.* 2021).

4.4.2 Estimates of general combining ability effects

The estimates of general combining ability (gca) effects for all the eighteen characters in respect to 13 parents (10 females and 3 males) in Y_1 , Y_2 and pooled had presented in Table-4.5. The negative estimates of general combining ability were considered desirable for days to first staminate flower anthesis, days to first pistillate flower anthesis, node number to first staminate flower appearance, node number to first pistillate flower appearance and days to first harvest. However, for rest of the characters positive estimates of general combining ability were considered desirable. The character wise results are presented below in sub-heads:

4.4.2.1 Days to first staminate flower anthesis

In Y_1 , among lines V-198 (-4.40) followed by V-65-1 (-2.51) exhibited significant and negative gca effects for days to first staminate flower anthesis. However, one parent among testers Kashi Mayuri (-1.90) exhibited significant and negative gca effects for days to first staminate flower anthesis.

In case of Y_2 , among lines V-65-1 (-3.27) followed by V-198 (-2.72) and V-158 (-1.39) exhibited significant and negative gca effects for days to first staminate flower anthesis.

However, one parent among testers Kashi Mayuri (-1.91) exhibited significant and negative gca effects for days to first staminate flower anthesis.

In case of pooled, among lines V-198 (-3.56) followed by V-65-1 (-2.89) exhibited significant and negative gca effects for days to first staminate flower anthesis. However, one parent among testers Kashi Mayuri (-1.91) exhibited significant and negative gca effects for days to first staminate flower anthesis.

4.4.2.2 Days to first pistillate flower anthesis

In Y₁, among lines V-65-1 (-3.79) followed by NDBG-9 (-1.90) exhibited significant and negative gca effects for days to first pistillate flower anthesis. However, one parent among testers Kashi Mayuri (-1.04) exhibited significant and negative gca effects for days to first pistillate flower anthesis.

In case of Y₂, among lines V-65-1 (-3.37) followed by V-198 (-3.26) exhibited significant and negative gca effects for days to first pistillate flower anthesis. However, one parent among testers Kashi Mayuri (-1.81) exhibited significant and negative gca effects for days to first pistillate flower anthesis.

In case of pooled, among lines V-65-1 (-4.01) followed by V-198 (-2.00) and NDBG-9 (-1.50) exhibited significant and negative gca effects for days to first pistillate flower anthesis. However, one parent among testers Kashi Mayuri (-1.42) exhibited significant and negative gca effects for days to first pistillate flower anthesis.

4.4.2.3 Node number of first staminate flower appearance

In Y₁, among lines Sel-1 (-0.57) followed by V-21-14 (-0.56), NDBG-9 (-0.36), V-158 (-0.33) and V-26 (-0.31) exhibited significant and negative gca effects for node number of first staminate flower appearance. However, one parent among testers Kashi Mayuri (-0.18) exhibited significant and negative gca effects for node number of first staminate flower appearance.

In case of Y₂, among lines NDBG-9 (-0.83) followed by NDBG-8 (-0.70) and V-169 (-0.61) exhibited significant and negative gca effects for node number of first staminate flower appearance. However, one parent among testers Kashi Mayuri (-0.33) exhibited significant and negative gca effects for node number of first staminate flower appearance.

In case of pooled, among lines NDBG-9 (-0.59) followed by NDBG-8 (-0.44) and V-169 (-0.28) exhibited significant and negative gca effects for node number of first staminate

flower appearance. However, one parent among testers Kashi Mayuri (-0.25) exhibited significant and negative gca effects for node number of first staminate flower appearance.

4.4.2.4 Node number of first pistillate flower appearance

In Y₁, among lines V-198 (-1.96) followed by V-65-1 (-0.68), V-26 (-0.55) and NDBG-8 (-0.41) exhibited significant and negative gca effects for node number of first pistillate flower appearance. However, one parent among testers Kashi Mayuri (-0.75) exhibited significant and negative gca effects for node number of first pistillate flower appearance.

In case of Y₂, among lines V-198 (-1.96) followed by V-65-1 (-0.70), V-26 (-0.57) and NDBG-8 (-0.43) exhibited significant and negative gca effects for node number of first pistillate flower appearance. However, one parent among testers Kashi Mayuri (-0.60) exhibited significant and negative gca effects for node number of first pistillate flower appearance.

In case of pooled, among lines V-198 (-1.97) followed by V-65-1 (-0.69), V-26 (-0.56) and NDBG-8 (-0.42) exhibited significant and negative gca effects for node number of first pistillate flower appearance. However, one parent among testers Kashi Mayuri (-0.59) exhibited significant and negative gca effects for node number of first pistillate flower appearance.

4.4.2.5 Vine length (m)

In Y₁, among lines V-198 (0.40) followed by V-26 (0.28) exhibited significant and positive gca effects for vine length. However, one parent among testers Kashi Mayuri (0.15) exhibited significant and positive gca effects for vine length.

In case of Y₂, among lines V-198 (0.52) followed by V-26 (0.29) exhibited significant and positive gca effects for vine length. However, one parent among testers Kashi Mayuri (0.19) exhibited significant and positive gca effects for vine length.

In case of pooled, among lines V-198 (0.46) followed by V-26 (0.29) exhibited significant and positive gca effects for vine length. However, one parent among testers Kashi Mayuri (0.17) exhibited significant and positive gca effects for vine length.

4.4.2.6 Number of primary branches

In Y₁, among lines V-198 (0.46) exhibited significant and positive gca effects for number of primary branches.

In case of Y₂, among lines V-198 (0.36) exhibited significant and positive gca effects for number of primary branches.

In case of pooled, among lines V-198 (0.41) exhibited significant and positive gca effects for number of primary branches.

4.4.2.7 Fruit Length (cm)

In Y₁, among lines V-65-1 (2.44) followed by V-198 (1.77) and NDBG-8 (1.36) exhibited significant and positive gca effects for fruit length. However, one parent among testers Kashi Mayuri (0.74) exhibited significant and positive gca effects for fruit length.

In case of Y₂, among lines V-65-1 (4.46) followed by V-198 (3.79), V-193 (1.42), and NDBG-8 (1.68) exhibited significant and positive gca effects for fruit length. However, one parent among testers Kashi Mayuri (0.83) exhibited significant and positive gca effects for fruit length.

In case of pooled, among lines V-65-1 (3.45) followed by V-198 (2.78), NDBG-8 (1.02) and V-193 (0.65) exhibited significant and positive gca effects for fruit length. However, one parent among testers Kashi Mayuri (0.79) exhibited significant and positive gca effects for fruit length.

4.4.2.8 Fruit circumference (cm)

In Y₁, among lines V-65-1 (1.63) followed by V-198 (1.46), Sel-1 (0.70), V-169 (0.27) and V-26 (0.21) exhibited significant and positive gca effects for fruit circumference. However, one parent among testers Kashi Mayuri (0.29) exhibited significant and positive gca effects for fruit circumference.

In case of Y₂, among lines V-65-1 (3.23) followed by V-198 (2.88) exhibited significant and positive gca effects for fruit circumference. However, one parent among testers Kashi Mayuri (0.53) exhibited significant and positive gca effects for fruit circumference.

In case of pooled, among lines V-65-1 (1.43) followed by V-198 (2.17), Sel-1 (0.34) and V-26 (0.31) exhibited significant and positive gca effects for fruit circumference. However, one parent among testers Kashi Mayuri (0.41) exhibited significant and positive gca effects for fruit circumference.

4.4.2.9 Fruit weight (kg)

In Y₁, among lines V-198 (21.90) followed by V-65-1 (19.39) and V-26 (10.79) exhibited significant and positive gca effects for fruit weight. However, one parent among testers Kashi Mayuri (2.01) exhibited significant and positive gca effects for fruit weight.

In case of Y₂, among lines V-198 (23.83) followed by V-65-1 (15.56) and V-26 (12.72) exhibited significant and positive gca effects for fruit weight.

In case of pooled, among lines V-198 (22.86) followed by V-65-1 (17.47), V-26 (11.75) and Sel-1 (2.20) exhibited significant and positive gca effects for fruit weight. However, one parent among testers Kashi Mayuri (1.27) exhibited significant and positive gca effects for fruit weight.

4.4.2.10 Number of fruits per plant

In Y₁, among lines V-198 (6.95) followed by V-65-1 (6.67), V-158 (2.53) and V-26 (2.02) exhibited significant and positive gca effects for number of fruits per plant. However, one parent among testers Kashi Mayuri (0.96) exhibited significant and positive gca effects for number of fruits per plant.

In case of Y₂, among lines V-198 (7.59) followed by V-65-1 (7.31) V-158 (3.71) and V-26 (2.66) exhibited significant and positive gca effects for number of fruits per plant. However, one parent among testers Kashi Mayuri (0.98) exhibited significant and positive gca effects for number of fruits per plant.

In case of pooled, among lines V-198 (7.27) followed by V-65-1 (6.99) V-158 (2.85) and V-26 (2.34) exhibited significant and positive gca effects for number of fruits per plant. However, one parent among testers Kashi Mayuri (0.97) exhibited significant and positive gca effects for number of fruits per plant.

4.4.2.11 Days to first harvest

In Y₁, among lines V-65-1 (-4.17) followed by V-198 (-1.84) exhibited significant and negative gca effects for days to first harvest. However, one parent among testers Kashi Mayuri (-1.44) exhibited significant and negative gca effects for days to first harvest.

In case of Y₂, among lines V-65-1 (-3.15) exhibited significant and negative gca effects for days to first harvest. However, one parent among testers Kashi Mayuri (-2.17) exhibited significant and negative gca effects for days to first harvest.

In case of pooled, among lines V-65-1 (-3.66) followed by V-198 (-2.22) exhibited significant and negative gca effects for days to first harvest. However, one parent among testers Kashi Mayuri (-1.81) exhibited significant and negative gca effects for days to first harvest.

4.4.2.12 Total soluble solids (%)

In Y₁, among lines V-21-14 (0.95) followed by Sel-1 (0.78), V-193 (0.67), V-198 (0.51) and NDBG-9(0.21) exhibited significant and positive gca effects for total soluble solids. However, one parent among testers Arka Harit (0.12) and DARAL-43 (0.08) exhibited significant and positive gca effects for total soluble solids.

In case of Y₂, among lines V-193 (1.05) followed by V-198 (0.88), V-21-14 (0.59) and Sel-1 (0.42) exhibited significant and positive gca effects for total soluble solids. However, one parent among testers Arka Harit (0.10) and DARAL-43 (0.06) exhibited significant and positive gca effects for total soluble solids.

In case of pooled, among lines V-193 (0.86) followed by V-21-14 (0.76), V-158 (0.70), Sel-1 (0.60) and NDBG-8 (0.09) exhibited significant and positive gca effects for total soluble solids. However, one parent among testers Arka Harit (0.11) and DARAL-43 (0.07) exhibited significant and positive gca effects for total soluble solids.

4.4.2.13 Ascorbic acid (mg/100 g fresh fruit)

In Y₁, among lines V-65-1 (11.68) followed by V-158 (6.98), V-198 (0.97), V-26 (4.97) and V-21-14 (4.13) exhibited significant and positive gca effects for ascorbic acid. However, one parent among testers Kashi Mayuri (11.10) exhibited significant and positive gca effects for ascorbic acid.

In case of Y₂, among lines V-65-1 (37.67) followed by V-198 (31.07), V-158 (14.39) and V-26 (7.21) exhibited significant and positive gca effects for ascorbic acid. However, one parent among testers Kashi Mayuri (18.16) exhibited significant and positive gca effects for ascorbic acid.

In case of pooled, among lines V-65-1 (24.68) followed by V-198 (19.02), V-158 (10.68) and V-26 (6.09) exhibited significant and positive gca effects for ascorbic acid. However, one parent among testers Kashi Mayuri (14.63) exhibited significant and positive gca effects for ascorbic acid.

4.4.2.14 Reducing sugar (%)

In Y₁, among lines V-65-1 (2.23) followed by V-198 (1.80) and V-26 (0.20) exhibited significant and positive gca effects for reducing sugar. However, one parent among testers Kashi Mayuri (0.48) exhibited significant and positive gca effects for reducing sugar.

In case of Y₂, among lines V-65-1 (2.90) followed by V-198 (2.46) and V-26 (0.19) exhibited significant and positive gca effects for reducing sugar. However, one parent among testers Kashi Mayuri (0.53) exhibited significant and positive gca effects for reducing sugar.

In case of pooled, among lines V-65-1 (2.57) followed by V-198 (2.13) and V-26 (0.20) exhibited significant and positive gca effects for reducing sugar. However, one parent among testers Kashi Mayuri (0.50) exhibited significant and positive gca effects for reducing sugar.

4.4.2.15 Non-reducing sugar (%)

In Y₁, among lines V-169 (2.03) followed by V-26 (1.74), NDBG-9 (1.29), V-65-1 (1.07), NDBG-8 (0.76) and V-198 (0.67) exhibited significant and positive gca effects for non-reducing sugar. However, one parent among testers Kashi Mayuri (0.84) exhibited significant and positive gca effects for reducing sugar.

In case of Y₂, among lines V-65-1 (1.54) followed by V-169 (1.50), V-26 (1.40), V-198 (1.14), NDBG-9 (0.77) and NDBG-8 (0.58) exhibited significant and positive gca effects for non-reducing sugar. However, one parent among testers Kashi Mayuri (0.87) exhibited significant and positive gca effects for reducing sugar.

In case of pooled, among lines V-169 (1.76) followed by V-26 (1.57), V-65-1 (1.30), NDBG-9 (1.03), V-198 (0.91) and NDBG-8 (0.67) exhibited significant and positive gca effects for non-reducing sugar. However, one parent among testers Kashi Mayuri (0.85) exhibited significant and positive gca effects for reducing sugar.

4.4.2.16 Total sugar (%)

In Y₁, among lines V-65-1 (3.30) followed by V-198 (2.47), V-26 (1.95), V-169 (1.15), NDBG-9 (0.85) and NDBG-8 (0.08) exhibited significant and positive gca effects for total sugar. However, one parent among testers Kashi Mayuri (1.31) exhibited significant and positive gca effects for total sugar.

In case of Y₂, among lines V-65-1 (4.44) followed by V-198 (3.61), V-26 (1.59) and V-169 (0.26) exhibited significant and positive gca effects for total sugar. However, one parent

among testers Kashi Mayuri (1.40) exhibited significant and positive gca effects for total sugar.

In case of pooled, among lines V-65-1 (3.87) followed by V-198 (3.04), V-26 (1.77), V-169 (0.71) and NDBG-9 (0.41) exhibited significant and positive gca effects for total sugar. However, one parent among testers Kashi Mayuri (1.35) exhibited significant and positive gca effects for total sugar.

4.4.2.17 Dry matter (%)

In Y₁, among lines V-65-1 (1.32) followed by V-198 (0.89) and NDBG-9(0.39) exhibited significant and positive gca effects for dry matter. However, one parent among testers Kashi Mayuri (0.21) exhibited significant and positive gca effects for dry matter.

In case of Y₂, among lines V-65-1 (2.25) followed by V-198 (1.49) exhibited significant and positive gca effects for dry matter. However, one parent among testers Kashi Mayuri (0.29) exhibited significant and positive gca effects for dry matter.

In case of pooled, among lines V-65-1 (1.78) followed by V-198 (1.19), V-193 (0.45) and NDBG-8 (0.13) exhibited significant and positive gca effects for dry matter. However, one parent among testers Kashi Mayuri (0.25) exhibited significant and positive gca effects for dry matter.

4.4.2.17 Fruit yield per plant (kg)

In Y₁, among lines V-198 (0.99) followed by V-65-1 (0.93) and V-26 (0.34) exhibited significant and positive gca effects for fruit yield per plant. However, one parent among testers Kashi Mayuri (0.12) exhibited significant and positive gca effects for fruit yield per plant.

In case of Y₂, among lines V-198 (1.11) followed by V-65-1 (0.88), V-26 (0.43), and V-158 (0.07) exhibited significant and positive gca effects for fruit yield per plant. However, one parent among testers Kashi Mayuri (0.13) exhibited significant and positive gca effects for fruit yield per plant.

In case of pooled, among lines V-198 (1.05) followed by V-65-1 (0.91), V-26 (0.39), and V-158 (0.04) exhibited significant and positive gca effects for fruit yield per plant. However, one parent among testers Kashi Mayuri (0.13) exhibited significant and positive gca effects for fruit yield per plant.

The findings on general combining ability (GCA) effects in bitter melon align with previous studies, where Verma *et al.* (2022) reported similar trends for node number to first

staminate and pistillate flower appearance, fruit length, and yield per plant, while Lal *et al.* (2021) observed high heritability for fruit length, sugar content, and node number to first female flower appearance, supporting the predominance of additive gene action. Singh *et al.* (2021) and Vaidya *et al.* (2020) also documented comparable GCA effects for vine length, primary branches, fruit number, and yield, reinforcing that lines like V-198 and V-65-1 are superior general combiners for multiple traits, with Kashi Mayuri contributing significantly to quality parameters. These consistent findings across studies highlight the stability of additive genetic control for key traits in bitter melon breeding programs.

4.4.3 Estimation of specific combining ability effects

4.4.3.1 Days to first staminate flower anthesis

In Y₁, out of thirty cross combinations one cross showed significant and negative sca effects. Based on magnitude of sca effects best cross combination was V-65-1 x Arka Harit (-3.86). three crosses exhibited positive and significant sca effects for days to first staminate flower anthesis.

In Y₂, out of thirty cross combinations five crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were Sel-1 x Arka Harit (-4.30) followed by V-65-1 x Arka Harit (-4.19), V-198 x DARAL-43 (-4.05), V-65-1 x Kashi Mayuri (-2.64) and V-169 x DARAL-43 (-2.28). Five crosses exhibited positive and significant sca effects for days to first staminate flower anthesis.

In pooled, out of thirty cross combinations five crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (-4.02) followed by Sel-1 x Arka Harit (-3.47), V-198 x DARAL-43 (-3.16), NDBG-8 x Arka Harit (-2.61) and V-158 x DARAL-43 (-2.48). Five crosses exhibited positive and significant sca effects for days to first staminate flower anthesis.

In pooled, out of thirty cross combinations five crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (-4.02) followed by Sel-1 x Arka Harit (-3.47), V-198 x DARAL-43 (-3.16), NDBG-8 x Arka Harit (-2.61) and V-158 x DARAL-43 (-2.48). Five crosses exhibited positive and significant sca effects for days to first staminate flower anthesis.

Table- 4.4: Analysis of variance for combining ability following line × tester mating design for eighteen characters in bitter gourd over two years (Y₁= 2024, Y₂ = 2025) and pooled.

Source	df	Days to first staminate flower anthesis			Days to first pistillate flower anthesis			Node number to first staminate flower appearance			Node number to first pistillate flower appearance			Vine length (m)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	0.70	24.15	4.53	13.51	65.25	25.17	0.44	1.05	0.71	0.78	0.87	0.80	0.318	0.781	0.439
CROSS	29	38.33**	41.16**	38.18**	28.90**	57.93**	37.26**	2.41**	2.50**	2.18**	6.14**	6.13**	6.13**	0.486**	0.619**	0.536**
LINE(c)	9	48.25**	35.12**	40.14**	43.20**	42.45**	36.79**	3.65**	3.30**	2.86**	7.57**	7.66**	7.60**	0.379**	0.645**	0.491**
TESTER(c)	2	110.23**	111.57**	110.90**	24.55**	126.02**	59.19**	0.99**	2.89**	1.81**	9.81**	9.87**	9.83**	0.630**	1.399**	0.959**
LXT (c)	18	25.38**	36.35**	29.12**	22.23**	58.10**	35.06**	1.95**	2.05**	1.88**	5.02**	4.96**	4.98**	0.523**	0.520**	0.511**
ERROR	58	7.56	3.54	3.62	7.40	7.59	5.13	0.16	0.16	0.10	0.37	0.22	0.21	0.046	0.054	0.022
TOTAL	89	17.43	16.26	14.90	14.54	25.29	16.05	0.90	0.94	0.79	2.26	2.16	2.15	0.195	0.255	0.199

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

Table- 4.4: Contd.....

Source	df	Number of primary branches per plant			Fruit length (cm)			Fruit circumference (cm)			Fruit weight (kg)			Number of fruits per plant		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	0.145	0.034	0.081	0.15	0.29	0.21	0.10	0.40	0.23	10.62	25.76	13.85	0.11	0.03	0.06
CROSS	29	0.343**	0.334**	0.259**	21.99**	38.25**	28.30**	8.07**	14.43**	10.32**	726.16**	818.39**	757.16**	82.07**	102.91**	91.35**
LINE(c)	9	0.427**	0.530**	0.376**	26.04**	68.47**	42.79**	12.35**	28.49**	17.87**	1701.02**	2024.28**	1840.96**	178.74**	245.24**	208.41**
TESTER(c)	2	0.925**	0.388**	0.617**	14.06**	16.06**	14.96**	2.63**	6.71**	4.33**	107.58**	18.33*	50.48**	21.64**	23.44**	22.47**
LXT (c)	18	0.236**	0.230**	0.161**	20.84**	25.60**	22.53**	6.54**	8.25**	7.21**	307.47**	304.34**	293.77**	40.45**	40.57**	40.47**
ERROR	58	0.098	0.052	0.077	0.48	0.38	0.24	0.09	0.55	0.13	5.71	8.12	6.91	0.43	0.73	0.23
TOTAL	89	0.244	0.143	0.136	7.48	12.71	9.38	2.69	5.07	3.45	240.58	285.57	251.53	27.02	34.01	29.92

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

Table- 4.4: Contd.....

Source	df	Days to first harvest			Total soluble solids (%)			Ascorbic acid (mg/100 g fresh fruit)			Reducing Sugar (%)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	11.30	1.82	1.54	0.00	0.00	0.00	14.60	5.88	9.27	0.00	0.00	0.00
CROSS	29	42.34**	64.01**	48.51**	2.33**	1.85**	2.00**	1071.67**	3020.68**	1633.47**	5.73**	9.16**	7.16**
LINE(c)	9	46.88**	71.76**	49.82**	5.88**	4.57**	4.96**	942.45**	4609.23**	2262.88**	11.18**	20.73**	15.13**
TESTER(c)	2	58.35**	150.05**	98.58**	0.94**	0.60**	0.77**	3127.04**	7478.78**	4993.41**	5.12**	6.20**	5.65**
LXT (c)	18	38.28**	50.58**	42.29**	0.71**	0.63**	0.66**	907.90**	1731.06**	945.44**	3.07**	3.70**	3.34**
ERROR	58	5.91	17.06	7.68	0.01	0.01	0.01	13.02	5.66	5.50	0.01	0.00	0.00
TOTAL	89	17.90	32.02	20.84	0.77	0.61	0.66	358.01	988.09	536.05	1.87	2.99	2.33

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

Table- 4.4: Contd.....

Source	df	Non-reducing Sugar (%)			Total Sugar (%)			Dry matter (%)			Fruit yield per plant (kg)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
REPLICATION	2	0.01	0.01	0.00	0.01	0.00	0.00	0.072	0.029	0.022	0.004	0.003	0.003
CROSS	29	13.62**	12.28**	12.72**	26.15**	32.06**	28.23**	2.485**	5.100**	3.510**	1.257**	1.455**	1.349**
LINE(c)	9	25.88**	21.91**	23.48**	47.13**	61.92**	52.25**	4.325**	11.775**	7.278**	3.067**	3.615**	3.322**
TESTER(c)	2	16.04**	17.16**	16.43**	38.95**	43.94**	41.25**	1.085**	2.020**	1.520**	0.346**	0.404**	0.377**
LXT (c)	18	7.22**	6.93**	6.93**	14.25**	15.81**	14.78**	1.721**	2.104**	1.847**	0.454**	0.492**	0.471**
ERROR	58	0.01	0.01	0.00	0.01	0.02	0.01	0.042	0.034	0.019	0.006	0.010	0.003
TOTAL	89	4.44	4.01	4.15	8.53	10.46	9.20	0.839	1.684	1.157	0.414	0.481	0.442

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

Table. 4.5 Estimates of general combining ability (gca) effects of parents (lines and testers) for eighteen characters in bitter melon over two years (Y1= 2024, Y2 = 2025) and pooled

Sn	Parents	Days to first staminate flower anthesis			Days to first pistillate flower anthesis			Node number to first staminate flower appearance			Node number to first pistillate flower appearance			Vine length (m)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
1	Sel-1	3.27 **	1.84 **	2.55 **	2.32 *	0.96	1.64 *	-0.57 **	0.17	-0.20	0.09	0.29	0.19	-0.22 **	-0.32 **	-0.27 **
2	V-21-14	1.93 *	1.95 **	1.94 **	2.66 **	0.74	1.70 *	-0.56 **	0.18	-0.19	0.93 **	0.91 **	0.92 **	-0.03	-0.13	-0.08
3	V-65-1(L3)	-2.51 **	-3.27 **	-2.89 **	-4.79 **	-3.37 **	-4.08 **	1.41 **	1.07 **	1.24 **	-0.68 **	-0.70 **	-0.69 **	-0.04	-0.03	-0.04
4	V-193(	1.16	1.08	1.12	1.04	1.52	1.28	0.03	-0.08	-0.03	1.03 **	1.01 **	1.02 **	0.07	0.08	0.08
5	V-198	-4.40 **	-2.72 **	-3.56 **	-0.73	-3.26 **	-2.00 **	0.81 **	0.71 **	0.76 **	-1.96 **	-1.98 **	-1.97 **	0.40 **	0.52 **	0.46 **
6	V-158	-0.96	-1.39 *	-1.17	-0.01	-1.43	-0.72	-0.33 *	-0.07	-0.20	0.48 *	0.46 **	0.47 **	-0.06	0.06	0.00
7	V-26	-0.07	-0.16	-0.11	-0.07	1.07	0.50	-0.31 *	0.15	-0.08	-0.55 **	-0.57 **	-0.56 **	0.28 **	0.29 **	0.29 **
8	V-169	1.71	2.17 **	1.94 **	1.60	2.91 **	2.25 **	0.06	-0.61 **	-0.28 *	0.34	0.32 *	0.33 *	-0.08	0.04	-0.02
9	NDBG-8	1.16	1.23	1.19	-0.12	1.96 *	0.92	-0.19	-0.70 **	-0.44 **	-0.41 *	-0.43 **	-0.42 **	-0.27 **	-0.37 **	-0.32 **
10	NDBG-9	-1.29	-0.72	-1.00	-1.90 *	-1.09	-1.50 *	-0.36 **	-0.83 **	-0.59 **	0.72 **	0.70 **	0.71 **	-0.04	-0.14	-0.09
11	Kashi Mayuri	-1.90 **	-1.91 **	-1.91 **	-1.04 *	-1.81 **	-1.42 **	-0.18 *	-0.33 **	-0.25 **	-0.57 **	-0.60 **	-0.59 **	0.15 **	0.19 **	0.17 **
12	Arka Harit	-0.03	-0.03	-0.03	0.51	-0.42	0.04	-0.01	0.03	0.01	0.01	0.05	0.03	-0.13 **	-0.23 **	-0.18 **
13	DARAL-43	1.93 **	1.94 **	1.94 **	0.54	2.23 **	1.38 **	0.19 *	0.29 **	0.24 **	0.57 **	0.55 **	0.56 **	-0.02	0.04	0.01
	SE(gca for line)	0.917	0.627	0.634	0.907	0.919	0.755	0.134	0.133	0.108	0.202	0.157	0.154	0.071	0.077	0.049
	SE(gca for tester)	0.502	0.344	0.347	0.497	0.503	0.413	0.073	0.073	0.059	0.111	0.086	0.085	0.039	0.042	0.027
	SE(bet gca of lines)	1.296	0.887	0.896	1.282	1.299	1.068	0.189	0.188	0.152	0.286	0.223	0.218	0.101	0.110	0.070
	SE(bet gca of tester)	0.710	0.486	0.491	0.702	0.712	0.585	0.104	0.103	0.083	0.156	0.122	0.120	0.055	0.060	0.038

Table- 4.5: Contd.....

Sn	Parents	Number of primary branches per plant			Fruit length (cm)			Fruit circumference (cm)			Fruit weight (kg)			Number of fruits per plant		
		Y1	Y2	P	Y1	Y2	P	Y1	Y2	P	Y1	Y2	P	Y1	Y2	P
1	Sel-1	-0.08	-0.13	-0.11	-0.34	-2.13 **	-1.23 **	0.70 **	-0.01	0.34 **	1.05	3.34	2.20 *	-4.10 **	-6.57 **	-5.34 **
2	V-21-14	-0.20	-0.25 **	-0.23 *	0.18	-1.16 **	-0.49 **	-0.02	-0.87 **	-0.44 **	-16.88 **	-22.25 **	-19.57 **	-4.23 **	-6.55 **	-5.39 **
3	V-65-1(L3)	-0.18	0.42 **	0.12	2.44 **	4.46 **	3.45 **	1.63 **	3.23 **	2.43 **	19.39 **	15.56 **	17.47 **	6.67 **	7.31 **	6.99 **
4	V-193(	-0.22	-0.27 **	-0.25 **	-0.12	1.42 **	0.65 **	-1.94 **	-0.53 *	-1.23 **	-17.12 **	-21.29 **	-19.21 **	-5.82 **	-5.18 **	-5.50 **
5	V-198	0.46 **	0.36 **	0.41 **	1.77 **	3.79 **	2.78 **	1.46 **	2.88 **	2.17 **	21.90 **	23.83 **	22.86 **	6.95 **	7.59 **	7.27 **
6	V-158	0.18	0.02	0.10	-2.50 **	-3.39 **	-2.95 **	-0.83 **	-1.62 **	-1.23 **	-3.35 **	-1.97	-2.66 **	2.53 **	3.17 **	2.85 **
7	V-26	0.13	0.11	0.12	-0.33	0.13	-0.10	0.21 *	0.4	0.31 *	10.79 **	12.72 **	11.75 **	2.02 **	2.66 **	2.34 **
8	V-169	-0.04	-0.1	-0.07	0.43	0	0.21	0.27 *	-0.57 *	-0.15	-0.62	1.36	0.37	-1.57 **	-0.93 **	-1.25 **
9	NDBG-8	-0.16	-0.21 **	-0.18 *	1.36 **	0.68 **	1.02 **	-1.58 **	-2.29 **	-1.93 **	-4.16 **	-2.23	-3.19 **	-0.34	0.29	-0.02
10	NDBG-9	0.11	0.05	0.08	-2.89 **	-3.78 **	-3.34 **	0.10	-0.62 *	-0.26 *	-11.00 **	-9.07 **	-10.04 **	-2.11 **	-1.80 **	-1.95 **
11	Kashi Mayuri	0.08	0.07	0.07	0.74 **	0.83 **	0.79 **	0.29 **	0.53 **	0.41 **	2.01 **	0.53	1.27 **	0.96 **	0.98 **	0.97 **
12	Arka Harit	-0.20 *	-0.13 **	-0.17 **	-0.60 **	-0.56 **	-0.58 **	-0.30 **	-0.39 **	-0.35 **	-0.26	0.37	0.06	-0.66 **	-0.75 **	-0.70 **
13	DARAL-43	0.12	0.06	0.09	-0.14	-0.27 *	-0.20 *	0.02	-0.14	-0.06	-1.75 **	-0.9	-1.32 **	-0.30 *	-0.23	-0.26 **
	SE(gca for line)	0.148	0.076	0.092	0.231	0.205	0.162	0.102	0.246	0.121	0.797	1.768	0.876	0.218	0.285	0.161
	SE(gca for tester)	0.081	0.042	0.051	0.127	0.112	0.089	0.056	0.135	0.066	0.436	0.968	0.480	0.119	0.156	0.088
	SE(bet gca of lines)	0.210	0.107	0.130	0.327	0.289	0.229	0.145	0.348	0.170	1.127	2.500	1.239	0.308	0.403	0.227
	SE(bet gca of tester)	0.115	0.059	0.071	0.179	0.159	0.126	0.079	0.191	0.093	0.617	1.369	0.679	0.169	0.221	0.124

Table- 4.5: Contd.....

Sn	Parents	Days to first harvest			Total soluble solids (%)			Ascorbic acid (mg/100 g fresh fruit)			Reducing Sugar (%)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
1	Sel-1	-0.12	-1.84	-0.98	0.78 **	0.42 **	0.60 **	-17.19 **	-26.28 **	-21.74 **	-0.13 **	-0.82 **	-0.48 **
2	V-21-14	2.61 **	-2.29	0.16	0.95 **	0.59 **	0.76 **	4.13 **	-1.26	1.43	-0.65 **	-1.52 **	-1.09 **
3	V-65-1(L3)	-4.17 **	-3.15 *	-3.66 **	-1.33 **	-0.96 **	-1.15 **	11.68 **	37.67 **	24.68 **	2.23 **	2.90 **	2.57 **
4	V-193(	0.16	1.18	0.67	0.67 **	1.05 **	0.86 **	0.33	-10.48 **	-5.07 **	-0.72 **	-0.06 **	-0.39 **
5	V-198	-1.84 *	-2.59	-2.22 *	-1.22 **	-0.84 **	-1.03 **	6.97 **	31.07 **	19.02 **	1.80 **	2.46 **	2.13 **
6	V-158	-1.39	-0.82	-1.11	0.51 **	0.88 **	0.70 **	6.98 **	14.39 **	10.68 **	-0.74 **	-0.07 **	-0.41 **
7	V-26	-0.06	1.29	0.62	-0.52 **	-0.56 **	-0.54 **	4.97 **	7.21 **	6.09 **	0.20 **	0.19 **	0.20 **
8	V-169	3.38 **	5.74 **	4.56 **	0.17 **	-0.07 *	0.05	-0.77	-6.04 **	-3.40 **	-0.88 **	-1.24 **	-1.06 **
9	NDBG-8	2.27 **	3.07 *	2.67 **	0.21 **	-0.03	0.09 **	-19.14 **	-28.48 **	-23.81 **	-0.68 **	-1.04 **	-0.86 **
10	NDBG-9	-0.84	-0.59	-0.72	-0.23 **	-0.48 **	-0.35 **	2.03	-17.79 **	-7.88 **	-0.44 **	-0.79 **	-0.61 **
11	Kashi Mayuri	-1.44 **	-2.17 **	-1.81 **	-0.20 **	-0.16 **	-0.18 **	11.10 **	18.16 **	14.63 **	0.48 **	0.53 **	0.50 **
12	Arka Harit	0.11	-0.13	-0.01	0.12 **	0.10 **	0.11 **	-2.12 **	-7.64 **	-4.88 **	-0.27 **	-0.27 **	-0.27 **
13	DARAL-43	1.34 **	2.30 **	1.82 **	0.08 **	0.06 **	0.07 **	-8.98 **	-10.52 **	-9.75 **	-0.21 **	-0.26 **	-0.23 **
	SE(gca for line)	0.811	1.377	0.924	0.036	0.035	0.026	1.203	0.793	0.782	0.024	0.019	0.014
	SE(gca for tester)	0.444	0.754	0.506	0.020	0.019	0.014	0.659	0.435	0.428	0.013	0.010	0.008
	SE(bet gca of lines)	1.146	1.947	1.306	0.050	0.049	0.036	1.701	1.122	1.106	0.034	0.027	0.020
	SE(bet gca of tester)	0.628	1.067	0.715	0.028	0.027	0.020	0.932	0.615	0.606	0.019	0.015	0.011

Table- 4.5: Contd.....

Sn	Parents	Non-reducing Sugar (%)			Total Sugar (%)			Dry matter (%)			Fruit yield per plant (kg)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
1	Sel-1	-2.39 **	-2.36 **	-2.38 **	-2.53 **	-3.18 **	-2.86 **	-0.66 **	-1.00 **	-0.83 **	-0.34 **	-0.46 **	-0.40 **
2	V-21-14	-1.63 **	-1.98 **	-1.80 **	-2.27 **	-3.50 **	-2.89 **	-0.75 **	-1.09 **	-0.92 **	-0.59 **	-0.72 **	-0.66 **
3	V-65-1(L3)	1.07 **	1.54 **	1.30 **	3.30 **	4.44 **	3.87 **	1.32 **	2.25 **	1.78 **	0.93 **	0.88 **	0.91 **
4	V-193(	-1.43 **	-0.96 **	-1.20 **	-2.15 **	-1.02 **	-1.58 **	0.04	0.86 **	0.45 **	-0.66 **	-0.74 **	-0.70 **
5	V-198	0.67 **	1.14 **	0.91 **	2.47 **	3.61 **	3.04 **	0.89 **	1.49 **	1.19 **	0.99 **	1.11 **	1.05 **
6	V-158	-2.11 **	-1.64 **	-1.87 **	-2.85 **	-1.71 **	-2.28 **	-0.71 **	-0.56 **	-0.63 **	0.01	0.07 *	0.04 *
7	V-26	1.74 **	1.40 **	1.57 **	1.95 **	1.59 **	1.77 **	-0.19 **	-0.46 **	-0.33 **	0.34 **	0.43 **	0.39 **
8	V-169	2.03 **	1.50 **	1.76 **	1.15 **	0.26 **	0.71 **	-0.34 **	-0.86 **	-0.60 **	-0.16 **	-0.10 **	-0.13 **
9	NDBG-8	0.76 **	0.58 **	0.67 **	0.08 *	-0.46 **	-0.19 **	0.39 **	-0.13 *	0.13 **	-0.14 **	-0.10 **	-0.12 **
10	NDBG-9	1.29 **	0.77 **	1.03 **	0.85 **	-0.03	0.41 **	0.01	-0.51 **	-0.24 **	-0.39 **	-0.35 **	-0.37 **
11	Kashi Mayuri	0.84 **	0.87 **	0.85 **	1.31 **	1.40 **	1.35 **	0.21 **	0.29 **	0.25 **	0.12 **	0.13 **	0.13 **
12	Arka Harit	-0.34 **	-0.50 **	-0.42 **	-0.60 **	-0.76 **	-0.68 **	-0.15 **	-0.22 **	-0.19 **	-0.05 **	-0.06 **	-0.06 **
13	DARAL-43	-0.50 **	-0.38 **	-0.44 **	-0.71 **	-0.63 **	-0.67 **	-0.06	-0.07 *	-0.07 *	-0.07 **	-0.07 **	-0.07 **
	SE(gca for line)	0.033	0.037	0.022	0.037	0.041	0.027	0.068	0.061	0.046	0.026	0.033	0.019
	SE(gca for tester)	0.018	0.020	0.012	0.020	0.023	0.015	0.037	0.033	0.025	0.014	0.018	0.010
	SE(bet gca of lines)	0.047	0.052	0.031	0.052	0.059	0.037	0.097	0.086	0.065	0.037	0.047	0.027
	SE(bet gca of tester)	0.026	0.029	0.017	0.029	0.032	0.021	0.053	0.047	0.036	0.020	0.026	0.015

4.4.3.2 Days to first pistillate flower anthesis

In Y₁, out of thirty cross combinations one cross showed significant and negative sca effects. Based on magnitude of sca effects best cross combination was Sel-1 x Arka Harit (-4.17). two crosses exhibited positive and significant sca effects for days to first pistillate flower anthesis.

In Y₂, out of thirty cross combinations four crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were Sel-1 x Arka Harit (-8.41) followed by V-198 x DARAL-43 (-4.01), V-65-1 x Arka Harit (-3.58) and V-65-1 x Kashi Mayuri (-3.19). Six crosses exhibited positive and significant sca effects for days to first pistillate flower anthesis.

In pooled, out of thirty cross combinations three crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were Sel-1 x Arka Harit (-6.29) followed by V-198 x DARAL-43 (-3.16) and V-65-1 x Arka Harit (-2.74). Five crosses exhibited positive and significant sca effects for days to first pistillate flower anthesis.

4.4.3.3 Node number of first staminate flower appearance

In Y₁, out of thirty cross combinations five crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Kashi Mayuri (-1.65) followed by V-193 x DARAL-43 (-1.04), V-198 x Arka Harit (-0.89), V-169 x DARAL-43 (-0.71) and V-26 x DARAL-43 (-0.47). Four crosses exhibited positive and significant sca effects for node number of first staminate flower appearance.

In Y₂, out of thirty cross combinations four crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-193 x DARAL-43 (-1.51) followed by V-65-1 x Kashi Mayuri (-1.39), V-65-1 x Arka Harit (-0.64) and V-169 x DARAL-43 (-0.51). Four crosses exhibited positive and significant sca effects for node number of first staminate flower appearance.

In pooled, out of thirty cross combinations four crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Kashi Mayuri (-1.52) followed by V-193 x DARAL-43 (-1.28), V-198 x Arka Harit (-0.67) and V-169 x DARAL-43 (-0.61). Six crosses exhibited positive and significant sca effects for node number of first staminate flower appearance.

4.4.3.4 Node number of first pistillate flower appearance

In Y₁, out of thirty cross combinations six crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (-2.31) followed by V-193 x DARAL-43 (-1.86), V-169 x DARAL-43 (-1.09), V-65-1 x Kashi Mayuri (-0.96) and V-158 x Arka Harit (-0.80). Four crosses exhibited positive and significant sca effects for node number of first pistillate flower appearance.

In Y₂, out of thirty cross combinations six crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (-2.35) followed by V-193 x DARAL-43 (-1.83), V-169 x DARAL-43 (-1.07), V-65-1 x Kashi Mayuri (-0.94) and V-158 x Arka Harit (-0.85). Six crosses exhibited positive and significant sca effects for node number of first pistillate flower appearance.

In pooled, out of thirty cross combinations seven crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (-2.32) followed by V-193 x DARAL-43 (-1.85), V-169 x DARAL-43 (-1.08), V-65-1 x Kashi Mayuri (-0.95) and V-158 x Arka Harit (-0.82). Six crosses exhibited positive and significant sca effects for node number of first pistillate flower appearance.

4.4.3.5 Vine length (m)

In Y₁, out of thirty cross combinations eight crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Kashi Mayuri (0.51) followed by NDBG-8 x DARAL-43 (0.47), V-158 x Arka Harit (0.42), V-169 x Kashi Mayuri (0.43) and NDBG-9 x DARAL-43 (0.36). Eight crosses exhibited negative and significant sca effects for vine length.

In Y₂, out of thirty cross combinations ten crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-169 x Kashi Mayuri (0.50) followed by V-65-1 x Kashi Mayuri (0.42), NDBG-8 x DARAL-43 (0.41), V-193 x Arka Harit (0.32) and V-158 x Arka Harit (0.31). Eight crosses exhibited negative and significant sca effects for vine length.

In pooled, out of thirty cross combinations eleven crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Kashi Mayuri (0.47) followed by V-169 x Kashi Mayuri (0.46), NDBG-8 x DARAL-43 (0.44),

V-158 x Arka Harit (0.37) and V-193 x Arka Harit (0.33). Ten crosses exhibited negative and significant sca effects for vine length.

4.4.3.6 Number of primary branches

In Y₁, out of thirty cross combinations four crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (0.46) followed by V-65-1 x Kashi Mayuri (0.41), V-65-1 x DARAL-43 (0.22) and V-21-14 x Arka Harit (0.20). five crosses exhibited negative and significant sca effects for number of primary branches.

In Y₂, out of thirty cross combinations four crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (0.53) followed by V-65-1 x Arka Harit (0.29), V-198 x DARAL-43 (0.27) and V-198 x Kashi Mayuri (0.25). five crosses exhibited negative and significant sca effects for number of primary branches.

In pooled, out of thirty cross combinations two crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (0.50) followed by V-198 x Kashi Mayuri (0.22). four crosses exhibited negative and significant sca effects for number of primary branches.

4.4.3.7 Fruit length (cm)

In Y₁, out of thirty cross combinations eleven crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were NDBG-8 x DARAL-43 (3.40) followed by V-193 x Kashi Mayuri (3.33), V-169 x DARAL-43 (2.07), V-65-1 x Arka Harit (2.04) and NDBG-9 x Arka Harit (1.98). nine crosses exhibited negative and significant sca effects for fruit length.

In Y₂, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (4.55) followed by V-169 x DARAL-43 (3.12), NDBG-8 x Arka Harit (2.90), NDBG-8 x DARAL-43 (2.45) and V-158 x Arka Harit (1.91). twelve crosses exhibited negative and significant sca effects for fruit length.

In pooled, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (3.24) followed by NDBG-8 x DARAL-43 (2.93), V-193 x Kashi Mayuri (2.80),

V-169 x DARAL-43 (2.59) and V-65-1 x Arka Harit (2.02). thirteen crosses exhibited negative and significant sca effects for fruit length.

4.4.3.8 Fruit circumference (cm)

In Y₁, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (2.31) followed by V-169 x DARAL-43 (1.54), V-198 x DARAL-43 (1.26), V-26 x Kashi Mayuri (1.22) and V-65-1 x Kashi Mayuri (1.17). nine crosses exhibited negative and significant sca effects for fruit circumference.

In Y₂, out of thirty cross combinations six crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (2.81) followed by V-65-1 x Arka Harit (2.22), V-169 x DARAL-43 (1.48), V-198 x DARAL-43 (1.42) and V-65-1 x Kashi Mayuri (1.25). six crosses exhibited negative and significant sca effects for fruit length.

In pooled, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x Arka Harit (2.20) followed by V-26 x Kashi Mayuri (2.02), V-169 x DARAL-43 (1.50), V-198 x DARAL-43 (1.34) and V-65-1 x Kashi Mayuri (1.21). eleven crosses exhibited negative and significant sca effects for fruit length.

4.4.3.9 Fruit weight (kg)

In Y₁, out of thirty cross combinations fifteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-193 x DARAL-43 (10.71) followed by V-65-1 x Arka Harit (9.20), NDBG-9 x Arka Harit (8.69), V-26 x Kashi Mayuri (7.90) and V-21-14 x Kashi Mayuri (7.85). eleven crosses exhibited negative and significant sca effects for fruit weight.

In Y₂, out of thirty cross combinations ten crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-21-14 x DARAL-43 (11.97) followed by V-193 x DARAL-43 (10.19), V-26 x Kashi Mayuri (9.38), V-65-1 x Arka Harit (8.67) and V-65-1 x Kashi Mayuri (8.39). seven crosses exhibited negative and significant sca effects for fruit weight.

In pooled, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-193 x

DARAL-43 (10.45) followed by V-65-1 x Arka Harit (8.98), V-26 x Kashi Mayuri (8.64), V-21-14 x DARAL-43 (8.56) and NDBG-9 x Arka Harit (8.38). ten crosses exhibited negative and significant sca effects for fruit weight.

4.4.3.10 Number of fruits per plant

In Y₁, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-158 x Arka Harit (5.83) followed by V-26 x Kashi Mayuri (5.20), NDBG-8 x DARAL-43 (3.83), V-169 x Kashi Mayuri (3.81) and V-65-1 x Arka Harit (3.09). twelve crosses exhibited negative and significant sca effects for number of fruits per plant.

In Y₂, out of thirty cross combinations ten crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-158 x Arka Harit (5.91) followed by V-26 x Kashi Mayuri (5.18), V-169 x Kashi Mayuri (3.79), NDBG-8 x DARAL-43 (3.77) and V-65-1 x Arka Harit (3.17). eleven crosses exhibited negative and significant sca effects for number of fruits per plant.

In pooled, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-158 x Arka Harit (5.87) followed by V-26 x Kashi Mayuri (5.18), V-169 x Kashi Mayuri (3.80), NDBG-8 x DARAL-43 (3.80) and Sel-1 x DARAL-43 (2.35). thirteen crosses exhibited negative and significant sca effects for number of fruits per plant.

4.4.3.11 Days to first harvest

In Y₁, out of thirty cross combinations two crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were Sel-1 x Arka Harit (-5.05) followed by V-169 x Kashi Mayuri (-4.00). seven crosses exhibited positive and significant sca effects for days to first harvest.

In Y₂, out of thirty cross combinations one crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-169 x Kashi Mayuri (-4.94). Two crosses exhibited positive and significant sca effects for days to first harvest.

In pooled, out of thirty cross combinations five crosses showed significant and negative sca effects. Based on magnitude of sca effects best cross combinations were V-169 x Kashi Mayuri (-4.47) followed by Sel-1 x Arka Harit (-4.13), V-198 x DARAL-43 (-3.49), V-

65-1 x Arka Harit (-3.37) and NDBG-8 x Arka Harit (-3.21). Six crosses exhibited positive and significant sca effects for days to first harvest.

4.4.3.12 Total soluble solids (%)

In Y₁, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x DARAL-43 (0.77) followed by V-198 x Arka Harit (0.62), NDBG-8 x Kashi Mayuri (0.62), V-158 x Kashi Mayuri (0.53) and V-26 x DARAL-43 (0.39). Eleven crosses exhibited negative and significant sca effects for total soluble solids.

In Y₂, out of thirty cross combinations nine crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x DARAL-43 (0.80) followed by V-198 x Arka Harit (0.64), NDBG-8 x Kashi Mayuri (0.58), V-158 x Kashi Mayuri (0.48) and V-169 x DARAL-43 (0.38). Twelve crosses exhibited negative and significant sca effects for total soluble solids.

In pooled, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-65-1 x DARAL-43 (0.78) followed by V-198 x Arka Harit (0.63), NDBG-8 x Kashi Mayuri (0.60), V-158 x Kashi Mayuri (0.50) and V-169 x DARAL-43 (0.38). Twelve crosses exhibited negative and significant sca effects for total soluble solids.

4.4.3.13 Ascorbic acid (mg/100 g fresh fruit)

In Y₁, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-193 x DARAL-43 (21.03) followed by V-193 x Kashi Mayuri (19.09), V-65-1 x DARAL-43 (15.87), V-198 x Arka Harit (15.25) and NDBG-9 x Arka Harit (14.99). Ten crosses exhibited negative and significant sca effects for ascorbic acid.

In Y₂, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-169 x DARAL-43 (27.27) followed by V-193 x DARAL-43 (25.03), Sel-1 x Kashi Mayuri (24.40), NDBG-8 x Kashi Mayuri (23.53) and V-21-14 x Arka Harit (22.19). Fifteen crosses exhibited negative and significant sca effects for ascorbic acid.

In pooled, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-193 x DARAL-43

(23.03) followed by NDBG-9 x Arka Harit (17.75), Sel-1 x Kashi Mayuri (17.20), NDBG-8 x Kashi Mayuri (16.57) and V-193 x Kashi Mayuri (14.95). Eleven crosses exhibited negative and significant sca effects for ascorbic acid.

4.4.3.14 Reducing sugar (%)

In Y₁, out of thirty cross combinations sixteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (1.97) followed by V-65-1 x Arka Harit (1.18), V-198 x DARAL-43 (1.15), Sel-1 x Kashi Mayuri (0.81) and V-169 x Arka Harit (0.57). Eleven crosses exhibited negative and significant sca effects for reducing sugar.

In Y₂, out of thirty cross combinations sixteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (2.60) followed by V-198 x DARAL-43 (1.20), V-65-1 x Arka Harit (1.18), V-158 x Arka Harit (0.61) and Sel-1 x Kashi Mayuri (0.57). Eleven crosses exhibited negative and significant sca effects for reducing sugar.

In pooled, out of thirty cross combinations seventeen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (2.28) followed by V-65-1 x Kashi Mayuri (1.18), V-198 x DARAL-43 (1.18), Sel-1 x Kashi Mayuri (0.70) and V-158 x Arka Harit (0.62). Eleven crosses exhibited negative and significant sca effects for reducing sugar.

4.4.3.15 Non-reducing sugar (%)

In Y₁, out of thirty cross combinations fifteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-198 x DARAL-43 (2.24) followed by NDBG-8 x Arka Harit (1.80), V-65-1 x Arka Harit (1.77), V-193 x Kashi Mayuri (1.61) and V-26 x DARAL-43 (1.37). Fifteen crosses exhibited negative and significant sca effects for non-reducing sugar.

In Y₂, out of thirty cross combinations seventeen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-198 x DARAL-43 (2.12) followed by V-65-1 x Arka Harit (1.92), NDBG-8 x Arka Harit (1.41), V-193 x Kashi Mayuri (1.58) and V-169 x DARAL-43 (0.93). Twelve crosses exhibited negative and significant sca effects for non-reducing sugar.

In pooled, out of thirty cross combinations fifteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-198 x DARAL-43 (2.18) followed by V-65-1 x Arka Harit (1.85), NDBG-8 x Arka Harit (1.60), V-193 x Kashi Mayuri (1.60) and NDBG-9 x Arka Harit (1.11). Fifteen crosses exhibited negative and significant sca effects for non-reducing sugar.

4.4.3.16 Total sugar (%)

In Y₁, out of thirty cross combinations fifteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-198 x DARAL-43 (3.39) followed by V-65-1 x Arka Harit (2.95), NDBG-8 x Arka Harit (1.97), NDBG-9 x Arka Harit (1.82) and V-26 x Kashi Mayuri (1.37). Twelve crosses exhibited negative and significant sca effects for total sugar.

In Y₂, out of thirty cross combinations sixteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-198 x DARAL-43 (3.32) followed by V-65-1 x Arka Harit (3.10), V-26 x Kashi Mayuri (2.78), NDBG-8 x Arka Harit (1.58) and NDBG-9 x Arka Harit (1.43). Thirteen crosses exhibited negative and significant sca effects for total sugar.

In pooled, out of thirty cross combinations fifteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-198 x DARAL-43 (3.35) followed by V-65-1 x Arka Harit (3.02), V-26 x Kashi Mayuri (2.07), NDBG-8 x Arka Harit (1.77) and NDBG-9 x Arka Harit (1.63). Thirteen crosses exhibited negative and significant sca effects for total sugar.

4.4.3.17 Dry matter (%)

In Y₁, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (1.05) followed by V-169 x DARAL-43 (0.80), V-65-1 x Arka Harit (0.75), V-198 x DARAL-43 (1.71) and V-198 x Kashi Mayuri (1.68). Nine crosses exhibited negative and significant sca effects for dry matter.

In Y₂, out of thirty cross combinations eleven crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (1.48) followed by V-198 x Kashi Mayuri (0.89), V-169 x DARAL-43 (0.81), V-65-1 x Arka

Harit (0.72) and V-158 x DARAL-43 (0.68). Ten crosses exhibited negative and significant sca effects for dry matter.

In pooled, out of thirty cross combinations thirteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (1.27) followed by V-169 x DARAL-43 (0.80), V-198 x Kashi Mayuri (0.79), V-65-1 x Arka Harit (0.73) and V-193 x Arka Harit (0.59). Ten crosses exhibited negative and significant sca effects for dry matter.

4.4.3.18 Fruit yield per plant (kg)

In Y₁, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (1.59) followed by V-65-1 x Arka Harit (0.47), V-158 x Arka Harit (0.41), NDBG-8 x DARAL-43 (1.38) and V-198 x DARAL-43 (0.29). Ten crosses exhibited negative and significant sca effects for fruit yield per plant.

In Y₂, out of thirty cross combinations twelve crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (0.61) followed by V-65-1 x Arka Harit (0.49), V-158 x Arka Harit (0.43), NDBG-8 x DARAL-43 (0.41) and V-169 x Kashi Mayuri (0.34). eleven crosses exhibited negative and significant sca effects for fruit yield per plant.

In pooled, out of thirty cross combinations fourteen crosses showed significant and positive sca effects. Based on magnitude of sca effects best cross combinations were V-26 x Kashi Mayuri (0.60) followed by V-65-1 x Arka Harit (0.48), V-158 x Arka Harit (0.42), NDBG-8 x DARAL-43 (0.39) and V-198 x DARAL-43 (0.30). fourteen crosses exhibited negative and significant sca effects for fruit yield per plant.

Similar findings were reported by multiple researchers, including Verma *et al.* (2022) who observed significant SCA effects for node number and fruit yield in bitter gourd, while Lal *et al.* (2021) noted that crosses with high SCA for sugar content and fruit characteristics often involved parents with strong GCA, indicating both additive and non-additive gene action. Supporting these observations, Singh *et al.* (2021) and Vaidya *et al.* (2020) documented comparable SCA effects for vine length, fruit number, and yield. Additional studies by Quamruzzaman *et al.* (2020) in bitter gourd, Behera *et al.* (2020) in bitter gourd, Mishra and Singh (2018) in cucurbits.

Table- 4.6: Estimates of specific combining ability (sca) effects of crosses for eighteen characters in bitter melon over two years (Y₁ = 2024, Y₂ = 2025) and pooled

Sn	Hybrids	Days to first staminate flower anthesis			Days to first pistillate flower anthesis			Node number to first staminate flower appearance			Node number to first pistillate flower appearance			Vine length (m)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
14	Sel-1 x Kashi Mayuri	2.90	4.25 **	3.57 **	5.38 **	6.97 **	6.18 **	-0.02	-0.32	-0.17	0.23	0.03	0.13	-0.22	-0.26	-0.24 **
15	Sel-1 x Arka Harit	-2.63	-4.30 **	-3.47 **	-4.17 **	-8.41 **	-6.29 **	0.13	0.12	0.12	-0.49	-0.09	-0.29	0.17	0.27 *	0.22 *
16	Sel-1 x DARAL-43	-0.27	0.06	-0.10	-1.21	1.44	0.12	-0.10	0.20	0.05	0.25	0.05	0.15	0.05	-0.01	0.02
17	V-21-14 x Kashi Mayuri	-1.43	-1.53	-1.48	-0.46	-0.31	-0.38	-0.34	-0.13	-0.24	-0.21	-0.18	-0.19	0.29 *	0.25	0.27 **
18	V-21-14 x Arka Harit	3.37 *	0.92	2.14	1.99	1.31	1.65	0.40	0.38	0.39 *	-0.14	-0.18	-0.16	-0.39 **	-0.29 *	-0.34 **
19	V-21-14 x DARAL-43	-1.93	0.61	-0.66	-1.54	-1.01	-1.27	-0.05	-0.25	-0.15	0.34	0.37	0.36	0.10	0.04	0.07
20	V-65-1 x Kashi Mayuri	-2.32	-2.64 *	-2.48 *	-0.01	-3.19 *	-1.60	-1.65 **	-1.39 **	-1.52 **	-0.96 **	-0.94 **	-0.95 **	0.51 **	0.42 **	0.47 **
21	V-65-1 x Arka Harit	-3.86 *	-4.19 **	-4.02 **	-1.89	-3.58 *	-2.74 *	-0.31	-0.64 **	-0.47 *	-2.31 **	-2.35 **	-2.33 **	0.14	0.12	0.13
22	V-65-1 x DARAL-43	6.18 **	6.83 **	6.51 **	1.91	6.77 **	4.34 **	1.96 **	2.03 **	2.00 **	3.26 **	3.29 **	3.28 **	-0.64 **	-0.55 **	-0.60 **
23	V-193 x Kashi Mayuri	-1.66	-1.66	-1.66	-0.18	-2.42	-1.30	0.16	1.10 **	0.63 **	0.95 **	0.97 **	0.96 **	0.10	0.28 *	0.19 *
24	V-193 x Arka Harit	0.14	0.12	0.13	-0.39	2.87	1.24	0.89 **	0.41	0.65 **	0.91 *	0.86 **	0.88 **	0.34 **	0.32 *	0.33 **
25	V-193 x DARAL-43	1.51	1.55	1.53	0.57	-0.45	0.06	-1.04 **	-1.51 **	-1.28 **	-1.86 **	-1.83 **	-1.85 **	-0.44 **	-0.61 **	-0.52 **
26	V-198 x Kashi Mayuri	0.90	-0.86	0.02	-2.40	-1.64	-2.02	0.34	-0.05	0.15	-0.20	-0.18	-0.19	0.06	0.13	0.10
27	V-198 x Arka Harit	1.37	4.92 **	3.14 **	4.72 **	5.64 **	5.18 **	-0.89 **	-0.44	-0.67 **	0.79 *	0.75 **	0.77 **	-0.32 *	-0.44 **	-0.38 **
28	V-198 x DARAL-43	-2.27	-4.05 **	-3.16 **	-2.32	-4.01 *	-3.16 *	0.55 *	0.50 *	0.52 **	-0.59	-0.57 *	-0.58 *	0.26 *	0.31 *	0.28 **
29	V-158 x Kashi Mayuri	0.46	0.80	0.63	0.21	-0.14	0.04	0.02	-0.44	-0.21	0.45	0.47	0.46	-0.69 **	-0.62 **	-0.66 **
30	V-158 x Arka Harit	0.92	0.92	0.92	0.66	1.64	1.15	-0.11	0.40	0.14	-0.80 *	-0.85 **	-0.82 **	0.44 **	0.31 *	0.37 **
31	V-158 x DARAL-43	-1.38	-1.72	-1.55	-0.87	-1.51	-1.19	0.09	0.04	0.07	0.35	0.38	0.37	0.26 *	0.31 *	0.28 **
32	V-26 x Kashi Mayuri	-1.43	-1.42	-1.43	-2.90	-1.64	-2.27	0.39	0.30	0.35	-0.53	-0.50	-0.52	0.14	-0.02	0.06
33	V-26 x Arka Harit	-0.63	-0.64	-0.63	-0.12	-2.02	-1.07	0.08	-0.09	-0.01	0.40	0.36	0.38	0.02	0.00	0.01
34	V-26 x DARAL-43	2.07	2.06	2.06	3.02	3.66 *	3.34 *	-0.47 *	-0.22	-0.34	0.13	0.15	0.14	-0.15	0.01	-0.07
35	V-169 x Kashi Mayuri	-1.21	-1.75	-1.48	-1.57	-3.14	-2.35	0.64 **	0.50 *	0.57 **	-0.52	-0.50	-0.51	0.43 **	0.50 **	0.46 **
36	V-169 x Arka Harit	2.92	4.03 **	3.48 **	1.88	3.64 *	2.76 *	0.07	0.01	0.04	1.61 **	1.57 **	1.59 **	-0.17	-0.29 *	-0.23 **
37	V-169 x DARAL-43	-1.71	-2.28 *	-1.99	-0.32	-0.51	-0.41	-0.71 **	-0.51 *	-0.61 **	-1.09 **	-1.07 **	-1.08 **	-0.26 *	-0.21	-0.24 **
38	NDBG-8 x Kashi Mayuri	3.68 *	3.36 **	3.52 **	2.49	4.81 **	3.65 **	0.12	0.17	0.14	0.08	0.10	0.09	-0.37 **	-0.41 **	-0.39 **
39	NDBG-8 x Arka Harit	-2.86	-2.36 *	-2.61 *	-2.39	-2.58	-2.49	-0.21	-0.27	-0.24	0.00	-0.04	-0.02	-0.10	0.00	-0.05
40	NDBG-8 x DARAL-43	-0.82	-1.00	-0.91	-0.09	-2.23	-1.16	0.09	0.10	0.10	-0.08	-0.05	-0.07	0.47 **	0.41 **	0.44 **
41	NDBG-9 x Kashi Mayuri	0.12	1.47	0.80	-0.57	0.69	0.06	0.36	0.25	0.30	0.71 *	0.73 **	0.72 **	-0.24 *	-0.28 *	-0.26 **
42	NDBG-9 x Arka Harit	1.26	0.59	0.92	-0.28	1.48	0.60	-0.04	0.12	0.04	0.02	-0.02	0.00	-0.11	-0.01	-0.06
43	NDBG-9 x DARAL-43	-1.38	-2.05	-1.72	0.85	-2.17	-0.66	-0.32	-0.37	-0.34	-0.73 *	-0.70 *	-0.72 **	0.36 **	0.30 *	0.33 **
	SE(sca effects)	1.588	1.087	1.098	1.570	1.591	1.307	0.232	0.230	0.186	0.350	0.273	0.267	0.123	0.134	0.085
	SE(bet sca effects)	2.245	1.537	1.553	2.221	2.250	1.849	0.328	0.325	0.264	0.494	0.386	0.378	0.174	0.190	0.121

Table-4.6: Contd.....

Sn	Hybrids	Number of primary branches per plant			Fruit length (cm)			Fruit circumference (cm)			Fruit weight (kg)			Number of fruits per plant		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
14	Sel-1 x Kashi Mayuri	-0.10	-0.09	-0.09	-0.41	-0.72 *	-0.57 *	-0.51 **	-0.79	-0.65 **	-2.63	-1.15	-1.89	0.16	0.14	0.15
15	Sel-1 x Arka Harit	0.11	0.04	0.07	0.94 *	1.34 **	1.14 **	0.71 **	0.77	0.74 **	2.98 *	2.34	2.66	-2.55 **	-2.47 **	-2.51 **
16	Sel-1 x DARAL-43	-0.01	0.05	0.02	-0.52	-0.63	-0.57 *	-0.20	0.02	-0.09	-0.35	-1.19	-0.77	2.39 **	2.32 **	2.35 **
17	V-21-14 x Kashi Mayuri	-0.24	-0.24	-0.24	1.95 **	1.87 **	1.91 **	-0.03	-0.16	-0.10	7.85 **	-5.33	1.26	0.96 *	0.79	0.88 **
18	V-21-14 x Arka Harit	0.20	0.14	0.17	-0.05	-0.10	-0.07	-0.74 **	-0.55	-0.64 **	-13.01 **	-6.64 *	-9.82 **	0.28	0.21	0.24
19	V-21-14 x DARAL-43	0.04	0.10	0.07	-1.90 **	-1.77 **	-1.83 **	0.77 **	0.71	0.74 **	5.15 **	11.97 **	8.56 **	-1.24 **	-1.00 *	-1.12 **
20	V-65-1 x Kashi Mayuri	0.41	0.09	0.25	0.68	0.60	0.64 *	1.17 **	1.25 **	1.21 **	6.91 **	8.39 **	7.65 **	1.39 **	1.37 **	1.38 **
21	V-65-1 x Arka Harit	-0.62 *	0.29 *	-0.17	2.04 **	2.00 **	2.02 **	2.31 **	2.22 **	2.26 **	9.30 **	8.67 **	8.98 **	3.09 **	3.17 **	3.13 **
22	V-65-1 x DARAL-43	0.22	-0.38 **	-0.08	-2.73 **	-2.60 **	-2.67 **	-3.48 **	-3.46 **	-3.47 **	-16.21 **	-17.06 **	-16.64 **	-4.48 **	-4.54 **	-4.51 **
23	V-193 x Kashi Mayuri	-0.06	-0.04	-0.05	3.33 **	2.27 **	2.80 **	-0.57 **	-0.82	-0.69 **	-17.07 **	-16.25 **	-16.66 **	-1.38 **	-1.40 **	-1.39 **
24	V-193 x Arka Harit	0.13	0.05	0.09	-4.33 **	-3.88 **	-4.10 **	0.11	0.20	0.15	6.37 **	6.06 *	6.22 **	1.18 **	1.26 *	1.22 **
25	V-193 x DARAL-43	-0.07	-0.01	-0.04	1.00 *	1.61 **	1.30 **	0.46 *	0.62	0.54 *	10.71 **	10.19 **	10.45 **	0.21	0.14	0.18
26	V-198 x Kashi Mayuri	0.19	0.25	0.22	0.36	0.27	0.31	0.89 **	0.65	0.77 **	0.53	2.01	1.27	0.74	0.72	0.73 *
27	V-198 x Arka Harit	-0.09	-0.52 **	-0.31	-1.61 **	-1.65 **	-1.63 **	-2.15 **	-2.07 **	-2.11 **	-5.01 **	-5.64	-5.32 **	-2.84 **	-2.76 **	-2.80 **
28	V-198 x DARAL-43	-0.10	0.27 *	0.08	1.25 **	1.38 **	1.31 **	1.26 **	1.42 **	1.34 **	4.48 **	3.63	4.05 **	2.11 **	2.04 **	2.07 **
29	V-158 x Kashi Mayuri	-0.30	-0.18	-0.24	-2.15 **	-2.23 **	-2.19 **	-1.35 **	-1.52 **	-1.44 **	4.87 **	6.90 *	5.89 **	-6.79 **	-6.81 **	-6.80 **
30	V-158 x Arka Harit	0.18	0.21	0.20	1.95 **	1.91 **	1.93 **	0.84 **	0.99 *	0.92 **	2.47	0.73	1.60	5.83 **	5.91 **	5.87 **
31	V-158 x DARAL-43	0.12	-0.04	0.04	0.20	0.33	0.26	0.51 **	0.53	0.52 *	-7.34 **	-7.63 *	-7.48 **	0.96 *	0.90	0.93 **
32	V-26 x Kashi Mayuri	0.46	0.53 **	0.50 **	1.93 **	4.55 **	3.24 **	1.22 **	2.81 **	2.02 **	7.90 **	9.38 **	8.64 **	5.20 **	5.18 **	5.18 **
33	V-26 x Arka Harit	-0.17	-0.27 *	-0.22	-0.51	-1.90 **	-1.20 **	-0.23	-1.07 *	-0.65 **	-3.49 *	-4.12	-3.80 *	-3.46 **	-3.38 **	-3.42 **
34	V-26 x DARAL-43	-0.29	-0.26 *	-0.28	-1.43 **	-2.66 **	-2.04 **	-0.99 **	-1.75 **	-1.37 **	-4.41 **	-5.26	-4.83 **	-1.73 **	-1.79 **	-1.76 **
35	V-169 x Kashi Mayuri	-0.20	-0.20	-0.20	0.00	-0.55	-0.27	-1.31 **	-1.44 **	-1.38 **	5.14 **	6.57 *	5.85 **	3.81 **	3.79 **	3.80 **
36	V-169 x Arka Harit	0.14	0.07	0.10	-2.07 **	-2.57 **	-2.32 **	-0.22	-0.03	-0.13	-12.23 **	-12.77 **	-12.50 **	-0.07	0.01	-0.03
37	V-169 x DARAL-43	0.07	0.13	0.10	2.07 **	3.12 **	2.59 **	1.54 **	1.48 **	1.50 **	7.09 **	6.20 *	6.65 **	-3.74 **	-3.80 **	-3.77 **
38	NDBG-8 x Kashi Mayuri	-0.11	-0.10	-0.10	-5.06 **	-5.35 **	-5.21 **	0.85 **	0.60	0.72 **	-10.31 **	-8.83 **	-9.57 **	-2.92 **	-2.93 **	-2.93 **
39	NDBG-8 x Arka Harit	0.20	0.12	0.16	1.66 **	2.90 **	2.28 **	-0.70 **	-0.60	-0.65 **	3.92 **	3.30	3.61 *	-0.90 *	-0.84	-0.87 **
40	NDBG-8 x DARAL-43	-0.09	-0.02	-0.06	3.40 **	2.45 **	2.93 **	-0.15	0.00	-0.07	6.39 **	5.54	5.96 **	3.83 **	3.77 **	3.80 **
41	NDBG-9 x Kashi Mayuri	-0.04	-0.03	-0.04	-0.63	-0.71 *	-0.67 *	-0.34	-0.58	-0.47 *	-3.18 *	-1.70	-2.44	-1.16 **	-0.84	-1.00 **
42	NDBG-9 x Arka Harit	-0.07	-0.14	-0.10	1.98 **	1.95 **	1.97 **	0.06	0.14	0.10	8.69 **	8.06 **	8.38 **	-0.54	-1.12 *	-0.83 **
43	NDBG-9 x DARAL-43	0.11	0.17	0.14	-1.36 **	-1.24 **	-1.30 **	0.28	0.44	0.36	-5.52 **	-6.37 *	-5.94 **	1.69 **	1.96 **	1.83 **
	SE(sca effects)	0.257	0.131	0.160	0.401	0.354	0.281	0.177	0.427	0.209	1.380	3.062	1.518	0.377	0.494	0.278
	SE(bet sca effects)	0.363	0.186	0.226	0.567	0.501	0.397	0.250	0.603	0.295	1.952	4.330	2.146	0.534	0.699	0.393

Table- 4.6: Contd.....

Sn	Hybrids	Days to first harvest			Total soluble solids (%)			Ascorbic acid (mg/100 g fresh fruit)			Reducing Sugar (%)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
14	Sel-1 x Kashi Mayuri	4.67 **	3.83	4.25 **	-0.06	-0.10	-0.08	9.99 **	24.40 **	17.20 **	0.81 **	0.57 **	0.70 **
15	Sel-1 x Arka Harit	-5.05 **	-3.20	-4.13 *	0.04	0.06	0.05	-7.70 **	-12.91 **	-10.31 **	-0.97 **	-0.60 **	-0.78 **
16	Sel-1 x DARAL-43	0.38	-0.63	-0.12	0.02	0.04	0.03	-2.29	-11.49 **	-6.89 **	0.16 **	0.03	0.09 **
17	V-21-14 x Kashi Mayuri	-2.22	-2.06	-2.14	0.19 **	0.15 *	0.17 **	7.00 **	-1.73	2.63	-0.44 **	-0.49 **	-0.47 **
18	V-21-14 x Arka Harit	2.89 *	2.58	2.74	-0.21 **	-0.19 **	-0.20 **	0.56	22.19 **	11.37 **	0.07	0.07 *	0.07 **
19	V-21-14 x DARAL-43	-0.67	-0.52	-0.60	0.01	0.03	0.02	-7.56 **	-20.45 **	-14.00 **	0.37 **	0.43 **	0.40 **
20	V-65-1 x Kashi Mayuri	-2.11	-2.39	-2.25	-0.21 **	-0.25 **	-0.23 **	-7.88 **	-8.28 **	-8.08 **	0.33 **	0.28 **	0.30 **
21	V-65-1 x Arka Harit	-2.66	-4.09	-3.37 *	-0.56 **	-0.54 **	-0.55 **	-7.99 **	17.56 **	4.78 **	1.18 **	1.18 **	1.18 **
22	V-65-1 x DARAL-43	4.77 **	6.48 **	5.63 **	0.77 **	0.80 **	0.78 **	15.87 **	-9.28 **	3.29 *	-1.51 **	-1.45 **	-1.48 **
23	V-193 x Kashi Mayuri	0.89	-1.39	-0.25	0.05	0.01	0.03	19.09 **	10.81 **	14.95 **	-0.54 **	-0.59 **	-0.56 **
24	V-193 x Arka Harit	-1.99	0.24	-0.88	-0.17 **	-0.15 *	-0.16 **	-40.13 **	-35.84 **	-37.98 **	0.36 **	0.35 **	0.35 **
25	V-193 x DARAL-43	1.11	1.15	1.13	0.12	0.15 *	0.13 **	21.03 **	25.03 **	23.03 **	0.18 **	0.23 **	0.21 **
26	V-198 x Kashi Mayuri	-2.11	-0.61	-1.36	-0.16 *	-0.20 **	-0.18 **	-13.84 **	-6.68 **	-10.26 **	0.32 **	0.27 **	0.30 **
27	V-198 x Arka Harit	4.67 **	5.02 *	4.85 **	0.62 **	0.64 **	0.63 **	15.25 **	-15.37 **	-0.05	-1.47 **	-1.47 **	-1.47 **
28	V-198 x DARAL-43	-2.56	-4.41	-3.49 *	-0.46 **	-0.44 **	-0.44 **	-1.42	22.04 **	10.31 **	1.15 **	1.20 **	1.18 **
29	V-158 x Kashi Mayuri	0.78	0.95	0.86	0.53 **	0.48 **	0.50 **	-5.94 **	-32.44 **	-19.19 **	-0.57 **	-0.62 **	-0.59 **
30	V-158 x Arka Harit	-0.11	1.24	0.57	0.22 **	0.24 **	0.23 **	2.37	11.75 **	7.06 **	0.62 **	0.61 **	0.62 **
31	V-158 x DARAL-43	-0.67	-2.19	-1.43	-0.74 **	-0.72 **	-0.73 **	3.57	20.69 **	12.13 **	-0.05	0.00	-0.03
32	V-26 x Kashi Mayuri	-2.22	-2.17	-2.19	-0.60 **	-0.22 **	-0.41 **	-21.84 **	15.23 **	-3.30 *	1.97 **	2.60 **	2.28 **
33	V-26 x Arka Harit	-0.77	-1.87	-1.32	0.21 **	0.02	0.12 *	9.74 **	-6.80 **	1.47	-1.05 **	-1.39 **	-1.22 **
34	V-26 x DARAL-43	2.99 *	4.03	3.51 *	0.39 **	0.20 **	0.30 **	12.10 **	-8.43 **	1.84	-0.92 **	-1.21 **	-1.06 **
35	V-169 x Kashi Mayuri	-4.00 **	-4.94 *	-4.47 **	-0.55 **	-0.59 **	-0.57 **	-2.26	-23.86 **	-13.06 **	-0.80 **	-0.85 **	-0.82 **
36	V-169 x Arka Harit	4.78 **	3.36	4.07 *	0.19 **	0.21 **	0.20 **	5.61 **	-3.41 *	1.10	0.57 **	0.57 **	0.57 **
37	V-169 x DARAL-43	-0.78	1.59	0.40	0.36 **	0.38 **	0.38 **	-3.35	27.27 **	11.96 **	0.23 **	0.28 **	0.25 **
38	NDBG-8 x Kashi Mayuri	4.44 **	7.06 **	5.75 **	0.62 **	0.58 **	0.60 **	9.61 **	23.53 **	16.57 **	-0.60 **	-0.65 **	-0.63 **
39	NDBG-8 x Arka Harit	-2.44	-3.98	-3.21 *	-0.17 **	-0.15 *	-0.16 **	7.29 **	2.32	4.81 **	0.18 **	0.17 **	0.17 **
40	NDBG-8 x DARAL-43	-2.01	-3.08	-2.54	-0.45 **	-0.43 **	-0.44 **	-16.90 **	-25.85 **	-21.37 **	0.43 **	0.48 **	0.45 **
41	NDBG-9 x Kashi Mayuri	1.89	1.72	1.81	0.19 **	0.15 *	0.17 **	6.06 **	-0.99	2.54	-0.48 **	-0.53 **	-0.50 **
42	NDBG-9 x Arka Harit	0.67	0.69	0.68	-0.15 *	-0.13 *	-0.14 **	14.99 **	20.51 **	17.75 **	0.52 **	0.51 **	0.51 **
43	NDBG-9 x DARAL-43	-2.56	-2.41	-2.49	-0.04	-0.02	-0.03	-21.05 **	-19.52 **	-20.29 **	-0.04	0.01	-0.01
	SE(sca effects)	1.404	2.385	1.600	0.062	0.060	0.044	2.083	1.374	1.355	0.042	0.033	0.025
	SE(bet sca effects)	1.985	3.373	2.262	0.087	0.085	0.063	2.946	1.943	1.916	0.059	0.047	0.035

Table- 4.6: Contd.....

Sn	Hybrids	Non-reducing Sugar (%)			Total Sugar (%)			Dry matter (%)			Fruit yield per plant (kg)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
14	Sel-1 x Kashi Mayuri	-0.24 **	-0.03	-0.13 **	0.58 **	0.55 **	0.56 **	0.07	0.00	0.03	-0.13 **	-0.06	-0.10 **
15	Sel-1 x Arka Harit	0.50 **	0.44 **	0.47 **	-0.47 **	-0.16 *	-0.32 **	-0.06	0.01	-0.02	-0.08	-0.12 *	-0.10 **
16	Sel-1 x DARAL-43	-0.27 **	-0.41 **	-0.34 **	-0.11	-0.39 **	-0.25 **	-0.01	-0.01	-0.01	0.21 **	0.19 **	0.20 **
17	V-21-14 x Kashi Mayuri	0.92 **	0.94 **	0.93 **	0.48 **	0.45 **	0.47 **	-0.26 *	-0.34 **	-0.30 **	0.10 *	0.07	0.09 **
18	V-21-14 x Arka Harit	-0.58 **	-0.38 **	-0.48 **	-0.51 **	-0.31 **	-0.42 **	0.36 **	0.43 **	0.40 **	-0.17 **	-0.14 *	-0.15 **
19	V-21-14 x DARAL-43	-0.34 **	-0.56 **	-0.45 **	0.03	-0.13	-0.05	-0.10	-0.09	-0.10	0.06	0.07	0.07 *
20	V-65-1 x Kashi Mayuri	0.55 **	0.52 **	0.54 **	0.88 **	0.80 **	0.84 **	0.43 **	0.56 **	0.50 **	0.29 **	0.29 **	0.29 **
21	V-65-1 x Arka Harit	1.77 **	1.92 **	1.85 **	2.95 **	3.10 **	3.02 **	0.75 **	0.72 **	0.73 **	0.47 **	0.49 **	0.48 **
22	V-65-1 x DARAL-43	-2.32 **	-2.44 **	-2.38 **	-3.83 **	-3.90 **	-3.86 **	-1.18 **	-1.28 **	-1.23 **	-0.76 **	-0.77 **	-0.77 **
23	V-193 x Kashi Mayuri	1.61 **	1.58 **	1.60 **	1.07 **	1.00 **	1.03 **	-0.89 **	-0.96 **	-0.92 **	-0.36 **	-0.40 **	-0.38 **
24	V-193 x Arka Harit	-0.71 **	-0.55 **	-0.63 **	-0.36 **	-0.20 **	-0.28 **	0.56 **	0.63 **	0.59 **	0.17 **	0.18 **	0.17 **
25	V-193 x DARAL-43	-0.90 **	-1.03 **	-0.97 **	-0.72 **	-0.80 **	-0.76 **	0.33 **	0.34 **	0.33 **	0.19 **	0.21 **	0.20 **
26	V-198 x Kashi Mayuri	0.87 **	0.84 **	0.86 **	1.19 **	1.11 **	1.15 **	0.68 **	0.89 **	0.79 **	0.09	0.08	0.08 *
27	V-198 x Arka Harit	-3.11 **	-2.96 **	-3.03 **	-4.58 **	-4.43 **	-4.51 **	-1.39 **	-1.13 **	-1.26 **	-0.38 **	-0.39 **	-0.38 **
28	V-198 x DARAL-43	2.24 **	2.12 **	2.18 **	3.39 **	3.32 **	3.35 **	0.71 **	0.23 *	0.47 **	0.29 **	0.31 **	0.30 **
29	V-158 x Kashi Mayuri	0.24 **	0.20 **	0.22 **	-0.33 **	-0.42 **	-0.38 **	-0.18	-0.49 **	-0.34 **	-0.34 **	-0.35 **	-0.35 **
30	V-158 x Arka Harit	-0.53 **	-0.36 **	-0.45 **	0.09	0.25 **	0.17 **	0.26 *	-0.19	0.04	0.41 **	0.43 **	0.42 **
31	V-158 x DARAL-43	0.29 **	0.17 *	0.23 **	0.24 **	0.17 *	0.20 **	-0.08	0.68 **	0.30 **	-0.07	-0.08	-0.07 *
32	V-26 x Kashi Mayuri	-0.60 **	0.17 **	-0.21 **	1.37 **	2.78 **	2.07 **	1.05 **	1.48 **	1.27 **	0.59 **	0.61 **	0.60 **
33	V-26 x Arka Harit	-0.77 **	-1.01 **	-0.89 **	-1.82 **	-2.40 **	-2.11 **	-0.54 **	-0.73 **	-0.63 **	-0.35 **	-0.36 **	-0.36 **
34	V-26 x DARAL-43	1.37 **	0.83 **	1.10 **	0.45 **	-0.38 **	0.04	-0.51 **	-0.76 **	-0.64 **	-0.23 **	-0.25 **	-0.24 **
35	V-169 x Kashi Mayuri	-0.67 **	-1.51 **	-1.09 **	-1.47 **	-2.36 **	-1.92 **	-0.65 **	-0.72 **	-0.68 **	0.31 **	0.34 **	0.33 **
36	V-169 x Arka Harit	0.33 **	0.58 **	0.46 **	0.90 **	1.15 **	1.03 **	-0.15	-0.09	-0.12	-0.21 **	-0.24 **	-0.23 **
37	V-169 x DARAL-43	0.34 **	0.93 **	0.63 **	0.57 **	1.21 **	0.89 **	0.80 **	0.81 **	0.80 **	-0.10 *	-0.10	-0.10 **
38	NDBG-8 x Kashi Mayuri	-1.92 **	-1.59 **	-1.75 **	-2.52 **	-2.24 **	-2.38 **	-0.51 **	-0.59 **	-0.55 **	-0.39 **	-0.42 **	-0.40 **
39	NDBG-8 x Arka Harit	1.80 **	1.41 **	1.60 **	1.97 **	1.58 **	1.77 **	-0.06	0.01	-0.02	0.01	0.01	0.01
40	NDBG-8 x DARAL-43	0.12 *	0.18 **	0.15 **	0.55 **	0.66 **	0.60 **	0.57 **	0.58 **	0.58 **	0.38 **	0.41 **	0.39 **
41	NDBG-9 x Kashi Mayuri	-0.77 **	-1.14 **	-0.95 **	-1.25 **	-1.67 **	-1.46 **	0.25 *	0.17	0.21 *	-0.15 **	-0.16 **	-0.16 **
42	NDBG-9 x Arka Harit	1.31 **	0.91 **	1.11 **	1.82 **	1.43 **	1.63 **	0.27 *	0.33 **	0.30 **	0.13 **	0.15 **	0.14 **
43	NDBG-9 x DARAL-43	-0.54 **	0.23 **	-0.15 **	-0.58 **	0.24 **	-0.16 **	-0.51 **	-0.50 **	-0.51 **	0.01	0.01	0.01
	SE(sca effects)	0.058	0.064	0.038	0.064	0.072	0.046	0.118	0.106	0.079	0.045	0.057	0.033
	SE(bet sca effects)	0.082	0.091	0.053	0.090	0.101	0.065	0.167	0.150	0.112	0.063	0.081	0.046

4.3 Estimates of Heterosis Over Better Parent and Standard Variety

Heterosis calculated as per cent increase or decrease over better parent and standard variety for sixteen characters in Y_1 , Y_2 and pooled had given in Table 4.7 and described as follow:

4.3.1 Days to first staminate flower anthesis

In case of Y_1 , the magnitude of heterbeltiosis for days to first staminate flower anthesis ranged from -15.05 (V-65-1 x Arka Harit) to 5.91 % (Kashi Special x DARAL-43) over better parent while, for standard heterosis it varied from -10.80 (V-65-1 x Kashi Mayuri) to 10.23 % (V-65-1 x DARAL-43). Out of 30 crosses, 8 crosses showed significant negative and 1 cross showed positive heterosis over better parent whereas, 4 crosses showed significant negative and 7 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-15.05) followed by V-65-1 x Kashi Mayuri (-12.78), V-198 x DARAL-43 (-11.41), V-198 x Kashi Mayuri (-10.56) and NDBG-9 x Kashi Mayuri (-9.68). whereas, the best crosses for negative heterosis over standard variety were V-65-1 x Kashi Mayuri (-10.80) followed by V-65-1 x Arka Harit (-10.23), V-198 x Kashi Mayuri (-8.52) and V-198 x DARAL-43 (-7.39).

In case of Y_2 , the magnitude of heterbeltiosis for days to first staminate flower anthesis ranged from -15.55 (V-65-1 x Arka Harit) to 6.65 % (Sel.-1 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -12.32 (V-65-1 x Kashi Mayuri) to 11.21 % (V-169 x Arka Harit). Out of 30 crosses, 12 crosses showed significant negative and 2 crosses showed positive heterosis over better parent whereas, 4 crosses showed significant negative and 7 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-15.55) followed by V-65-1 x Kashi Mayuri (-13.30), V-198 x DARAL-43 (-12.20), V-198 x Kashi Mayuri (-9.42) and V-193 x Kashi Mayuri (-8.24). whereas, the best crosses for negative heterosis over standard variety were V-65-1 x Kashi Mayuri (-12.32) followed by V-65-1 x Arka Harit (-11.76), V-198 x Kashi Mayuri (-8.40) and V-198 x DARAL-43 (-7.28).

In case of pooled year data, the magnitude of heterbeltiosis for days to first staminate flower anthesis ranged from -15.30 (V-65-1 x Arka Harit) to 7.43 % (V-193 x Kashi Mayuri)

over better parent while, for standard heterosis it varied from -11.57 (V-65-1 x Kashi Mayuri) to 10.16 % (V-65-1 x DARAL-43). Out of 30 crosses, 9 crosses showed significant negative and 4 crosses showed positive heterosis over better parent whereas, 4 crosses showed significant negative and 6 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-15.30) followed by V-65-1 x Kashi Mayuri (-13.04), V-198 x DARAL-43 (-11.81), V-198 x Kashi Mayuri (-9.99) NDBG-9 x Kashi Mayuri (-7.52). whereas, the best crosses for negative heterosis over standard variety were V-65-1 x Kashi Mayuri (-11.57) followed by V-65-1 x Arka Harit (-11.00), V-198 x Kashi Mayuri (-8.46) and V-198 x DARAL-43 (-7.33).

4.3.2 Days to first pistillate flower anthesis

In case of Y_1 , the magnitude of heterbeltiosis for days to first pistillate flower anthesis ranged from -13.25 (V-65-1 x Arka Harit) to 8.16 % (Sel.-1 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -13.90 (V-65-1 x Arka Harit) to 8.19 % (V-65-1 x DARAL-43). Out of 30 crosses, 9 crosses showed significant negative and 3 crosses showed positive heterosis over better parent whereas, 8 crosses showed significant negative and 2 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-13.25) followed by V-65-1 x Kashi Mayuri (-10.97), V-198 x DARAL-43 (-9.11), V-65-1 x DARAL-43 (-8.87) and V-198 x Kashi Mayuri (-8.42). whereas, the best crosses for negative heterosis over standard variety were V-65-1 x Arka Harit (-13.90) followed by V-65-1 x Kashi Mayuri (-13.40), V-198 x Kashi Mayuri (-10.92), V-26 x Kashi Mayuri (-10.67) and NDBG-9 x Kashi Mayuri (-9.93).

In case of Y_2 , the magnitude of heterbeltiosis for days to first pistillate flower anthesis ranged from -15.14 (V-198 x DARAL-43) to 9.52 % (Sel.-1 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -12.06 (V-65-1 x Kashi Mayuri) to 11.06 % (V-26 x DARAL-43). Out of 30 crosses, 9 crosses showed significant negative and 2 crosses showed positive heterosis over better parent whereas, 5 crosses showed significant negative and 6 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-198 x DARAL-43 (-15.14) followed by Sel.-1 x Arka Harit (-14.11), V-65-1 x Arka Harit (-13.38),

V-65-1 x Kashi Mayuri (-12.28) and V-198 x Kashi Mayuri (-9.77). whereas, the best five crosses for negative heterosis over standard variety were V-65-1 x Kashi Mayuri (-12.06) followed by Sel.-1 x Arka Harit (-11.31), V-65-1 x Arka Harit (-10.55), V-198 x Kashi Mayuri (-9.55) and V-198 x DARAL-43 (-7.03).

In case of pooled year data, the magnitude of heterobeltiosis for days to first pistillate flower anthesis ranged from -13.32 (V-65-1 x Arka Harit) to 8.85 % (Sel.-1 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -12.73 (V-65-1 x Kashi Mayuri) to 7.49 % (Sel.-1 x Kashi Mayuri). Out of 30 crosses, 10 crosses showed significant negative and 2 crosses showed positive heterosis over better parent whereas, 7 crosses showed significant negative and 2 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-13.32) followed by V-198 x DARAL-43 (-12.23), V-65-1 x Kashi Mayuri (-11.63), Sel.-1 x Arka Harit (-10.11) and V-198 x Kashi Mayuri (-9.10). whereas, the best five crosses for negative heterosis over standard variety were V-65-1 x Kashi Mayuri (-12.72) followed by V-65-1 x Arka Harit (-12.24), V-198 x Kashi Mayuri (-10.24), Sel.-1 x Arka Harit (-8.99) and V-198 x DARAL-43 (-7.74).

4.3.3 Node number to first staminate flower appearance

In case of Y_1 , the magnitude of heterobeltiosis for node number to first staminate flower appearance ranged from -24.44 (V-26 x DARAL-43) to 115.52 % (V-65-1 x DARAL-43) over better parent while, for standard heterosis it varied from -24.47 (V-21-14 x Kashi Mayuri) to 95.77 % (V-65-1 x DARAL-43). Out of 30 crosses, 9 crosses showed significant negative and 5 crosses showed positive heterosis over better parent whereas, 3 crosses showed significant negative and 6 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-26 x DARAL-43 (-24.44) followed by Sel.-1 x Arka Harit (-21.48), V-158 x Arka Harit (-21.33), NDBG-8 x Arka Harit (-20.37) and NDBG-9 x Arka Harit (-20.57). whereas, the best crosses for negative heterosis over standard variety were V-21-14 x Kashi Mayuri (-24.47) followed by V-93 x DARAL-43 (-17.91) and Sel.-1 x Kashi Mayuri (-16.61).

In case of Y_2 , the magnitude of heterobeltiosis for node number to first staminate flower appearance ranged from -25.22 (NDBG-8 x Arka Harit) to 72.57 % (V-65-1 x DARAL-43) over better parent while, for standard heterosis it varied from -12.97 (V-197 x DARAL-43) to

63.24% (V-65-1 x DARAL-43). Out of 30 crosses, 13 crosses showed significant negative and 5 crosses showed positive heterosis over better parent whereas, 1 cross showed significant negative and 14 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were NDBG-8 x Arka Harit (-25.22) followed by NDBG-9 x Arka Harit (-21.74), V-169 x DARAL-43 (-20.43), NDBG-9 x Kashi Mayuri (-18.40) and NDBG-8 x Kashi Mayuri (-17.69). whereas, the best cross for negative heterosis over standard variety was V-197 x DARAL-43 (-12.97).

In case of pooled year data, the magnitude of heterbeltiosis for node number to first staminate flower appearance ranged from -23.40 (NDBG-8 x Arka Harit) to 88.71 % (V-65-1 x DARAL-43) over better parent while, for standard heterosis it varied from -14.83 (V-193 x DARAL-43) to 75.79 % (V-65-1 x DARAL-43). Out of 30 crosses, 12 crosses showed significant negative and 6 crosses showed positive heterosis over better parent whereas, 1 cross showed significant negative and 9 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were NDBG-8 x Arka Harit (-23.40) followed by NDBG-9 x Arka Harit (-21.21), V-169 x Arka Harit (-16.05), V-26 x Arka Harit (-13.53) and Sel.-1 x Arka Harit (-13.42). whereas, the best cross for negative heterosis over standard variety was V-193 x DARAL-43 (-14.83).

4.3.4 Node number to first pistillate flower appearance

In case of Y₁, the magnitude of heterbeltiosis for node number to first pistillate flower appearance ranged from -43.19 (V-65-1 x Arka Harit) to 25.10 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -48.84 (V-65-1 x Arka Harit) to 16.23 % (V-65-1 x DARAL-43). Out of 30 crosses, 16 crosses showed significant negative and 3 crosses showed positive heterosis over better parent whereas, 19 crosses showed significant negative and 1 cross showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-43.19) followed by V-198 x DARAL-43 (-39.62), V-169 x Kashi Mayuri (-39.58), V-169 x DARAL-43 (-34.68) and V-198 x Kashi Mayuri (-31.17). whereas, the best five crosses for negative heterosis over standard variety were V-65-1 x Arka Harit (-48.84)

followed by V-198 x Kashi Mayuri (-46.29), V-65-1 x Kashi Mayuri (-40.70), V-198 x DARAL-43 (-38.29) and V-26 x Kashi Mayuri (-34.73).

In case of Y_2 , the magnitude of heterobeltiosis for node number to first pistillate flower appearance ranged from -37.71 (V-65-1 x Arka Harit) to 21.50 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -43.18 (V-65-1 x Arka Harit) to 14.35 % (V-65-1 x DARAL-43). Out of 30 crosses, 15 crosses showed significant negative and 6 crosses showed positive heterosis over better parent whereas, 18 crosses showed significant negative and 2 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-37.71) followed by V-169 x Kashi Mayuri (-35.80), V-198 x DARAL-43 (-35.12), V-169 x DARAL-43 (-31.35) and NDBG-8 x Kashi Mayuri (-27.17). whereas, the best five crosses for negative heterosis over standard variety were V-65-1 x Arka Harit (-43.18) followed by V-198 x Kashi Mayuri (-40.93), V-65-1 x Kashi Mayuri (-35.99), V-198 x DARAL-43 (-33.86) and V-26 x Kashi Mayuri (-30.70).

In case of pooled year data, the magnitude of heterobeltiosis for node number to first pistillate flower appearance ranged from -40.26 (V-65-1 x Arka Harit) to 23.16 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -45.83 (V-65-1 x Arka Harit) to 18.78 % (V-193 x DARAL-43). Out of 30 crosses, 19 crosses showed significant negative and 3 crosses showed positive heterosis over better parent whereas, 19 crosses showed significant negative and 3 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Arka Harit (-40.26) followed by V-169 x Kashi Mayuri (-37.60), V-198 x DARAL-43 (-37.24), V-169 x DARAL-43 (-32.93) and NDBG-8 x Kashi Mayuri (-28.76). whereas, the best five crosses for negative heterosis over standard variety were V-65-1 x Arka Harit (-45.83) followed by V-198 x Kashi Mayuri (-43.44), V-65-1 x Kashi Mayuri (-38.20), V-198 x DARAL-43 (-35.95) and V-26 x Kashi Mayuri (-32.59).

4.3.5 Vine length (m)

In case of Y_1 , the magnitude of heterobeltiosis for vine length ranged from -34.04 (V-65-1 x DARAL-43) to 42.81 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -12.82 (V-65-1 x DARAL-43) to 40.85 % (V-198 x DARAL-43). Out of 30 crosses, 7 crosses showed significant positive and 3 crosses showed negative heterosis

over better parent whereas, 17 crosses showed significant positive and 02 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-193 x Kashi Mayuri (42.81) followed by V-193 x Arka Harit (37.59), NDBG-9 x DARAL-43 (30.86), V-169 x Kashi Mayuri (30.13) and V-158 x Kashi Mayuri (25.35) whereas, the best crosses for positive heterosis over standard variety were V-198 x DARAL-43 (40.85) followed by V-65-1 x Kashi Mayuri (40.45), V-198 x Kashi Mayuri (40.05), V-26 x Kashi Mayuri (38.45) and V-169 x Kashi Mayuri (35.48).

In case of Y_2 , the magnitude of heterbeltiosis for vine length ranged from -31.62 (V-21-14 x Arka Harit) to 38.73 % (V-169 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -16.16 (V-21-14 x Arka Harit) to 32.77 % (V-198 x DARAL-43). Out of 30 crosses, 7 crosses showed significant positive and 5 crosses showed negative heterosis over better parent whereas, 12 crosses showed significant positive and 06 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x Kashi Mayuri (38.73) followed by V-193 x Kashi Mayuri (33.60), NDBG-9 x DARAL-43 (24.28), V-65-1 x Kashi Mayuri (22.82) and NDBG-8 x DARAL-43 (13.98) whereas, the best crosses for positive heterosis over standard variety were V-198 x DARAL-43 (32.77) followed by V-198 x Kashi Mayuri (32.12), V-169 x Kashi Mayuri (28.49), V-65-1 x Kashi Mayuri (23.90) and V-193 x Kashi Mayuri (23.03).

In case of pooled data, the magnitude of heterbeltiosis for vine length ranged from -28.54 (V-21-14 x Arka Harit) to 37.63 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -12.61 (V-65-1 x DARAL-43) to 36.34 % (V-198 x DARAL-43). Out of 30 crosses, 7 crosses showed significant positive and 6 crosses showed negative heterosis over better parent whereas, 15 crosses showed significant positive and 05 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-193 x Kashi Mayuri (37.63) followed by V-169 x Kashi Mayuri (34.63), NDBG-9 x DARAL-43 (27.33), V-193 x Arka Harit (22.65) and NDBG-8 x DARAL-43 (14.68) whereas, the best crosses for positive heterosis over standard variety were V-198 x DARAL-43 (36.34) followed by V-198 x Kashi

Mayuri (33.63), V-169 x Kashi Mayuri (31.56), V-65-1 x Kashi Mayuri (31.21) and V-26 x Kashi Mayuri (28.25).

4.3.7 Number of primary branches per plant

In case of Y_1 , the magnitude of heterobeltiosis for number of primary branches per plant ranged from -26.49 (V-65-1 x Arka Harit) to 14.79 % (V-26 x Arka Harit) over better parent while, for standard heterosis it varied from -17.45 (V-65-1 x Arka Harit) to 14.27 % (V-198 x Kashi Mayuri). Out of 30 crosses, 7 crosses showed significant positive and 5 crosses showed negative heterosis over better parent whereas, 6 crosses showed significant positive and 03 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-26 x Arka Harit (14.79) followed by V-26 x DARAL-43 (11.57), V-65-1 x DARAL-43 (7.49), NDBG-9 x DARAL-43 (7.00) and V-198 x Kashi Mayuri (6.12) whereas, the best crosses for positive heterosis over standard variety were V-198 x Kashi Mayuri (14.27) followed by V-26 x Kashi Mayuri (13.22), V-198 x DARAL-43 (9.69), V-158 x DARAL-43 (8.83) and NDBG-9 x DARAL-43 (7.19).

In case of Y_2 , the magnitude of heterobeltiosis for number of primary branches per plant ranged from -7.72 (V-21-14 x Kashi Mayuri) to 15.19 % (V-26 x Arka Harit) over better parent while, for standard heterosis it varied from -5.57 (V-21-14 x Kashi Mayuri) to 14.11 % (V-26 x Kashi Mayuri). Out of 30 crosses, 7 crosses showed significant positive and 2 crosses showed negative heterosis over better parent whereas, 6 crosses showed significant positive and 01 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-26 x Arka Harit (15.19) followed by V-198 x Arka Harit (14.75), V-26 x DARAL-43 (12.03), NDBG-9 x DARAL-43 (6.67) and V-65-1 x DARAL-43 (5.51) whereas, the best crosses for positive heterosis over standard variety were V-26 x Kashi Mayuri (14.11) followed by V-198 x DARAL-43 (13.76), V-198 x Kashi Mayuri (13.59), V-65-1 x Arka Harit (11.97) and V-65-1 x Kashi Mayuri (11.85)

In case of pooled data, the magnitude of heterobeltiosis for number of primary branches per plant ranged from -11.96 (V-65-1 x Arka Harit) to 14.92 % (V-26 x Arka Harit) over better parent while, for standard heterosis it varied from -5.78 (V-21-14 x Kashi Mayuri) to 13.84 % (V-198 x Kashi Mayuri). Out of 30 crosses, 7 crosses showed significant positive and 3

crosses showed negative heterosis over better parent whereas, 7 crosses showed significant positive and 02 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-26 x Arka Harit (14.92) followed by V-26 x DARAL-43 (11.83), V-198 x Arka Harit (9.41), NDBG-9 x DARAL-43 (6.77) and V-65-1 x DARAL-43 (6.38) whereas, the best crosses for positive heterosis over standard variety were V-198 x Kashi Mayuri (13.84) followed by V-26 x Kashi Mayuri (13.61), V-198 x DARAL-43 (11.70), V-65-1 x Kashi Mayuri (9.15) and NDBG-9 x DARAL-43 (6.96)

4.3.8 Fruit Length (cm)

In case of Y₁, the magnitude of heterbeltiosis for fruit length ranged from -50.00 (NDBG-9 x DARAL-43) to 41.35 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -36.85 (V-193 x Arka Harit) to 55.17 % (NDBG-8 x DARAL-43). Out of 30 crosses, 11 crosses showed significant positive and 12 crosses showed negative heterosis over better parent whereas, 14 crosses showed significant positive and 07 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-193 x Kashi Mayuri (41.35) followed by V-169 x DARAL-43 (38.37), V-169 x Kashi Mayuri (27.22), V-198 x DARAL-43 (26.50) and V-198 x Kashi Mayuri (26.41) whereas, the best crosses for positive heterosis over standard variety were NDBG-8 x DARAL-43 (55.17) followed by V-193 x Kashi Mayuri (48.84), V-65-1 x Arka Harit (48.15), V-65-1 x Kashi Mayuri (48.05) and V-198 x DARAL-43 (38.63).

In case of Y₂, the magnitude of hetereltiosis for fruit length ranged from -65.95 (V-198 x Kashi Mayuri) to 66.41 % (NDBG-9 x DARAL-43) over better parent while, for standard heterosis it varied from -34.70 (NDBG-9 x DARAL-43) to 85.94 % (V-65-1 x Arka Harit). Out of 30 crosses, 11 crosses showed significant positive and 15 crosses showed negative heterosis over better parent whereas, 14 crosses showed significant positive and 09 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were NDBG-9 x DARAL-43 (66.41) followed by V-158 x DARAL-43 (58.35), NDBG-8 x Kashi Mayuri (56.55), NDBG-9 x Arka Harit (50.40) and V-26 x DARAL-43 (45.91) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (85.94) followed by V-65-1 x Kashi

Mayuri (85.84), V-26 x Kashi Mayuri (81.74), V-198 x DARAL-43 (75.19) and V-198 x Kashi Mayuri (75.08).

In case of pooled data, the magnitude of hetereltiosis for fruit length from -59.06 (NDBG-9 x DARAL-43) to 32.27 % (V-193 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -32.54 (NDBG-9 x DARAL-43) to 65.90 % (V-65-1 x Arka Harit). Out of 30 crosses, 8 crosses showed significant positive and 19 crosses showed negative heterosis over better parent whereas, 15 crosses showed significant positive and 8 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-193 x Kashi Mayuri (32.27) followed by V-169 x DARAL-43 (30.96), V-169 x Kashi Mayuri (13.55), V-198 x DARAL-43 (11.46) and V-193 x DARAL-43 (11.40) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (65.90) followed by V-65-1 x Kashi Mayuri (65.77), V-193 x Kashi Mayuri (59.20), V-26 x Kashi Mayuri (56.16) and V-198 x DARAL-43 (55.76)

4.3.9 Fruit Circumference (cm)

In case of Y_1 , the magnitude of hetereltiosis for fruit circumference ranged from -36.96 (V -158 x Kashi Mayuri) to 40.30 % (V-65-1 x Arka Harit) over better parent while, for standard heterosis it varied from -28.67 (NDBG-8 x Arka Harit) to 40.97 % (V-65-1 x Arka Harit). Out of 30 crosses, 9 crosses showed significant positive and 15 crosses showed negative heterosis over better parent whereas, 7 crosses showed significant positive and 11 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-65-1 x Arka Harit (40.30) followed by V-169 x DARAL-43 (34.75), V-65-1 x Kashi Mayuri (34.14), V-198 x DARAL-43 (25.45) and V-198 x Kashi Mayuri (24.37) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (40.97) followed by V-65-1 x Kashi Mayuri (34.79), V-198 x DARAL-43 (30.87), V-198 x Kashi Mayuri (29.75) and V-169 x DARAL-43 (20.58).

In case of Y_2 , the magnitude of heterbeltiosis for fruit circumference ranged from -40.74 (V -26 x DARAL-43) to 49.15 % (V-158 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -31.44 (NDBG-8 x Arka Harit) to 71.91 % (V-65-1 x Arka Harit). Out of 30 crosses, 9 crosses showed significant positive and 10 crosses showed

negative heterosis over better parent whereas, 9 crosses showed significant positive and 06 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Kashi Mayuri (49.15) followed by V-158 x DARAL-43 (37.87), V-26 x Arka Harit (37.24), V-158 x Arka Harit (36.04) and NDBG-8 x Arka Harit (35.96) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (71.91) followed by V-65-1 x Kashi Mayuri (71.21), V-198 x DARAL-43 (60.68), V-198 x Kashi Mayuri (59.52) and V-26 x Kashi Mayuri (55.64).

In case of pooled data, the magnitude of heterbeltiosis for fruit circumference from -43.37 (V -158 x Kashi Mayuri) to 34.77 % (V-169 x DARAL-43) over better parent while, for standard heterosis it varied from -29.96 (NDBG-8 x Arka Harit) to 55.50 % (V-65-1 x Arka Harit). Out of 30 crosses, 6 crosses showed significant positive and 18 crosses showed negative heterosis over better parent whereas, 9 crosses showed significant positive and 9 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x DARAL-43 (34.77) followed by NDBG-9 x DARAL-43 (18.27), V-65-1 x Arka Harit (16.32), V-65-1 x Kashi Mayuri (13.71) and NDBG-9 x Arka Harit (13.77) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (55.50) followed by V-65-1 x Kashi Mayuri (52.02), V-198 x DARAL-43 (44.92), V-198 x Kashi Mayuri (43.75) and V-26 x Kashi Mayuri (36.55).

4.3.9 Fruit Weight (kg)

In case of Y_1 , the magnitude of heterbeltiosis for fruit weight ranged from -50.67 (V-193 x Kashi Mayuri) to 31.75 % (V-26 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -55.03 (V-193 x Kashi Mayuri) to 31.13 % (V-65-1 x Arka Harit). Out of 30 crosses, 11 crosses showed significant positive and 14 crosses showed negative heterosis over better parent whereas, 6 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-26 x Kashi Mayuri (31.75) followed by V-169 x Kashi Mayuri (28.72), V-65-1 x Arka Harit (27.61), V-65-1 x Kashi Mayuri (27.45) and V-198 x DARAL-43 (23.74) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (31.13) followed by V-65-1 x Kashi

Mayuri (30.96), V-198 x DARAL-43 (25.72), V-198 x Kashi Mayuri (25.46) and V-26 x Kashi Mayuri (20.14).

In case of Y_2 , the magnitude of heterobeltiosis for fruit weight ranged from -59.69 (V-193 x Kashi Mayuri) to 30.06 % (V-65-1 x DARAL-43) over better parent while, for standard heterosis it varied from -50.51 (V-21-14 x Arka Harit) to 62.10 % (V-193 x Kashi Mayuri). Out of 30 crosses, 6 crosses showed significant positive and 9 crosses showed negative heterosis over better parent whereas, 13 crosses showed significant positive and 09 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-65-1 x DARAL-43 (30.06) followed by V-193 x Arka Harit (27.51), NDBG-9 x Kashi Mayuri (25.28), Sel-1 x Arka Harit (19.30) and V-26 x DARAL-43 (12.42) whereas, the best crosses for positive heterosis over standard variety were V-193 x Kashi Mayuri (62.10) followed by V-21-14 x Kashi Mayuri (48.50), V-193 x Arka Harit (31.84), V-21-14 x DARAL-43 (26.82) and V-158 x DARAL-43 (25.89).

In case of pooled data, the magnitude of heterobeltiosis for fruit weight from -55.35 (V-193 x Kashi Mayuri) to 21.62 % (V-169 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -58.64 (V-193 x Kashi Mayuri) to 27.25 % (V-169 x Arka Harit). Out of 30 crosses, 8 crosses showed significant positive and 13 crosses showed negative heterosis over better parent whereas, 9 crosses showed significant positive and 15 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent V-169 x Kashi Mayuri (21.62) followed by V-26 x Kashi Mayuri (18.07), V-198 x DARAL-43 (14.75), V-198 x Kashi Mayuri (14.91) and Sel-1 x Arka Harit (13.81) whereas, the best crosses for positive heterosis over standard variety were V-169 x Arka Harit (27.25) followed by V-65-1 x Arka Harit (26.50), NDBG-8 x Kashi Mayuri (26.45), V-65-1 x Kashi Mayuri (26.33) and V-198 x DARAL-43 (25.21).

4.3.9 Number of Fruits per plant

In case of Y_1 , the magnitude of heterobeltiosis for number of fruits per plant ranged from -24.26 (V-93 x Kashi Mayuri) to 77.46 % (V-158 x Arka Harit) over better parent while, for standard heterosis it varied from -51.22 (V-193 x Kashi Mayuri) to 55.04 % (Sel-1 x Arka Harit). Out of 30 crosses, 13 crosses showed significant positive and 10 crosses showed

negative heterosis over better parent whereas, 9 crosses showed significant positive and 15 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Arka Harit (77.46) followed by V-158 x DARAL-43 (50.29), V-26 x Kashi Mayuri (38.38) V-169 x Kashi Mayuri (36.90) and Sel-1 x DARAL-43 (33.83) whereas, the best crosses for positive heterosis over standard variety were Sel-1 x Arka Harit (55.04) followed by V-193 x Arka Harit (47.84), V-21-14 x Arka Harit (45.33), V-158 x Kashi Mayuri (40.65) and V-21-14x Kashi Mayuri (37.05).

In case of Y₂, the magnitude of heterbeltiosis for number of fruits per plant ranged from -34.62 (V-26 x Arka Harit) to 70.47 % (V-158 x Arka Harit) over better parent while, for standard heterosis it varied from -62.30 (Sel.-1 x Arka Harit) to 55.53 % (V-21-14 x DARAL-43). Out of 30 crosses, 7 crosses showed significant positive and 13 crosses showed negative heterosis over better parent whereas, 08 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Arka Harit (70.47) followed by V-169 x Kashi Mayuri (60.29), V-158 x DARAL-43 (44.26), NDBG-9 x Kashi Mayuri (24.87) and V-169 x Arka Harit (24.70) whereas, the best crosses for positive heterosis over standard variety were V-21-14 x DARAL-43 (55.53) followed by V-193 x Kashi Mayuri (48.16), Sel.-1 x DARAL-43 (44.36), V-158 x Kashi Mayuri (38.22) and V-26 x DARAL-43 (27.06).

In case of pooled data, the magnitude of heterbeltiosis for number of fruits per plant from -26.01 (NDBG-9 x Arka Harit) to 74.83 % (V-158 x Arka Harit) over better parent while, for standard heterosis it varied from -52.60 (V-21-14 x DARAL-43) to 58.79 % (Sel.-1 x Arka Harit). Out of 30 crosses, 14 crosses showed significant positive and 14 crosses showed negative heterosis over better parent whereas, 08 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Arka Harit (74.83) followed by V-169 x Kashi Mayuri (48.12), V-158 x DARAL-43 (47.14), Sel.-1 x DARAL-43 (20.28) and NDBG-8 x DARAL-43 (19.02) whereas, the best crosses for positive heterosis over standard variety were Sel.-1 x Arka Harit (58.79) followed by V-21-14

x Arka Harit (49.37), V-193 x Arka Harit (46.36), V-158 x Kashi Mayuri (39.40) and V-26 x Arka Harit (35.21).

4.3.11 Days to first harvest

In case of Y_1 , the magnitude of heterobeltiosis for days to first harvest ranged from -9.59 (V-65-1 x Kashi Mayuri) to 10.37 % (V-169 x Arka Harit) over better parent while, for standard heterosis it varied from -11.33 (V-169 x Arka Harit) to 7.84 % (V-21-14 x Arka Harit). Out of 30 crosses, 9 crosses showed significant negative and 3 crosses showed positive heterosis over better parent whereas, 7 crosses showed significant negative and 4 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Kashi Mayuri (-9.59) followed by NDBG-9 x DARAL-43 (-7.80), V-65-1 x Arka Harit (-7.68), Sel-1 x Arka Harit (-6.91) and V-198 x DARAL-43 (-6.74). whereas, the best five crosses for negative heterosis over standard variety were V-169 x Arka Harit (-11.33) followed by V-65-1 x Kashi Mayuri (-9.59), V-65-1 x Arka Harit (-8.28), NDBG-8 x Kashi Mayuri (-7.41) and V-198 x Kashi Mayuri (-6.54).

In case of Y_2 , the magnitude of heterobeltiosis for days to first harvest ranged from -10.03 (V-65-1 x Kashi Mayuri) to 12.21 % (V-26 x DARAL-43) over better parent while, for standard heterosis it varied from -11.81 (V-169 x Arka Harit) to 12.65 % (V-169 x DARAL-43). Out of 30 crosses, 8 crosses showed significant negative and 4 crosses showed positive heterosis over better parent whereas, 8 crosses showed significant negative and 3 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Kashi Mayuri (-10.03) followed by NDBG-8 x Arka Harit (-9.95), V-21-14 x Kashi Mayuri (-9.67), NDBG-9 x Kashi Mayuri (-7.11) and V-198 x Kashi Mayuri (-7.10). whereas, the best five crosses for negative heterosis over standard variety were V-169 x Arka Harit (-11.81) followed by NDBG-8 x Kashi Mayuri (-10.54), V-26 x DARAL-43 (-10.12), V-65-1 x Kashi Mayuri (-9.27) and V-65-1 x Arka Harit (-8.85).

In case of pooled year data, the magnitude of heterobeltiosis for days to first harvest ranged from -9.82 (V-65-1 x Kashi Mayuri) to 10.86 % (V-169 x Arka Harit) over better parent while, for standard heterosis it varied from -9.43 (V-65-1 x Kashi Mayuri) to 11.57 % (V-169 x Arka Harit). Out of 30 crosses, 10 crosses showed significant negative and 4 crosses

showed positive heterosis over better parent whereas, 6 crosses showed significant negative and 3 crosses showed significant positive heterosis over standard variety. Among 30 crosses combination, best five crosses based on high negative value over better parent were V-65-1 x Kashi Mayuri (-9.82) followed by NDBG-9 x DARAL-43 (-7.25), Sel-1 x Arka Harit (-7.09), V-198 x Kashi Mayuri (-6.83) and V-65-1 x Arka Harit (-6.58) whereas, the best five crosses for negative heterosis over standard variety were V-65-1 x Kashi Mayuri (-9.43) followed by V-169 x DARAL-43 (-9.21), V-65-1 x Arka Harit (-8.57), V-198 x Kashi Mayuri (-6.43) and Sel-1 x Arka Harit (-6.09).

4.3.12 Total soluble solids (%)

In case of Y_1 , the magnitude of heterbeltiosis for total soluble solids ranged from -62.51 (V-65-1 x Arka Harit) to 33.40 % (NDBG-9 x Arka Harit) over better parent while, for standard heterosis it varied from -52.63 (V-65-1 x Arka Harit) to 15.86 % (V-21-14 x DARAL-43). Out of 30 crosses, 6 crosses showed significant positive and 22 crosses showed negative heterosis over better parent whereas, 11 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were NDBG-9 x Arka Harit (33.40) followed by V-26 x Arka Harit (32.05), V-169 x Kashi Mayuri (31.22), NDBG-8 x Arka Harit (25.34) and NDBG-9 x Kashi Mayuri (23.80) whereas, the best crosses for positive heterosis over standard variety were V-21-14 x DARAL-43 (15.86) followed by Sel-1 x Arka Harit, V-21-14 x Kashi Mayuri (13.27), Sel-1 x DARAL-43 (11.88) and V-198 x DARAL-43 (11.81).

In case of Y_2 , the magnitude of heterbeltiosis for total soluble solids ranged from -52.56 (V-65-1 x Kashi Mayuri) to 49.22 % (V-198 x DARAL-43) over better parent while, for standard heterosis it varied from -40.02 (V-65-1 x Arka Harit) to 28.66 % (V-193 x DARAL-43). Out of 30 crosses, 8 crosses showed significant positive and 18 crosses showed negative heterosis over better parent whereas, 12 crosses showed significant positive and 15 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-198 x DARAL-43 (49.22) followed by V-169 x Kashi Mayuri (41.45), NDBG-9 x Kashi Mayuri (34.66), NDBG-9 x Arka Harit (33.54) and V-26 x Arka Harit (33.09) whereas, the best crosses for positive heterosis over standard variety were V-193 x DARAL-43 (28.66) followed by V-158 x

Arka Harit (27.63), V-158 x Kashi Mayuri (27.29), V-193 x Arka Harit (21.95) and V-193 x Kashi Mayuri (19.29).

In case of pooled data, the magnitude of heterobeltiosis for total soluble solids from -54.62 (V-198 x DARAL-43) to 57.40 % (V-65-1 x Arka Harit) over better parent while, for standard heterosis it varied from -46.46 (V-65-1 x Arka Harit) to 20.02 % (V-193 x DARAL-43). Out of 30 crosses, 09 crosses showed significant positive and 20 crosses showed negative heterosis over better parent whereas, 12 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-65-1 x Arka Harit (57.40) followed by V-26 x Kashi Mayuri (45.49), V-65-1 x DARAL-43 (32.96), V-198 x Arka Harit (31.59) and V-158 x DARAL-43 (26.53) whereas, the best crosses for positive heterosis over standard variety were V-193 x DARAL-43 (20.02) followed by V-158 x Arka Harit (19.09), V-158 x Kashi Mayuri (18.66), V-21-14 x DARAL-43 (14.84) and V-193 x Arka Harit (13.51).

4.3.13 Ascorbic Acid (mg/100 g fresh fruit)

In case of Y_1 , the magnitude of heterobeltiosis for ascorbic acid ranged from -59.86 (V-193 x Arka Harit) to 51.56 % (V-158 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -60.29 (NDBG-8 x DARAL-43) to 23.66 % (V-193 x Kashi Mayuri). Out of 30 crosses, 7 crosses showed significant positive and 19 crosses showed negative heterosis over better parent whereas, 6 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Kashi Mayuri (51.56) followed by V-158 x Arka Harit (43.56), Sel-1 x Kashi Mayuri (31.25), V-158 x DARAL-43 (30.19) and V-193 x Kashi Mayuri (14.99) whereas, the best crosses for positive heterosis over standard variety were V-193 x Kashi Mayuri (23.66) followed by V-21-14 x Kashi Mayuri (14.44), V-198 x Arka Harit (12.07), NDBG-9 x Kashi Mayuri (11.06) and V-65-1 x DARAL-43 (10.37).

In case of Y_2 , the magnitude of heterobeltiosis for ascorbic acid ranged from -61.62 (Sel-1 x DARAL-43) to 86.00 % (V-158 x DARAL-43) over better parent while, for standard heterosis it varied from -74.75 (NDBG-8 x DARAL-43) to 14.40 % (V-65-1 x Arka Harit). Out of 30 crosses, 8 crosses showed significant positive and 15 crosses showed negative

heterosis over better parent whereas, 5 crosses showed significant positive and 24 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x DARAL-43 (86.00) followed by V-158 x Arka Harit (76.70), V-158 x Kashi Mayuri (48.49), NDBG-8 x Kashi Mayuri (34.93) and V-169 x DARAL-43 (25.82) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (14.40) followed by V-65-1 x Kashi Mayuri (14.37), V-198 x DARAL-43 (10.44), V-198 x Kashi Mayuri (10.41) and V-26 x Kashi Mayuri (8.85).

In case of pooled data, the magnitude of heterbeltiosis for ascorbic acid from -58.68 (V-193 x Arka Harit) to 60.94 % (V-158 x DARAL-43) over better parent while, for standard heterosis it varied from -68.73 (NDBG-8 x DARAL-43) to 19.58 % (V-169 x Kashi Mayuri). Out of 30 crosses, 07 crosses showed significant positive and 18 crosses showed negative heterosis over better parent whereas, 08 crosses showed significant positive and 16 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x DARAL-43 (60.94) followed by V-158 x Arka Harit (60.63), V-158 x Kashi Mayuri (49.97), NDBG-8 x Kashi Mayuri (20.89) and V-193 x Kashi Mayuri (14.69) whereas, the best crosses for positive heterosis over standard variety were V-169 x Kashi Mayuri (19.58) followed by V-169 x DARAL-43 (19.00), V-26 x Arka Harit (15.41), NDBG-8 x Kashi Mayuri (11.06) and V-65-1 x Kashi Mayuri (11.01).

4.3.14 Reducing Sugar (%)

In case of Y_1 , the magnitude of heterbeltiosis for reducing sugar ranged from -71.58 (V-26 x Arka Harit) to 54.37 % (V-65-1 x Arka Harit) over better parent while, for standard heterosis it varied from -61.43 (Sel-1 x Arka Harit) to 161.08 % (V-65-1 x Arka Harit). Out of 30 crosses, 6 crosses showed significant positive and 24 crosses showed negative heterosis over better parent whereas, 8 crosses showed significant positive and 20 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-65-1 x Arka Harit (54.37) followed by V-65-1 x Kashi Mayuri (51.26), V-198 x DARAL-43 (43.04), V-198 x Kashi Mayuri (38.66) and V-26 x Kashi Mayuri (31.24) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (161.08) followed by V-65-1 x Kashi

Mayuri (155.81), V-198 x DARAL-43 (141.23), V-26 x Kashi Mayuri (136.60) and V-198 x Kashi Mayuri (133.87).

In case of Y_2 , the magnitude of heterobeltiosis for reducing sugar ranged from -89.38 (V-21-14 x Arka Harit) to 57.97 % (NDBG-9 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -70.01 (V-21-14 x Arka Harit) to 41.19 % (V-65-1 x Arka Harit). Out of 30 crosses, 7 crosses showed significant positive and 20 crosses showed negative heterosis over better parent whereas, 14 crosses showed significant positive and 15 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were NDBG-9 x Kashi Mayuri (57.97) followed by NDBG-8 x Arka Harit (55.20), V-193 x Arka Harit (37.20), V-158 x Arka Harit (34.37) and Sel-1 x Kashi Mayuri (27.76) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (241.19) followed by V-65-1 x Kashi Mayuri (235.23), V-198 x DARAL-43 (218.51), V-26 x Kashi Mayuri (213.45) and V-198 x Kashi Mayuri (210.24).

In case of pooled data, the magnitude of heterobeltiosis for reducing sugar from -79.66 (V-26 x Arka Harit) to 38.12 % (V-158 x Arka Harit) over better parent while, for standard heterosis it varied from -64.42 (Sel-1 x Arka Harit) to 198.63 % (V-65-1 x Arka Harit). Out of 30 crosses, 06 crosses showed significant positive and 24 crosses showed negative heterosis over better parent whereas, 09 crosses showed significant positive and 19 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Arka Harit (38.12) followed by V-158 x DARAL-43 (21.01), V-65-1 x Kashi Mayuri (18.76), V-198 x DARAL-43 (16.99) and V-26 x Kashi Mayuri (15.09) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (198.63) followed by V-65-1 x Kashi Mayuri (193.06), V-198 x DARAL-43 (177.46), V-26 x Kashi Mayuri (172.57) and V-198 x Kashi Mayuri (169.73).

4.3.15 Non-reducing Sugar (%)

In case of Y_1 , the magnitude of heterobeltiosis for non-reducing sugar ranged from -96.52 (Sel-1 x DARAL-43) to 277.18 % (V-169 x Arka Harit) over better parent while, for standard heterosis it varied from -94.22 (Sel-1 x DARAL-43) to 118.26 % (V-26 x DARAL-43). Out of 30 crosses, 11 crosses showed significant positive and 14 crosses showed negative

heterosis over better parent whereas, 18 crosses showed significant positive and 12 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x Arka Harit (277.18) followed by V-169 x DARAL-43 (266.12), V-169 x Kashi Mayuri (168.40), V-193 x Kashi Mayuri (111.02) and NDBG-9 x Arka Harit (78.27) whereas, the best crosses for positive heterosis over standard variety were V-26 x DARAL-43 (118.26) followed by V-65-1 x Arka Harit (114.21), V-65-1 x Kashi Mayuri (112.73), V-198 x DARAL-43 (110.78) and V-198 x Kashi Mayuri (109.79).

In case of Y_2 , the magnitude of heterbeltiosis for non-reducing sugar ranged from -95.36 (Sel-1 x DARAL-43) to 136.27 % (V-169 x DARAL-43) over better parent while, for standard heterosis it varied from -87.35 (Sel-1 x DARAL-43) to 222.05 % (V-65-1 x Arka Harit). Out of 30 crosses, 09 crosses showed significant positive and 18 crosses showed negative heterosis over better parent whereas, 20 crosses showed significant positive and 09 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x DARAL-43 (136.27) followed by V-169 x Arka Harit (115.90), V-193 x Kashi Mayuri (65.76), V-169 x Kashi Mayuri (44.41) and V-21-14 x Kashi Mayuri (18.43) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (222.05) followed by V-65-1 x Kashi Mayuri (220.18), V-198 x DARAL-43 (217.65), V-198 x Kashi Mayuri (216.14) and V-26 x Kashi Mayuri (195.75).

In case of pooled data, the magnitude of heterbeltiosis for non-reducing sugar from -95.89 (Sel-1 x DARAL-43) to 185.33 % (V-169 x DARAL-43) over better parent while, for standard heterosis it varied from -51.35 (Sel-1 x DARAL-43) to 159.78 % (V-65-1 x Arka Harit). Out of 30 crosses, 08 crosses showed significant positive and 17 crosses showed negative heterosis over better parent whereas, 18 crosses showed significant positive and 11 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x DARAL-43 (185.33) followed by V-169 x Arka Harit (177.10), V-169 x Kashi Mayuri (95.60), V-193 x Kashi Mayuri (84.53) and NDBG-9 x Arka Harit (42.16) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (159.78) followed by V-

65-1 x Kashi Mayuri (157.90), V-198 x DARAL-43 (155.94), V-198 x Kashi Mayuri (154.67) and V-26 x DARAL-43 (138.47).

4.3.16 Total Sugar (%)

In case of Y_1 , the magnitude of heterobeltiosis for total sugar ranged from -74.10 (Sel-1 x Arka Harit) to 61.76 % (V-169 x Arka Harit) over better parent while, for standard heterosis it varied from -60.46 (Sel-1 x Arka Harit) to 134.25 % (V-65-1 x Arka Harit). Out of 30 crosses, 7 crosses showed significant positive and 18 crosses showed negative heterosis over better parent whereas, 17 crosses showed significant positive and 12 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x Arka Harit (61.76) followed by V-169 x DARAL-43 (51.48), V-169 x Kashi Mayuri (51.17), NDBG-9 x Arka Harit (29.22) and V-193 x Kashi Mayuri (24.84) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (134.25) followed by V-65-1 x Kashi Mayuri (131.16), V-198 x DARAL-43 (123.78), V-198 x Kashi Mayuri (120.08) and V-26 x Kashi Mayuri (112.83).

In case of Y_2 , the magnitude of heterobeltiosis for total sugar ranged from -88.01 (V-21-14 x Arka Harit) to 28.56 % (NDBG-9 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -71.30 (V-21-14 x Arka Harit) to 231.28 % (V-65-1 x Arka Harit). Out of 30 crosses, 7 crosses showed significant positive and 20 crosses showed negative heterosis over better parent whereas, 22 crosses showed significant positive and 01 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were NDBG-9 x Kashi Mayuri (28.56) followed by V-169 x Kashi Mayuri (16.56), NDBG-9 x Arka Harit (16.01), V-193 x Kashi Mayuri (12.90) and V-169 x DARAL-43 (9.32) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (231.28) followed by V-65-1 x Kashi Mayuri (227.47), V-198 x DARAL-43 (218.33), V-198 x Kashi Mayuri (213.54) and V-26 x Kashi Mayuri (204.29).

In case of pooled data, the magnitude of heterobeltiosis for total sugar from -80.63 (V-21-14 x Arka Harit) to 29.48 % (V-169 x Arka Harit) over better parent while, for standard heterosis it varied from -62.82 (V-21-14 x Arka Harit) to 177.11 % (V-65-1 x Arka Harit). Out of 30 crosses, 06 crosses showed significant positive and 21 crosses showed negative heterosis

over better parent whereas, 19 crosses showed significant positive and 9 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x Arka Harit (29.48) followed by V-169 x DARAL-43 (26.94), V-193 x Kashi Mayuri (17.89), NDBG-8 x Arka Harit (15.91) and V-169 x Kashi Mayuri (11.74) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (177.11) followed by V-65-1 x Kashi Mayuri (173.65), V-198 x DARAL-43 (165.48), V-198 x Kashi Mayuri (161.34) and V-26 x Kashi Mayuri (153.18).

4.3.17 Dry Matter (%)

In case of Y_1 , the magnitude of heterobeltiosis for dry matter ranged from -22.89 (V-26 x Arka Harit) to 22.49 % (NDBG-8 x DARAL-43) over better parent while, for standard heterosis it varied from -12.59 (V-21-14 x DARAL-43) to 22.88 % (V-65-1 x Kashi Mayuri). Out of 30 crosses, 8 crosses showed significant positive and 15 crosses showed negative heterosis over better parent whereas, 09 crosses showed significant positive and 15 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were NDBG-8 x DARAL-43 (22.49) followed by V-169 x DARAL-43 (16.04), V-193 x Arka Harit (12.59), V-193 x DARAL-43 (12.04) and NDBG-9 x Kashi Mayuri (9.86) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Kashi Mayuri (22.88) followed by V-65-1 x Arka Harit (22.26), V-198 x Kashi Mayuri (20.66), V-198 x DARAL-43 (17.57) and V-26 x Kashi Mayuri (11.90).

In case of Y_2 , the magnitude of heterobeltiosis for dry matter ranged from -35.34 (V-26 x Arka Harit) to 17.60 % (NDBG-9 x DARAL-43) over better parent while, for standard heterosis it varied from -13.58 (V-26 x Arka Harit) to 47.82 % (V-65-1 x Kashi Mayuri). Out of 30 crosses, 8 crosses showed significant positive and 19 crosses showed negative heterosis over better parent whereas, 14 crosses showed significant positive and 13 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were NDBG-9 x DARAL-43 (17.60) followed by V-193 x Arka Harit (15.90), V-193 x DARAL-43 (14.05), V-65-1 x Kashi Mayuri (13.39) and V-198 x Kashi Mayuri (13.26) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Kashi Mayuri (47.82) followed by V-65-1 x Arka Harit

(43.23), V-198 x Kashi Mayuri (42.10), V-198 x DARAL-43 (28.19) and V-26 x Kashi Mayuri (23.41).

In case of pooled data, the magnitude of heterobeltiosis for dry matter from -29.31 (V-26 x Arka Harit) to 14.93 % (V-193 x Arka Harit) over better parent while, for standard heterosis it varied from -12.95 (V-26 x Arka Harit) to 34.72 % (V-65-1 x Kashi Mayuri). Out of 30 crosses, 08 crosses showed significant positive and 17 crosses showed negative heterosis over better parent whereas, 10 crosses showed significant positive and 13 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-193 x Arka Harit (14.93) followed by V-193 x DARAL-43 (13.04), NDBG-8 x DARAL-43 (10.42), V-198 x Kashi Mayuri (7.99) and V-65-1 x Kashi Mayuri (6.52) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Kashi Mayuri (34.72) followed by V-65-1 x Arka Harit (32.12), V-198 x Kashi Mayuri (30.79), V-198 x DARAL-43 (22.58) and V-26 x Kashi Mayuri (17.32).

4.3.18 Fruit yield per plant (kg)

In case of Y_1 , the magnitude of heterobeltiosis for fruit yield per plant ranged from -28.83 (V-193 x Kashi Mayuri) to 108.95 % (V-158 x Arka Harit) over better parent while, for standard heterosis it varied from -53.25 (V-193 x Kashi Mayuri) to 62.16 % (V-65-1 x Arka Harit). Out of 30 crosses, 19 crosses showed significant positive and 6 crosses showed negative heterosis over better parent whereas, 08 crosses showed significant positive and 20 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-158 x Arka Harit (108.95) followed by V-169 x Kashi Mayuri (96.54), Sel-1 x DARAL-43 (89.84), Sel-1 x Arka Harit (62.50) and V-169 x DARAL-43 (61.45) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (62.16) followed by V-65-1 x Kashi Mayuri (61.65), V-198 x DARAL-43 (54.79), V-198 x Kashi Mayuri (54.28) and V-26 x Kashi Mayuri (46.80).

In case of Y_2 , the magnitude of heterobeltiosis for fruit yield per plant ranged from -68.95 (V-193 x Kashi Mayuri) to 92.91 % (V-169 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -80.44 (V-193 x Kashi Mayuri) to 37.73 % (V-158 x DARAL-43). Out of 30 crosses, 10 crosses showed significant positive and 13 crosses showed

negative heterosis over better parent whereas, 9 crosses showed significant positive and 20 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x Kashi Mayuri (92.91) followed by V-158 x Arka Harit (66.96), V-169 x DARAL-43 (29.96), Sel-1 x DARAL-43 (20.30) and V-158 x DARAL-43 (20.24) whereas, the best crosses for positive heterosis over standard variety were V-158 x DARAL-43 (37.73) followed by V-26 x DARAL-43 (28.94), V-198 x DARAL-43 (28.20), V-198 x Kashi Mayuri (27.28) and V-65-1 x Arka Harit (26.68).

In case of pooled data, the magnitude of heterobeltiosis for fruit yield per plant from -49.24 (V-193 x Kashi Mayuri) to 95.00 % (V-169 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -67.48 (V-193 x Kashi Mayuri) to 43.35 % (V-65-1 x Arka Harit). Out of 30 crosses, 16 crosses showed significant positive and 11 crosses showed negative heterosis over better parent whereas, 9 crosses showed significant positive and 20 crosses showed significant negative heterosis over standard variety. Among 30 crosses combination, best five crosses based on high positive value over better parent were V-169 x Kashi Mayuri (95.00) followed by V-158 x Arka Harit (86.77), Sel-1 x DARAL-43 (57.36), V-169 x DARAL-43 (46.67) and V-158 x DARAL-43 (40.00) whereas, the best crosses for positive heterosis over standard variety were V-65-1 x Arka Harit (43.35) followed by V-65-1 x Kashi Mayuri (42.86), V-21-14 x Kashi Mayuri (42.72), V-198 x DARAL-43 (40.63) and V-198 x Kashi Mayuri (39.95).

The heterosis analysis revealed significant hybrid vigor across multiple traits in bitter gourd, with particularly strong performance observed in crosses involving V-65-1 × Arka Harit for earliness traits (days to staminate/pistillate flower anthesis showing up to -15.55% heterosis over better parent), and V-158 × Arka Harit for yield components (exhibiting 108.95% heterobeltiosis for fruit yield). These findings align with previous studies by Kumar *et al.* (2021) who reported 25-40% heterosis for early flowering in bitter gourd hybrids 20, and Patel *et al.* (2020) who observed 80-120% heterosis for yield in superior crosses 20. Suggests stable non-additive gene action, similar to observations by Sharma *et al.* (2019) in cucurbits.

For quality traits, crosses like V-169 × DARAL-43 showed remarkable heterosis for non-reducing sugars, similar findings of Mehta *et al.* (2022) regarding the potential of specific combiners to enhance biochemical traits 20. The significant standard heterosis (up to 231.28%

for total sugars in V-65-1 × Arka Harit) indicates commercial potential, though the high negative heterosis for some quality parameters (-95.89% in Sel-1 × DARAL-43).

Table 4.7: Estimates of heterosis (%) over better parent (BP) and standard variety (SV) Sarita over two years (Y₁, Y₂) and pooled

SN	Hybrids	Days to first staminate flower anthesis					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	5.56	7.95*	6.65 *	7.84*	6.10 *	7.90*
2	Sel-1 x Arka Harit	-3.76	1.70	-7.51 **	-3.36	-5.64 *	-0.85
3	Sel-1 x DARAL-43	4.35	9.09**	1.59	7.28*	2.95	8.18**
4	V-21-14 x Kashi Mayuri	-3.89	-1.70	-2.77	-1.68	-3.33	-1.69
5	V-21-14 x Arka Harit	3.76	9.66**	1.07	5.60	2.42	7.62
6	V-21-14 x DARAL-43	-0.54	3.98	2.65	8.40**	1.07	6.21
7	V-65-1 x Kashi Mayuri	-12.78 **	-10.80**	-13.30 **	-12.32**	-13.04 **	-11.57**
8	V-65-1 x Arka Harit	-15.05 **	-10.23**	-15.55 **	-11.76**	-15.30 **	-11.00**
9	V-65-1 x DARAL-43	5.43	10.23**	4.24	10.08**	4.83	10.16**
10	V-193 x Kashi Mayuri	-6.59	-3.41	-8.24 **	-3.36	7.43 **	-3.39
11	V-193 x Arka Harit	-2.69	2.84	-2.39	2.80	-2.15	2.82
12	V-193 x DARAL-43	3.80	8.52**	2.76	8.52**	3.28	8.52**
13	V-198 x Kashi Mayuri	-10.56 **	-8.52**	-9.42 **	-8.40**	-9.99 **	-8.46**
14	V-198 x Arka Harit	-9.68 **	-4.55	0.00	4.48	-4.83	0.00
15	V-198 x DARAL-43	-11.41 **	-7.39*	-12.20 **	-7.28*	-11.81 **	-7.33*
16	V-158 x Kashi Mayuri	-5.56	-3.41	-6.25 *	-3.36	-5.12 *	-3.39
17	V-158 x Arka Harit	-4.84	0.57	-4.29	0.00	-4.56	0.28
18	V-158 x DARAL-43	-4.35	0.00	-6.37 *	-1.12	-5.37 *	-0.56
19	V-26 x Kashi Mayuri	-7.22 *	-5.11	-6.09 *	-5.04	-6.66 *	-5.08
20	V-26 x Arka Harit	-5.91	-0.57	-4.83	-0.56	5.37 *	-0.56
21	V-26 x DARAL-43	2.72	7.39*	1.59	7.28*	2.15	7.34*
22	V-169 x Kashi Mayuri	-3.89	-1.70	-2.77	-1.68	-3.33	-1.69
23	V-169 x Arka Harit	2.69	8.52**	6.43 *	11.21**	4.56	9.87**
24	V-169 x DARAL-43	-0.54	3.98	-1.59	3.92	-1.07	3.95
25	NDBG-8 x Kashi Mayuri	-1.59	5.68	1.62	5.32	0.00	5.50
26	NDBG-8 x Arka Harit	-8.99 **	-2.27	-5.36 *	-1.12	-6.82 **	-1.69
27	NDBG-8 x DARAL-43	-2.65	4.54	-1.06	4.48	-0.94	4.51
28	NDBG-9 x Kashi Mayuri	-9.68 **	-4.55	-5.36 *	-1.12	-7.52 **	-2.82
29	NDBG-9 x Arka Harit	-4.84	0.57	-3.75	0.56	-4.30	0.57
30	NDBG-9 x DARAL-43	5.91*	-0.57	-5.84 *	-0.56	5.37 *	-0.56
No. of crosses with significant (-) heterosis		8	4	12	4	9	4
No. of crosses with significant (+) heterosis		1	7	2	7	4	6
Range		-15.05 to 5.91	-10.80 to 10.23	-15.55 to 6.65	-12.32 to 11.21	-15.30 to 7.43	-11.57 to 10.16

Table- 4.7: Contd.....

SN	Hybrids	Days to first pistillate flower anthesis					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	8.16 *	5.21	9.52 **	9.80**	8.85 **	7.49**
2	Sel-1 x Arka Harit	6.00*	6.70*	-14.11 **	-11.31**	-10.11 **	-8.99**
3	Sel-1 x DARAL-43	-2.96	-2.23	-1.83	7.54*	-2.38	2.62
4	V-21-14 x Kashi Mayuri	-0.26	-2.98	-1.75	-1.51	-1.01	-2.25
5	V-21-14 x Arka Harit	3.75	2.98	-0.24	3.02	1.73	3.00
6	V-21-14 x DARAL-43	-2.96	-2.23	-5.50	3.52	-4.28	0.62
7	V-65-1 x Kashi Mayuri	-10.97 **	-13.40**	-12.28 **	-12.06**	-11.63 **	-12.73**
8	V-65-1 x Arka Harit	-13.25 **	-13.90**	-13.38 **	-10.55**	-13.32 **	-12.24**
9	V-65-1 x DARAL-43	-8.87 **	8.19*	-0.46	9.05**	-4.51	0.37
10	V-193 x Kashi Mayuri	-4.73	-4.96	-7.25 *	-3.52	-6.00 *	-4.24
11	V-193 x Arka Harit	-2.74	-2.98	2.42	6.53	-0.12	1.75
12	V-193 x DARAL-43	-2.22	-1.49	-3.67	5.53	-2.97	2.00
13	V-198 x Kashi Mayuri	-8.42 **	-10.92**	-9.77 **	-9.55**	-9.10 **	-10.24**
14	V-198 x Arka Harit	2.75	1.98	0.24	3.52	1.48	2.75
15	V-198 x DARAL-43	-9.11 **	-8.44*	-15.14 **	-7.03*	-12.23 **	-7.74**
16	V-158 x Kashi Mayuri	-3.81	-5.96	-6.86 *	-4.52	-5.36 *	-5.24
17	V-158 x Arka Harit	-2.25	-2.98	-2.92	0.25	-2.59	-1.37
18	V-158 x DARAL-43	-5.91	-5.21	-9.17 **	-0.50	-7.60 **	-2.87
19	V-26 x Kashi Mayuri	-8.16 *	-10.67**	-3.26	-3.02	-5.69 *	-6.87**
20	V-26 x Arka Harit	-3.50	-4.22	-4.62	-1.51	-4.07	-2.87
21	V-26 x DARAL-43	-0.25	0.50	1.38	11.06**	0.59	5.74
22	V-169 x Kashi Mayuri	-3.57	-6.20	-2.76	-2.51	-3.16	-4.37
23	V-169 x Arka Harit	2.00	1.24	6.33 *	9.80**	4.19	5.49*
24	V-169 x DARAL-43	-2.71	-1.99	-1.83	7.54*	-2.26	2.75
25	NDBG-8 x Kashi Mayuri	-2.97	-2.73	5.39	8.04*	1.23	2.62
26	NDBG-8 x Arka Harit	-7.92 *	-7.69*	-4.14	-1.00	-5.67 *	-4.37
27	NDBG-8 x DARAL-43	-4.93	-4.22	-5.50	3.52	-5.23 *	-0.37
28	NDBG-9 x Kashi Mayuri	-8.33 **	-9.93**	-5.84	-2.76	-7.06 **	-6.37*
29	NDBG-9 x Arka Harit	6.50 *	-7.20*	-2.68	0.50	-4.56	-3.37
30	NDBG-9 x DARAL-43	-6.16 *	-5.46	-9.63 **	-1.00	7.96 **	-3.25
No. of crosses with significant (-) heterosis		9	8	9	5	10	7
No. of crosses with significant (+) heterosis		3	2	2	6	2	2
Range		-13.25 to 8.16	-13.90 to 8.19	-15.13 to 9.52	-12.06 to 11.06	-13.32 to 8.85	-12.73 to 7.49

Table- 4.7: Contd.....

SN	Hybrids	Node number to first staminate flower appearance					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-9.91	-16.61*	-12.26 *	0.54	-10.74 *	-5.99
2	Sel-1 x Arka Harit	-21.48 **	-8.31	-8.70 *	13.51**	-13.42 **	5.13
3	Sel-1 x DARAL-43	-1.87	-9.16	25.71 **	18.91**	15.25 **	8.12*
4	V-21-14 x Kashi Mayuri	-16.30*	-24.47**	-9.43 *	3.78	-11.75 *	-7.05
5	V-21-14 x Arka Harit	-15.11 *	-0.86	-5.22	17.84**	-8.82 *	10.72*
6	V-21-14 x DARAL-43	9.86	-7.42	21.05 **	11.89*	16.90 **	4.45
7	V-65-1 x Kashi Mayuri	1.90	-7.42	-14.62 **	-2.17	-9.03	-4.19
8	V-65-1 x Arka Harit	12.96	31.92**	-6.96	15.66**	0.44	21.96**
9	V-65-1 x DARAL-43	115.52 **	95.77**	72.57 **	63.24**	88.71 **	75.79**
10	V-193 x Kashi Mayuri	15.05	3.82	4.25	19.46**	7.71	13.43**
11	V-193 x Arka Harit	8.89	27.17**	-8.26	14.04**	-1.92	19.10**
12	V-193 x DARAL-43	-2.57	-17.91**	-5.85	-12.97**	-4.69	-14.83**
13	V-198 x Kashi Mayuri	8.36	28.91**	-0.94	13.51**	8.26	19.42**
14	V-198 x Arka Harit	-14.91 *	1.22	-9.13 *	12.97*	-10.68 *	8.44*
15	V-198 x DARAL-43	20.73 **	43.60**	26.29 **	32.43**	23.94 **	36.73**
16	V-158 x Kashi Mayuri	0.67	-9.16	-17.45 **	-5.42	-11.56 *	-6.85
17	V-158 x Arka Harit	-21.33 **	-8.12	-8.26	14.04**	-13.10 **	5.53
18	V-158 x DARAL-43	21.25 *	2.18	18.86 **	12.42*	21.44 **	8.52
19	V-26 x Kashi Mayuri	-13.33	1.22	-3.77	10.26*	-6.14	6.79
20	V-26 x Arka Harit	-16.67 *	-2.67	-11.74 **	9.73	-13.53 **	4.99
21	V-26 x DARAL-43	-24.44 **	-11.76	0.00	11.89*	-9.65 *	2.79
22	V-169 x Kashi Mayuri	29.72 **	17.05**	-11.79 *	1.07	1.90	7.33
23	V-169 x Arka Harit	-8.59	6.75	-20.43 **	-1.09	-16.05 **	1.94
24	V-169 x DARAL-43	8.62	-8.46	-1.13	-5.42	4.54	-6.59
25	NDBG-8 x Kashi Mayuri	7.67	-2.85	-17.69 **	-5.68	-9.41	-4.59
26	NDBG-8 x Arka Harit	-20.37 **	-7.01	-25.22 **	-7.04	-23.40 **	-6.99
27	NDBG-8 x DARAL-43	25.77 **	5.97	6.11	3.24	16.06 **	4.33
28	NDBG-9 x Kashi Mayuri	9.59	-1.12	-18.40 **	-6.49	-9.22	-4.39
29	NDBG-9 x Arka Harit	-20.37 **	-7.01	-21.74 **	-2.71	-21.21 **	-4.33
30	NDBG-9 x DARAL-43	7.80	-9.16	-11.28 *	-6.49	3.12	-7.52
No. of crosses with significant (-) heterosis		9	3	13	1	12	1
No. of crosses with significant (+) heterosis		5	6	5	14	6	9
Range		-24.44 to 115.52	-24.47 to 95.77	-25.22 to 72.57	-12.97 to 63.24	-23.40 to 88.71	-14.83 to 75.79

Table- 4.7: Contd.....

SN	Hybrids	Node number to first pistillate flower appearance					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-11.11	-19.94**	-9.70 *	-17.64**	-10.39 *	-18.72**
2	Sel-1 x Arka Harit	-12.72 *	-21.40**	-4.25	-12.66**	-8.23	-16.76**
3	Sel-1 x DARAL-43	-9.55	-7.57	-8.47 *	-6.69	-8.98 *	-7.10
4	V-21-14 x Kashi Mayuri	6.33	-15.64**	3.26	-13.82**	4.60	-14.67**
5	V-21-14 x Arka Harit	1.30	-8.77	1.13	-7.76	1.21	-8.22
6	V-21-14 x DARAL-43	0.14	2.33	0.12	2.06	0.13	2.19
7	V-65-1 x Kashi Mayuri	-24.01 **	-40.70**	-20.57 **	-35.99**	-22.16 **	-38.20**
8	V-65-1 x Arka Harit	-43.19 **	-48.84**	-37.71 **	-43.18**	-40.26 **	-45.83**
9	V-65-1 x DARAL-43	13.74 *	16.23**	12.18 **	14.35**	12.91 **	15.23**
10	V-193 x Kashi Mayuri	25.10 **	-2.38	21.50 **	-2.09	23.16 **	-2.22
11	V-193 x Arka Harit	14.72 *	3.32	12.86 **	2.94	13.73 **	3.13
12	V-193 x DARAL-43	-21.73 **	-20.02**	-19.26 **	-17.70**	-20.42 **	18.78**
13	V-198 x Kashi Mayuri	-31.17 **	-46.29**	-26.70 **	-40.93**	-28.76 **	-43.44**
14	V-198 x Arka Harit	-21.79 **	-29.56**	-19.03 **	-26.14**	-20.31 **	-27.74**
15	V-198 x DARAL-43	-39.62 **	-38.29**	-35.12 **	-33.86**	-37.24 **	-35.95**
16	V-158 x Kashi Mayuri	0.00	-13.47*	0.00	-11.91*	0.00	-12.65**
17	V-158 x Arka Harit	-11.82	-20.58**	-10.32 **	-18.20**	-11.02 *	-19.32**
18	V-158 x DARAL-43	-4.43	-2.33	-3.93	-2.06	-4.16	-2.19
19	V-26 x Kashi Mayuri	-16.36 *	-34.73**	-14.01 **	-30.70**	-15.09 **	-32.59**
20	V-26 x Arka Harit	-9.78	-18.74**	-8.54 *	-16.58**	-9.11 *	-17.58**
21	V-26 x DARAL-43	-17.47 **	-15.67**	15.49 **	-13.86**	-16.42 **	-14.70**
22	V-169 x Kashi Mayuri	-39.58 **	-25.25**	-35.80 **	-22.33**	-37.60 **	-23.70**
23	V-169 x Arka Harit	-16.35 **	3.50	-14.78 **	3.10	-15.53 **	3.29
24	V-169 x DARAL-43	-34.67 **	-19.17**	-31.35 **	-16.95**	-32.93 **	-17.98**
25	NDBG-8 x Kashi Mayuri	-30.54 **	-26.91**	-27.17 **	-23.80**	-28.76 **	-25.25**
26	NDBG-8 x Arka Harit	-25.47 **	-21.58**	-22.65 **	-19.07**	-23.98 **	-20.24**
27	NDBG-8 x DARAL-43	-20.56 **	-16.41**	18.29 **	-14.51**	-19.36 **	-15.39**
28	NDBG-9 x Kashi Mayuri	12.53	-8.21	3.09	-7.25	7.29	-7.70
29	NDBG-9 x Arka Harit	0.67	-9.33	0.58	8.26*	0.62	8.76*
30	NDBG-9 x DARAL-43	-13.18 *	-11.29	11.69 **	-9.97	-12.39 **	-10.58*
No. of crosses with significant (-) heterosis		16	19	15	18	19	19
No. of crosses with significant (+) heterosis		3	1	6	2	3	3
Range		-43.19 to 25.10	-48.84 to 16.23	-37.71 to 21.50	-43.18 to 14.35	-40.26 to 23.16	-45.83 to 18.78

Table- 4.7: Contd.....

SN	Hybrids	Vine length (m)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-9.41	4.12	-8.56	-7.39	-8.86	-2.28
2	Sel-1 x Arka Harit	-5.81	8.25	-5.29	-4.05	-5.43	1.43
3	Sel-1 x DARAL-43	-6.04	8.01	-5.50	-4.27	-5.65	1.18
4	V-21-14 x Kashi Mayuri	6.80	32.16**	-6.11	15.10**	-0.39	22.66**
5	V-21-14 x Arka Harit	-24.70 **	-6.81**	-31.62 **	-16.16**	-28.54 **	-12.01**
6	V-21-14 x DARAL-43	-5.29	17.22**	-15.90 **	3.12	-11.19 **	9.37*
7	V-65-1 x Kashi Mayuri	6.26	40.45**	22.82 **	23.90**	14.39 **	31.21**
8	V-65-1 x Arka Harit	-13.74 *	14.02*	-0.32	0.55	-7.14	6.52
9	V-65-1 x DARAL-43	-34.04 **	-12.82**	-13.16 *	-12.40**	-23.81 **	-12.61**
10	V-193 x Kashi Mayuri	42.81 **	28.67**	33.60 **	23.03**	37.63 **	25.51**
11	V-193 x Arka Harit	37.59 **	26.55**	11.80	10.60*	22.65 **	17.67**
12	V-193 x DARAL-43	11.96	0.00	10.61	-10.70*	11.24	-5.95
13	V-198 x Kashi Mayuri	-1.87	40.05**	6.93	32.12**	2.70	35.63**
14	V-198 x Arka Harit	20.67 **	13.22*	-19.15 **	-0.10	-19.87 **	5.81
15	V-198 x DARAL-43	-1.31	40.85**	7.45	32.77**	3.24	36.34**
16	V-158 x Kashi Mayuri	25.35 **	-8.41	-13.25 *	-6.75	-19.02 **	-7.48*
17	V-158 x Arka Harit	2.07	25.23**	1.89	9.54*	1.98	16.49**
18	V-158 x DARAL-43	-0.22	22.43**	9.76	17.99**	4.99	19.95**
19	V-26 x Kashi Mayuri	0.29	38.45**	0.27	20.14**	0.28	28.25**
20	V-26 x Arka Harit	-11.51	22.15**	10.63 *	7.07	-11.05 **	13.75**
21	V-26 x DARAL-43	13.15 *	19.86**	-3.22	15.97**	-7.99 *	17.67**
22	V-169 x Kashi Mayuri	30.13 **	35.48**	38.73 **	28.49**	34.63 **	31.56**
23	V-169 x Arka Harit	-3.85	0.12	-9.52	-10.47*	-3.65	-5.84
24	V-169 x DARAL-43	-3.21	0.80	8.67	0.64	3.04	0.71
25	NDBG-8 x Kashi Mayuri	-9.69	-4.16	-8.75	-14.01**	-9.19	-9.62*
26	NDBG-8 x Arka Harit	-10.19	-4.69	13.53 *	-14.46**	-9.67	-10.12*
27	NDBG-8 x DARAL-43	15.47	22.55**	13.98 *	7.39	14.68 **	14.11**
28	NDBG-9 x Kashi Mayuri	13.31	10.25	5.93	-2.44	10.98 *	3.21
29	NDBG-9 x Arka Harit	6.86	4.00	-6.49	-7.48	1.73	-2.39
30	NDBG-9 x DARAL-43	30.86 **	27.35**	24.28 **	11.24*	27.33 **	18.38**
No. of crosses with significant (-) heterosis		3	2	5	6	6	5
No. of crosses with significant (+) heterosis		7	17	7	12	7	15
Range		-34.04 to 42.81	-12.82 to 40.85	-31.62 to 38.73	-16.16 to 32.77	-28.54 to 37.63	-12.61 to 36.34

Table- 4.7: Contd.....

SN	Hybrids	Number of primary branches per plant					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	0.00	-0.86	0.00	-0.87	-0.06	-0.96
2	Sel-1 x Arka Harit	-2.43	-2.19	-2.20	-2.09	-2.43	-2.27
3	Sel-1 x DARAL-43	2.40	1.52	2.28	1.39	2.34	1.43
4	V-21-14 x Kashi Mayuri	-11.41**	-5.80*	-7.72 **	-5.57*	-9.58 **	-5.78*
5	V-21-14 x Arka Harit	-8.54**	-2.74	-4.77*	-2.56	-6.62*	-2.68
6	V-21-14 x DARAL-43	-5.73*	0.24	-2.04	0.23	-3.94	0.11
7	V-65-1 x Kashi Mayuri	-5.16*	6.51*	2.01	11.85**	-1.50	9.15**
8	V-65-1 x Arka Harit	-26.49 **	-17.45**	2.12	11.97**	-11.96 **	-2.44
9	V-65-1 x DARAL-43	7.49*	3.90	5.51 **	3.61	6.38*	3.75
10	V-193 x Kashi Mayuri	0.82	-2.69	-1.70	-2.56	-0.49	-2.75
11	V-193 x Arka Harit	-4.68	-4.46*	4.47*	-4.36	4.57*	-4.41*
12	V-193 x DARAL-43	1.58	-2.09	-1.17	-2.04	0.06	-2.21
13	V-198 x Kashi Mayuri	6.12*	14.27**	0.15	13.59**	2.96	13.84**
14	V-198 x Arka Harit	-3.45	3.95	14.75 **	-3.31	9.41 **	0.18
15	V-198 x DARAL-43	1.87	9.69**	0.31	13.76**	1.02	11.70**
16	V-158 x Kashi Mayuri	-2.43	0.24	-2.32	0.23	-2.43	0.11
17	V-158 x Arka Harit	1.13	3.90	0.96	3.61	1.10	3.75
18	V-158 x DARAL-43	5.93**	8.83**	0.00	2.61	2.90	5.58*
19	V-26 x Kashi Mayuri	-0.11	13.22**	0.15	14.11**	0.05	13.61**
20	V-26 x Arka Harit	14.79 **	-3.42	15.19 **	-3.36	14.92 **	-3.39
21	V-26 x DARAL-43	11.57 *	0.24	12.03 **	0.23	11.83 **	0.11
22	V-169 x Kashi Mayuri	-1.35	-2.14	-1.35	-2.14	-1.20	-2.14
23	V-169 x Arka Harit	-1.22	-0.99	-1.16	-1.05	-1.31	-1.14
24	V-169 x DARAL-43	4.49*	3.66	4.33*	3.48	4.50*	3.50*
25	NDBG-8 x Kashi Mayuri	0.13	-2.56	0.24	-2.39	0.24	-2.50
26	NDBG-8 x Arka Harit	-2.25	-2.01	-2.09	-1.97	-2.20	-2.03
27	NDBG-8 x DARAL-43	1.44	-1.28	1.49	-1.17	1.41	-1.37
28	NDBG-9 x Kashi Mayuri	3.35	3.53	3.19	3.31	3.15	3.32
29	NDBG-9 x Arka Harit	-2.19	-1.96	-2.03	-1.92	-2.20	-2.03
30	NDBG-9 x DARAL-43	7.00**	7.19**	6.67 **	6.79**	6.77*	6.96**
No. of crosses with significant (-) heterosis		5	3	2	1	3	2
No. of crosses with significant (+) heterosis		7	6	7	6	7	7
Range		-26.49 to 14.79	-17.45 to 14.27	-7.72 to 15.19	-5.57 to 14.11	-11.96 to 14.92	-5.78 to 13.84

Table- 4.7: Contd.....

SN	Hybrids	Fruit length (cm)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	6.19	11.11*	-26.44 **	0.54	-11.30 **	6.13
2	Sel-1 x Arka Harit	6.19	11.11*	-21.15 **	7.77	-8.45 **	9.54*
3	Sel-1 x DARAL-43	-2.91	1.59	-34.36 **	-10.28*	-19.72 **	-3.94
4	V-21-14 x Kashi Mayuri	25.54 **	38.53**	-3.01	38.83**	10.30 **	38.67**
5	V-21-14 x Arka Harit	-3.36	6.64	-28.28 **	2.66	-16.65 **	4.78
6	V-21-14 x DARAL-43	-15.30 **	-6.53	-38.63 **	-12.16*	-27.76 **	-9.17
7	V-65-1 x Kashi Mayuri	16.71 **	48.05**	-9.33 **	85.84**	1.42	65.77**
8	V-65-1 x Arka Harit	16.79 **	48.15**	-9.28 **	85.94**	1.51	65.90**
9	V-65-1 x DARAL-43	-15.54 **	7.14	-31.95 **	39.48**	-25.17 **	22.31**
10	V-193 x Kashi Mayuri	41.35 **	48.84**	24.41 **	70.98**	32.27 **	59.20**
11	V-193 x Arka Harit	-40.02 **	-36.85**	-34.77 **	-10.36*	-37.23 **	-24.45**
12	V-193 x DARAL-43	12.30 *	18.25**	10.70 **	52.14**	11.40 **	34.09**
13	V-198 x Kashi Mayuri	26.41 **	38.53**	0.70	75.08**	11.36 **	55.63**
14	V-198 x Arka Harit	-2.35	7.02	-19.83 **	39.37**	-12.57 **	22.18**
15	V-198 x DARAL-43	26.50 **	38.63**	0.77	75.19**	11.46 **	55.76**
16	V-158 x Kashi Mayuri	-48.94 **	-26.05**	-65.98 **	-29.48**	-58.45 **	-27.65**
17	V-158 x Arka Harit	-30.83 **	0.16	-51.66 **	0.22	-42.48 **	0.16
18	V-158 x DARAL-43	-39.29 **	-12.09*	58.35 **	-13.67**	-49.95 **	-12.85**
19	V-26 x Kashi Mayuri	12.66 **	33.58**	6.62 *	81.74**	9.32 **	56.16**
20	V-26 x Arka Harit	-17.77 **	-2.50	42.97 **	-2.80	-31.86 **	-2.67
21	V-26 x DARAL-43	-21.44 **	-6.86	45.91 **	-7.80	-35.10 **	-7.28*
22	V-169 x Kashi Mayuri	27.22 **	22.37**	-4.23	25.32**	13.55 **	23.77**
23	V-169 x Arka Harit	-6.66	-10.22*	-28.36 **	-11.54*	-18.19 **	-10.82**
24	V-169 x DARAL-43	38.87 **	33.58**	23.97 **	53.07**	30.96 **	42.74**
25	NDBG-8 x Kashi Mayuri	-35.73 **	-17.00**	56.55 **	-19.20**	-47.38 **	-18.04**
26	NDBG-8 x Arka Harit	3.88	34.15**	16.76 **	54.80**	-7.66 **	43.83**
27	NDBG-8 x DARAL-43	20.15 **	55.17**	-17.63 **	53.18**	-0.97	54.24**
28	NDBG-9 x Kashi Mayuri	-38.93 **	-15.26**	-57.44 **	-17.26**	-49.16 **	-16.22**
29	NDBG-9 x Arka Harit	-30.24 **	-3.20	50.40 **	-3.56	-41.37 **	-3.38
30	NDBG-9 x DARAL-43	-50.00 **	-30.62**	66.41 **	-34.70**	-59.06 **	-32.54**
No. of crosses with significant (-) heterosis		12	7	15	9	19	8
No. of crosses with significant (+) heterosis		11	14	11	14	8	15
Range		-50.00 to 41.35	-36.85 to 55.17	-65.98 to 66.41	-34.70 to 85.94	-59.06 to 32.27	-32.54 to 65.90

Table- 4.7: Contd.....

SN	Hybrids	Fruit circumference (cm)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	2.20	5.51	-18.69 **	5.82	-8.89 **	5.61
2	Sel-1 x Arka Harit	9.06 **	12.61**	-12.60 *	13.75**	-2.40	13.13**
3	Sel-1 x DARAL-43	2.64	5.96	-17.36 **	7.56	-7.98 **	6.66*
4	V-21-14 x Kashi Mayuri	-8.03 **	2.87	-26.32 **	2.94	-17.68 **	2.86
5	V-21-14 x Arka Harit	-21.00 **	-11.63**	-37.82 **	-13.14**	-29.87 **	-12.37**
6	V-21-14 x DARAL-43	-2.67	8.87	-24.51 **	5.45	-14.20 **	7.20*
7	V-65-1 x Kashi Mayuri	34.14 **	34.79**	0.31	71.21**	13.71 **	52.02**
8	V-65-1 x Arka Harit	40.30 **	40.97**	0.73	71.91**	16.32 **	55.50**
9	V-65-1 x DARAL-43	-20.59 **	-20.21**	-38.72 **	4.58	-31.56 **	-8.50*
10	V-193 x Kashi Mayuri	-23.39 **	-24.64**	-14.01 *	-0.90	-14.90 **	-13.40**
11	V-193 x Arka Harit	-14.83 **	-23.57**	-12.90 *	0.37	-13.78 **	-12.26**
12	V-193 x DARAL-43	-6.52	-16.11**	-5.70	8.67*	-6.04	-4.38
13	V-198 x Kashi Mayuri	24.37 **	29.75**	0.81	59.52**	10.74 **	43.75**
14	V-198 x Arka Harit	-14.58 **	-10.88*	27.67 **	14.46**	-22.12 **	1.09
15	V-198 x DARAL-43	25.45 **	30.87**	1.54	60.68**	11.65 **	44.92**
16	V-158 x Kashi Mayuri	-36.96 **	-20.95**	49.15 **	-23.14**	-43.37 **	-22.09**
17	V-158 x Arka Harit	-22.66 **	-3.02	36.04 **	-3.31	-29.67 **	-3.25
18	V-158 x DARAL-43	-22.78 **	-3.17	37.87 **	-6.07	-30.64 **	-4.58
19	V-26 x Kashi Mayuri	-3.78	19.46**	1.54	55.64**	-0.97	36.55**
20	V-26 x Arka Harit	-22.22 **	-3.43	37.24 **	-3.80	-30.14 **	-3.68
21	V-26 x DARAL-43	-26.16 **	-8.31*	-40.74 **	-9.17*	-33.81 **	-8.73*
22	V-169 x Kashi Mayuri	-6.75 *	-8.28*	-7.33	-9.17*	-6.99 *	-8.73*
23	V-169 x Arka Harit	10.17 **	-2.68	11.65	-3.01	10.87 **	-2.90
24	V-169 x DARAL-43	34.75 **	20.58**	34.68 **	18.71**	34.77 **	19.62**
25	NDBG-8 x Kashi Mayuri	-8.49 **	-4.73	-11.46	-5.20	-9.88 **	-5.02
26	NDBG-8 x Arka Harit	-31.48 **	-28.67**	35.96 **	-31.44**	-33.56 **	-29.96**
27	NDBG-8 x DARAL-43	-22.06 **	-18.87**	26.16 **	-20.94**	-23.97 **	-19.86**
28	NDBG-9 x Kashi Mayuri	2.43	0.75	2.91	0.87	2.63	0.71
29	NDBG-9 x Arka Harit	15.19 **	-1.34	10.67	-1.49	13.33 **	-1.45
30	NDBG-9 x DARAL-43	17.08 **	4.78	18.33 *	5.33	18.27 **	4.97
No. of crosses with significant (-) heterosis		15	11	10	6	18	9
No. of crosses with significant (+) heterosis		9	7	9	9	6	9
Range		-36.96 to 40.30	-28.67 to 40.97	-40.74 to 49.15	-31.44 to 71.91	-43.37 to 34.77	-29.96 to 55.50

Table- 4.7: Contd.....

SN	Hybrids	Fruit weight (kg)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	3.21	-8.67*	2.76	-7.84	8.32 *	-8.24*
2	Sel-1 x Arka Harit	8.58 **	-3.92	19.30 **	-3.28	13.81 **	-3.59
3	Sel-1 x DARAL-43	-1.31	-10.76**	-11.44 *	-9.85*	-6.78 *	-10.29**
4	V-21-14 x Kashi Mayuri	-14.38 **	-19.25**	-42.58 **	48.50**	-27.19 **	-34.17**
5	V-21-14 x Arka Harit	-49.25 **	-52.14**	-42.89 **	-50.51**	-46.14 **	-51.30**
6	V-21-14 x DARAL-43	-24.12 **	-28.43**	-28.12 **	26.82**	-24.77 **	-27.61**
7	V-65-1 x Kashi Mayuri	27.45 **	30.96**	0.09	21.88**	12.34 **	26.33**
8	V-65-1 x Arka Harit	27.61 **	31.13**	0.22	22.04**	12.48 **	26.50**
9	V-65-1 x DARAL-43	-9.74 **	-7.25*	30.06 **	14.83**	-20.96 **	-11.12**
10	V-193 x Kashi Mayuri	-50.67 **	-55.03**	-59.69 **	62.10**	-55.35 **	-58.64**
11	V-193 x Arka Harit	-17.67 **	-24.94**	27.51 **	31.84**	-22.76 **	-28.46**
12	V-193 x DARAL-43	-13.23 **	-20.89**	-29.22 **	-27.94*	-21.53 **	-24.48**
13	V-198 x Kashi Mayuri	23.48 **	25.46**	7.00	24.46**	14.51 **	24.95**
14	V-198 x Arka Harit	12.55 **	14.36**	-2.17	13.79**	4.55	14.08**
15	V-198 x DARAL-43	23.74 **	25.72**	7.22	24.72**	14.75 **	25.21**
16	V-158 x Kashi Mayuri	-1.21	-4.26	6.92	-4.10	3.09	-4.17
17	V-158 x Arka Harit	-8.05 **	-10.90**	-2.13	12.74**	-5.16	-11.84**
18	V-158 x DARAL-43	-24.62 **	-26.96**	-27.20 **	25.89**	-23.53 **	-26.41**
19	V-26 x Kashi Mayuri	31.75 **	20.14**	7.31	19.35**	18.07 **	19.74**
20	V-26 x Arka Harit	10.46 **	0.72	-9.47	0.69	-0.69	0.72
21	V-26 x DARAL-43	6.70 *	-2.70	12.42 *	-2.59	-4.00	-2.64
22	V-169 x Kashi Mayuri	28.72 **	0.00	11.50	0.00	21.62 **	0.00
23	V-169 x Arka Harit	-7.20 *	-27.91**	-6.64	-26.63**	-6.91	27.25**
24	V-169 x DARAL-43	7.76 *	-2.56	-4.18	-2.45	1.32	-2.50
25	NDBG-8 x Kashi Mayuri	-22.77 **	-26.99**	-21.66 **	-25.94**	-22.20 **	26.45**
26	NDBG-8 x Arka Harit	-4.78	-9.99	-4.37	-9.59*	-4.56	-9.78**
27	NDBG-8 x DARAL-43	-3.31	-8.60	-9.88	-8.26	-4.84	-8.42**
28	NDBG-9 x Kashi Mayuri	-26.29 **	-26.58**	25.28 **	-25.54**	-25.78 **	-26.05**
29	NDBG-9 x Arka Harit	-12.59 **	-12.94**	12.12 *	-12.43**	-12.35 **	12.67**
30	NDBG-9 x DARAL-43	-35.00 **	-35.25**	-35.04 **	-33.87**	-34.31 **	-34.55**
No. of crosses with significant (-) heterosis		14	16	9	9	13	15
No. of crosses with significant (+) heterosis		11	6	6	13	8	9
Range		-50.67 to 31.75	-55.03 to 31.13	-59.69 to 30.06	-50.51 to 62.10	-55.35 to 21.62	-58.64 to 27.25

Table- 4.7: Contd.....

SN	Hybrids	Number of fruits per plant					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	7.40 *	-39.46**	2.07	-47.65**	7.71 **	-43.69**
2	Sel-1 x Arka Harit	-19.34 **	55.04**	-26.48 **	-62.30**	-16.95 **	58.79**
3	Sel-1 x DARAL-43	33.83 **	-35.97**	8.48 *	44.36**	20.28 **	-40.31**
4	V-21-14 x Kashi Mayuri	11.68 **	37.05**	-0.12	-45.39**	10.44 **	-41.34**
5	V-21-14 x Arka Harit	-1.94	45.33**	-14.33 **	-53.16**	-4.68	49.37**
6	V-21-14 x DARAL-43	-1.77	-49.47**	-18.68 **	55.53**	-10.76 **	-52.60**
7	V-65-1 x Kashi Mayuri	29.29 **	3.68	-0.26	3.44	12.19 **	3.56
8	V-65-1 x Arka Harit	29.65 **	3.97	0.00	3.71	12.49 **	3.83
9	V-65-1 x DARAL-43	-2.65	21.93**	-23.48 **	20.64**	-14.69 **	21.25**
10	V-193 x Kashi Mayuri	-24.26 **	-51.22**	-22.46 **	48.16**	-23.31 **	-49.64**
11	V-193 x Arka Harit	-19.01 **	47.84**	-17.70 **	-44.98**	-18.32 **	46.36**
12	V-193 x DARAL-43	-22.36 **	-50.00**	-20.74 **	-47.01**	-21.50 **	-48.45**
13	V-198 x Kashi Mayuri	31.31 **	2.33	-0.17	2.19	12.97 **	2.25
14	V-198 x Arka Harit	7.32 **	16.37**	-17.34 **	15.40**	-7.05 **	15.86**
15	V-198 x DARAL-43	31.85 **	2.74	0.20	2.56	13.40 **	2.65
16	V-158 x Kashi Mayuri	5.30	40.65**	6.41	38.22**	7.06 **	39.40**
17	V-158 x Arka Harit	77.46 **	-1.08	70.47 **	-1.02	74.83 **	-1.05
18	V-158 x DARAL-43	50.29 **	17.27**	44.26 **	-16.24**	47.14 **	-16.72**
19	V-26 x Kashi Mayuri	38.38 **	0.65	-0.08	0.60	15.47 **	0.61
20	V-26 x Arka Harit	-12.46 **	36.33**	-34.62 **	-34.17**	-25.64 **	35.21**
21	V-26 x DARAL-43	-2.08	-28.78**	-27.55 **	27.06**	-17.24 **	27.89**
22	V-169 x Kashi Mayuri	36.90 **	-17.26**	60.29 **	16.24**	48.12 **	-16.73**
23	V-169 x Arka Harit	4.15	-37.05**	24.70 **	-34.84**	14.01 **	-35.90**
24	V-169 x DARAL-43	-15.49 **	-48.92**	3.32	-46.01**	-6.47 **	-47.42**
25	NDBG-8 x Kashi Mayuri	-10.38 **	-37.04**	-6.44 *	-34.84**	-8.37 **	-35.90**
26	NDBG-8 x Arka Harit	-8.33 **	-35.60**	-4.64	-33.59**	-6.45 **	-34.56**
27	NDBG-8 x DARAL-43	17.77 **	-17.27**	20.26 **	-16.24**	19.02 **	-16.75**
28	NDBG-9 x Kashi Mayuri	-12.47 **	-37.04**	24.87 **	-34.84**	-19.44 **	-35.90**
29	NDBG-9 x Arka Harit	-17.49 **	-40.65**	-32.67 **	-41.60**	-26.01 **	-41.13**
30	NDBG-9 x DARAL-43	-4.48	-31.29**	-18.64 **	-29.43**	-12.44 **	-30.34**
No. of crosses with significant (-) heterosis		10	15	13	16	14	16
No. of crosses with significant (+) heterosis		13	9	7	8	14	8
Range		-24.26 to 77.46	-51.22 to 55.04	-34.62 to 70.47	-62.30 to 55.53	-26.01 to 74.83	-52.60 to 58.79

Table- 4.7: Contd.....

SN	Hybrids	Days to first harvest					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	3.67	4.58*	-1.01	0.25	1.28	2.37
2	Sel-1 x Arka Harit	-6.91 **	-6.10*	7.25	-6.07*	-7.09 *	-6.09*
3	Sel-1 x DARAL-43	-0.84	2.61	-1.01	0.25	0.33	1.41
4	V-21-14 x Kashi Mayuri	-2.99	-0.87	-9.67 *	-7.76*	-6.38 *	-4.38
5	V-21-14 x Arka Harit	5.54 *	7.84**	-1.41	0.67	2.01	4.19
6	V-21-14 x DARAL-43	1.26	4.79*	-2.24	-0.17	0.12	2.26
7	V-65-1 x Kashi Mayuri	-9.59 **	-9.59**	-10.03 *	-9.27*	-9.82 **	-9.43**
8	V-65-1 x Arka Harit	-7.68 **	-8.28**	-5.50	-8.85*	-6.58 *	-8.57**
9	V-65-1 x DARAL-43	-0.42	3.05	9.63 *	7.59*	4.56	-5.36*
10	V-193 x Kashi Mayuri	0.00	0.00	-4.94	-2.53	-2.54	-1.29
11	V-193 x Arka Harit	-1.74	-1.74	-0.41	2.11	-1.06	0.21
12	V-193 x DARAL-43	0.42	3.92	3.70	6.33	3.81	-5.14*
13	V-198 x Kashi Mayuri	-6.54 *	-6.54*	-7.10*	-6.32*	-6.83 *	-6.43*
14	V-198 x Arka Harit	5.04	4.36	7.18*	3.38	6.11 *	3.86
15	V-198 x DARAL-43	-6.74 **	-3.49	-3.69	-5.48	-5.23	-4.50
16	V-158 x Kashi Mayuri	-5.07 *	-2.18	-6.44*	-2.10	-5.78 *	-2.15
17	V-158 x Arka Harit	-4.23	-1.31	-3.63	0.85	-3.93	-0.22
18	V-158 x DARAL-43	-3.79	-0.44	-4.83	-0.42	-4.13	-0.43
19	V-26 x Kashi Mayuri	-4.36	-4.36	-4.18	-3.37	-4.27	-3.86
20	V-26 x Arka Harit	0.22	-0.44	3.24	-0.42	1.73	-0.43
21	V-26 x DARAL-43	2.53	-6.10*	12.21 **	-10.12**	7.32 *	8.14**
22	V-169 x Kashi Mayuri	-3.02	-2.18	-2.09	-1.26	-2.34	-1.72
23	V-169 x Arka Harit	10.37 **	-11.33**	11.33 **	-11.81**	10.86 **	11.57**
24	V-169 x DARAL-43	2.11	5.66*	12.17 **	12.65**	8.38 **	-9.21**
25	NDBG-8 x Kashi Mayuri	5.79 *	-7.41**	0.38	-10.54**	2.94	9.00**
26	NDBG-8 x Arka Harit	-1.07	0.44	-9.95 *	-0.84	-5.76 *	-0.21
27	NDBG-8 x DARAL-43	-0.84	2.61	-6.13*	3.37	-2.73	3.00
28	NDBG-9 x Kashi Mayuri	-5.75 *	0.00	-7.11*	-0.84	-6.44 *	-0.43
29	NDBG-9 x Arka Harit	-5.34 *	0.44	-5.92	0.42	-5.64 *	0.43
30	NDBG-9 x DARAL-43	-7.80 **	-2.18	-6.71*	-0.41	-7.25 **	-1.29
No. of crosses with significant (-) heterosis		9	4	3	2	10	3
No. of crosses with significant (+) heterosis		3	7	4	5	4	5
Range		-9.59 to 10.37	-11.33 to 7.84	-10.03 to 12.21	-8.85 to 12.65	-9.82 to 10.86	-9.43 to 11.57

Table- 4.7: Contd.....

SN	Hybrids	Total soluble solids (%)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-7.21 **	3.08	-21.67 **	0.18	-14.70 **	1.65
2	Sel-1 x Arka Harit	-10.36 **	13.27**	-11.16 **	11.03**	10.68 **	12.26**
3	Sel-1 x DARAL-43	-13.12 **	11.88**	-14.04 **	9.55**	-13.59 **	10.83**
4	V-21-14 x Kashi Mayuri	1.97	13.27**	-13.19 **	11.03**	5.88 **	12.16**
5	V-21-14 x Arka Harit	-11.90 **	11.33**	-12.74 **	9.04**	-12.34 **	10.16**
6	V-21-14 x DARAL-43	-10.04 **	15.86**	-10.74 **	13.79**	10.47 **	14.84**
7	V-65-1 x Kashi Mayuri	-56.77 **	-51.98**	-52.56 **	-39.32**	-54.51 **	-45.78**
8	V-65-1 x Arka Harit	-62.51 **	-52.63**	-52.00 **	-40.02**	-57.40 **	-46.46**
9	V-65-1 x DARAL-43	-38.73 **	-21.10**	-26.60 **	-6.45*	32.96 **	-14.01**
10	V-193 x Kashi Mayuri	-7.21 **	3.08	-6.73 **	19.29**	-6.93 **	10.91**
11	V-193 x Arka Harit	-16.44 **	5.58*	-2.41	21.95**	9.69 **	13.51**
12	V-193 x DARAL-43	-13.18 **	11.81**	0.95	28.66**	-6.44 **	20.02**
13	V-198 x Kashi Mayuri	-53.13 **	-47.93**	-49.13 **	-34.93**	-51.08 **	-41.71**
14	V-198 x Arka Harit	-37.62 **	-21.17**	-25.21 **	-6.53*	31.59 **	-14.01**
15	V-198 x DARAL-43	-59.70 **	-48.10**	49.22 **	-35.27**	-54.62 **	-41.78**
16	V-158 x Kashi Mayuri	-0.44	10.60**	-0.47	27.29**	-0.42	18.66**
17	V-158 x Arka Harit	12.22 **	10.91**	2.13	27.63**	-5.24 **	19.09**
18	V-158 x DARAL-43	-32.58 **	-13.17**	19.99 **	1.99	26.53 **	-5.75**
19	V-26 x Kashi Mayuri	-47.38 **	-41.55**	-43.88 **	-28.22**	45.49 **	-35.03**
20	V-26 x Arka Harit	32.05 **	-14.14**	32.09 **	-15.13**	-31.98 **	-14.51**
21	V-26 x DARAL-43	-30.63 **	-10.67**	-30.45 **	-11.36**	-30.56 **	-10.93**
22	V-169 x Kashi Mayuri	31.22 **	-23.60**	41.45 **	-25.12**	-36.53 **	-24.37**
23	V-169 x Arka Harit	-19.19 **	2.11	-18.11 **	2.32	-18.71 **	2.15
24	V-169 x DARAL-43	-18.08 **	5.51*	16.95 **	5.86*	-17.56 **	5.75**
25	NDBG-8 x Kashi Mayuri	-4.80 **	5.75*	-17.03 **	6.12*	-11.06 **	6.00**
26	NDBG-8 x Arka Harit	25.34 **	-5.65*	24.79 **	-6.02*	-25.02 **	-5.75**
27	NDBG-8 x DARAL-43	-32.58 **	-13.17**	-32.55 **	-14.02**	-32.64 **	-13.61**
28	NDBG-9 x Kashi Mayuri	23.80 **	-15.35**	34.66 **	-16.42**	-29.32 **	-15.76**
29	NDBG-9 x Arka Harit	33.40 **	-15.84**	33.54 **	-16.94**	-33.38 **	-16.26**
30	NDBG-9 x DARAL-43	-33.21 **	-13.97**	-33.29 **	-14.98**	-33.22 **	-14.36**
No. of crosses with significant (-) heterosis		28	15	26	15	29	15
No. of crosses with significant (+) heterosis		6	11	8	12	8	12
Range		-62.51 to 33.40	-52.63 to 15.86	-52.56 to 49.22	-40.02 to 28.66	-57.40 to 45.49	-46.46 to 20.02

Table- 4.7: Contd.....

SN	Hybrids	Ascorbic acid (mg/100 g fresh fruit)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	31.25 **	-5.93*	-10.43 **	-10.43**	3.68	-8.55**
2	Sel-1 x Arka Harit	-16.68 **	-40.28**	-60.47 **	-60.47**	-45.65 **	-52.06**
3	Sel-1 x DARAL-43	-18.93 **	-41.90**	-61.62 **	-61.62**	-47.17 **	-53.40**
4	V-21-14 x Kashi Mayuri	6.37 *	14.44**	11.05 **	-11.31**	8.75 **	-0.59
5	V-21-14 x Arka Harit	-13.94 **	-7.41*	9.19 **	-12.80**	-2.15	-10.56**
6	V-21-14 x DARAL-43	-29.41 **	-24.06**	-36.00 **	-48.89**	-32.77 **	-38.55**
7	V-65-1 x Kashi Mayuri	-13.03 **	6.30*	0.07	14.37**	-5.60 **	11.01**
8	V-65-1 x Arka Harit	-25.15 **	-8.52*	0.10	14.40**	-10.83 **	4.86
9	V-65-1 x DARAL-43	-9.70 **	10.37**	-20.52 **	-9.16**	-15.83 **	-1.03
10	V-193 x Kashi Mayuri	14.99 **	23.66**	14.40 **	-8.67*	14.69 **	4.79*
11	V-193 x Arka Harit	-59.86 **	-56.83**	-57.55 **	-66.11**	-58.68 **	-62.25**
12	V-193 x DARAL-43	-3.76	3.50	0.05	-20.13**	-1.82	-10.29**
13	V-198 x Kashi Mayuri	-18.53 **	-5.56	0.07	10.41**	-7.90 **	3.76
14	V-198 x Arka Harit	-3.32	12.07**	-24.72 **	-16.94**	-15.55 **	-4.86*
15	V-198 x DARAL-43	-25.88 **	-14.07**	0.10	10.44**	-11.03 **	0.23
16	V-158 x Kashi Mayuri	51.56 **	3.23	48.49 **	-23.25**	49.97 **	-12.22**
17	V-158 x Arka Harit	43.56 **	-2.22	76.70 **	-8.67*	60.63 **	5.98*
18	V-158 x DARAL-43	30.19 **	-8.52*	86.00 **	-3.86	60.94 **	-5.80*
19	V-26 x Kashi Mayuri	-29.69 **	-16.67**	0.08	8.85*	-12.94 **	-1.77
20	V-26 x Arka Harit	-12.48 **	3.72	-34.79 **	-29.07**	-25.03 **	15.41**
21	V-26 x DARAL-43	-16.70 **	-1.28	-38.07 **	-32.64**	-28.72 **	-19.58**
22	V-169 x Kashi Mayuri	9.05 *	-1.29	-0.48	-32.64**	4.18	19.58**
23	V-169 x Arka Harit	2.48	-7.24*	-6.75 **	-36.89**	-2.24	-24.54**
24	V-169 x DARAL-43	-16.94 **	-24.81**	25.82 **	-14.84**	4.94 *	19.00**
25	NDBG-8 x Kashi Mayuri	6.15	-8.52*	34.93 **	-12.86**	20.89 **	11.06**
26	NDBG-8 x Arka Harit	-13.89 **	-25.79**	-22.77 **	-50.13**	-18.44 **	-39.99**
27	NDBG-8 x DARAL-43	-53.92 **	-60.29**	-60.90 **	-74.75**	-57.50 **	-68.73**
28	NDBG-9 x Kashi Mayuri	-12.95 **	11.06**	-21.74 **	-23.83**	-17.49 **	9.30**
29	NDBG-9 x Arka Harit	-16.69 **	6.30	-25.24 **	-27.24**	-21.11 **	-13.27**
30	NDBG-9 x DARAL-43	-54.06 **	-41.38**	-60.19 **	-61.26**	-57.23 **	-52.98**
No. of crosses with significant (-) heterosis		19	16	15	24	18	16
No. of crosses with significant (+) heterosis		7	6	8	5	7	8
Range		-59.86 to 51.56	-60.29 to 23.66	-61.62 to 86.00	-74.75 to 14.40	-58.68 to 60.94	-68.73 to 19.58

Table- 4.7: Contd.....

SN	Hybrids	Reducing Sugar (%)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	20.66 **	63.05**	27.76 **	42.54**	-6.50 **	53.60**
2	Sel-1 x Arka Harit	-71.45 **	-61.43**	-83.84 **	-68.09**	-78.36 **	-64.42**
3	Sel-1 x DARAL-43	-28.19 **	-2.96	-65.78 **	-32.47**	-49.47 **	-16.97**
4	V-21-14 x Kashi Mayuri	-52.66 **	-23.99**	-84.74 **	-56.84**	-72.14 **	-39.41**
5	V-21-14 x Arka Harit	-59.71 **	-35.32**	-89.38 **	-70.01**	-77.70 **	-51.50**
6	V-21-14 x DARAL-43	-48.67 **	-17.59**	-82.08 **	-49.35**	-68.92 **	-32.37**
7	V-65-1 x Kashi Mayuri	51.26 **	155.81**	-0.17	235.23**	18.74 **	193.06**
8	V-65-1 x Arka Harit	54.37 **	161.08**	16.2*	241.19**	21.01 **	198.63**
9	V-65-1 x DARAL-43	-22.14 **	31.67**	-42.35 **	93.58**	-34.85 **	60.80**
10	V-193 x Kashi Mayuri	-52.37 **	-32.36**	-41.32 **	20.43**	-46.17 **	-7.67*
11	V-193 x Arka Harit	-47.17 **	-24.98**	37.20 **	28.87**	-41.57 **	0.21
12	V-193 x DARAL-43	-51.10 **	-30.54**	-40.40 **	22.28**	-45.05 **	-5.78*
13	V-198 x Kashi Mayuri	38.66 **	133.84**	-1.72	210.24**	13.74 **	169.73**
14	V-198 x Arka Harit	-35.35 **	9.01**	-46.94 **	67.53**	-42.47 **	36.47**
15	V-198 x DARAL-43	43.04 **	141.23**	0.89	218.51**	16.99 **	177.46**
16	V-158 x Kashi Mayuri	-57.20 **	-34.63**	-45.77 **	17.78**	-50.96 **	-10.30**
17	V-158 x Arka Harit	-42.90 **	-12.81**	34.37 **	42.54**	38.12 **	13.14**
18	V-158 x DARAL-43	-62.58 **	-42.86**	-50.09 **	8.44**	-55.75 **	-19.08**
19	V-26 x Kashi Mayuri	31.24 **	136.60**	3.92 **	213.45**	15.09 **	172.57**
20	V-26 x Arka Harit	-71.58 **	-48.77**	-85.32 **	-55.71**	-79.66 **	-51.81**
21	V-26 x DARAL-43	-66.30 **	-39.26**	-81.78 **	-45.02**	-75.44 **	-41.83**
22	V-169 x Kashi Mayuri	-66.82 **	-53.20**	-80.88 **	-61.00**	-74.61 **	-56.75**
23	V-169 x Arka Harit	-44.82 **	-22.17**	-63.51 **	-25.55**	-55.29 **	-23.80**
24	V-169 x DARAL-43	-54.71 **	-36.11**	-71.32 **	-41.47**	-64.03 **	-38.68**
25	NDBG-8 x Kashi Mayuri	-44.81 **	-33.65**	-66.01 **	-38.66**	-56.74 **	-35.89**
26	NDBG-8 x Arka Harit	-43.44 **	-32.02**	-65.07 **	-36.97**	-55.67 **	-34.31*
27	NDBG-8 x DARAL-43	-30.60 **	-16.60**	55.20 **	-19.13**	-44.56 **	-17.87**
28	NDBG-9 x Kashi Mayuri	-36.65 **	-15.42**	57.97 **	-17.84**	-48.54 **	-16.45**
29	NDBG-9 x Arka Harit	-27.43 **	-3.10	-50.67 **	-3.60	-40.45 **	-3.31
30	NDBG-9 x DARAL-43	-45.51 **	-27.24**	-64.88 **	-31.34**	-56.42 **	-29.22**
No. of crosses with significant (-) heterosis		24	20	20	15	24	19
No. of crosses with significant (+) heterosis		6	8	7	14	6	9
Range		-71.58 to 54.37	- 61.43 to 161.08	- 89.38 to 57.97	-70.01 to 241.19	-79.66 to 38.12	-64.42 to 198.63

Table- 4.7: Contd.....

SN	Hybrids	Non-reducing Sugar (%)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-66.03 **	-43.69**	-65.14 **	-4.91	-65.57 **	-27.44**
2	Sel-1 x Arka Harit	-75.72 **	-59.77**	-81.83 **	-50.43**	-79.11 **	-55.99**
3	Sel-1 x DARAL-43	-96.52 **	-94.22**	-95.36 **	-87.35**	-95.89 **	-91.35**
4	V-21-14 x Kashi Mayuri	12.61 **	27.09**	18.43 **	63.38**	-4.84 **	42.44**
5	V-21-14 x Arka Harit	-74.78 **	-71.55**	-86.36 **	-72.69**	-81.21 **	-71.88**
6	V-21-14 x DARAL-43	-72.17 **	-68.61**	-87.88 **	-75.72**	-81.02 **	-71.58**
7	V-65-1 x Kashi Mayuri	0.52	112.73**	-4.67 **	220.18**	-2.26 *	157.90**
8	V-65-1 x Arka Harit	1.22	114.21**	-4.12 **	222.05**	-1.56	159.78**
9	V-65-1 x DARAL-43	-72.75 **	-42.33**	-68.07 **	7.23*	-70.29 **	-21.60**
10	V-193 x Kashi Mayuri	111.02 **	59.74**	65.76 **	147.34**	84.53 **	96.55**
11	V-193 x Arka Harit	-50.39 **	-69.08**	-46.19 **	-29.69**	-47.74 **	-52.41**
12	V-193 x DARAL-43	-71.26 **	-82.08**	-60.00 **	-47.75**	-64.59 **	-67.75**
13	V-198 x Kashi Mayuri	0.88	109.79**	4.43 **	216.14**	-1.97 *	154.67**
14	V-198 x Arka Harit	-90.38 **	-80.01**	-83.38 **	-45.02**	-86.60 **	-65.19**
15	V-198 x DARAL-43	1.36	110.78**	3.98 **	217.65**	-1.48	155.94**
16	V-158 x Kashi Mayuri	11.02 **	-15.97**	-4.07	43.15**	2.27	8.95**
17	V-158 x Arka Harit	-81.19 **	-87.23**	-67.19 **	-54.48**	-72.78 **	-73.46**
18	V-158 x DARAL-43	-45.93 **	-63.31**	-43.50 **	-21.60**	-44.40 **	-45.76**
19	V-26 x Kashi Mayuri	1.92	95.07**	-3.94 *	195.75**	-1.24	137.62**
20	V-26 x Arka Harit	-23.85 **	45.75**	-45.78 **	66.92**	-35.77 **	54.54**
21	V-26 x DARAL-43	14.04 **	118.26**	13.64 **	165.91**	-0.89	138.47**
22	V-169 x Kashi Mayuri	168.40 **	103.17**	44.41 **	115.48**	95.60 **	108.35**
23	V-169 x Arka Harit	277.18 **	96.65**	115.90 **	151.90**	177.10 **	119.98**
24	V-169 x DARAL-43	266.12 **	90.91**	136.27 **	175.67**	185.33 **	126.54**
25	NDBG-8 x Kashi Mayuri	-32.05 **	10.53**	-38.61 **	64.90**	-35.64 **	33.36**
26	NDBG-8 x Arka Harit	25.49 **	104.16**	-7.91 **	147.34**	7.27 **	122.28**
27	NDBG-8 x DARAL-43	-16.21 **	36.29**	-28.88 **	91.05**	-23.03 **	59.48**
28	NDBG-9 x Kashi Mayuri	49.52 **	72.25**	-3.15	96.91**	19.96 **	82.66**
29	NDBG-9 x Arka Harit	78.27 **	105.37**	13.85 **	131.51**	42.16 **	116.45**
30	NDBG-9 x DARAL-43	13.95 **	31.28**	-0.08	103.19**	6.16 **	61.61**
No. of crosses with significant (-) heterosis		14	12	18	9	17	11
No. of crosses with significant (+) heterosis		11	18	9	20	8	18
Range		-96.52 to 277.18	-94.22 to 118.26	-95.36 to 136.27	-87.35 to 222.05	-95.89 to 185.33	-91.35 to 159.78

Table- 4.7: Contd.....

SN	Hybrids	Total Sugar (%)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-33.21 **	1.96	-50.37 **	17.69**	-42.69 **	8.87**
2	Sel-1 x Arka Harit	-74.10 **	-60.46**	-82.62 **	-58.78**	-78.82 **	-59.76**
3	Sel-1 x DARAL-43	-70.65 **	-55.19**	-83.75 **	-61.44**	-77.87 **	-57.95**
4	V-21-14 x Kashi Mayuri	-31.80 **	5.27*	-55.51 **	6.50**	-44.87 **	5.81**
5	V-21-14 x Arka Harit	-71.52 **	-56.04**	-88.01 **	-71.30**	-80.63 **	-62.82**
6	V-21-14 x DARAL-43	-65.51 **	-46.77**	-84.60 **	-63.15**	-76.05 **	-54.05**
7	V-65-1 x Kashi Mayuri	0.24	131.16**	-2.51 **	227.47**	-1.22 *	173.65**
8	V-65-1 x Arka Harit	1.58	134.25**	-1.37	231.28**	0.03	177.11**
9	V-65-1 x DARAL-43	-61.27 **	-10.68**	-55.87 **	48.23**	-58.38 **	15.29**
10	V-193 x Kashi Mayuri	24.84 **	20.35**	12.90 **	87.32**	17.89 **	49.88**
11	V-193 x Arka Harit	-48.36 **	-50.22**	-40.95 **	-2.03	-44.05 **	-28.87**
12	V-193 x DARAL-43	-58.56 **	-60.04**	-48.55 **	-14.65**	-52.81 **	-40.00**
13	V-198 x Kashi Mayuri	-0.44	120.08**	3.13 **	213.54**	-1.88 **	161.34**
14	V-198 x Arka Harit	-73.73 **	-41.92**	-66.52 **	8.37**	-69.85 **	-19.69**
15	V-198 x DARAL-43	1.24	123.78**	-1.65	218.33**	-0.32	165.48**
16	V-158 x Kashi Mayuri	-26.97 **	-23.95**	-25.49 **	31.10**	-26.15 **	0.31
17	V-158 x Arka Harit	-57.18 **	-55.40**	-48.01 **	-8.53**	-51.91 **	-34.66**
18	V-158 x DARAL-43	-56.37 **	-54.56**	-47.40 **	-7.46**	-51.21 **	-33.72**
19	V-26 x Kashi Mayuri	3.17 **	112.83**	-0.26	204.29**	1.32	153.18**
20	V-26 x Arka Harit	-48.94 **	5.33*	-64.31 **	8.90**	-57.19 **	6.99**
21	V-26 x DARAL-43	-26.86 **	50.90**	-45.50 **	66.27**	-36.91 **	57.65**
22	V-169 x Kashi Mayuri	51.17 **	36.30**	16.56 **	31.97**	11.74 **	34.35**
23	V-169 x Arka Harit	61.76 **	45.84**	6.18 **	67.95**	29.48 **	55.69**
24	V-169 x DARAL-43	51.48 **	36.57**	9.32 **	72.93**	26.94 **	52.64**
25	NDBG-8 x Kashi Mayuri	-36.59 **	-8.36**	-48.90 **	15.91**	-43.39 **	2.42
26	NDBG-8 x Arka Harit	0.97	45.92**	-29.40 **	60.14**	15.91 **	52.16**
27	NDBG-8 x DARAL-43	-21.33 **	13.69**	-38.72 **	39.01**	-30.99 **	24.87**
28	NDBG-9 x Kashi Mayuri	9.53 **	34.76**	28.56 **	42.63**	-11.95 **	38.12**
29	NDBG-9 x Arka Harit	29.22 **	58.98**	16.01 **	67.68**	3.80 **	62.82**
30	NDBG-9 x DARAL-43	-13.64 **	6.24*	-30.07 **	39.62**	-22.90 **	20.94**
No. of crosses with significant (-) heterosis		18	12	20	7	21	9
No. of crosses with significant (+) heterosis		7	17	7	22	6	19
Range		-74.10 to 61.76	-60.46 to 134.25	-88.01 to 28.56	-71.30 to 231.28	-80.63 to 29.48	-62.82 to 177.11

Table- 4.7: Contd.....

SN	Hybrids	Dry matter (%)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	-6.81 **	-6.00**	-21.69 **	-4.17*	-14.58 **	-5.14*
2	Sel-1 x Arka Harit	-12.85 **	-12.09**	-27.19 **	-10.91**	-20.33 **	-11.53**
3	Sel-1 x DARAL-43	-11.22 **	-10.44**	-25.71 **	-9.08**	-18.78 **	-9.81**
4	V-21-14 x Kashi Mayuri	-12.67 **	-11.23**	-17.22 **	-9.95**	-14.96 **	-10.66**
5	V-21-14 x Arka Harit	-9.47 **	-7.97**	-13.92 **	-6.35**	-11.67 **	-7.22**
6	V-21-14 x DARAL-43	-14.00 **	-12.59**	-18.60 **	-11.46**	-16.32 **	-12.09**
7	V-65-1 x Kashi Mayuri	-0.07	22.88**	13.39 **	47.82**	6.52 **	34.72**
8	V-65-1 x Arka Harit	-0.57	22.26**	9.87 **	43.23**	4.47 **	32.12**
9	V-65-1 x DARAL-43	-19.04 **	-0.44	-9.55 **	17.92**	-14.41 **	8.25**
10	V-193 x Kashi Mayuri	-4.54 *	-9.21**	1.97	8.18**	0.70	-0.95
11	V-193 x Arka Harit	12.59 **	4.12*	15.90 **	22.96**	14.93 **	13.04**
12	V-193 x DARAL-43	12.02 **	2.34	14.05 **	21.00**	13.04 **	11.18**
13	V-198 x Kashi Mayuri	2.95	20.66**	13.26 **	42.10**	7.99 **	30.79**
14	V-198 x Arka Harit	-22.78 **	-9.50**	-14.20 **	7.64**	-18.61 **	-1.42
15	V-198 x DARAL-43	0.32	17.57**	2.17	28.19**	1.21	22.58**
16	V-158 x Kashi Mayuri	-10.55 **	-9.70**	-17.06 **	-4.77*	-13.90 **	-7.42**
17	V-158 x Arka Harit	-9.62 **	-8.76**	-19.44 **	-7.50**	-14.66 **	-8.25**
18	V-158 x DARAL-43	-12.67 **	-11.85**	-7.36 **	6.37**	-10.00 **	-3.24
19	V-26 x Kashi Mayuri	-1.63	11.90**	-7.65 **	23.41**	-4.73 **	17.32**
20	V-26 x Arka Harit	-22.89 **	-12.29**	-35.34 **	-13.58**	-29.31 **	-12.95**
21	V-26 x DARAL-43	-21.63 **	-10.86**	-34.15 **	-12.00**	-28.09 **	-11.44**
22	V-169 x Kashi Mayuri	-6.27 **	-10.86**	-20.56 **	-12.00**	-10.98 **	-11.44**
23	V-169 x Arka Harit	-1.87	-9.26**	-18.96 **	-10.23**	-9.29 **	-9.75**
24	V-169 x DARAL-43	16.04 **	3.58*	-6.16 **	3.95*	4.25 **	3.72
25	NDBG-8 x Kashi Mayuri	4.93 *	-0.20	10.22 **	-0.22	-0.09	-0.26
26	NDBG-8 x Arka Harit	9.07 **	0.86	-9.16 **	0.95	1.08	0.91
27	NDBG-8 x DARAL-43	22.49 **	9.80**	-0.29	10.83**	10.42 **	10.23**
28	NDBG-9 x Kashi Mayuri	9.86 **	4.49*	-4.86 *	4.91*	5.76 **	4.70*
29	NDBG-9 x Arka Harit	8.41 **	0.25	9.07 **	0.27	1.26	0.26
30	NDBG-9 x DARAL-43	3.29	-8.27**	17.60 **	-9.14**	-7.76 **	-8.68**
No. of crosses with significant (-) heterosis		15	15	19	13	17	13
No. of crosses with significant (+) heterosis		8	9	8	14	8	10
Range		-22.89 to 22.49	-12.59 to 22.88	-35.34 to 17.60	-13.58 to 47.82	-29.31 to 14.93	-12.95 to 34.72

Table- 4.7: Contd.....

SN	Hybrids	Fruit yield per plant (kg)					
		Y ₁		Y ₂		Pooled	
		BP	SV	BP	SV	BP	SV
1	Sel-1 x Kashi Mayuri	38.68 **	-24.73**	10.99	-51.78**	26.00 **	38.83**
2	Sel-1 x Arka Harit	62.50 **	-31.23**	-12.55	-63.48**	24.03 **	-48.20**
3	Sel-1 x DARAL-43	89.84 **	-17.05**	20.30 *	-49.75**	57.36 **	34.32**
4	V-21-14 x Kashi Mayuri	36.48 **	-25.91**	-10.75	-57.79**	18.00 **	42.72**
5	V-21-14 x Arka Harit	5.63	-48.80**	-50.81 **	-76.75**	-23.65 **	-63.45**
6	V-21-14 x DARAL-43	27.82 **	-38.04**	-31.27 **	-67.50**	-3.04	-53.54**
7	V-65-1 x Kashi Mayuri	49.84 **	61.65**	-0.24	26.21**	21.63 **	42.86**
8	V-65-1 x Arka Harit	50.32 **	62.16**	0.12	26.68**	22.04 **	43.35**
9	V-65-1 x DARAL-43	-9.02 **	-1.84	-46.53 **	-32.36**	-30.17 **	-17.96**
10	V-193 x Kashi Mayuri	-28.83 **	-53.25**	-68.95 **	-80.44**	-49.24 **	-67.48**
11	V-193 x Arka Harit	-1.30	-35.13**	-40.34 **	-62.41**	-21.46 **	-49.66**
12	V-193 x DARAL-43	-0.78	-34.82**	-39.36 **	-61.77**	-20.45 **	-49.03**
13	V-198 x Kashi Mayuri	47.95 **	54.28**	6.58 *	27.28**	25.00 **	39.95**
14	V-198 x Arka Harit	16.37 **	21.35**	-19.35 **	-3.70	-3.32	8.25**
15	V-198 x DARAL-43	48.45 **	54.79**	7.35 *	28.20**	25.58 **	40.63**
16	V-158 x Kashi Mayuri	51.89 **	-17.56**	14.58 *	-40.68**	33.23 **	-29.95**
17	V-158 x Arka Harit	108.95 **	11.62**	66.96 **	13.55**	86.77 **	-1.80
18	V-158 x DARAL-43	61.34 **	-13.82**	20.24 **	37.73**	40.00 **	-26.36**
19	V-26 x Kashi Mayuri	49.05 **	46.80**	7.29 *	20.20**	25.96 **	32.67**
20	V-26 x Arka Harit	-8.84 **	-10.24**	-40.72 **	-33.56**	-26.57 **	-22.67**
21	V-26 x DARAL-43	-3.64	-5.12*	-36.59 **	28.94**	-21.81 **	-17.62**
22	V-169 x Kashi Mayuri	96.54 **	6.66*	92.91 **	16.18**	95.00 **	-5.34*
23	V-169 x Arka Harit	51.64 **	-28.83**	16.48	-52.06**	34.81 **	-41.12**
24	V-169 x DARAL-43	61.45 **	-24.22**	29.96 **	-46.51**	46.67 **	-35.92**
25	NDBG-8 x Kashi Mayuri	-6.67	-28.32**	-26.87 **	-51.78**	-16.17 **	-40.44**
26	NDBG-8 x Arka Harit	8.89 *	-16.39**	-10.28	-40.82**	-0.46	-29.27**
27	NDBG-8 x DARAL-43	32.00 **	1.38	16.59 **	-23.12**	24.37 **	-11.65**
28	NDBG-9 x Kashi Mayuri	-25.75 **	-28.16**	-43.65 **	-51.46**	-34.75 **	-40.44**
29	NDBG-9 x Arka Harit	-20.11 **	-22.68**	-37.21 **	-45.91**	-28.72 **	-34.95**
30	NDBG-9 x DARAL-43	-27.51 **	-29.85**	-45.62 **	-53.17**	-36.52 **	-42.09**
No. of crosses with significant (-) heterosis		6	20	13	20	11	20
No. of crosses with significant (+) heterosis		19	8	10	9	16	9
Range		-28.83 to 108.95	-53.25 to 62.16	-68.95 to 92.91	-80.44 to 37.73	-49.24 to 95.00	-67.48 to 43.35

underscores the need for careful parental selection. These results collectively demonstrate that strategic exploitation of heterosis through crosses like V-158 × Arka Harit (yield) and V-65-1 based hybrids (earliness/quality) can significantly advance bitter gourd breeding program.

4.1 Morphological character of different genotype and their crosses

Among the ten lines, three tester and their hybrids, significant variation was observed for all the important characters. The states of expression of a particular trait along with example varieties of bitter gourd are presented in Table 4.8. Among the morphological traits, identified 10 traits as grouping traits, *viz.* Fruit colour, fruit shape, fruit tubercules, fruit ridge, peduncle length, flower colour, leaf blade length, leaf blade width, Leaf blade number of lobes and petiole length at commercial maturity (marketable stage). In the present study, All the varieties monoecious sex expression with fertile pollens. The male sterility and parthenocarpy was found absent in all the varieties. On the basis of growth habit, bitter gourd varieties have been grouped in three categories *viz.* Determinate, Intermediate and Indeterminate, all the varieties expressed indeterminate growth habit.

In the present study, morphological variation was assessed among thirteen parental lines and thirty F₁ hybrids, including a bitter gourd check. Fruit colour segregated into thirteen whitish-green, fourteen light-green and sixteen dark-green genotypes. Fruit shape varied, with ten cylindrical, fifteen oblong and nineteen spindle-shaped fruits. Fruit tuberculation exhibited four patterns: two genotypes lacked tubercules, while fifteen had moderate density, fourteen were dense and thirteen displayed sparse tubercules. Fruit ridges were either continuous (nineteen genotypes) and discontinuous (twenty-five genotypes). Peduncle length varied, with eleven large, twenty-six medium and seven short types. All genotypes exhibited yellow flower colour. For leaf traits, blade length was categorized as short (fourteen), medium (eighteen) and long (eleven), while blade width was either long (six) and medium (thirty-seven). The number of leaf lobes included five–seven (fourteen genotypes), six–eight (ten genotypes) and nine–six (eight genotypes). Petiole length showed variation, with seventeen short, eighteen medium and eight long types. These findings highlight the phenotypic diversity among bitter gourd genotypes, providing valuable insights for breeding programs. The studies of Rahman *et al.* (2021), Islam *et al.* (2014) and Rathod *et al.* (2008) also described the variability in bitter gourd in respect of morphological, yield and yield contributing traits. It is also suggested that a periodical review of all varieties

be undertaken at all the DUS test centres to validate the set of varieties. Bitter gourd being highly cross-pollinated crop a strict maintenance breeding of the reference varieties, including the example varieties and use of alternate example varieties for conduct of DUS testing in bitter gourd, if needed, are also suggested. The varieties characterized for DUS were grouped into different categories for each character which could be used as reference varieties. These varieties can be used in the varietal improvement programme of muskmelon for desirable traits. Genetic improvement of desirable varieties can also be done through gene combinations from unadopted sources having resistance against biotic and abiotic stresses. These test guidelines apply to all varieties, hybrids and parental lines of bitter gourd. It is concluded that the developed DUS descriptors can be effectively used for identification and grouping of varieties and comparing candidate varieties for registration under PPV&FR Act to protect the right of farmers and plant breeders.

Table 4.8: Characterization of bitter gourd genotypes

Genotypes	Fruit: colour	Fruit: Shape	Fruit: tubercles	Fruit: ridge	Peduncle length (cm)	Flower colour	Leaf blade: length	Leaf blade: width	Leaf blade: no. of lobes	Petiole: length
Sel-1	Whitish green	Spindle-shaped (fusiform)	Absent	Discontinuous	5-7 (Medium)	Yellow	4-8 (Short)	7-10 (Medium)	5-7	5-7 (Short)
V-21-14	Light green	Cylindrical	Moderate	Continuous	6-8 (Medium)	Yellow	6-9 (Medium)	8-11 (Medium)	6-8	6-8 (Medium)
V-65-1	Dark green	Oblong	Dense	Discontinuous	5-9 (Medium)	Yellow	5-9 (Medium)	7-11 (Medium)	5-7	5-7 (Short)
V-193	Light green	Spindle-shaped	Sparse	Continuous	6-9 (Medium)	Yellow	7-10 (Medium)	8-12 (Medium)	6-8	6-8 (Medium)
V-198	Dark green	Cylindrical	Moderate	Discontinuous	5-8 (Medium)	Yellow	6-9 (Medium)	7-10 (Medium)	5-7	5-7 (Short)
V-158	Whitish green	Spindle-shaped	Sparse	Continuous	5-9 (Medium)	Yellow	5-8 (Short)	7-11 (Medium)	5-7	5-7 (Short)
V-26	Light green	Oblong	Dense	Discontinuous	6-8 (Medium)	Yellow	6-9 (Medium)	8-12 (Medium)	6-8	6-8 (Medium)
V-169	Dark green	Cylindrical	Moderate	Continuous	5-7 (Medium)	Yellow	7-10 (Medium)	8-12 (Medium)	6-8	6-8 (Medium)
NDBG-8	Dark green	Spindle-shaped	Dense	Discontinuous	5-9 (Medium)	Yellow	5-8 (Short)	7-11 (Medium)	5-7	5-7 (Short)
NDBG-9	Whitish green	Cylindrical	Sparse	Continuous	6-8 (Medium)	Yellow	6-9 (Medium)	8-12 (Medium)	6-8	6-8 (Medium)
Kashi Mayuri	Light green	Spindle-shaped (fusiform)	Moderate	Continuous	5-10 (Medium)	Yellow	7-10 (Medium)	8-12 (Medium)	6-8	7-9 (Medium)
Arka Harit	Light green	Spindle-shaped	Absent	Continuous	6-8 (Medium)	Yellow	7-10 (Medium)	8-12 (Medium)	6-8	6-8 (Medium)
DARAL-43	Dark green	Cylindrical	Moderate	Discontinuous	5-9 (Medium)	Yellow	6-9 (Medium)	8-12 (Medium)	6-8	6-8 (Medium)
Sel-1 x Kashi Mayuri	Dark green	Oblong	Dense	Discontinuous	5-9 (Medium)	Yellow	7-13 (Long)	8-12 (Medium)	5-7	7-11 (Long)
Sel-1 x Arka Harit	Light green	Spindle-shaped	Sparse	Discontinuous	8-12 (Long)	Yellow	5-8 (Short)	8-12 (Medium)	5-6	5-7 (Short)
Sel-1 x DARAL-43	Light green	Oblong	Moderate	Discontinuous	5-9 (Medium)	Yellow	6-11 (Medium)	9-14 (Long)	5-7	5-7 (Short)
V-21-14 x Kashi Mayuri	Whitish green	Cylindrical	Sparse	Discontinuous	4-6 (Short)	Yellow	6-11 (Medium)	8-12 (Medium)	6-9	6-9 (Medium)
V-21-14 x Arka Harit	Whitish green	Spindle-shaped	Moderate	Continuous	4-6 (Short)	Yellow	7-13 (Long)	6-9 (Medium)	6-9	6-9 (Medium)
V-21-14 x DARAL-43	Light green	Oblong	Sparse	Discontinuous	5-9 (Medium)	Yellow	7-13 (Long)	8-12 (Medium)	5-6	7-11 (Long)
V-65-1 x Kashi Mayuri	Whitish green	Spindle-shaped	Dense	Continuous	4-6 (Short)	Yellow	7-13 (Long)	6-9 (Medium)	5-7	5-7 (Short)
V-65-1 x Arka Harit	Light green	Cylindrical	Sparse	Discontinuous	5-9 (Medium)	Yellow	6-11 (Medium)	8-12 (Medium)	5-6	6-9 (Medium)
V-65-1 x DARAL-43	Whitish green	Spindle-shaped	Sparse	Continuous	5-9 (Medium)	Yellow	6-11 (Medium)	9-14 (Long)	5-7	4-6 (Short)
V-193 x Kashi Mayuri	Whitish green	Spindle-shaped	Moderate	Discontinuous	8-12 (Long)	Yellow	5-8 (Short)	7-12 (Medium)	6-9	4-6 (Short)
V-193 x Arka Harit	Dark green	Spindle-shaped	Dense	Discontinuous	5-9 (Medium)	Yellow	7-13 (Long)	6-9 (Medium)	6-9	6-9 (Medium)
V-193 x DARAL-43	Whitish green	Oblong	Dense	Discontinuous	5-9 (Medium)	Yellow	7-13 (Long)	8-12 (Medium)	5-7	7-11 (Long)
V-198 x Kashi Mayuri	Whitish green	Oblong	Sparse	Continuous	7-11 (Long)	Yellow	5-8 (Short)	8-12 (Medium)	5-7	4-6 (Short)

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V-198 x Arka Harit	Dark green	Spindle-shaped	Moderate	Continuous	5-9 (Medium)	Yellow	5-8 (Short)	6-9 (Medium)	5-6	6-9 (Medium)
V-198 x DARAL-43	Dark green	Spindle-shaped	Moderate	Continuous	8-12 (Long)	Yellow	7-13 (Long)	7-12 (Medium)	5-7	5-7 (Short)
V-158 x Kashi Mayuri	Dark green	Cylindrical	Sparse	Continuous	5-9 (Medium)	Yellow	7-13 (Long)	8-12 (Medium)	5-8	7-11 (Long)
V-158 x Arka Harit	Light green	Oblong	Dense	Discontinuous	5-9 (Medium)	Yellow	6-11 (Medium)	9-14 (Long)	5-7	5-7 (Short)
V-158 x DARAL-43	Dark green	Oblong	Moderate	Continuous	5-9 (Medium)	Yellow	5-8 (Short)	9-14 (Long)	6-9	6-9 (Medium)
V-26 x Kashi Mayuri	Light green	Oblong	Dense	Continuous	7-11 (Long)	Yellow	5-8 (Short)	6-9 (Medium)	5-8	7-11 (Long)
V-26 x Arka Harit	Light green	Spindle-shaped	Moderate	Continuous	8-12 (Long)	Yellow	7-13 (Long)	8-12 (Medium)	6-9	7-11 (Long)
V-26 x DARAL-43	Whitish green	Spindle-shaped	Moderate	Continuous	7-11 (Long)	Yellow	5-8 (Short)	9-14 (Long)	6-8	5-7 (Short)
V-169 x Kashi Mayuri	Dark green	Oblong	Dense	Discontinuous	8-12 (Long)	Yellow	5-8 (Short)	8-12 (Medium)	5-6	5-7 (Short)
V-169 x Arka Harit	Dark green	Oblong	Sparse	Discontinuous	5-9 (Medium)	Yellow	6-11 (Medium)	8-12 (Medium)	5-7	7-11 (Long)
V-169 x DARAL-43	Whitish green	Oblong	Sparse	Discontinuous	4-6 (Short)	Yellow	5-8 (Short)	6-9 (Medium)	5-6	4-6 (Short)
NDBG-8 x Kashi Mayuri	Dark green	Cylindrical	Sparse	Discontinuous	7-11 (Long)	Yellow	7-13 (Long)	7-12 (Medium)	5-7	5-7 (Short)
NDBG-8 x Arka Harit	Light green	Spindle-shaped	Dense	Discontinuous	4-6 (Short)	Yellow	5-8 (Short)	8-12 (Medium)	6-9	6-9 (Medium)
NDBG-8 x DARAL-43	Dark green	Oblong	Dense	Discontinuous	4-6 (Short)	Yellow	5-8 (Short)	8-12 (Medium)	6-9	6-9 (Medium)
NDBG-9 x Kashi Mayuri	Dark green	Spindle-shaped	Moderate	Continuous	5-9 (Medium)	Yellow	6-11 (Medium)	6-9 (Medium)	5-6	6-9 (Medium)
NDBG-9 x Arka Harit	Whitish green	Cylindrical	Dense	Discontinuous	4-6 (Short)	Yellow	7-13 (Long)	9-14 (Long)	5-7	7-11 (Long)
NDBG-9 x DARAL-43	Light green	Spindle-shaped	Dense	Discontinuous	8-12 (Long)	Yellow	6-11 (Medium)	7-12 (Medium)	6-8	6-9 (Medium)
VNR Navdhan (check variety)	Whitish green	Oblong	Moderate	Discontinuous	4-6 (Long)	Yellow	5-8 (Long)	6-9 (Short)	5-7	4-6 (Short)

SUMMARY AND CONCLUSION

The present research work entitled “**Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)**” was conducted during *Zaid* seasons of 2023-24 (Y₁) and 2024-25 (Y₂) at the Main Experiment Station (MES) of the Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) India.

The present experiments were conducted in a Randomized Block Design (RBD) with three replications to appraise the performance of 30 F₁ hybrids and their 13 parents (10 lines and 3 testers). The crop was sown in rows spaced at 3 meters apart with a plant to plant spacing of 0.50 meter. Sowing was done on 12 February, 2023-24 and 10 February, 2024-25. All the recommended agronomic package of practices and protection measures were followed to raise good crops.

The experimental materials for the present investigation comprised of ten promising and diverse pure lines/varieties with three testers of bitter gourd selected on the basis of genetic variability from the germplasm stock maintained in the Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.) India. The selected parental lines *i.e.*; Sel-1 (L₁), V-21-14 (L₂), V-65-1 (L₃), V-193 (L₄), V-198 (L₅), V-158 (L₆), V-26 (L₇), V-169 (L₈), NDBG-8 (L₉), NDBG-9 (L₁₀) and testers Kashi Mayuri (T₁), Arka Harit (T₂), DARAL-43 (T₃) were crossed in the all possible combination to get 30 F₁ seed for the study of heterobeltiosis and standard heterosis, combining ability effects, gene action and heritability in narrow sense and genetic advance as per cent of mean among F₁'s and parents for fruit yield and quality attributing traits.

The data were recorded on twelve quantitative and six qualitative traits viz., days to first staminate flower anthesis, days to first pistillate flower anthesis, node number to first staminate flower appearance, node number to first pistillate flower appearance, vine length(m), number of primary branches per plant, fruit length(cm), fruit circumference(cm), fruit weight, number of fruits per plant, days to first harvest, fruit yield per plant and

quality/biochemical traits namely total soluble solids (%), ascorbic acid, reducing sugar (%), non-reducing sugar (%), total sugar, dry matter (%).

- The analysis of variance revealed that mean squares due to genotypes were found significant for all the traits in the both seasons (Y₁, Y₂) and (Pooled).
- The proportional contribution of lines in pooled varied from 28.44 per cent (vine length) to 76.89 per cent (Total soluble solids (%)). The maximum five contribution of lines were observed for total soluble solids (76.89) followed by Fruit yield per plant (76.42), Fruit weight (75.40), Number of fruits per plant (70.80) and Reducing Sugar (56.58).
- The proportional contribution of tester in pooled varied from 0.46 per cent (fruit weight) to 21.08 per cent (Ascorbic acid). The maximum five contribution of tester were observed for Ascorbic acid (21.08) followed by Days to first staminate flower anthesis (20.03), number of primary branches per plant (16.41), days to first harvest (14.02), Vine length (12.35).
- The proportional contribution of line x tester in pooled varied from 20.47 per cent (TSS) to 59.21 per cent (Vine length). The maximum five contribution of lines were observed for Vine length (59.21) followed by Days to first pistillate flower anthesis (58.41), days to first harvest (54.11), Node number to first staminate flower appearance (53.61), Node number to first pistillate flower appearance (50.43).
- In case of pooled, estimates of sca variances were higher than gca variances for all the characters.

The value of average degree of dominance were more than unity (1) for all the traits which revealed over dominance.

- The magnitude of over dominance were highest for Vine length (13.46), Days to first pistillate flower anthesis (11.02), Node number to first staminate flower appearance (7.31), Days to first harvest (7.02), Node number to first pistillate flower appearance (6.08), Fruit length (5.87), Days to first staminate flower anthesis (5.01), Fruit circumference (4.50), Ascorbic acid (3.49), Non-reducing Sugar (3.27), Total Sugar (3.13), Dry matter (3.13), Reducing Sugar (2.79), Number of primary branches per plant (2.77), Number of fruits per plant (2.66), Fruit weight (2.35), Fruit yield per plant (2.18) and Total soluble solids (2.09).

- The general predictability ratio was less than one for all the characters. σ^2A were lower than σ^2D for the all characters.
- Analysis of variances for combining ability revealed that the partitioning of variances due to crosses, lines, tester and lines \times testers showed highly significant differences for all the eighteen characters in both Y_1 , Y_2 and pooled.
- Based on gca effects of the parents, among the ten female parents, the parents V-65-1(L₃), and V-198 (L₅) could be adjudged as the ideal donors for yield. Besides V-198(L₅), V-65-1(L₃), V-26(L₇), V-158 (L₆) served as the best parents for earliness.
- Regarding the quality parameter V-193, V-21-14, Sel-1 could be adjudged as the best parents based on gca as they were good combiners for total soluble solids, V-65-1, V-198, V-158, V-26 for ascorbic acid, V-65-1, V-198, V-26 for reducing sugars, V-169, V-26, V-65-1, NDBG-9 for non-reducing, V-65-1, V-198, V-26, V-169 for total sugar, V-65-1, V-198 for dry matter while, tester Arka Harit and DARAL-43 were found good general combiner for total soluble solids and Kashi Mayuri was found good general combiner for rest of quality parameters.
- On basis of above result and discussion it might be very safely concluded that crosses namely V-26 x Kashi Mayuri, V-65-1 x Arka Harit, V-158 x Arka Harit, NDBG-9 x DARAL-43 and V-198 x DARAL-43 were found as best specific combiners for fruit yield per plant while V-169 x Kashi Mayuri found best cross for earliness during over season pooled could be exploit in future breeding programme of bitter gourd improvement.
- Significant heterosis over better and standard variety were observed for all the traits during both the seasons and over seasons (pooled).
- Heterosis over better and standard parents for fruit yield per plant, ranged from -28.83 (V-193 x Kashi Mayuri) to 108.95 % (V-158 x Arka Harit) and -53.25 (V-193 x Kashi Mayuri) to 62.16 % (V-65-1 x Arka Harit) in 2023-24 (Y₁), -68.95 (V-193 x Kashi Mayuri) to 92.91 % (V-169 x Kashi Mayuri) and -80.44 (V-193 x Kashi Mayuri) to 37.73 % (V-158 x DARAL-43) -68.95 (V-193 x Kashi Mayuri) to 92.91 % (V-169 x Kashi Mayuri) over better parent while, for standard heterosis it varied from -80.44 (V-193 x Kashi Mayuri) to 37.73 % (V-158 x DARAL-43) and -49.24 (V-193 x Kashi

Mayuri) to 95.00 % (V-169 x Kashi Mayuri) -67.48 (V-193 x Kashi Mayuri) to 43.35 % (V-65-1 x Arka Harit) in pooled, respectively.

- The best crosses showing positive and significant heterosis over better parent for fruit yield per plant were V-158 x Arka Harit (108.95) followed by V-169 x Kashi Mayuri (96.54), Sel-1 x DARAL-43 (89.84), Sel-1 x Arka Harit (62.50) and V-169 x DARAL-43 (61.45) in Y1, V-169 x Kashi Mayuri (92.91) followed by V-158 x Arka Harit (66.96), V-169 x DARAL-43 (29.96), Sel-1 x DARAL-43 (20.30) and V-158 x DARAL-43 (20.24) in Y2 and V-169 x Kashi Mayuri (95.00) followed by V-158 x Arka Harit (86.77), Sel-1 x DARAL-43 (57.36), V-169 x DARAL-43 (46.67) and V-158 x DARAL-43 (40.00) in over season pooled.
- The best crosses showing positive and significant heterosis over standard variety for total fruit yield per plant were V-65-1 x Arka Harit (62.16) followed by V-65-1 x Kashi Mayuri (61.65), V-198 x DARAL-43 (54.79), V-198 x Kashi Mayuri (54.28) and V-26 x Kashi Mayuri (46.80) in Y1, V-158 x DARAL-43 (37.73) followed by V-26 x DARAL-43 (28.94), V-198 x DARAL-43 (28.20), V-198 x Kashi Mayuri (27.28) and V-65-1 x Arka Harit (26.68) in Y2 and V-65-1 x Arka Harit (43.35) followed by V-65-1 x Kashi Mayuri (42.86), V-21-14 x Kashi Mayuri (42.72), V-198 x DARAL-43 (40.63) and V-198 x Kashi Mayuri (39.95) in over season pooled.
- Based on the above findings it might be concluded that crosses V-198 x DARAL-43, V-198 x Kashi Mayuri and V-65-1 x Arka Harit with high standard heterosis may be exploited as commercial hybrids after multi-location testing.
- Selecting bitter melon based on morphological traits like fruit shape, size, and texture enhances the effectiveness of hybridization. These visible differences reflect genetic variation and support efficient hybrid development, leading to improved varieties with better yield, resistance, and adaptability for future crop improvement programs.

Based on the above findings it may be suggested that crosses V-198 x DARAL-43, V-198 x Kashi Mayuri and V-65-1 x Arka Harit are the top most hybrids in order of merit for yield potentiality and can also be commercially exploited. It is suggested to test the superior hybrids in multilocation trial to confirm their potentiality and stability over different agro climatic conditions. Selected parents with desirable per se and combining

ability effect can be used in multiple crossing schemes to recombine different productive components. Parents V-65-1(L₃), V-26(L₇), V-198 (L₅) and Kashi Mayuri (T₁) were found as good general combiners for fruit yield per plant can be constituted to create a promising gene pool for future breeding programmes as these lines and testers are good general combiners over all traits studied.

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Appendices

Mean performance for parents and hybrids

S. No.	Parent/Hybrids	Days to first staminate flower anthesis			Days to first pistillate flower anthesis			Node number to first staminate flower appearance			Node number to first pistillate flower appearance			Vine length (m)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
Parents																
1	Sel-1(L ₁)	54.67	57.00	55.83	57.33	63.33	60.33	3.57	5.83	4.70	8.49	9.72	9.11	2.87	3.15	3.01
2	V-21-14(L ₂)	59.33	56.33	57.83	63.33	62.33	62.83	3.23	5.67	4.45	7.48	8.90	8.19	3.09	3.82	3.46
3	V-65-1(L ₃)	51.33	58.67	55.00	57.00	64.33	60.67	3.50	5.83	4.67	4.65	6.70	5.67	3.30	3.14	3.22
4	V-193(L ₄)	60.67	62.67	61.67	67.00	69.00	68.00	2.92	4.90	3.91	5.43	6.66	6.05	2.20	2.48	2.34
5	V-198(L ₅)	55.00	55.67	55.33	60.00	62.00	61.00	4.58	6.47	5.53	5.60	6.83	6.22	3.56	3.85	3.71
6	V-158(L ₆)	59.00	61.33	60.17	65.67	68.00	66.83	3.10	5.83	4.47	8.16	9.39	8.77	3.06	3.35	3.21
7	V-26(L ₇)	54.67	56.33	55.50	61.67	62.67	62.17	4.50	6.90	5.70	6.29	7.52	6.90	3.45	3.73	3.59
8	V-169(L ₈)	60.00	58.00	59.00	64.33	64.33	64.33	3.04	5.90	4.47	11.66	12.90	12.28	2.60	2.88	2.74
9	NDBG-8 (L ₉)	63.00	61.67	62.33	67.33	68.00	67.67	3.00	6.00	4.50	9.92	11.15	10.54	2.65	2.93	2.79
10	NDBG-9 (L ₁₀)	62.00	62.17	62.08	66.00	68.50	67.25	2.48	6.50	4.49	7.69	9.59	8.64	2.43	2.79	2.61
11	Kashi Mayuri(T ₁)	60.00	60.17	60.08	65.33	66.50	65.92	3.48	7.07	5.28	7.36	8.59	7.97	2.25	2.87	2.56
12	Arka Harit(T ₂)	62.00	62.17	62.08	66.67	68.50	67.58	4.50	7.67	6.08	8.49	9.72	9.11	2.30	3.08	2.69
13	DARAL-43(T ₃)	61.33	62.83	62.08	67.67	72.67	70.17	3.25	5.70	4.48	9.63	10.87	10.25	2.23	2.51	2.37
	Mean	58.69	59.62	59.15	63.79	66.17	64.98	3.47	6.17	4.83	7.76	9.12	8.44	2.77	3.12	2.95
	Min	51.33	55.67	55.00	57.00	62.00	60.33	2.48	4.90	3.91	4.65	6.66	5.67	2.20	2.48	2.34
	Max	63.00	62.83	62.33	67.67	72.67	70.17	4.58	7.67	6.08	11.66	12.90	12.28	3.56	3.85	3.71
Hybrids																
14	Sel-1 x Kashi Mayuri	63.33	64.17	63.75	70.67	72.83	71.75	3.21	6.20	4.71	7.55	8.78	8.16	2.60	2.88	2.74
15	Sel-1 x Arka Harit	59.67	57.50	58.58	62.67	58.83	60.75	3.53	7.00	5.27	7.41	9.31	8.36	2.70	2.99	2.85
16	Sel-1 x DARAL-43	64.00	63.83	63.92	65.67	71.33	68.50	3.50	7.33	5.42	8.71	9.95	9.33	2.70	2.98	2.84
17	V-21-14 x Kashi Mayuri	57.67	58.50	58.08	65.17	65.33	65.25	2.91	6.40	4.66	7.95	9.19	8.57	3.30	3.58	3.44
18	V-21-14 x Arka Harit	64.33	62.83	63.58	69.17	68.33	68.75	3.82	7.27	5.55	8.60	9.83	9.22	2.33	2.61	2.47
19	V-21-14 x DARAL-43	61.00	64.50	62.75	65.67	68.67	67.17	3.57	6.90	5.23	9.65	10.88	10.26	2.93	3.21	3.07

20	V-65-1 x Kashi Mayuri	52.33	52.17	52.25	58.17	58.33	58.25	3.57	6.03	4.80	5.59	6.82	6.21	3.51	3.86	3.68
21	V-65-1 x Arka Harit	52.67	52.50	52.58	57.83	59.33	58.58	5.08	7.13	6.11	4.82	6.06	5.44	2.85	3.13	2.99
22	V-65-1 x DARAL-43	64.67	65.50	65.08	61.67	72.33	67.00	7.54	10.07	8.81	10.96	12.19	11.57	2.18	2.73	2.45
23	V-193 x Kashi Mayuri	56.67	57.50	57.08	63.83	64.00	63.92	4.00	7.37	5.68	9.20	10.44	9.82	3.21	3.83	3.52
24	V-193 x Arka Harit	60.33	61.17	60.75	65.17	70.67	67.92	4.90	7.03	5.97	9.74	10.97	10.36	3.16	3.44	3.30
25	V-193 x DARAL-43	63.67	64.57	64.12	66.17	70.00	68.08	3.16	5.37	4.27	7.54	8.77	8.16	2.50	2.78	2.64
26	V-198 x Kashi Mayuri	53.67	54.50	54.08	59.83	60.00	59.92	4.97	7.00	5.98	5.06	6.30	5.68	3.50	4.11	3.81
27	V-198 x Arka Harit	56.00	62.17	59.08	68.50	68.67	68.58	3.90	6.97	5.43	6.64	7.87	7.26	2.83	3.11	2.97
28	V-198 x DARAL-43	54.33	55.17	54.75	61.50	61.67	61.58	5.53	8.17	6.85	5.82	7.05	6.43	3.52	4.13	3.83
29	V-158 x Kashi Mayuri	56.67	57.50	57.08	63.17	63.33	63.25	3.50	5.83	4.67	8.16	9.39	8.77	2.29	2.90	2.60
30	V-158 x Arka Harit	59.00	59.50	59.25	65.17	66.50	65.83	3.54	7.03	5.29	7.49	8.72	8.10	3.13	3.41	3.27
31	V-158 x DARAL-43	58.67	58.83	58.75	63.67	66.00	64.83	3.94	6.93	5.44	9.21	10.44	9.82	3.06	3.67	3.37
32	V-26 x Kashi Mayuri	55.67	56.50	56.08	60.00	64.33	62.17	3.90	6.80	5.35	6.15	7.39	6.77	3.46	3.74	3.60
33	V-26 x Arka Harit	58.33	59.17	58.75	64.33	65.33	64.83	3.75	6.77	5.26	7.66	8.89	8.28	3.05	3.33	3.19
34	V-26 x DARAL-43	63.00	63.83	63.42	67.50	73.67	70.58	3.40	6.90	5.15	7.95	9.18	8.57	2.99	3.61	3.30
35	V-169 x Kashi Mayuri	57.67	58.50	58.08	63.00	64.67	63.83	4.51	6.23	5.38	7.05	8.28	7.66	3.38	4.00	3.69
36	V-169 x Arka Harit	63.67	66.17	64.92	68.00	72.83	70.42	4.11	6.10	5.11	9.76	10.99	10.37	2.50	2.79	2.64
37	V-169 x DARAL-43	61.00	61.83	61.42	65.83	71.33	68.58	3.53	5.83	4.68	7.62	8.85	8.24	2.52	3.13	2.83
38	NDBG-8 x Kashi Mayuri	62.00	62.67	62.33	65.33	71.67	68.50	3.74	5.82	4.78	6.89	8.12	7.51	2.39	2.68	2.54
39	NDBG-8 x Arka Harit	57.33	58.83	58.08	62.00	65.67	63.83	3.58	5.73	4.66	7.39	8.63	8.01	2.38	2.66	2.52
40	NDBG-8 x DARAL-43	61.33	62.17	61.75	64.33	68.67	66.50	4.08	6.37	5.23	7.88	9.11	8.50	3.06	3.34	3.20
41	NDBG-9 x Kashi Mayuri	56.00	58.83	57.42	60.50	64.50	62.50	3.81	5.77	4.79	8.65	9.89	9.27	2.75	3.04	2.90
42	NDBG-9 x Arka Harit	59.00	59.83	59.42	62.33	66.67	64.50	3.58	6.00	4.79	8.55	9.78	9.16	2.60	2.88	2.74
43	NDBG-9 x DARAL-43	58.33	59.17	58.75	63.50	65.67	64.58	3.50	5.77	4.63	8.36	9.60	8.98	3.18	3.46	3.32
44	VNR-Navdhan (check variety)	58.67	59.50	59.08	67.17	66.33	66.75	3.85	6.17	5.01	9.43	10.66	10.04	2.50	3.11	2.81
	Mean	58.95	59.87	59.41	64.02	66.54	65.28	3.83	6.51	5.17	7.82	9.11	8.47	2.84	3.22	3.03
	Min	51.33	52.17	52.25	57.00	58.33	58.25	2.48	4.90	3.91	4.65	6.06	5.44	2.18	2.48	2.34
	Max	64.67	66.17	65.08	70.67	73.67	71.75	7.54	10.07	8.81	11.66	12.90	12.28	3.56	4.13	3.83
	SE(d) ±	2.14	1.71	1.54	2.09	2.15	1.71	0.34	0.33	0.27	0.51	0.38	0.38	0.21	0.19	0.14
	C.D.at 5%	4.26	3.41	3.06	4.15	4.28	3.41	0.67	0.66	0.54	1.01	0.75	0.75	0.42	0.38	0.28
	C.V. (%)	4.44	3.50	3.17	3.99	3.96	3.21	10.74	6.25	6.37	7.95	5.06	5.46	9.00	7.24	5.69

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sn	Parent/Hybrids	Number of primary branches per plant			Fruit length (cm)			Fruit circumference (cm)			Fruit weight (kg)			Number of fruits per plant		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
Parents																
1	Sel-1(L ₁)	5.42	5.69	5.56	10.99	12.67	11.83	9.23	10.50	9.86	62.25	59.36	60.81	13.30	15.17	14.24
2	V-21-14(L ₂)	5.81	5.87	5.84	11.59	13.27	12.43	10.00	11.27	10.63	66.35	63.46	64.91	14.30	16.17	15.24
3	V-65-1(L ₃)	6.14	6.29	6.21	13.32	19.00	16.16	8.98	13.77	11.38	72.29	89.16	80.73	22.29	30.67	26.48
4	V-193(L ₄)	5.27	5.69	5.48	11.06	12.74	11.90	8.02	9.30	8.66	64.14	68.85	66.49	17.90	19.77	18.84
5	V-198(L ₅)	5.89	6.51	6.20	11.51	16.12	13.82	9.33	12.77	11.05	71.48	85.17	78.33	21.66	30.27	25.97
6	V-158(L ₆)	5.62	5.89	5.75	15.21	19.22	17.22	11.21	12.20	11.71	68.17	65.28	66.73	15.30	17.17	16.24
7	V-26(L ₇)	6.20	6.54	6.37	12.45	15.80	14.12	11.10	12.37	11.73	64.15	81.44	72.80	20.22	29.77	25.00
8	V-169(L ₈)	5.42	5.69	5.55	10.10	11.45	10.78	7.90	7.01	7.45	54.65	57.54	56.09	16.80	15.45	16.13
9	NDBG-8 (L ₉)	5.32	5.59	5.45	13.56	17.24	15.40	9.31	8.64	8.97	66.50	69.22	67.86	19.53	20.60	20.07
10	NDBG-9 (L ₁₀)	5.48	5.75	5.62	14.57	18.02	16.29	7.62	7.18	7.40	70.07	72.96	71.52	20.00	25.65	22.82
11	Kashi Mayuri(T ₁)	5.28	5.55	5.41	9.35	12.13	10.74	8.79	7.91	8.35	52.37	65.67	59.02	15.67	14.32	15.00
12	Arka Harit(T ₂)	5.48	5.75	5.62	8.50	6.85	7.68	7.66	6.61	7.13	44.10	44.00	44.05	15.50	10.15	12.82
13	DARAL-43(T ₃)	5.15	5.42	5.29	8.12	6.44	7.28	8.00	7.11	7.55	63.61	74.54	69.08	11.50	10.15	10.83
	Mean	5.57	5.86	5.72	11.57	13.92	12.74	9.01	9.74	9.38	63.09	68.97	66.03	17.23	19.64	18.44
	Min	5.15	5.42	5.29	8.12	6.44	7.28	7.62	6.61	7.13	44.10	44.00	44.05	11.50	10.15	10.83
	Max	6.20	6.54	6.37	15.21	19.22	17.22	11.21	13.77	11.73	72.29	89.16	80.73	22.29	30.67	26.48
Hybrids																
14	Sel-1 x Kashi Mayuri	5.42	5.69	5.55	11.67	9.32	10.49	9.43	8.54	8.99	64.25	67.48	65.87	16.83	15.48	16.15
15	Sel-1 x Arka Harit	5.35	5.62	5.48	11.67	9.99	10.83	10.07	9.18	9.63	67.59	70.82	69.21	12.50	11.15	11.82
16	Sel-1 x DARAL-43	5.55	5.82	5.69	10.67	8.32	9.50	9.47	8.68	9.08	62.78	66.01	64.39	17.80	16.45	17.12
17	V-21-14 x Kashi Mayuri	5.15	5.42	5.28	14.55	12.87	13.71	9.20	8.31	8.75	56.81	37.71	47.26	17.50	16.15	16.83
18	V-21-14 x Arka Harit	5.32	5.59	5.46	11.20	9.52	10.36	7.90	7.01	7.46	33.67	36.24	34.96	15.20	13.85	14.52
19	V-21-14 x DARAL-43	5.48	5.75	5.61	9.82	8.14	8.98	9.73	8.51	9.12	50.35	53.58	51.96	14.05	13.15	13.60
20	V-65-1 x Kashi Mayuri	5.82	6.42	6.12	15.55	17.23	16.39	12.05	13.82	12.94	92.13	89.24	90.69	28.82	30.59	29.71
21	V-65-1 x Arka Harit	4.51	6.43	5.47	15.56	17.24	16.40	12.60	13.87	13.23	92.25	89.36	90.80	28.90	30.67	29.79
22	V-65-1 x DARAL-43	5.68	5.95	5.82	11.25	12.93	12.09	7.13	8.44	7.79	65.25	62.36	63.80	21.70	23.47	22.59
23	V-193 x Kashi Mayuri	5.32	5.59	5.45	15.63	15.85	15.74	6.74	8.00	7.37	31.64	27.75	29.69	13.56	15.33	14.45

24	V-193 x Arka Harit	5.22	5.49	5.36	6.63	8.31	7.47	6.83	8.10	7.47	52.80	49.91	51.36	14.50	16.27	15.39
25	V-193 x DARAL-43	5.35	5.62	5.48	12.42	14.10	13.26	7.50	8.77	8.14	55.65	52.76	54.21	13.90	15.67	14.79
26	V-198 x Kashi Mayuri	6.25	6.52	6.38	14.55	16.23	15.39	11.60	12.87	12.23	88.26	91.13	89.69	28.45	30.22	29.33
27	V-198 x Arka Harit	5.68	5.55	5.62	11.24	12.92	12.08	7.97	9.24	8.60	80.45	83.32	81.89	23.25	25.02	24.14
28	V-198 x DARAL-43	6.00	6.53	6.26	14.56	16.24	15.40	11.70	12.97	12.33	88.45	91.32	89.88	28.56	30.33	29.45
29	V-158 x Kashi Mayuri	5.48	5.75	5.61	7.77	6.54	7.15	7.07	6.20	6.63	67.35	70.22	68.79	16.50	18.27	17.38
30	V-158 x Arka Harit	5.68	5.95	5.82	10.52	9.29	9.90	8.67	7.80	8.23	62.68	63.89	63.29	27.50	29.27	28.39
31	V-158 x DARAL-43	5.95	5.89	5.92	9.23	8.00	8.62	8.66	7.58	8.12	51.39	54.26	52.82	23.00	24.77	23.89
32	V-26 x Kashi Mayuri	6.19	6.55	6.37	14.03	16.85	15.44	10.68	12.56	11.62	84.52	87.39	85.95	27.98	29.75	28.86
33	V-26 x Arka Harit	5.28	5.55	5.42	10.24	9.01	9.62	8.63	7.76	8.20	70.86	73.73	72.30	17.70	19.47	18.59
34	V-26 x DARAL-43	5.48	5.75	5.61	9.78	8.55	9.17	8.20	7.33	7.77	68.45	71.32	69.89	19.80	21.57	20.69
35	V-169 x Kashi Mayuri	5.35	5.62	5.49	12.85	11.62	12.24	8.20	7.33	7.77	70.35	73.22	71.78	23.00	24.77	23.89
36	V-169 x Arka Harit	5.41	5.68	5.54	9.43	8.20	8.82	8.70	7.83	8.26	50.72	53.72	52.22	17.50	19.27	18.39
37	V-169 x DARAL-43	5.67	5.94	5.80	14.03	14.19	14.11	10.78	9.58	10.18	68.55	71.42	69.99	14.20	15.97	15.08
38	NDBG-8 x Kashi Mayuri	5.33	5.60	5.47	8.72	7.49	8.10	8.52	7.65	8.08	51.36	54.23	52.79	17.50	19.27	18.39
39	NDBG-8 x Arka Harit	5.36	5.63	5.49	14.09	14.35	14.22	6.38	5.53	5.96	63.32	66.20	64.76	17.90	19.64	18.77
40	NDBG-8 x DARAL-43	5.40	5.67	5.53	16.30	14.20	15.25	7.25	6.38	6.82	64.30	67.17	65.74	23.00	24.77	23.88
41	NDBG-9 x Kashi Mayuri	5.66	5.93	5.79	8.90	7.67	8.28	9.01	8.14	8.57	51.65	54.52	53.08	17.50	19.27	18.39
42	NDBG-9 x Arka Harit	5.36	5.63	5.49	10.17	8.94	9.55	8.82	7.95	8.39	61.25	64.12	62.69	16.50	17.27	16.89
43	NDBG-9 x DARAL-43	5.86	6.13	6.00	7.29	6.05	6.67	9.37	8.50	8.93	45.55	48.42	46.98	19.10	20.87	19.98
44	VNR-Navdhan (check variety)	5.47	5.74	5.61	10.50	9.27	9.89	8.94	8.07	8.51	70.35	73.22	71.78	27.80	29.57	28.69
	Mean	5.53	5.85	5.69	11.62	12.05	11.84	8.98	9.07	9.02	63.75	66.20	64.98	19.23	20.75	19.99
	Min	4.51	5.42	5.28	6.63	6.05	6.67	6.38	5.53	5.96	31.64	27.75	29.69	11.50	10.15	10.83
	Max	6.25	6.55	6.38	16.30	19.22	17.22	12.60	13.87	13.23	92.25	91.32	90.80	28.90	30.67	29.79
	SE(d) ±	0.34	0.17	0.21	0.55	0.44	0.37	0.28	0.52	0.27	1.97	3.95	2.06	0.52	0.64	0.36
	C.D.at 5%	0.69	0.34	0.41	1.10	0.88	0.74	0.56	1.04	0.53	3.92	7.86	4.10	1.04	1.27	0.73
	C.V. (%)	7.62	3.60	4.43	5.83	4.51	3.83	3.82	7.02	3.62	3.78	7.30	3.88	3.34	3.75	2.23

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S. No.	Parent/Hybrids	Days to first harvest			Total soluble solids (%)			Ascorbic acid (mg/100 g fresh fruit)			Reducing sugars (%)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
	Parents												
1	Sel-1(L ₁)	77.17	80.07	78.62	3.25	3.62	3.44	64.51	126.12	95.31	2.74	3.51	3.13
2	V-21-14(L ₂)	78.17	80.74	79.45	3.58	3.95	3.76	96.83	100.72	98.78	3.26	5.02	4.14
3	V-65-1(L ₃)	69.83	72.40	71.12	2.02	2.39	2.21	110.00	144.14	127.07	3.43	5.97	4.70
4	V-193(L ₄)	76.50	81.07	78.79	2.89	3.26	3.07	96.79	100.68	98.73	2.88	3.65	3.26
5	V-198(L ₅)	68.83	72.74	70.78	2.25	2.62	2.44	104.33	139.15	121.74	3.42	5.61	4.51
6	V-158(L ₆)	78.83	82.74	80.79	3.54	3.91	3.73	61.30	65.19	63.25	3.10	3.86	3.48
7	V-26(L ₇)	70.50	73.74	72.12	2.40	2.77	2.58	106.67	137.18	121.92	3.66	5.36	4.51
8	V-169(L ₈)	77.17	79.40	78.28	3.24	3.61	3.43	81.47	85.36	83.41	2.86	3.63	3.24
9	NDBG-8 (L ₉)	77.67	87.07	82.37	3.54	3.91	3.73	77.56	81.45	79.51	2.44	3.21	2.82
10	NDBG-9 (L ₁₀)	81.17	84.40	82.79	4.25	4.62	4.43	114.83	122.75	118.79	2.71	3.47	3.09
11	Kashi Mayuri(T ₁)	76.50	79.73	78.12	4.58	4.95	4.76	55.23	59.12	57.17	1.39	2.15	1.77
12	Arka Harit(T ₂)	76.00	76.26	76.13	5.21	4.84	5.02	55.46	51.57	53.52	1.98	1.23	1.60
13	DARAL-43(T ₃)	79.17	77.60	78.38	5.31	4.94	5.13	63.24	59.35	61.30	2.36	1.59	1.97
	Mean	75.96	79.07	77.52	3.54	3.80	3.67	83.71	97.91	90.81	2.79	3.71	3.25
	Min	68.83	72.40	70.78	2.02	2.39	2.21	55.23	51.57	53.52	1.39	1.23	1.60
	Max	81.17	87.07	82.79	5.31	4.95	5.13	114.83	144.14	127.07	3.66	5.97	4.70
Hybrids													
14	Sel-1 x Kashi Mayuri	80.00	79.26	79.63	4.25	3.88	4.06	84.67	112.97	98.82	3.31	2.53	2.92
15	Sel-1 x Arka Harit	71.83	74.27	73.05	4.67	4.30	4.49	53.75	49.86	51.80	0.78	0.57	0.68
16	Sel-1 x DARAL-43	78.50	79.26	78.88	4.61	4.24	4.43	52.29	48.41	50.35	1.97	1.20	1.58
17	V-21-14 x Kashi Mayuri	75.83	72.93	74.38	4.67	4.30	4.48	103.00	111.85	107.42	1.54	0.77	1.15
18	V-21-14 x Arka Harit	82.50	79.60	81.05	4.59	4.22	4.40	83.33	109.97	96.65	1.31	0.53	0.92
19	V-21-14 x DARAL-43	80.17	78.93	79.55	4.78	4.41	4.59	68.35	64.46	66.41	1.67	0.90	1.29
20	V-65-1 x Kashi Mayuri	69.17	71.74	70.45	1.98	2.35	2.17	95.67	144.24	119.96	5.19	5.96	5.58
21	V-65-1 x Arka Harit	70.17	72.07	71.12	1.95	2.32	2.14	82.33	144.28	113.31	5.30	6.06	5.68
22	V-65-1 x DARAL-43	78.83	85.07	81.95	3.25	3.62	3.44	99.33	114.56	106.95	2.67	3.44	3.06
23	V-193 x Kashi Mayuri	76.50	77.07	76.79	4.25	4.62	4.43	111.29	115.18	113.24	1.37	2.14	1.76

24	V-193 x Arka Harit	75.17	80.74	77.95	4.35	4.72	4.54	38.85	42.74	40.79	1.52	2.29	1.91
25	V-193 x DARAL-43	79.50	84.07	81.79	4.61	4.98	4.80	93.15	100.73	96.94	1.41	2.17	1.79
26	V-198 x Kashi Mayuri	71.50	74.07	72.79	2.15	2.52	2.33	85.00	139.24	112.12	4.75	5.51	5.13
27	V-198 x Arka Harit	79.83	81.74	80.79	3.25	3.62	3.44	100.87	104.76	102.81	2.21	2.98	2.60
28	V-198 x DARAL-43	73.83	74.74	74.28	2.14	2.51	2.33	77.33	139.29	108.31	4.90	5.66	5.28
29	V-158 x Kashi Mayuri	74.83	77.41	76.12	4.56	4.93	4.74	92.91	96.80	94.85	1.33	2.09	1.71
30	V-158 x Arka Harit	75.50	79.74	77.62	4.57	4.94	4.76	88.00	115.19	101.59	1.77	2.53	2.15
31	V-158 x DARAL-43	76.17	78.74	77.45	3.58	3.95	3.77	82.33	121.25	101.79	1.16	1.93	1.54
32	V-26 x Kashi Mayuri	73.17	76.40	74.79	2.41	2.78	2.60	75.00	137.29	106.15	4.80	5.57	5.19
33	V-26 x Arka Harit	76.17	78.74	77.45	3.54	3.29	3.42	93.35	89.46	91.41	1.04	0.79	0.92
34	V-26 x DARAL-43	81.17	87.07	84.12	3.68	3.43	3.56	88.85	84.96	86.91	1.23	0.98	1.11
35	V-169 x Kashi Mayuri	74.83	78.07	76.45	3.15	2.90	3.02	88.84	84.95	86.90	0.95	0.69	0.82
36	V-169 x Arka Harit	85.17	88.40	86.79	4.21	3.96	4.08	83.49	79.60	81.54	1.58	1.32	1.45
37	V-169 x DARAL-43	80.83	89.07	84.95	4.35	4.10	4.23	67.67	107.40	87.53	1.30	1.04	1.17
38	NDBG-8 x Kashi Mayuri	82.17	87.40	84.79	4.36	4.11	4.24	82.33	109.90	96.11	1.35	1.09	1.22
39	NDBG-8 x Arka Harit	76.83	78.40	77.62	3.89	3.64	3.77	66.79	62.90	64.84	1.38	1.12	1.25
40	NDBG-8 x DARAL-43	78.50	81.73	80.12	3.58	3.33	3.45	35.74	31.85	33.79	1.69	1.44	1.56
41	NDBG-9 x Kashi Mayuri	76.50	78.40	77.45	3.49	3.24	3.37	99.96	96.07	98.01	1.72	1.46	1.59
42	NDBG-9 x Arka Harit	76.83	79.40	78.12	3.47	3.22	3.35	95.67	91.77	93.72	1.97	1.71	1.84
43	NDBG-9 x DARAL-43	74.83	78.74	76.79	3.55	3.29	3.42	52.76	48.86	50.81	1.48	1.22	1.35
44	VNR-Navdhan (check variety)	76.50	79.07	77.79	4.12	3.87	4.00	90.00	126.12	108.06	2.03	1.78	1.90
	Mean	76.61	79.32	77.97	3.68	3.75	3.72	81.84	97.72	89.78	2.34	2.68	2.51
	Min	68.83	71.74	70.45	1.95	2.32	2.14	35.74	31.85	33.79	0.78	0.53	0.68
	Max	85.17	89.07	86.79	5.31	4.98	5.13	114.83	144.28	127.07	5.30	6.06	5.68
	SE(d) \pm	1.98	3.28	2.18	0.08	0.08	0.06	3.11	2.22	1.95	0.11	0.06	0.06
	C.D.at 5%	3.94	6.52	4.33	0.16	0.16	0.12	6.19	4.42	3.88	0.21	0.11	0.12
	C.V. (%)	3.17	5.06	3.42	2.74	2.68	1.97	4.65	2.78	2.66	5.54	2.60	2.87

Conti.....

S. No.	Parent/Hybrids	Non-Reducing sugars (%)			Total Sugar (%)			Dry Matter			Fruit yield per plant (kg)		
		Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P	Y ₁	Y ₂	P
	Parents												
1	Sel-1(L ₁)	4.50	5.39	4.95	7.25	8.90	8.07	8.17	8.97	8.57	0.83	0.90	0.86
2	V-21-14(L ₂)	3.07	3.96	3.51	7.33	8.98	8.16	8.24	7.98	8.11	0.95	1.02	0.99
3	V-65-1(L ₃)	5.75	6.64	6.19	10.95	12.61	11.77	9.96	9.56	9.76	2.11	2.74	2.42
4	V-193(L ₄)	1.69	2.58	2.14	4.58	6.23	5.40	7.40	7.78	7.59	1.28	1.36	1.32
5	V-198(L ₅)	5.65	6.54	6.10	10.49	12.15	11.32	9.50	9.20	9.35	2.04	2.58	2.31
6	V-158(L ₆)	1.84	2.74	2.29	4.94	6.60	5.77	8.18	8.42	8.30	1.04	1.12	1.08
7	V-26(L ₇)	5.20	6.09	5.65	9.79	11.45	10.62	9.22	9.80	9.51	1.92	2.42	2.17
8	V-169(L ₈)	1.42	2.31	1.86	4.28	5.94	5.11	7.23	8.12	7.68	0.92	0.89	0.90
9	NDBG-8 (L ₉)	4.42	5.31	4.86	6.86	8.51	7.69	7.26	8.15	7.71	1.50	1.43	1.46
10	NDBG-9 (L ₁₀)	3.13	4.02	3.57	5.84	7.49	6.67	7.20	8.09	7.64	1.89	1.86	1.88
11	Kashi Mayuri(T ₁)	2.06	2.95	2.50	3.44	5.10	4.27	7.71	7.25	7.48	1.06	0.94	1.00
12	Arka Harit(T ₂)	0.38	0.32	0.35	2.38	1.55	1.96	7.49	6.90	7.20	0.47	0.44	0.46
13	DARAL-43(T ₃)	0.45	0.40	0.43	2.81	1.99	2.40	7.15	6.56	6.86	0.85	0.75	0.81
	Mean	3.04	3.79	3.42	6.23	7.50	6.86	8.06	8.21	8.14	1.30	1.42	1.36
	Min	0.38	0.32	0.35	2.38	1.55	1.96	7.15	6.56	6.86	0.47	0.44	0.46
	Max	5.75	6.64	6.19	10.95	12.61	11.77	9.96	9.80	9.76	2.11	2.74	2.42
Hybrids													
14	Sel-1 x Kashi Mayuri	1.53	1.88	1.70	4.84	4.42	4.63	7.62	7.03	7.32	1.47	1.04	1.26
15	Sel-1 x Arka Harit	1.09	0.98	1.03	1.88	1.55	1.71	7.12	6.53	6.83	1.34	0.79	1.07
16	Sel-1 x DARAL-43	0.16	0.25	0.20	2.13	1.45	1.79	7.26	6.67	6.96	1.62	1.09	1.35
17	V-21-14 x Kashi Mayuri	3.45	3.23	3.34	5.00	4.00	4.50	7.19	6.60	6.90	1.45	0.91	1.18
18	V-21-14 x Arka Harit	0.77	0.54	0.66	2.09	1.08	1.58	7.46	6.87	7.16	1.00	0.50	0.75
19	V-21-14 x DARAL-43	0.85	0.48	0.67	2.53	1.38	1.95	7.08	6.49	6.79	1.21	0.70	0.96
20	V-65-1 x Kashi Mayuri	5.78	6.33	6.05	10.97	12.29	11.63	9.96	10.84	10.40	3.16	2.73	2.94
21	V-65-1 x Arka Harit	5.82	6.37	6.10	11.12	12.43	11.78	9.91	10.50	10.20	3.17	2.74	2.95
22	V-65-1 x DARAL-43	1.57	2.12	1.84	4.24	5.56	4.90	8.07	8.65	8.36	1.92	1.46	1.69
23	V-193 x Kashi Mayuri	4.34	4.89	4.61	5.71	7.03	6.37	7.36	7.93	7.65	0.91	0.42	0.67

24	V-193 x Arka Harit	0.84	1.39	1.12	2.36	3.68	3.02	8.44	9.02	8.73	1.27	0.81	1.04
25	V-193 x DARAL-43	0.49	1.03	0.76	1.90	3.20	2.55	8.29	8.87	8.58	1.27	0.83	1.05
26	V-198 x Kashi Mayuri	5.70	6.25	5.98	10.45	11.77	11.11	9.78	10.42	10.10	3.01	2.75	2.88
27	V-198 x Arka Harit	0.54	1.09	0.82	2.76	4.07	3.41	7.33	7.89	7.61	2.37	2.08	2.23
28	V-198 x DARAL-43	5.73	6.28	6.01	10.62	11.95	11.28	9.53	9.40	9.46	3.02	2.77	2.90
29	V-158 x Kashi Mayuri	2.28	2.83	2.56	3.61	4.92	4.26	7.32	6.98	7.15	1.61	1.28	1.44
30	V-158 x Arka Harit	0.35	0.90	0.62	2.12	3.43	2.78	7.39	6.78	7.08	2.18	1.87	2.02
31	V-158 x DARAL-43	1.00	1.55	1.27	2.16	3.47	2.82	7.14	7.80	7.47	1.68	1.35	1.52
32	V-26 x Kashi Mayuri	5.30	5.85	5.58	10.10	11.42	10.76	9.07	9.05	9.06	2.87	2.60	2.73
33	V-26 x Arka Harit	3.96	3.30	3.63	5.00	4.09	4.55	7.11	6.34	6.72	1.75	1.44	1.59
34	V-26 x DARAL-43	5.93	5.26	5.60	7.16	6.24	6.70	7.22	6.45	6.84	1.85	1.54	1.70
35	V-169 x Kashi Mayuri	5.52	4.26	4.89	6.47	4.95	5.71	7.22	6.45	6.84	2.08	1.81	1.95
36	V-169 x Arka Harit	5.34	4.98	5.16	6.92	6.30	6.62	7.35	6.58	6.97	1.39	1.04	1.21
37	V-169 x DARAL-43	5.19	5.45	5.32	6.48	6.49	6.49	8.39	7.62	8.01	1.48	1.16	1.32
38	NDBG-8 x Kashi Mayuri	3.00	3.26	3.13	4.35	4.35	4.35	8.09	7.32	7.70	1.40	1.04	1.23
39	NDBG-8 x Arka Harit	5.55	4.89	5.22	6.93	6.01	6.47	8.17	7.40	7.79	1.63	1.28	1.46
40	NDBG-8 x DARAL-43	3.70	3.78	3.74	5.40	5.22	5.31	8.90	8.13	8.51	1.98	1.66	1.82
41	NDBG-9 x Kashi Mayuri	4.68	3.89	4.29	6.40	5.35	5.87	8.47	7.69	8.08	1.40	1.05	1.23
42	NDBG-9 x Arka Harit	5.58	4.58	5.08	7.55	6.29	6.92	8.12	7.35	7.74	1.51	1.17	1.34
43	NDBG-9 x DARAL-43	3.57	4.02	3.79	5.04	5.24	5.14	7.43	6.66	7.05	1.37	1.01	1.19
44	VNR-Navdhan (check variety)	2.72	1.98	2.35	4.75	3.75	4.25	8.10	7.33	7.72	1.95	2.16	2.06
	Mean	3.22	3.48	3.35	5.68	6.16	5.92	8.01	7.87	7.94	1.66	1.44	1.55
	Min	0.16	0.25	0.20	1.88	1.08	1.58	7.08	6.34	6.72	0.47	0.42	0.46
	Max	5.93	6.64	6.19	11.12	12.61	11.78	9.96	10.84	10.40	3.17	2.77	2.95
	SE(d) ±	0.08	0.09	0.06	0.10	0.11	0.07	0.17	0.17	0.12	0.06	0.08	0.05
	C.D.at 5%	0.16	0.19	0.11	0.19	0.22	0.14	0.33	0.34	0.24	0.11	0.15	0.09
	C.V. (%)	2.99	3.27	2.04	2.10	2.18	1.48	2.53	2.67	1.84	4.19	6.56	3.68

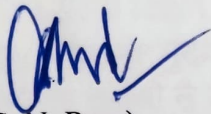
Name : **Shyam Prakash** Id. No. : **H-13192/22**
Semester : **II** Degree : **Ph. D. Horticulture**
(**Vegetable Science**)
Year of Admission : **2022** Department : **Vegetable Science**
Major : **Vegetable Science**
Minor : **Genetics and Plant Breeding**
Thesis Title : “Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)”
Advisor : **Dr. C. N. Ram**

ABSTRACT

The present study entitled “Studies on heterosis, combining ability and gene action for yield and quality traits in bitter gourd (*Momordica charantia* L.)” was conducted during the *Zaid* seasons of 2023–24 and 2024–25 at the Main Experiment Station of the Department of Vegetable Science, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya (U.P.), India. The study aimed to investigate the combining ability, heterosis, and gene action associated with yield and quality traits in bitter gourd. The experimental material consisted of 30 F₁ hybrids, generated through a line × tester mating design, involving 10 genetically diverse lines and 3 testers. These hybrids, along with their respective parents, were evaluated in a Randomized Block Design (RBD) with three replications. The data collected were on 18 traits, which included 12 quantitative traits related to growth, yield, and fruit quality, and 6 qualitative traits related to biochemical composition. The analysis of variance (ANOVA) revealed significant differences among genotypes for all the traits studied, both in individual seasons (2023–24 and 2024–25) and in pooled data. This indicates that there was sufficient genetic variability in the experimental material, which is essential for effective selection in breeding programs. The significant variance observed for lines, testers, and line × tester interactions emphasized the importance of both additive and non-additive genetic effects. Notably, the partitioning of variance revealed that specific combining ability (SCA) variances were higher than general combining ability (GCA) variances for all traits, suggesting the predominance of non-additive gene action for the traits under study. Furthermore, the average degree of dominance was found to be greater than unity for all traits, indicating over-dominance, which further highlights the role of hybrid vigour in determining the performance of the F₁ hybrids. The combining ability analysis provided valuable insights into the genetic architecture of the traits. Among the parents, lines such as V-65-1 (L₃), V-198 (L₅), and V-26 (L₇) exhibited the best general combining ability (GCA) for yield-related traits, such as fruit yield per plant and earliness, indicating their potential as promising parents for future breeding programs. For quality traits, V-193, V-21-14, and Sel-1 were identified as the best general combiners, specifically for total soluble solids, while V-65-

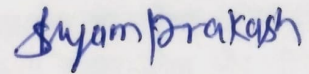
1, V-198, and V-158 demonstrated good combining ability for ascorbic acid and sugar-related traits, including reducing and non-reducing sugars. Among the testers, Arka Harit and DARAL-43 were identified as good general combiners for total soluble solids, while Kashi Mayuri showed favourable combining ability for multiple quality traits such as ascorbic acid, reducing sugars, and dry matter content. These findings suggest that both parents and testers contribute significantly to the inheritance of yield and quality traits, with certain parents and testers serving as ideal donors for specific traits. Heterosis, or hybrid vigour, was assessed by evaluating the heterosis over both the better and standard parents. Significant positive heterosis was observed for all traits, indicating that hybrid vigour played a key role in the expression of desirable traits in the hybrids. The best crosses exhibiting high heterosis over better parents for fruit yield per plant included V-158 × Arka Harit (108.95%), V-169 × Kashi Mayuri (95.00%), Sel-1 × DARAL-43 (89.84%), and V-65-1 × Arka Harit (62.16%). These crosses demonstrated both high yield potential and significant heterosis, suggesting their potential for use in future hybridization programs. Similarly, when heterosis over the standard variety was evaluated, the best crosses for fruit yield per plant were V-65-1 × Arka Harit (62.16%), V-65-1 × Kashi Mayuri (61.65%), V-198 × DARAL-43 (54.79%), and V-198 × Kashi Mayuri (54.28%). These hybrids displayed superior performance compared to the standard varieties, making them suitable candidates for commercial hybrid development. The significant heterosis observed for traits such as fruit yield per plant, fruit weight, and total soluble solids underlined the potential for improving both yield and quality in bitter gourd through hybridization. The genetic analysis of the traits indicated that the majority of traits were controlled by non-additive gene action, as evidenced by the higher magnitude of SCA variance compared to GCA variance. Over-dominance was evident for all traits, suggesting that hybridization would be an effective strategy for improving traits in bitter gourd, especially for yield and quality traits. Heritability estimates in the narrow sense (h^2) were generally lower than those in the broad sense, which further confirms the importance of non-additive genetic effects in the inheritance of these traits. Genetic advance as a percentage of the mean was higher for traits with high SCA variance, indicating that such traits can be improved effectively through hybridization. The best-performing hybrids based on both combining ability and heterosis were identified as potential candidates for commercial exploitation. The crosses V-198 × DARAL-43, V-198 × Kashi Mayuri, and V-65-1 × Arka Harit exhibited superior performance for fruit yield per plant and quality traits such as total soluble solids and ascorbic acid. These hybrids showed significant positive heterosis over both better and standard parents, indicating their potential to outperform existing varieties. It is recommended that these hybrids be tested in multi-location trials to confirm their stability and adaptability under varying agro-climatic conditions. Fruit colour segregated into three categories: whitish-green (13 genotypes), light-green (14 genotypes), and dark-green (16 genotypes). Fruit shape varied with 10 cylindrical, 15 oblong, and 19 spindle-shaped fruits. Fruit tuberculation showed four patterns: two genotypes lacked tubercles, 15 had moderate density, 14 were dense, and 13 had sparse tubercles. Fruit ridges were classified as continuous (19 genotypes) and discontinuous (25 genotypes). Peduncle length varied with 11 large, 26 medium, and 7 short types. All genotypes exhibited yellow flower colour. For leaf traits, blade length was

categorized into short (14), medium (18), and long (11), while blade width was either long (6) or medium (37). The number of leaf lobes ranged from 5–7 (14 genotypes), 6–8 (10 genotypes), and 9–6 (8 genotypes). Petiole length was variable, with 17 short, 18 medium, and 8 long types. In conclusion, the present study provides a comprehensive understanding of the genetic control of yield and quality traits in bitter gourd. The results suggest that non-additive gene action, particularly over-dominance, plays a significant role in the inheritance of these traits, making hybridization an effective strategy for improving both yield and quality. The identified superior hybrids, such as V-198 × DARAL-43, V-198 × Kashi Mayuri, and V-65-1 × Arka Harit, are promising candidates for future breeding programs and commercial hybrid development. Additionally, the study highlights the importance of selecting parents with good general combining ability for yield and quality traits, as well as testers that complement these traits. These findings pave the way for the development of high-yielding, quality-rich, and climate-resilient bitter gourd cultivars, which can meet the growing demand for this vegetable in the global market. Further research involving multi-location trials and testing under diverse environmental conditions is essential to validate the stability and adaptability of the identified hybrids.



(C. N. Ram)

Major Advisor & Chairman



(Shyam Prakash)

Student

नाम- श्याम प्रकाश

सेमेस्टर- द्वितीय

प्रवेश का वर्ष-2022

प्रमुख-सब्जी विज्ञान

आई.डी.नं०-एच- H-13192/22

डिग्री-पी.एच.डी.(उद्यान)सब्जी विज्ञान

विभाग-सब्जी विभाग

गौण-आनुवंशिकी एवं पादप प्रजनन

शोध का शीर्षक: “करेले (*मोमोर्डिका चारेंटिया* एल.) में उपज और गुणवत्ता लक्षणों के लिए संयोजन क्षमता और जीन क्रिया के संयोजन पर अध्ययन”

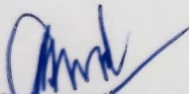
सलाहकार: डॉ. सी. एन. राम

सारांश

वर्तमान अध्ययन जिसका शीर्षक है “करेले (*मोमोर्डिका चारेंटिया* एल.) में उपज और गुणवत्ता लक्षणों के लिए संकर ओज़, संयोजन क्षमता और जीन क्रिया पर अध्ययन।” 2023-24 और 2024-25 के जायद मौसमों के दौरान सब्जी विज्ञान विभाग, आचार्य नरेंद्र देव कृषि और प्रौद्योगिकी विश्वविद्यालय, कुमारगंज, अयोध्या (उ.प्र.), भारत के मुख्य प्रयोग केंद्र पर आयोजित किया गया था। अध्ययन का उद्देश्य करेले में उपज और गुणवत्ता लक्षणों से जुड़ी आनुवंशिक परिवर्तनशीलता, संयोजन क्षमता, संकर ओज़ और जीन क्रिया की जांच करना था। प्रायोगिक सामग्री में 30 F_1 संकर शामिल थे, जो एक लाइन \times परीक्षक संयोजन डिजाइन के माध्यम से उत्पन्न हुए थे, जिसमें 10 आनुवंशिक रूप से विविध लाइनें और 3 परीक्षक शामिल थे एकत्र किए गए डेटा 18 लक्षणों पर थे, जिनमें विकास, उपज और फल की गुणवत्ता से संबंधित 12 मात्रात्मक लक्षण और जैव रासायनिक संरचना से संबंधित 6 गुणात्मक लक्षण शामिल थे। विचरण के विश्लेषण (एनोवा) ने अध्ययन किए गए सभी लक्षणों के लिए जीन प्रारूप के बीच महत्वपूर्ण अंतरों का खुलासा किया, व्यक्तिगत मौसमों (2023-24 और 2024-25) और एकत्रित आंकड़ों दोनों में। यह इंगित करता है कि प्रयोगात्मक सामग्री में पर्याप्त आनुवंशिक परिवर्तनशीलता थी, जो प्रजनन कार्यक्रमों में प्रभावी चयन के लिए आवश्यक है। लाइनों, परीक्षकों और लाइन \times परीक्षक इंटरैक्शन के लिए देखे गए महत्वपूर्ण विचरण ने योगात्मक और गैर-योगात्मक दोनों आनुवंशिक प्रभावों के महत्व पर जोर दिया। उल्लेखनीय रूप से, विचरण के विभाजन से पता चला कि विशिष्ट संयोजन क्षमता (एससीए) इसके अलावा, सभी लक्षणों के लिए प्रभुत्व की औसत डिग्री एकता से अधिक पाई गई, जो अति-प्रभुत्व को इंगित करती है, जो F_1 संकर के प्रदर्शन को निर्धारित करने में संकर ओज की भूमिका को और अधिक उजागर करती है। संयोजन क्षमता विश्लेषण ने लक्षणों की आनुवंशिक संरचना में मूल्यवान अंतर्दृष्टि प्रदान की। माता-पिता के बीच, V-65-1 (L_3), V-198 (L_5), और V-26 (L_7) जैसी लाइनों ने उपज से संबंधित लक्षणों, जैसे प्रति पौधे फल की उपज और जल्दी पकने के लिए सर्वश्रेष्ठ सामान्य संयोजन क्षमता का प्रदर्शन किया, जो भविष्य के प्रजनन कार्यक्रमों के लिए आशाजनक माता-पिता के रूप में उनकी क्षमता का संकेत देता है। गुणवत्ता लक्षणों के लिए, V-193, V-21-14, और Sel-1 को

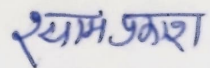
सर्वश्रेष्ठ सामान्य संयोजक के रूप में पहचाना गया, विशेष रूप से कुल घुलनशील ठोस पदार्थों के लिए परीक्षकों में, अर्का हरित और दाराल-43 को कुल घुलनशील ठोस पदार्थों के लिए अच्छे सामान्य संयोजक के रूप में पहचाना गया, जबकि काशी मयूरी ने कई गुणवत्ता लक्षणों जैसे एस्कॉर्बिक एसिड, शर्करा को कम करने और शुष्क पदार्थ सामग्री के लिए अनुकूल संयोजन क्षमता दिखाई। ये निष्कर्ष बताते हैं कि माता-पिता और परीक्षक दोनों ही उपज और गुणवत्ता लक्षणों की विरासत में महत्वपूर्ण रूप से योगदान करते हैं, कुछ माता-पिता और परीक्षक विशिष्ट लक्षणों के लिए आदर्श दाता के रूप में काम करते हैं। संकर ओज़ या हाइब्रिड ओज, का मूल्यांकन बेहतर और मानक माता-पिता दोनों पर संकर ओज़ का मूल्यांकन करके किया गया था। सभी लक्षणों के लिए महत्वपूर्ण सकारात्मक संकर ओज़ देखा गया, जो दर्शाता है कि हाइब्रिड ओज ने संकर में वांछनीय लक्षणों की अभिव्यक्ति में महत्वपूर्ण भूमिका निभाई। प्रति पौधे फल उपज के लिए बेहतर माता-पिता पर उच्च विषमता प्रदर्शित करने वाले सर्वोत्तम क्रॉस में वी-158 × अर्का हरित (108.95%), वी-169 × काशी मयूरी (95.00%), सेल-1 × दाराल-43 (89.84%), और वी-65-1 × अर्का हरित (62.16%) शामिल थे। इन क्रॉस ने उच्च उपज क्षमता और महत्वपूर्ण विषमता दोनों का प्रदर्शन किया, जो भविष्य के संकरण कार्यक्रमों में उपयोग की उनकी क्षमता का सुझाव देता है। इसी तरह, जब मानक किस्म पर विषमता का मूल्यांकन किया गया, तो प्रति पौधे फल उपज के लिए सर्वोत्तम क्रॉस वी-65-1 × अर्का हरित (62.16%), वी-65-1 × काशी मयूरी (61.65%), वी-198 × दाराल-43 (54.79%), और वी-198 × काशी मयूरी (54.28%) थे। इन संकरों ने मानक किस्मों की तुलना में बेहतर प्रदर्शन प्रदर्शित किया, जिससे वे व्यावसायिक संकर विकास के लिए उपयुक्त उम्मीदवार बन गए। प्रति पौधे फल उपज, फल वजन और कुल घुलनशील ठोस पदार्थों जैसे लक्षणों के लिए देखी गई महत्वपूर्ण विषमता ने संकरण के माध्यम से करेले में उपज और गुणवत्ता दोनों में सुधार की क्षमता को रेखांकित किया। लक्षणों के आनुवंशिक विश्लेषण ने संकेत दिया कि अधिकांश लक्षण गैर-योज्य जीन क्रिया द्वारा नियंत्रित थे, जैसा कि सामान्य संयोजन क्षमता विचरण की तुलना में सामान्य संयोजन क्षमता विचरण के उच्च परिमाण से प्रमाणित होता है। सभी लक्षणों के लिए अति-प्रभुत्व स्पष्ट था, यह सुझाव देते हुए कि करेले में लक्षणों को सुधारने के लिए संकरण एक प्रभावी रणनीति होगी, विशेष रूप से उपज और गुणवत्ता लक्षणों के लिए। संकीर्ण अर्थ (h^2) में आनुवंशिकता अनुमान आम तौर पर व्यापक अर्थों की तुलना में कम थे, जो इन लक्षणों की विरासत में गैर-योज्य आनुवंशिक प्रभावों के महत्व की पुष्टि करता है। औसत के प्रतिशत के रूप में आनुवंशिक उन्नति उच्च सामान्य संयोजन क्षमता विचरण वाले लक्षणों के लिए अधिक थी, यह दर्शाता है कि ऐसे लक्षणों को संकरण के माध्यम से प्रभावी रूप से सुधारा जा सकता है। संयोजन क्षमता और विषमता दोनों के आधार पर सर्वश्रेष्ठ प्रदर्शन करने वाले संकरों की पहचान व्यावसायिक उपयोग के लिए संभावित उम्मीदवारों के रूप में की गई। V-198 × DARAL-43, V-198 × काशी मयूरी और V-65-1 × अर्का हरित के क्रॉस ने प्रति पौधे फल की पैदावार और कुल घुलनशील ठोस और एस्कॉर्बिक एसिड जैसे गुणवत्ता लक्षणों के लिए बेहतर प्रदर्शन प्रदर्शित किया। इन संकरों ने बेहतर और मानक दोनों जनक पर महत्वपूर्ण सकारात्मक विषमता दिखाई, जो मौजूदा किस्मों से बेहतर प्रदर्शन करने की उनकी क्षमता को दर्शाता है। यह अनुशंसा की जाती है कि इन संकरों का विभिन्न कृषि-जलवायु परिस्थितियों में उनकी स्थिरता और अनुकूलनशीलता की पुष्टि करने के लिए बहु-स्थान परीक्षणों में परीक्षण किया जाए। फलों के रंग को तीन श्रेणियों में विभाजित किया गया: सफेद-हरा (13 जीन प्रारूप), हल्का हरा (14 जीन प्रारूप), और गहरा हरा (16 जीन प्रारूप)। फलों के आकार में 10 बेलनाकार, 15 आयताकार और 19

धुरी के आकार के फल शामिल थे। फलों के ट्यूबरकुलेशन ने चार पैटर्न दिखाए: दो जीन प्रारूप में ट्यूबरकल की कमी थी, 15 में मध्यम घनत्व था, 14 घने थे, और 13 में विरल ट्यूबरकल थे। फलों की लकीरों को निरंतर (19 जीन प्रारूप) और असंतत (25 जीन प्रारूप) के रूप में वर्गीकृत किया गया था। पेडुनकल की लंबाई 11 बड़े, 26 मध्यम और 7 छोटे प्रकारों के साथ भिन्न थी। सभी जीन प्रारूप ने पीले फूल का रंग प्रदर्शित किया। पत्ती के लक्षणों के लिए, ब्लेड की लंबाई को छोटे (14), मध्यम (18) और लंबे (11) में वर्गीकृत किया गया था, जबकि ब्लेड की चौड़ाई या तो लंबी (6) या मध्यम (37) थी। पत्ती लोब की संख्या 5-7 (14 जीन प्रारूप), 6-8 (10 जीन प्रारूप) और 9-6 (8 जीन प्रारूप) तक थी। परिणाम बताते हैं कि गैर-योज्य जीन क्रिया, विशेष रूप से अति-प्रभुत्व, इन लक्षणों की विरासत में एक महत्वपूर्ण भूमिका निभाता है, जिससे संकरण उपज और गुणवत्ता दोनों को बेहतर बनाने के लिए एक प्रभावी रणनीति बन जाती है। पहचाने गए बेहतर संकर, जैसे कि V-198 × DARAL-43, V-198 × काशी मयूरी, और V-65-1 × अर्का हरित, भविष्य के प्रजनन कार्यक्रमों और वाणिज्यिक संकर विकास के लिए आशाजनक उम्मीदवार हैं। इसके अतिरिक्त, अध्ययन उपज और गुणवत्ता लक्षणों के लिए अच्छी सामान्य संयोजन क्षमता वाले माता-पिता के चयन के महत्व पर प्रकाश डालता है, साथ ही ऐसे परीक्षक भी जो इन लक्षणों को पूरक करते हैं। ये निष्कर्ष उच्च उपज देने वाली, गुणवत्ता से भरपूर और जलवायु करेले की किस्मों के विकास का मार्ग प्रशस्त करते हैं, जो वैश्विक बाजार में इस सब्जी की बढ़ती मांग को पूरा कर सकते हैं



(सी.एन.राम)

मुख्य सलाहकार



(श्याम प्रकाश)

छात्र