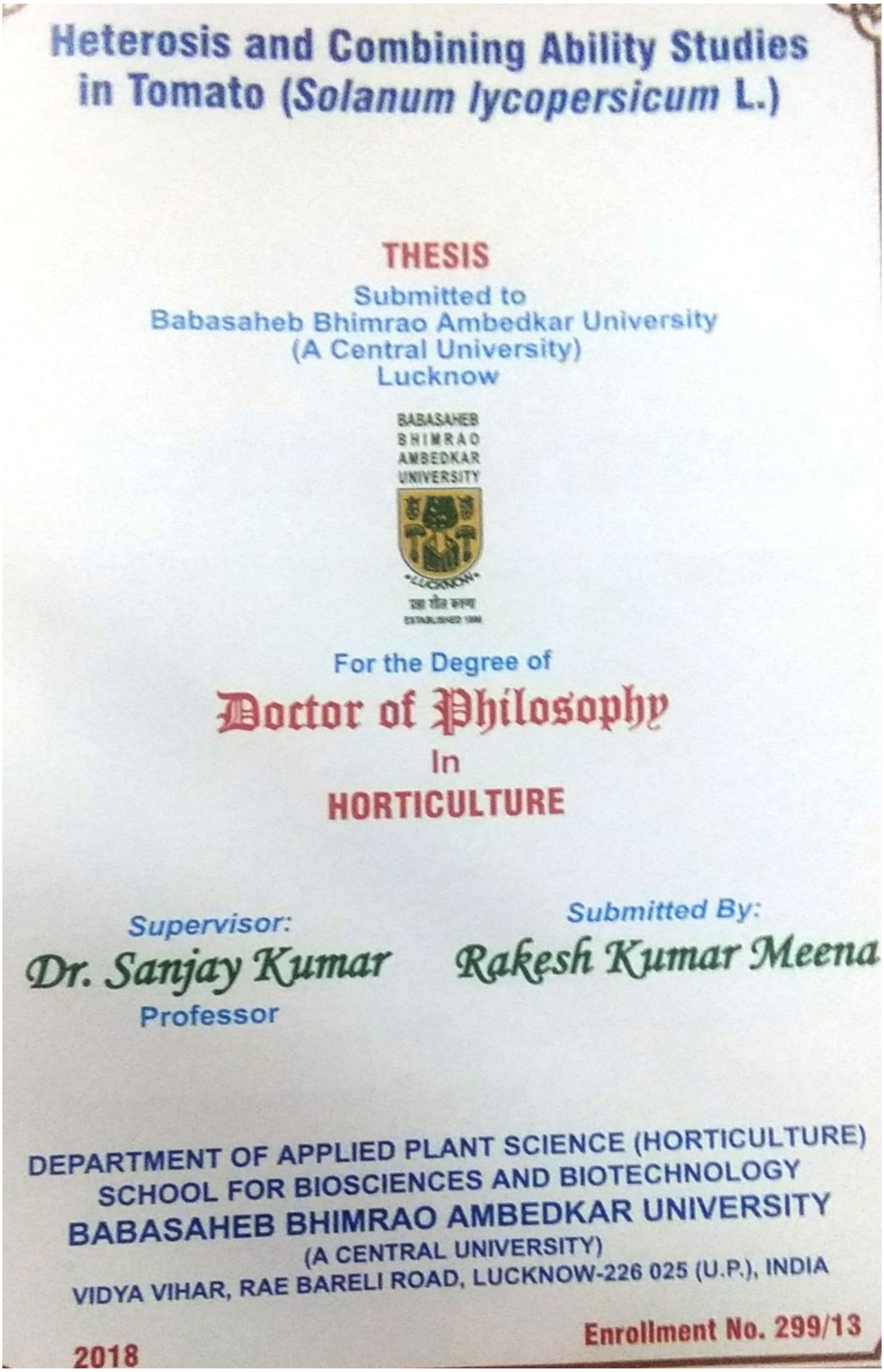

# Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)

**THESIS**

Submitted to
Babasaheb Bhimrao Ambedkar University
(A Central University)
Lucknow

For the Degree of

**Doctor of Philosophy**

In

**HORTICULTURE**

Supervisor:
*Dr. Sanjay Kumar*
Professor

Submitted By:
*Rakesh Kumar Meena*

DEPARTMENT OF APPLIED PLANT SCIENCE (HORTICULTURE)
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**Enrollment No. 299/13**

**2018**

Dedicated To

My

Loving Parents

Who gave me a lot of moral support and
encouragement which cannot be expressed in words.

Rakesh Kumar Meena

# DECLARATION

I, **Rakesh Kumar Meena**, Enrollment No. 299/13, hereby declare that I am a candidate for the degree of **Doctor of Philosophy in Horticulture**, Department of Applied Plant Sciences (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidhya-Vihar, Rac Bareli Road, Lucknow-226025 (U.P.), India and have carried out my research work entitled **"Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)".**This submitted for the award of the degree of Doctor of Philosophy in Horticulture is my original research work.

Date: 13-07-2018
Place: Lucknow

**(Rakesh Kumar Meena)**

# CERTIFICATE

This is to certify that the thesis titled "**Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)**"Submitted by Mr. **Rakesh Kumar Meena**, Enrollment No. 299/13 is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other university.

The thesis submitted to Babasaheb Bhimrao Ambedker University, Lucknow satisfies all the requirements as stipulated in the Doctor of Philosophy (Ph.D.) regulations- 1999 as amended in 2008/2010/2013 and it is fit for submission and evaluation for the award of the degree of Doctor of Philosophy of the University.

Date: 13-07-2010

**Supervisor**

24/10/18

**Head of the Department**

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**Date:** 13-07-2018 **(Rakesh Kumar Meena )**

**Place: Lucknow**

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of variance |
| CD | Critical Difference |
| cm | Centimetre |
| CV | Coefficient of variation |
| *per se* | As such with mean |
| *et al.* | and others |
| Fig | Figure |
| g | Gram |
| kg | Kilogram |
| m | Metre |
| ha | Hectare |
| mg | Milligram |
| SE (d) | Standard error difference |
| S.Em | Standard error mean |
| df | Degrees of freedom |
| RBD | Randomized Block Design |
| Vit-C | Ascorbic Acid |
| *viz.,* | Namely |
| vs. | Against |
| No. | Number |
| L x T | Line x Tester |
| HD | Half diallel |
| FD | Full diallel |
| *GCA* | General combining ability |
| *SCA* | Specific combining ability |
| *gca* | General combining ability |
| *sca* | Specific combining ability |
| $\sigma^2 GCA$ | Variance due to General combining ability |

| | | |
|---|---|---|
| $\sigma^2 SCA$ | : | Variance due to Specific combining ability |
| Cov. (F.S) | : | Covariance of Full sib |
| Cov. (H.S) | : | Covariance of Half sib |
| $F_1$ | : | First Filial Generation |
| *i.e.* | : | That is |
| @ | : | at the rate of |
| SS | : | Sum of Squares |
| MSS | : | Mean Sum of Squares |
| % | : | per cent |
| @ | : | at the rate of |
| & | : | And |
| $0_C$ | : | degree Celsius |
| A.P | : | Andhra Pradesh |
| VRS | | Vegetable Research Station |

## Chapter I

# INTRODUCTION

Vegetable is the most important component of a balanced diet and acts as a protective food. India is the second largest producer of vegetables only next to china and is leader in the production of peas. Besides this, India also occupies the second position in the production of brinjal, cabbage, cauliflower and onion and third in the production of potato and tomato in the world.

Total vegetable production in the country has been estimated to be about 175.01 million tonnes from an area 10.29 million hectare. The area under tomato cultivation in India was 808.54 thousand hectares with a production of 19696.92 thousand metric tonnes **(NHB, 2017).**

According to ICMR about 300 g vegetables (125g leafy, 100g root and 75g other vegetables) per capita per day is required. But the availability of vegetables in India is only 180g per capita per day, which is very low as compared to the recommended intake.

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop and particularly now a commercial crop widely grown all over tropical, sub-tropical and temperate regions of the world for both fresh and processing purpose. It ranks second only after potato **(Bose *et al.,* 2002)**. Tomato (*Solanum lycopersicum* L.) belongs to Solanaceae family having chromosome number 2n=2x=24. It has originated from wild form in the Peru- Equador-Bolivia region of South America **(Rick, 1969).**

Previously classified as *Lycopersicon esculentum*, tomato was renamed as *Solanum lycopersicum* L. on the basis of morphological and molecular studies. A high- quality genome sequencing of domesticated tomato has been completed by 'The Tomato Genome Consortium' in May, 2012, opening a new vista in tomato improvement.

As far as botany of the fruit is concerned its classification was given by the scientist Miller. Tomato belongs to Nightshade family Solanaceae and genus *Lycopercicon*, having two distinct species *L. esculentum* and *L. pimpinellifolium.* The immediate ancestor of cultivated tomato was probably *L. esculentum* var. *ceraciforme* found throughout tropical and subtropical America. The largest concentration of wild tomatoes is in Mexico. The genus *Lycopersicon* is further divided in to two subgeneras: *Eulycopersicon* which is red fruited type and are self-compatible (Miller) and *Eriopersicon* which is green fruited and are selfincompatible. *Eulycopersicon* consist of (a*) L. esculentum* (b) *L. pimpinelifolium* Mill, and *Eriopersicon* consists of (a) *L. hirsutum* var *glabratum* (b*) L. cheesmani* (c) *L. peruvianum* Miller, (d) *L. pissisi* (e*) L. Glandulosum, (f) L. Chilense etc* **(Peter and Kumar, 2008).**

Tomato plants typically reach 3–10 ft in height and have a weak, woody stem that often vines over other plants. The leaves are 10–25 cm long, odd pinnate with 5–9 leaflets on petiole and each leaflet up to 8 cm long, with a serrated margin both the stem and leaves are densely glandular hairy. The flowers are 1–2 cm across, yellow with five pointed lobes on the corolla they are borne in a cyme of 3–12 together. Its nature a perennial, often grown outdoors in temperate climates as an annual. *Lycopersicon esculentum* and near relatives are self-fertile but the former is outcrossed to a considerable extent in certain part of subtropical areas and its native region.

Tomato is universally known as "Protective Food". It is a versatile vegetable for culinary purpose. Tomato is generally consumed as salad, cooked or as processed food. The unripe green fruits are used for making pickles, preserves and are consumed after cooking as vegetable **(Kaur *et al.*, 2004).** Tomato is a rich source of antioxidants (mainly lycopene and β-carotene), Vitamin A, Vitamin C and minerals like Ca, P and Fe **.** In tomato total antioxidant capacity ranges from 80 to 200 µ mol**.** Ascorbic acid contents of tomatoes have been found to vary according to color and it ranged from 23.21- 40.44 and 24.38 - 33.87 mg/100g in red and yellow cultivars, respectively **(Singh *et al.*, 2010)**.

In view of such an importance the tomato crop has gained, increasing the production per unit area by even lesser degree assumes greater significance.

To meet the ever increasing demand for this vegetable, there is a need for development of genotypes with improved yield and quality. Hybrid vigour in tomato was first observed by **Hedrick and Booth** (**1907).** Tremendous improvement has been made in various aspects of exploitation of heterosis in vegetable crops. **Wellington (1912)** pointed out the commercial possibilities of $F_1$ hybrid production in tomato. The term heterosis was coined by **Shull** (**1914).** Use of $F_1$ hybrids is the quickest way of combining the traits into one, besides the added advantages of heterotic yield. The progress in this direction depends on the nature, extent and magnitude of genetic variability present in the material and the extent to which it is heritable. Successful development of high yielding hybrids using inbred lines derived from heterotic population usually depends on the genetic divergence of the two parental populations. In self-pollinated crop like tomato the successful crop improvement can be achieved through wider genetic base.

Use of $F_1$ hybrids is the quickest way of combining the traits into one, besides the added advantages of heterotic yield. Tomato genotype varies not only in the morphological features but also in the quality **(Abhusita *et al.*, 1997)**. Most of the quality traits in tomato show continuous variation and is strongly influenced by environmental conditions. The genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance and include dominance and epitasis (non-allelic interaction) therefore, it is essential to partition the estimated phenotypic variability into its heritable and non-heritable components with suitable parameters such as genetic variance, phenotypic variance, genotypic coefficient of variation, phenotypic coefficient of variation, genetic advance and heritability. If high values of PCV and GCV were present for different traits as fruit per plant and plant height indicates the existence of higher magnitude of variability. Systematic study and evaluation of tomato germplasm is of great importance for current and future agronomic and genetic improvement of the crop. Evaluation of germplasm is imperative in order to understand the genetic background and the breeding value of the available germplasm **(Agong *et al.,* 2000)**. Heritability and genetic advance help in determining the influence of environment in expression of the characters and the extent to which improvement is possible after selection **(Robinson *et al.*, 1949)**. Heritable variation can be effectively studied in conjunction with genetic advance. High heritability alone is not enough to make efficient selection in segregation, unless the information is accompanied for substantial amount of genetic advance.Combining ability of genetic stocks is helpful in selecting the parents aiming to exploit hybrid for increasing the productivity.

Keeping in view of the above present investigation "**Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)**"was undertaken to generate information about general and specific combining ability effect, heterosis, inbreeding depression, variability, heritability, genetic advance, correlation coefficient and path analysis through line × tester analysis. The findings of this study would be helpful in the selection of promising $F_1$ hybrids for yield and other characters and to formulate appropriate breeding programme for achieving the desired genetic improvement in tomato.

The present investigation was taken up in tomato with the following objectives:

(1) To find out the general and specific combining ability studies of parents and their crosses of tomato.
(2) To estimate the standard heterosis, heterobeltiosis and inbreeding depression for different characters of tomato.
(3) To investigate the genetic variability, heritability and genetic advance of tomato.
(4) To ascertain the correlation coefficient and path analysis among the different economic traits of tomato.

## Chapter II

# REVIEW OF LITERATURE

The information available in the literature pertaining to various aspects of the study has been reviewed in this chapter under following headings,:

**2.1.** Combining ability and gene action.

**2.2.** Heterosis and inbreeding depression.

**2.3.** Genetic variability, heritability and genetic advance.

**2.4.** Correlation **c**oefficients and path coefficient analysis.

The genetic improvement of both quantitative and qualitative characters is the main interest of the plant breeder. The success of such a creative manipulation requires adequate knowledge of genetics of various characters. Hence, for the improvement of tomato, detailed investigation regarding genetic architecture of fruit yield and it attributes should be the main focus.

## 2.1 COMBINING ABILITY AND GENE ACTION:

The combining ability generates valuable information on potential of genetic stocks involved, thus enabling plant breeder to take critical decisions regarding the selection of parents and employing suitable procedures in various crop improvement programmes. The concept of general combining ability (GCA) and specific combining ability (SCA) were proposed for the first time by **Sprague and Tatum (1942)** in relation to single cross of corn, but later the concept has been widely used in other crops.

**Natrajan (1992)** reported that variance component due to GCA was higher than SCA, indicating preponderance of additive gene action for days to first flowering, whereas, Cheema *et al.* (1996) reported that GCA depicting importance of non-additive gene action for earliness.

**Dod *et al*., (1992**) studied in a set of 12 × 12 diallel (excluding reciprocals) in tomato and reported that the estimates of variance component due to SCA were higher than GCA for yield per plant, number of fruits per plant, days to first harvest and plant height indicating preponderance of non-additive gene action for these traits. The parents Pusa Ruby and Marglobe were the good combiners for yield per plant, number of fruits per plant and plant height. Pusa Ruby for days to first harvest and Marglobe for average fruit weight also exhibited good general combining ability. The cross combination HS101 × S12 had the promise for further exploitation.

**Bhutani and Kalloo (1993)** observed that the SCA effects for pericarp thickness were significant in combinations *viz*., Best of All × Punjab Chhuhara, HS110 × Roma and Roma × Punjab Chhuhara. The parents Punjab Chhuhara and Roma were rated as good general combiners.

**Perera and Liyanaarachchi (1993)** reported significant additive genetic effects for fruit number, fruit weight and days to 50 per cent flowering.

**Sharma *et al*., (1999)** reported the variances due to lines and crosses were significant for all the traits studied. It also revealed that lines BTL-33 and BTL-11 and tester Roma as the best general combiners for yield and its component traits. The best specific cross-combinations were BTN-46 × Roma, BTL-11 × AC-402 and BTR-49 × Roma. Observed the best cross-combinations did not necessarily involve good general combiners as their parents.

**Dhaliwal *et al*., (1999)** studied in a diallel mating study involving 12 tomato parents reported that general combining ability as well as specific combining ability effects were important for the characters studied *viz*., TSS, pericarp thickness and number of locules. Improvement for these processing attributes can be accomplished both through pure line breeding as well as heterosis breeding by choosing appropriate parental lines and cross combinations respectively.

**Baishya *et al*., (2000)** studied in a diallel mating design involving 36 $F_1$ hybrids and 9 parental lines of tomato and reported significant GCA and SCA effects for days to flowering and ripening, fruits per plant, fruit weight and yield per plant. Azad T-2, EC-89264 and EC-429 appeared to be the best general combiners for yield. EC-429 × Azad

T-2, EC- 32557 × Azad T-2 and EC-4881 × EC-130204 showed significant and positive SCA effects for fruit yield.

**Thakur and Joshi (2000)** studied in a line (18) × tester (2) study revealed that SCA variances were higher in magnitude than general combining ability variances, which indicated the preponderance of non-additive gene action for yield and other horticultural traits.

**Nemati *et al.,* (2000)** found the high values for number of fruits due to combined effect of high GCA and SCA.

**Dhatt *et al.,* (2001)** were observed in line × tester analysis of tomato involving ripening mutants as testers observed highly significant SCA effect for 34 crosses out of 60 crosses and highly significant GCA effects for six parents out of 17 parents in desired direction.

**Chadha *et al.*, (2001)** evaluated 10 lines, 4 testers and their 40 F1s in 2 environments for combining ability × environment interaction. It was reported that both general and specific combining abilities were influenced by the environment. Out of 40 F1s, only 3 showed good specific combining ability for days to 50 per cent flowering, 6 for marketable yield per plant, 2 for marketable fruits per plant and 3 for percentage of marketable fruits. The testers Solan Gola and Roma and the lines Hissar Arun and Pusa Gaurav were promising genotypes for improving tomato yield. Hissar Arun × Solan Gola and Pusa Gaurav × Roma were the best specific combinations. Additive gene action was observed for days to 50 per cent flowering, marketable fruits per plant and locules per fruits, while non-additive gene action was observed for marketable yield per plant and percentage marketable fruits.

**Bhatt *et al.*, (2001)** reported that the significant general combining ability and specific combining ability variances for all the characters studied *viz*., days to harvest, plant height, fruits per plant and yield per plant. Results showed the predominance of non-additive gene action for all the traits. Punjab Chhuhara showed significant desirable GCA effects for number of fruits per plant and yield per plant, while, Sweet-72 exhibited highly significant negative GCA for early maturity. The highest significant SCA effect for yield per plant was observed in the cross Punjab Chhuhara × Azad

Kranti, while Arka Saurabh × NDT-5 showed the highest negative SCA for earliness.

**Makesh *et al.,* (2002)** studied gene action for yield and yield components (days to flowering, plant height, number of fruits per plant and average fruit weight) using the F1 progenies of crosses involving six tomato lines. Both additive and non-additive gene action were reported to be involved in the inheritance of all the traits.

**Sharma *et al.*, (2003)** evaluated 28 $F_1$ tomato hybrids to study gene action for fruit yield per plant, mean fruit weight, number of fruits per plant following diallel analysis and reported the preponderance of additive variances for all the 3 characters studied.

**Cheema *et al.*, (2003)** studied in a 9 × 9 diallel cross (excluding reciprocals) involving heat tolerant lines of tomato and reported that the importance of additive and non-additive gene action for fruit weight, total fruit yield, marketable yield and number of locules per fruit which is indicated by their significant GCA and SCA variances.

**Pratta *et al.,* (2003)** reported that a nonreciprocal diallel combination involving 5 homozygous parents the predominance of additive gene action for fruit weight and shape.

**Rai *et al.,* (2003)** evaluated in a diallel mating design (excluding reciprocals) involving 28 $F_1$ hybrids and 8 parental diverse lines of tomato and reported significant GCA and SCA effects for all the characters studied *viz*., plant height, average fruit weight, fruit length, fruit breadth, fruit firmness, TSS, number of locules per fruit, pulp thickness and yield. The magnitude of general combining ability variances was higher than the specific combining variances indicating importance of additive component for all charactersexcept fruit breadth. The parents EC-368860, BT-17, BT-18, EC-164336-A-1 and EC- 369060-A were observed good general combinations for one or more of the character contributing yield. The crosses EC-339074 × EC 366090-A and EC-164336A × BT-18 was most promising combination for quality and yield, respectively.

**Kaur *et al*., (2004)** revealed that the importance of additive gene effects for fruit weight while deriving information on combining ability analysis.

**Rai *et al.*, (2005)** evaluated 28 hybrids developed through half diallel mating design alongwith 8 parental lines. The estimates of dominance components were higher than the estimates of additive components for average fruit weight, fruit length, TSS and yield per plant. Additive as well as dominance components were significant for all the characters except the number of locules per fruit.

**Singh *et al.,* (2005)** studied 9 tomato cultivars crossed in all possible combinations except reciprocals and reported higher values of GCA than SCA for all characters studied *viz*., plant height, days to flowering, fruit weight, fruit length and fruit width except TSS. Twelve crosses showed significant positives SCA effects for yield and other crosses Arka Abha × CH-189-1 and CH-48 × CH-171 were desirable for plant height; CH-48 × CH-171 and CH-159 × CH-242 for earliness; Arka Abha × CH-17, Arka Abha × CH-180 and CHRT-4 × CH-159 for fruit weight; Arka Abha × CH-171 for fruit length; Arka Abha × CH-180 for fruit width; CH- 159 × CH-180 for TSS.

**Thakur and Kohli (2005)** crossed eight diverse lines of tomato in half-diallel and found involvement of additive gene effects with partial dominance towards higher fruit firmness and fewer locules per fruit, while prominent role of non-additive effects was found with over dominance towards thicker pericarp and higher TSS. The lines found to be good general combiners were UHF-107, UHF-120 and FT-5 for pericarp thickness; UHF-107 and UHF-260 for number of locules per fruit; FT-5 and Solan Vajr for fruitfirmness; UHF-265, FT-5 and Solan Vajr for TSS. The best three specific combinations were UHF-260 × FT-5, UHF-265 × UHF-260 and BL-342-1 × Solan Vajr for TSS and UHF-265 × UHF-120, BL-342-1 × FT-5 and EC-191536 × Solan Vajr for pericarp thickness.

**Brar *et al.,* (2005)** studied combining ability effects of different heat tolerant tomato cultivars. For number of flowers per cluster, N-29 x EC 177824 had maximum SCA effects, while N-summer set x NS-815 was best cross combination for number of flowers per plant. For both characters, all the good cross combination involved one parent with high GCA effects and other with poor GCA effects.

**Veer *et al.*, (2006)** revealed that the line AC-1036 exhibited high positive significant GCA effect followed by AC-1019 and S-22 indicating their good general combining ability.

**Joshi and Kohli (2006)** studied 45 cross combinations obtained from crossing 10 diverse lines of tomato in half-diallel fashion and revealed that the ratio of additive variance to dominance variance indicated the predominance of non-additive gene actions for TSS, ascorbic acid content, fruit shape index, stem end SCAr size and number of locules. The high *per se* performance along with high GCA estimates of lines CLN-1351E and FT-5 suggested that these lines may be utilized for incorporating high TSS, smaller stem end SCAr size and lower number of locules. Line EC-401927 appeared to be good general combiners for ascorbic acid content and may be utilized in future tomato breeding programmes. The crosses UHF-II × EC-401927 and CLN5915-206D4-2-2-0 × FT-5 exhibited highest SCA estimates for TSS and number of locules, respectively. However, the combination CLN1462A × FT-5 gave significant SCA estimates in desirable direction for ascorbic contents and stem end SCAr size in tomato.

**Singh *et al.*, (2006)** crossed eight inbred lines of tomato in diallel mating design without reciprocals and observed that IIVR Sel-2 was found to be the best general combiner for plant height, fruit length, fruit weight and TSS. ATL-13 was the best combiner for number of fruits, ascorbic acid and TSS and H-36 for yield and TSS.

**Pandey *et al.*, (2006)** studied in a line (10) × tester (3) analysis over 2 environment reported the importance of additive as well as non-additive gene action with predominance of non-additive gene action for traits *viz*., plant height, fruits per plant, average fruit weight, fruit length, fruit diameter, TSS, ascorbic acid content, titrable acidity, early yield per plant and total yield per plant except pericarp thickness. The parents, Moneymaker, NDT-3, Bilahi-2, EC-168282, EC-7343, H-86, H-24 and KS-60 were good general combiners for more than one yield contributing characters. The cross combinations Bilahi 2 × H-86, Himlata × H-86, EC-168282 × H-24, EC-6148 × H-86, NDT-3 × H-88 and KS-60 × H-86 were most promising for yield and other contributing characters in both the environments.

**Mirshamssi *et al.,* (2006)** evaluated 21 $F_1$ hybridsderived from 7 parental half diallel mating design and reported highly significant GCA for all the character studied *viz*., plant height, days to flowering, days to ripening, fruit weight, fruit number and yield per plant, showed the role of additive effects of gene.

**Hannan *et al.,* (2007)** evaluated in a diallel study comprising of 10 parents and reported good general combining ability effects for yield per plant in Deshy, for Brix per cent in Japany and for days to first fruit ripening in Japany whereas, the cross combinations Deshy × Dynamo for Brix per cent, Namdhari × Japany for days to first fruit ripening and Deshy × Epoch for fruit yield per plant showed good specific combining ability effects.

**Kumari and Srivastava (2007)** revealed significant variance for GCA and SCA for all the character studied except for early yield and total yield for general combining ability. However, the magnitude of general combining ability variance was lower than estimates of specific combining ability variance for TSS, acidity, early yield and total yield indicating preponderance of non-additive genetic variance while, preponderance of additive genetic variance was observed for ascorbic acid.

**Sharma *et al.,* (2007)** evaluated in a diallel cross comprising 9 parents and reported that there was preponderance of non-additive genetic component for most of the traits, except for fruit weight and plant height. The marketable fruits per plant and locules per fruit had additive and non-additive gene actions. The parents Hawaii 7998, BL-342, EC-191536 and PTOM-9301 were the best general combiners for most of the traits across the environments. The crosses BL-342 × Hawaii 7998, BL-342 × EC 191536 and BWR (FR) × EC 191536 revealed promise for further exploitation.

**Garg *et a*l., (2008)** reported that there was a poor association between GCA of lines and their per se performance, leading to the conclusion that although per se performance may reflect the GCA of a line to some extent but it is not a reliable parameter.

**Chishti *et al.,* (2008)** evaluated 12 parental lines alongwith their 66 F1 hybrids and reported that non-additive variance prevailed in the genetic determination of most of the characters.

**Puja *et al*., (2008)** revealed that the majority of cross combinations exhibiting desirable SCA effects had at least one of the parents as good or average general combiners.

**Saleem *et al*., (2009)** reported the estimate of variance of GCA, SCA, their ratio and degree of dominance indicated preponderance of non-additive gene action for all the traitss suggesting that selection might not be made in the early generations and recurrent selection with periodic intercrossing appeared to be the best method. Based on mean performance and GCA effects, line 88572 and UC-134 and tester Nagina were better for yield and its various components.

**Sekhar *et al*., (2010)** were reported GCA and SCA expressed the role of both additive and in individual fruit weight, yield per plant and locule number non-additive gene active in control of these traits.

**Kumari *et al.,* (2010)** evaluated 10 hybrids developed through diallel mating design excluding reciprocals along with 5 parental lines for yield and other contributing traits *viz*., days to flowering, days to maturity, weight per fruit (g), fruit length (cm), fruit width (cm), total number of fruits per plant, plant height (cm) and total yield (kg/plant). The crosses *viz*., KS-16 × Azad T-3, Azad T-3 × KS-7, Angoor Lata × K6-7 and KS-16 × Angoor Lata were found to be good specific combinations.

**Sharma and Sharma (2010)** studied ten parental lines and 45 cross combinations of tomato in a diallel mating design excluding reciprocals and reported significant GCA and SCA effects for plant height, days to first picking, number of fruits per plant, fruit shape index, average fruit weight, pericarp thickness and fruit yield per plant. AI-9, FT-5 and Solan Vajr were observed to be good general combiners for fruit yield per plant. Hybrids, FT-5 × Solan Vajr, EC-15998 × AI-9 and AI-9 × Solan Vajr exhibited high SCA effects for fruit yield. The combining ability analysis revealed the preponderance of non-additive gene action for the expression of fruit yield per plant.

**Singh and Asati (2011)** were identified genotypes Sel-2, DVR-2, Sikkim Local, 97/640, BT-117-5-3-1, Flora-Dade and KT-15 as good general combiners for most of the yield and quality contributing characters, and these may be used as valuable donors in the hybridization programme and different cross combinations studied, BT-207 × KT-15, Type-I × KT-15, and FEB-2 × BT-117-5-3-l were the most valuable combiners for yield and other characters.

## 2.2 **Heterosis:**

Heterosis is superiority of the hybrids over their parents in vegetative growth, adaptiveness and productivity **(Shull, 1914)**, **Hedrick and Booth (1907)** were the first to notice heterosis in tomato. But it was who first advocated the use of $F_1$ hybrids for boosting tomato production (**Wellington 1912)**.

**Perera and Liyanaarachchi (1993)** reported significant heterobeltiosis for fruit number in 78 crosses produced in a 13 × 13 half diallel design, while heterosis over mid parent was observed for days to 50 per cent flowering. For fruit weight, heterosis over either mid or better parent was absent. Sidhu and Singh (1993) in diallel set of crosses between 11 varieties reported a range of 0.826 kg (Ace VF × VFN 8) to 2.426 kg (F24 × Ronita) for mean yield per plant in the resulting 55 hybrids. Heterosis ranged from 0.7 per cent in Ace VDF × F24 to 71.7 per cent in Ohio 7663 × Rossol. Eleven hybrids showed significant heterosis ranging from 23.8 to 71.7 per cent.

**Chadha (1994**) reported that 12 out of 24 hybrids showed hybrid vigour for marketable yield over better parent and two over standard checks and also observed positive and significant heterosis in most of the hybrids for marketable yield per plant, marketable fruits per plant, duration of harvest and TSS but, in relatively lesser proportion of the hybrids for days to 50 per cent flowering, days to first harvest, average fruit weight, polar diameter, equatorial diameter, pericarp thickness, locules per fruit and plant height. He also reported that hybrid vigour for marketable yield per plant was mainly due to increase in harvest period for marketable fruits per plant. He further reported that hybrid 92H-2 produced the highest marketable yield per plant followed by 92H-1, 92H-4, 92H-10 and 92H-22. Dev et al. (1994) reported EC156 × Marglobe as the best F1 hybrid as it gave 83.18 and 29.23 per cent higher yield than the better parent and the standard check Naveen, respectively.

**Uppal *et al.,* (1997)** crossed 18 lines with 5 testers and evaluated 90 hybrids along with 4 commercial and 2 experimental hybrids. The cross 01 × 41 was superior to control for early maturity, while the crosses 21 × 02 and 20 × 42 had long harvesting span (39.6 days). Hybrids were observed which exceeded the controls for total yield per plant (4.99 kg), marketable yield per plant (4.41 kg), number of fruits per plant (90), pericarp thickness (10.3 mm) and TSS (6%).

**Kurian *et al.,* (2001)** studied heterotic hybrids identified for average fruit weight (Sakthi x Fresh Market 9, Sakthi x HW 208F), yield / plant (Sakthi x TH 318, Sakthi x Fresh Market 9), locule number (LE 206 x Ohio 8129, LE 214 x St 64) and pericarp thickness (Sakthi x St 64, LE 206 x 64, LE 214 x St 64). All the hybrids were late to harvest and they produced fruits with round Shape. Heterosis in tomato was observed for average fruit weight (Sakthi x Fresh Market 9, Sakthi x HW 208F), yield per plant (Sakthi x TH 318, Sakthi x Fresh Market 9), locule number (LE 206 x Ohio 8129, LE 214 x St 64) and pericarp thickness (Sakthi x St 64, LE 206 x 64, LE 214 x St 64). The heterobeltiosis ranged from 5.95 to 21.37 per cent, whereas relative heterosis ranged from 2.14 to 14.37 per cent**.**

**Alice and Peter (2001)** reported that Shakthi x HW 208E showed 9.18 % heterosis for total soluble solids while, LE-206 x T64 showed 7.0 %. Heterosis for this character.

**Fageria *et al.,* (2001)** evaluated 45 hybrids alongwith 10 genotypes and reported negative heterobeltiosis for fruit weight and number of fruits per cluster and observed positive heterobeltiosis for plant height, harvest duration and yield in tomato.

**Chaudhary and Malhotra (2001)** studied the mean performance of 24 $F_1$ hybrids alongwith the standard checks Rupali (SC1) and Naveen (SC2) and reported that 19 hybrids over SC1 and 10 over SC2 for fruit weight, 7 hybrids over SC1 and 8 over SC2 for pericarp thickness and only one hybrid over SC1 for plant height surpassed the respective standard checks.

**Rana (2002**) studied reciprocal cross hybrids in tomato and reported that the top best hybrid BWR-5 × Hawaii 7998 gave a difference of marketable yield to the tune of 1.26 kg per plant. BWR-5 as female parent proved to be the best in combination with Hawaii 7998, EC 191536 and EC 191538 as male parents. The hybrid combinations EC 191536 × Hawaii 7998 (first fruit harvest), EC 191538 × LE 79-5 (gross yield/plant), BT-18 × Hawaii 7998 (total number of fruits/plant), BWR-5 × EC191536 (average fruit weight and locules/fruit), LE 79-5 × BWR-5 (pericarp thickness), EC 191536 × Hawaii 7998 (plant height and duration of harvest) and Hawaii 7998 × LE 79-5 (TSS) were the top best for respective traits.

**Tiwari and Lal (2004)** evaluated nine tomato hybrid combinations. The cross Pant T-5 x NDT-9 showed maximum heterosis over better parent for marketable yield per hectare. It also exhibited high heterobeltiosis, relative heterosis and standard heterosis for number of fruits per plant and yield per plant.

**Anita *et al.,* (2005)** studied eight F1 hybrids and their 16 parents and observed heterosis to the extent of 63.30 per cent for fruit weight, 25 per cent for number of locules per fruit, 23.33 per cent for number of fruits per plant, 109.11 per cent for yield per plant, 29.03 per cent for TSS and 32.25 per cent for ascorbic acid content over better parent. The cross NDT-15 × Pant T-5 manifested maximum heterosis for fruit number and total yield.

**Rattan (2007)** evaluated the mean performance of 28 hybrids (7 line × 4 testers) and the standard check (7711). Variable number of hybrids outperformed the standard check for the traits viz., days to 50 per cent flowering (25 crosses), days to first harvest (18 crosses), gross yield per plant (15 crosses), total number of fruits per plant (22 crosses), marketable fruits per plant (27 crosses), fruit shape index (13 crosses), pericarp thickness (8 crosses), locules per fruit (3 crosses), plant height (12 crosses) and TSS (15 crosses). No hybrid could surpass the standard check for fruit weight.

**Sharma and Thakur (2007)** evaluated 45 hybrids (developed in a half diallel fashion) alongwith 10 parents reported EC-15998 × AI-9, FT-5 × Solan Vajr, AI-9 × Solan Vajr and Solan Vajr × UHF695 as superior crosses on the basis of per se performance. Significant heterobeltiosis in desirable direction was recorded for all the traits (plant height, average fruit weight, pericarp thickness, number of fruits per plant, fruit yield and harvest duration) under study except days to first picking and TSS.

**Shankarappa *et al*., (2008**) observed in tomato line x tester experiment, most crosses manifested in significantly positive heterosis over the check US-618 for plant vegetative growth and fruit yield, indicating non-additive gene effects for these traits. However, hybrid BLRH-2 (53%) expressed the highest significant positive heterosis.

**Kumar *et al*., (2009)** studied in tomato for majority of the traits, appreciable amount of heterobeltiosis and standard heterosis. Heterosis over mid parent and better parent in tomato ranged from -9.18 to 7.65 per cent and 8.57 to 11.79 per cent, respectively also reported 60 per cent hybrid vigour in tomato.

**Mondal *et al*., (2009)** were crossed of nine parental lines in line × tester fashion to estimate heterosis in tomato for fruit yield, yield components and fruit quality traits revealed H-24 × NF-31 and H-24 × Hissar Arun as the best hybrids.

**Cheema *et al*., (2009**) reported that out of the 36 $F_1$ crosses produced from 9 heat tolerant lines crossed in a diallel fashion excluding reciprocals, 5 hybrids contributed significant heterosis effect over their respective better parent and 23 over check for longer harvesting span. For fruit weight, only 5 crosses showed significant positive heterosis over their respective better parent and only one cross showed heterosis in desired direction over standard check. Significant positive heterosis for total fruit yield per plant was observed in 4 crosses over their better parent and check hybrid, respectively. For TSS, only 2 hybrids exhibited significant positive heterosis over their respective better parent while none of the hybrids showed desired heterotic effect over check.

**Gaikwad and Cheema (2010)** reported that the useful heterobeltiosis for almost all the characters studied in 66 crosses produced in a 12 × 12 half diallel design. The cross combinations LST-65-2 × NaGCArlan, LST-6 × CLN 5915-206 and LST-6 × 2123-E-1 were the best crosses for marketable fruit yield per plant and they showed 160.8, 328.8 and 156.1 per cent heterosis over their respective better parents, respectively.

**Gul *et al.,* (2010)** evaluated 8 × 8 half diallel and reported maximum significant positive heterosis for fruit length (15.5%) and fruit weight (45.0%) over better parent. On the basis of *per se* performance, three single cross hybrids E-02 × P28, E-02 × P45 and E-02 × P51 were among the top.

**Kumari and Sharma (2011)** observed maximum and significant heterosis in favourable direction for yield, fruit number, plant height and fruits per cluster. Heterosis was appreciable in all hybrids, but was more in four hybrids viz Sioux x FT-5, S-1001 x Solan Vajr, EC-521041 x FT-5 and S-1001 x EC-15998.

**Saeed *et al.*, (2011)** found that the highest heterosis for most of the parameters studied was observed in cross combinations BL-1176 × LO-2875 and CLN-2498A x LO-2875.

**Gaikwad and Cheema (2012)** studied twelve genetically diverse heat tolerant lines and their 66 $F_1$ hybrids (diallel mating design excluding reciprocals) and reported that cross combination LST-6 × CLN 5915-206 had maximum fruit yield of 1.17 kg per plant and showed 193.3 per cent increase over better parent and 291.11 per cent increase over standard check TH-1.

**Chattopadhyay and Paul (2012)** studied 25 entries consisting of 13 diversified genotypes along with their 12 $F_1$ hybrid of tomato and observed that the crosses Utkal Pallavi × Pathar Kuchi, EC 110964 × Utkal Deepti, Sel 12 × Utkal Deepti, Elegant × Pusa Ruby were the most outstanding on the basis of *per se* performance. Only nine crosses for fruit length, three crosses for fruit width, three crosses for locules per fruit, five crosses for TSS, two crosses for vitamin C and only one cross for pericarp thickness and total acidity expressed significant positive heterobeltiosis.

**Islam *et al.,* (2012)** evaluated 19 cross combinations from a half diallel cross without reciprocals and observed the highest heterobeltiosis in the cross P3 × P8 (-18.46%) for earliness, P6 × P7 (75.54%) for plant height, P5 × P6 (67.44%) for fruits per plant, P9 × P10 (54.82%) for yield per plant, P2 × P8 (21.21%) for individual fruit weight, P7 × P8 (3.09%) for fruit length, P3 × P8 (14.11%) for fruit diameter and P1 × P6 (13.11%) for Brix content. In respect of fruit external characters like shape, pedicel area, shape of pistil SCAr, blossom end shape genotypes were found diverse. Internal qualitative character like firmness, fleshiness and less seeded and locule numbers were highly variable among the genotypes.

**Kumar *et al.,* (2012)** studied 23 genotypes including 5 lines, 3 testers and 15 F1s of tomato. On the basis of heterobeltiosis H-24 × Azad T-5 (25.27%), Pant T-3 × Floradade (25.13%) and Pant T-3 × Azad T-5 (21.13%) for number of fruits per plant, H-24 × Kashi Sharad (13.08%) and CO-3 × Azad T-5 (10.84%) for average fruit weight, CO-3 × Kashi Sharad (32.06%), H-24 × Azad T-5 (18.34%), H-24 × Kashi Sharad (13.36%) and Pant T-3 × Azad T-5 (11.27%) for total yield per plant and on the basis of economic heterosis CO-3 × Kashi Sharad (29.95%), H-24 × Azad T-5

(25.27%) andPunjab Upma × Azad T-5 (24.46%) for number of fruits per plant, H-24 × Kashi Sharad (23.53%), DT-2 × Kashi Sharad (14.71%) and DT-2 × Azad T-5 (14.20%) for average fruit weight, CO-3 × Floradade (31.83%), CO-3 × Kashi Sharad (31.14%), Punjab Upma × Azad T-5 (30.10%) and Pant T-3 × Azad T-5 (25.26%) for total yield per plant were the top ranking cross combinations.

**Negi *et al.,* (2012)** carried out an investigation on seven character in $F_1$ crosses comprising a total of six parental lines of two cold set (Pusa Sheetal and Pusa Sadabahar) and four non-cold set (Booster, DT-39, Pusa Uphar and Chiku) were crossed in a diallel fashion without reciprocals to obtain 15 F1s and reported their best heterotic combinations over better parent for various characters. These crosses were PSH × DT 39 for first fruit set (-7.55%), PSH × PS for days to first harvest (-8.79%), PSH × PS for days to 50 per cent flowering (-11.56%), PSH × PS for yield per plant (133.77%), PHS × CH for plant height (34.66%), PS × CH for fruit weight (51.92%) and PSH × PS for number of fruits per plant (68.99%). They revealed that PSH × PS ranked top position for most of the characters studied followed by PSH × CH.

**Singh *et al.,* (2012)** revealed that heterosis over better parent to the extent of 22.05 per cent for days to flowering, 139.61 per cent for plant height, 98.70 per cent for fruit weight, 102.08 per cent for number of fruits per plant, 163.20 per cent for yield per plant, 110.98 per cent for fruit size and 165.03 per cent for number of locules per fruit in 7 × 7 half diallel cross of tomato. They also reported that cross combinations *viz*., Ox-heart × Sutton Roma, Marglobe Supreme × Sutton Roma, Money Maker × Pusa Early Dwarf, Marglobe Supreme × Money Maker and Sutton Roma × Pusa Early Dwarf were the most outstanding for yield and its component traits.

**Shetty (2013)** observed that the hybrids PT-2007-09 x Pant Bahar and PT-2009-08 x Arka Vikas were most promising for earliness exhibiting highest negative heterosis.With respect to plant height PT-2009-08 x PT-3 recorded negative heterosis for dwarfness. Hybrid combination, S-108 x PT-3 exhibited most promising results with respect to heterosis for fruit yield per plant and total soluble solids. Most promising hybrid for number of locules was PT-42 x Arka Vikas which exhibited negative heterosis. The best hybrids with respect to heterosis were S-108 x Arka Vikas for average fruit weight, PT-18 x PT-3 for fruit yield per hectare, PT-18 x Arka Vikas for number of fruits per plant.

**Kumar *et al.,* (2013)** evaluated a line (10) × tester (3) analysis and observed maximum significant positive heterosis over better parent in cross combination SEL-7 × BT-12 (7.14%) for fruit shape index, Fla-7171 × Arka Abha (36.96%) for pericarp thickness, ATL-239 × BT-12 (10.28%) for ascorbic acid, ATL-239 × (BT-12 for titrable acidity and H-24 × Arka Abha (43.59%) for TSS. While, cross combination Fla-7171 × Kashi Sharad (13.79%) for fruit shape index, Fla-7171 × BT-12 (32.52) for pericarp thickness and Flora dade × Arka Abha (16.09%) for titrable acidity exhibited significant positive heterosis over standard check (Shaktiman). The heterobeltiosis was revealed only in one cross for fruit shape index, 7 crosses for pericarp thickness, 6 crosses for ascorbic acid, 3crosses for titrable acidity and 13 crosses for TSS out of 30 crosses studied by them. The economic heterosis was observed in 2 crosses for fruit shape index, 8 crosses for pericarp thickness and 7 crosses for titrable acidity while none of the hybrids showed desired heterotic effect over check for ascorbic acid and TSS.

**Yadav *et al.*, (2013)** studied line (10) × tester (3) and revealed that CO-3 × Arka Vikas, CO-3 × NDT-5 and potato leaf × NDT-5 were the most promising cross combinations and showed maximum standard heterosis to the extent of 29.57 per cent, 22.14 per cent and 20.66 per cent for fruit yield per plant, respectively. Variable number of hybrids outperformed the better parent and standard check for the traits plant height (22 and 21 crosses), number of fruits per plant (23 and 20 crosses), fruit length (11 and 17 crosses), fruit diameter (23 and 23 crosses), average fruit weight (15 and 16 crosses) and fruit yield per plant (each 16 crosses), respectively.

**Solieman *et al.*, (2013)** found that mid-parent heterosis varied from−16.04 to 29.75% for plant height,−5.74 to 20.95 for number of primary Number of branches per plant, −34.72 to 15.18% for fruit shape index, −35.72 to 49.02% for number of locules per fruit, −9.22 to 25.88% for pericarp thickness, −5.02 to 15.21% for fruit firmness, −11.46 to 25.50 for total soluble solids, −1.26 to 15.66% for ascorbic acid content, −9.39 to 22.48% for number of flowers per cluster, 4.37 to 104.69% for number of fruits per plant, −32.78 to 11.29% for average fruit weight, 22.29 to 64.33% for total fruits yield per plant.

**Agarwal *et al.*, (2014)** studied heterosis using 8 × 8 diallel set (excluding reciprocals) and observed that cross combinations *viz*., CLN 5915-206 × CLN 1314G (56.32%), CLN 5915-206 × Best of All (17.98%) and CLN 2264J × CLN 1314G

(13.30%) for fruit yield, CLN 2264H × DARL-1 (117.27%), DARL-2 × CLN 1314G (109.35%) and Best of All × DARL-1 (103.60%) for average fruit weight and CLN 2264H × Pith Sel (40.74%), DARL-2 × Best of All (26.67%) and CLN 2264J × Best of All for TSS (25.93%) were the top ranking cross combinations on the basis of standard heterosis.

**Chauhan *et al*., (2014)** studied eight parents and their 28 $F_1$ hybrids (half diallel mating design) and reported that hybrids Pusa Gaurav × Taiwan, Pusa Rohini × Pusa Gaurav and Pusa Rohini × Roma were most promising for yield and its contributing traits. These hybrid exhibited heterosis to the extent of 48.14 per cent, 44.47 per cent and 73.41 per cent over better parents and 83.43 per cent, 76.78 per cent and 74.24 per cent, respectively over the standard check for fruit yield per plant. The cross combination Pusa Gaurav × Taiwan expressed highest significant heterosis over standard check.

**Aisyah *et al*.,(2017)** The tomato genotype IPB 78 is parental with the best general combining ability for yield per plant, individual fruit weight, fruit length, and fruit thickness. The tomato genotype IPB T73 x IPB T3 proved to be the best general combiner for yield and number of fruits per plant. The tomato genotype IPB T3 x IPB T1 proved to exhibit best heterosis for yield per plant and fruit thicknes.

## 2.3 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE:

A critical estimate and study of genetic variability is pre-requisite for initiating appropriate breeding procedures in crop improvement programmes, which demands wide range of variability in a population. The determination of genetic variability and its partitioning into various components in crop plants is necessary to have an insight into genic nature of yield and its components. The degree to which variability of a character may be transmitted to the progeny is referred to as its heritability. The heritable variation is marked by non-heritable components hence, it is necessary to split the overall heritability using genetic parameters.

According to **Hanson *et al.*, (1956)**, heritability in broad sense is the ratio of genotypic variance to total variance in non-segregating population. A high heritability is not always accompanied by high genetic advance but, in the presence of fixable gene effects high genetic advance should be expected (Panse and Sukhatme, 1967). Genetic advance under selection is the improvement in the mean genotypic value of the selected families over base population which depends upon the genetic variability existing in the population, the heritability of the character under selection and the intensity of selection. Hence, the components of variances and heritable components with genetic parameters, such as genetic coefficient, of variation, heritability estimate and genetic advance are important tools for the breeders to plan suitable breeding strategy.

**Baishya *et al.*, (2001)** reported that 113 percent heterosis in the cross EC-4881 x EC 130204 for fruit yield per plant. They also found 70.59 and 120 per cent heterosis for number of fruits and fruit weight, respectively.

**Sharma *et al.*, (2001)** observed hybrid vigour over better parent and standard 10 checks (Rupali and Naveen) for fruit yield and the component traits *viz.,* marketable fruits, non-marketable fruits, fruit weight, fruit length, fruit diameter, pericarp thickness, TSS, plant height and maturity.

**Thakur (2004)** evaluated 36 hybrids developed by crossing 18 lines and 2 testers. Amongst crosses, H-711492 x 101 and 260 x V-16 exhibited the maximum heterosis, whereas cross combination FT-15 x V-16 recorded the highest significant heterobeltiosis.

**Joshi and Thakur (2005)** evaluated 34 hybrids developed by crossing 17 lines and 2 testers. Sixteen hybrids showed significant heterobeltiosis for yield per plant. Negative heterosis over better parent was observed for days to flowering in BT-12-2-1 x V-16. The cross 187 x 101 (41.13%) and BT-12 x 101 (39.61%) showed the highest significant heterosis over better parent for fruit weight. Twenty one hybrids gave significantly positive heterosis over better parent for plant height. The highest heterobeltiosis for prolonged harvest duration (11.40 %) was observed in the cross combination 1874 x 101.

## 2.4 CORRELATION COEFFICIENTS AND PATH COEFFICIENT ANALYSIS:

Information of genotypic, phenotypic and environmental inter relationship between various economic traits are of interest to the plant breeder, not only from a heterotic consideration of quantitative inheritance of traits but also from practical point of view. Selection is usually, considered with change in two or more characters simultaneously. The information may be used in the predication of correlation response induced and detection of some characters which may have no value by themselves, but are useful as indicators of more important ones under consideration **(Johanson *et al.,* 1955)**.

Phenotypic correlation is due to genotypic and environmental factors and phenotypic origin provides apparent information about association observed between two characters and is generally used in selection of one characters as a mean for improving the other. Such correlation coefficient provides information by them **(Miller *et al.,* 1958)**.

The concept of correlation was presented by **Galton (1989)** which was elaborated later by **Fisher (1918)**. The statistics which measures the relationship and its extent between two or more variables is known as correlation coefficient.

Path coefficient analysis was proposed by **Wright (1921)** and later more lucidly explained by **Dewey and Lu (1959**). Path coefficient analysis is a measure of the direct influence of one variable upon another which permits the separation of correlation coefficient into component of direct and indirect effect. The use of path coefficient analysis requires a cause and effect situation among variables.

**Srivastava and Srivastava (1976)** revealed that number of female flower per plant had maximum direct effect on yield followed by number of fruits per plant and number of lateral Number of branches per plant. Path analysis revealed that harvesting span, number of leaves per vine, fruit length, average fruit weight, number of seeds per fruit, and number of fruits per vine, biological yield and keeping quality had direct positive effect on fruit yield whereas fruit length had positive but indirect effect on fruit yield.

**Parhi *et al.*, (1995)** observed that the width of fruit had highest positive direct effect on yield per plant followed by days to opening of first male flower, days to opening of first female flower, vine length, seed number and seed/flesh ratio, whereas characters like number of primary Number of branches per plant and fruit length had weak positive direct effect on yield.

Path analysis indicated that fruits per plant had the highest direct contribution towards yield, followed by chlorophyll a content, fruit length and fruit diameter, while vine length had the highest indirect contribution towards yield, followed by internodal length, average fruit weight, fruit diameter and fruit length via number of fruits per plant.

**Dey *et al.,* (2005)** emphasized that fruit weight exhibited maximum positive direct effect towards yield followed by fruits per plant and fruit length whereas fruit index exhibited high negative direct effect upon yield but showed strong positive indirect effect through fruit weight and fruit length. Traits like sex ratio, days to first male flower and node number to first female flower exhibited negative effect upon yield.

**Islam *et al.,* (2009)** found that yield per plant had high positive and high significant relation with number of nodes per vine. Path coefficient analysis revealed maximum direct contribution towards yield per plant with number of fruit per plant followed by vine length.

The portioning of correlation coefficients into direct and indirect effects revealed that the highest positive direct effect on yield was recorded by number of fruits vine followed by fruit girth and node of first male flower appearance. The maximum value for the indirect positive effect on yield was recorded for number of female flowers per vine through number of fruits per vine (**Sundaram, 2010**)

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## Chapter III

# MATERIALS AND METHODS

The present investigation entitled **"Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)"** was carried out at Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow- 226025 (U.P.), India, during the summer season of 2014-15 and 2015-16. The details of materials used and methodology to execute the investigation have been described under chapter are given below:

### 3.1 LOCATION AND SITE OF EXPERIMENT:

The Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Vidya- Vihar, Rae Bareli Road, Lucknow is situated at an elevation of 111 meter above mean sea level in the subtropical tracts of central U.P. at $26^0$ 56' North latitude. The Horticulture Research Farm is located approximately 10 km away from the Lucknow Railway station towards South-East on Lucknow, Rae Bareli Road, near South city.

### 3.2 TOPOGRAPHY, CLIMATE AND WEATHER CONDITIONS:

The climate of this region is subtropical with maximum temperature ranging from $29.3^0$C to $45^0$C in summer and minimum temperature ranging from 3.5 to $15^0$C in winter and relative humidity (RH) of 60-80% during different seasons of the year. Lucknow is characterized by subtropical climate with hot summer and cold winter. The annual rainfall is about 750 mm, most of which is received from June to September with some irregular showers in winters from the North-East monsoon.

## 3.3 EXPERIMENTAL MATERIALS:

The experimental materials consisted of 12 lines, 3 testers and 36 $F_1$ hybrids obtained from Line x Tester mating design. The parents were randomly selected representing wide range of variation in yield and different yield attributing traits. The name and sources of parents (Line and Tester) are given in Table-3.1.

## 3.4 DESIGN OF THE EXPERIMENT AND LAYOUT PLAN:

The 36 $F_1$ and their 15 parents (12 lines and 3 testers) were sown during summer season of 2014-15 and 2015-16 under Randomized Block Design with three replications. Each treatment was sown with row to row spacing of 60 cm and plant to plant spacing of 45 cm. The plan of work for the experimentation was as under:

**First season:** Selected lines used as tester (male parents) were crossed with other promising lines (used as female parents to raise $F_1$ progeny).

**Second season:** $F_1$ population along with parents were raised and selfed to produce $F_2$ seeds. Simultaneously parents were also crossed for getting new $F_1$ seeds.

**Third season:** $F_1$, $F_2$ and their respective parents (male and female) were grown out in Randomized Block Design with three replications.

All the recommended agronomic practices were followed to raise a healthy and vigorous crop.

**Table- 3.1: Name and sources of the lines and testers**

| S. No. | Name of Parents | Symbol | Sources of origin |
|---|---|---|---|
| **Lines** | IIVR-Sel.-1 | $L_1$ | IIVR, Varanasi |
| | G-3 | $L_2$ | IIVR, Varnasi |
| | S. Naveen | $L_3$ | IIVR, Varanasi |
| | DVRT-2 | $L_4$ | IIVR, Varanasi |
| | H-24 | $L_5$ | IIVR, Varanasi |
| | H-86 | $L_6$ | IIVR, Varanasi |
| | H-88 | $L_7$ | IIVR, Varanasi |
| | Pusa Sheetal | $L_8$ | IIVR, Varanasi |
| | FLA 7171 | $L_9$ | IIVR, Varanasi |
| | Hisar Arun | $L_{10}$ | IIVR, Varanasi |
| | Sel.-32 | $L_{11}$ | IIVR, Varanasi |
| | Flora Dode | $L_{12}$ | IIVR, Varanasi |
| **Testers** | Pusa Sadabahar | $T_1$ | IARI, New Delhi |
| | Kashi Vishesh | $T_2$ | IIVR, Varanasi |
| | Kashi Amrit | $T_3$ | IIVR, Varanasi |
| **Standard variety** | Pusa Rohini | | IARI, New Delhi |

## 3.5 OBSERVATIONS WERE RECORDED:

The observations were recorded on randomly selected five plants in each genotype from each replication. The selected plants were tagged and properly labeled before flowering for recording the observations. The data on following characters were recorded:

**3.5.1 Plant height:** The height of five tagged plants was measured in centimetres from the ground level to the tip of the main stem at final picking, with the help of meter scale and the average plant height was worked out.

**3.5.2 Number of branches per plant:** Number of branches per plant was counted at final harvest for five tagged plants and the average was calculated.

**3.5.3 Days to 50% flowering:** Number of days taken from date of transplanting to days on which 50% of the plants in a plot flowered was recorded.

**3.5.4 Number of clusters per plant:** The total number of clusters in each of the tagged plants was recorded just before fourth picking and at time of final harvest. The final count of clusters per plant was noted in second observation was taken as number of clusters per plant.

**3.5.5 Number of flowers per cluster:** Five inflorescences were randomly selected in each treatment at the time of peak flowering stage and the total number of flowers in each inflorescence was counted and then the average number of flowers per cluster was worked out.

**3.5.6 Number of fruits per cluster:** Number of fruits in each cluster of five plants were counted to arrive at mean number of fruits per cluster in each entry.

**3.5.7 Number of fruits per plant:** The marketable fruits harvested from randomly taken plants were counted at each harvest, summed up and averaged to obtain number of fruits per plant.

**3.5.8 Average fruit weight (g):** Total weight of fruits from five randomly taken plants at every picking was recorded and divided by total number of fruits of all the harvests to compute the mean fruit weight in grams.

**3.5.9 Number of locules per fruit:** Fruits were cut in horizontal axis and number of locules was counted.

**3.5.10 Pericarp thickness (mm):** Pericarp thickness of five randomly taken fruits of second harvest in each entry was measured after cutting the fruits transversely. Measurement was done with Digital Vernier Callipper in millimeters and mean value was worked out.

**3.5.11 Fruit length (cm):** Fruit length was measured from stalk end to blossom end of the fruit at third harvest by using vernier callipers and average of 10 fruits was computed and expressed in centimeters

**3.5.12 Fruit width (cm):** Width of the fruit at the highest bulged portion was measured at third harvest by using vernier callipers and average of 10 fruits was computed and expressed in centimetres.

**3.5.13 Number of ridges on fruit:** The total number of ridges on fruit were counted.

**3.5.14 Fruit yield per plant (kg):** Total yield per plant was obtained by summing up the fruit weight from all the pickings and averaged.

**3.5.15 TSS ($^0$Brix):** From each plant five fruits were taken at random. TSS (%) of each fruit was recorded using Hand Refractometer and average is recorded in %.

**3.5.16 Vitamin C (mg/100g):** The vitamin C content was determined by 2, 6-dichlorophenol indophenol visual titration method as described by Ranganna (1994). Aliquotes prepared by macerating freshly harvested fully ripe tomato fruits in the presence of 3% metaphosphoric acid and titrated against 2, 6-dichlorophenol indophenols dye to pink end point persisting at least for 15 seconds.

**Plate-1:A general view of  tomato nursery in the nursery bed**

**Plate- 2:A general view of lay-out plan of experimental site**

## Plate-3: A general view of tomato crop at the time of irrigation

## 3.6 STATISTICAL AND GENETICAL ANALYSIS:

### 3.6.1 Analysis of variance for design of experiment:

The analysis of variance of the experimental design was carried out for each character separately as following **(Panse and Sukhatme, 1967)**.

| **Source of Variation** | **D.F.** | **S.S.** | **M.S.S.** | **F-calculated values** |
|---|---|---|---|---|
| Replications | (r-1) | RSS | MSR | MSR/MSE |
| Treatments | (t-1) | TSS | MST | MST/MSF |
| Parents | (p-1) | PSS | MSP | MSP/MSE |
| Lines | (f-1) | FSS | MSF | MSF/SME |
| Tester | (m-1) | MSS | MSM | MSM/MSE |
| Lines vs. tester | 1 | FSS vs. MSS | MSR vs. MSM | MSF s.MSM/MS |
| Hybrids/$F_1$ population | ($F_1$-1) | $F_1$SS | MSF$_1$ | MSF$_1$/MSE |
| Parents vs. hybrids | 1 | PSS vs. $F_1$SS | MSP vs. MSF$_1$ | MSP vs. SF$_1$/MS |
| $F_2$ population | ($F_2$-1) | $F_2$SS | MSF$_2$ | MSF$_2$/MSE |
| Parents vs. $F_2$s | 1 | PSS vs. $F_2$SS | MSP vs. MSF$_2$ | MSP vs. SF$_2$/MS |
| Error | (r-1) (t-1) | ESS | MSE | - |

Whereas,

r = number of replications

t = total number of treatments

p = number of parents

f = number of lines

m = number of tester

$F_1$ = number of hybrids

$F_2$ = number of populations

### 3.6.2 CRITICAL DIFFERENCE:

In order to compare the means of variance critical difference (CD) was calculated by the following formula:

CD = SE x t at 5 percent and 1 percent

Where,

SE is the standard error of the difference of the treatment means to be compared and calculated by following formula:

$SE = \sqrt{2}Ve/r$

Where,

Ve = error mean sum of squares

r = number of replications

T(5% or1%) = tabulated value at 5 percent or 1 percent level of significance for error degree of freedom.

### 3.6.3 COMBINING ABILITY ANALYSIS:

The analysis of variance for combining ability was carried out according to the method outlined by **Kempthorne (1957).** The partitioning of treatments was done into males female and females x males for $F_1$ generation. The skeleton of analysis of variance for combining ability as follows:

### 3.6.3.1 Analysis of variance for combining ability:

| **Source of variation** | **D.F.** | **M.S.** | **Expectation of M.S.** |
|---|---|---|---|
| Replications | (r-1) | | - |
| Hybrids | (fm-1) | | - |
| Lines | (f-1) | $m_1$ | $\delta^2_e$ +r[Cov(F.S.) – 2Cov(H.S.)] + Mr Cov (H.S.) |
| Testers | (m-1) | $m_2$ | $\delta^2_e$ +r[Cov(F.S.) – 2Cov(H.S.)] + fr Cov (H.S.) |
| Lines x Tester | (m-1) x (f-1) | $m_3$ | $\delta^2_e$ +r[Cov(F.S.) – 2Cov(H.S.)] |
| Error | (r-1) x (mf-1) | $m_4$ | $\delta^2_e$ |
| Total | (mf-1) | | - |

Kempthorne (1957) advocated general combining ability (GCA) and specific combining ability (SCA) in forms of covariance of half-sibs (H.S.) and covariance of full-sibs (F.S.) as below:

$\delta^2$ GCA = Cov (H.S.)

$\delta^2$ SCA = Cov (F.S.) – 2Cov. (H. S.)

Where,

Cov (H.S.) = $[(m_1-m_1+(m_2-m_3)/r\ (1+m)]$

Cov (H.S.) = $[(m_1-m_4+(m_2-m_4)/r\ (m_3,\ m_4)+6r$ cov (H.S.) – r (f+m) Cov (H.S.)]3r

### 3.6.3.2 Estimation of general and specific combining ability effects:

The following mathematical models were applied to estimate the general and combining ability effects of $i_{jk}$ observations.

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

$\mu$ = general mean

$g_i$ = general combining ability effect of i^th male parent.

$g_j$ = general combining ability affect of j^th female parent.

$s_{ij}$ = specific combining ability effect of ij^th combination

$e_{ijk}$ = error associated with ij^th observation at $X_{ijk}$

I = number of male's parents, 1, 2………..n.

j = number of female parents, 1, 2 ……….f.

k = number of replication, 1, 2 …………..r.

The individual effects of g.c.a. and s.c.a. was estimated as under

$\mu$ = (X./mfr) where, X… = Total of all hybrid combinations

$g_i$ = $(X_i../f_r) - (X.../m_{rf})$, where, $X_i...$ = Total of i^th male parents over all the females and replications.

$g_j$ = $(X_{ij}../m_r) - (X.../m_{fr})$, where, $X_{ij}...$ = total of j^th female parents over all the males and replications.

$S_{ij}$ = $[X_{ij}/r\text{-}X_i../f_r - (X_{ij}/m_r + X./m_{rf})$, where,

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

The following restrictions apply on combining ability effects.

(i) Σgi = 0

(ii) Σgi = 0

(iii) Σgij = 0 (for each i and j)

### 3.6.3.3 Test of significance for general and specific combining ability effect:

Standard error effects were computed by taking the square foot variance of effects.

S.E. (gi) = $\sqrt{\delta 2e/fr}$

S.E. (gj) = $\sqrt{\delta 2e/mr}$

S.E. (gij) = $\sqrt{\delta 2e/r}$

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

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

S.E. (gi - gj) = $\sqrt{}\delta^2 e/mr$

S.E. (gij - gij) = $\sqrt{}\delta^2 e/r$

### 3.6.3.4 Average Degree of Dominance:

The average degree of dominance was calculated using the formula given by **Kempthorne and Curnow (1961)**:

Degree of dominance = $(\delta^2 s/\delta^2 g)$ 0.5

Where,

$\delta^2 s$ = estimated variance due to s.c.a.

$\delta^2 g$ = estimated variance due to g.c.a

### 3.6.4 HETEROSIS:

It was estimated in percent increase or decrease in the performance of $F_1$ hybrids over better parent and economic parent (Pusa Rohini).

**Heterosis over better parent (%)** = $\frac{\overline{F}_1 - \overline{BP}}{\overline{BP}} \times 100$

**Heterosis over standard variety (%)** = $\frac{\overline{F}_1 - \overline{SV}}{\overline{SV}} \times 100$

Where,

$\overline{F_1}$ = mean of the $F_1$ hybrids

$\overline{BP}$ = mean value of better parent, and

$\overline{SV}$ = mean value of SV (Pusa Rohini)

The significance of the estimates of heterosis was tested with the help of cross combination and $p = 0.05$ and 0.01 calculated on the basis of S.E. in the ANOVA for the design of experiment.

### 3.6.5 INBREEDING DEPRESSION:

The inbreeding depression was calculated from the deviation between $F_1$ and its corresponding $F_2$ for each character separately. Inbreeding depression (%) was calculated by formula.

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

Where,

$F_1$ and $F_2$ are the mean values of $F_1$ and $F_2$ populations respectively.

The test of significance was done on $F_1$ - $F_2$ values and indicated in percentage value of inbreeding depression. The value of C.D. was used for testing significance.

### 3.6.6 GENETIC COMPONENTS:

$$CovHS\ (line) = \frac{M_1 - M_{it}}{rt}$$

$$CovHS\ (tester) = \frac{M_1 - M_{it}}{rt}$$

*CovHS* (*tester*) = _____1________1

Where,

Ml = Mean squares due to lines

Mt = Mean squares due to testers

Mlt = Mean squares due to lines x testers

Me = Mean squares due to error

r = Number of replications

l = Number of lines

t = Number of testers

$\delta^2$ g (*testers*) = Cov. H.S. (testers)

$\delta^2$ g (*lines*) = Cov. H.S. (average)

SCA variance ($\delta^2$ s) = $M_{it} \underline{- M_e}$

### 3.6.6.1 Degree of dominance:

It was calculated using the formula given by **Kempthorne and Curnow (1961)**:

Degree of dominance

$\delta^2_D$ = Dominance variance

$\delta^2_A$ = Additive variance

### 3.6.6.2 Gene action:

Gene action was worked out following Kempthorne (1957)

Additive genetic variance $\delta^2_A$ = 4 Cov. H.S. (average) with F = 0

Dominance variance ($\delta^2_D$) = $\delta^2_{SCA}$ with F = 0

Where,

F = inbreeding co-efficient

### 3.6.6.3 Predictability ratio:

Predictability ratio =

Where,

$\delta^2_{SCA}$ = Estimated variance due to SCA

$\delta^2_{SCA}$ = Estimated variance due to GCA

### 3.6.6.4 Testing of inbreeding depression:

The test of significance was done on $F_1 - F_2$ values and indicated in percentage value of inbreeding depression. The value of C.D. was used for testing significance.

### 3.6.7 ESTIMATION OF VARIATIONS:

The mean sum of squares for error was subtracted from the mean sum of squares due to strains for obtaining the genetic variance which was calculated according to the method as suggested by **Burton (1952)** and phenotypic variance calculation method as suggested by **Burton and De Vane (1953).**

Environmental variance ($\sigma^2 e$) = F

Genotypic variance ($\sigma^2 e$) = V – E/r

Phenotypic variance ($\sigma^2 e$) = ($\sigma^2 g + \sigma^2 e$)

Genotypic coefficient of variation = $\frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$

Phenotypic coefficient of variation = $\frac{\sqrt{\sigma^2 e}}{\bar{X}} \times 100$

Where,

V = strain mean square

E = error mean square

r = number of replications and

$\bar{X}$ = general mean of the characters

| **3.6.7.1 PCV and GCV** | >30% | - | High |
|---|---|---|---|
| | 15-30% | - | Moderate |
| | < 15% | - | Low |

### 3.6.7.2 Heritability:

The heritability in broad sense ($h^2 b^2$) was calculated as suggested by **Hanson *et al.* (1956)**.

$$h^2 (\%) = \frac{\delta^2 g \times 100}{\delta^2 p}$$

Where,

$\delta^2 g$ = Genotypic variance

$\delta^2p$ = Phenotypic variance

| | | | |
|---|---|---|---|
| Heritability ($h^2$) | >80% | - | High |
| | 50-80% | - | Moderate |
| | < 50% | - | Low |

### 3.6.7.3 Genetic advance:

It was calculated using the following formula suggested by **Allard (1960)**.

$$Gs = (K)\ (\delta ph)\ (h^2)$$

Where,

G = the estimation of genetic advance under selection.

K = selection differential (2.06), constant at 5 percent selection intensity

$\delta ph$ = the phenotypic standard deviation.

$h^2$ = the estimation of heritability coefficient.

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

$$Gs\ (\%) = [G_s/\bar{X}] \times 100$$

Where,

Gs = expectation of genetic advance

$\bar{X}$ = mean of the character

Gs (%) = genetic advance in percent to mean of character.

Genetic gain

| | | |
|---|---|---|
| >80% | - | High |
| 50-80% | - | Moderate |
| < 50% | - | Low |

### 3.6.8 CORRELATION AND PATH COEFFICIENT:

The formula for calculation of the genotypic phenotypic coefficient of correlation was worked out as suggested by **Robinson *et al*., (1951)**.

**3.6.8.1 Genotypic correlation $r_{xy}$ (g)** = $Cov._{xy}\ (g)$

$$\overline{[V_x(g).V_y(g)]^{0.5}}$$

$Cov._{xy}$ (g) = Genotypic covariance between character x and y, and this was computed as

$Cov._{xy}$ (g) = $[Cov._{xy}$ (p) - $Cov._{xy}$ (e)]/r

$V_x$ (g) and $V_y$ (g) = Genotypic variance for the characters x and y respectively.

r = number of replication

**3.6.8.2 Phenotypic correlation $r_{xy}$ (p)** $= \dfrac{Cov._{xy}\ (p)}{[V_x(p).V_y(p)]^{0.5}}$

Where,

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

$Cov._{xy}$ (p) = $[Cov._{xy}$ (g) + $Cov._{xy}$ (e)]/r

$V_x$ (p) and $V_y$ (p) = Phenotypic variance for the characters x and y, respectively.

$V^{xy}$ (e) = the error variance for character x and y, respectively.

**3.6.8.3 Test of significance of correlation coefficient:**

$$t = \frac{\sqrt{(n-2)}}{\sqrt{(1-2)}}$$

Where,

r = correlation coefficient

n = number of treatment

The significance of correlation coefficient was tested against ‘r’ values from r-table of **Fisher and Yates (1938)** for (n-2) degree of freedom where, ‘n’ is the number of treatments:

### 3.6.8.4 Path coefficient analysis:

**Wright (1921)** defined the path coefficient as the ratio of standard deviation of the all causes is constant, except one in question the variability of which kept in changed. Path coefficient is simply a standardized partial regression coefficient and as such measures the direct influence on variable upon another and permits the correlation coefficient into component of direct and indirect effects . The concept of path analysis was later on elaborated by **Dewey and Lu (1959)**.

### 3.6.9 CAUSAL SYSTEM:

The causal system indicates mutual association as measured by correlation coefficient and the direct influence as measured by path coefficients.

The path coefficient was obtained by the simultaneous equations which expressed between correlation and path coefficient as suggested by **Dewey and Lu (1959)**.

### 3.6.9.1 Calculation of direct effect:

$r_{1.9} = p_{1.9} + p_{2.9} + r_{1.3} + p_{3.9} + r_{1.4} + r_{1.5} + r_{1.6}\, p_{6.9} + r_{1.7}p_{7\cdot 9} + r_{1.8}p_{8.9} + r_{1.9}p_{9.9}$

$r_{2.9} = r_{2.9}p_{1.9} + p_{2.9} + r_{2.3}p_{3.9} + r_{2.4}p_{4.9} + r_{2.5}\, p_{5.9} + r_{2.6}p_{7\cdot 9} + r_{2.8}p_{8.9} + r_{2.9}p_{9.9}$

$r_{3.9} = r_{3.1}p_{1.9} + r_{3.2}p_{2.9} + p_{3.9} + r_{3.9}p_{4.10} \ldots\ldots r_{38}p_{89}$

$r_{4.9} = r_{42}p_{19} + r_{42}p_{29} + r_{43}p_{39} + \ldots\ldots\ldots r_{48}p_{89}$

$r_{5.9} = r_{15}p_{19} + r_{42}p_{29} + r_{53}p_{39} + \ldots\ldots\ldots r_{58}p_{89}$

$r_{6.9} = r_{62}p_{19} + r_{62}p_{29} + r_{63}p_{39} + \ldots\ldots\ldots r_{68}p_{89}$

$r_{7.9} = r_{71}p_{19} + r_{72}p_{29} + r_{73}p_{39} + \ldots\ldots\ldots r_{78}p_{89}$

$r_{8.9} = r_{81}p_{19} + r_{82}p_{29} + r_{83}p_{39} + \ldots\ldots\ldots r_{89}p$

Where ‘r’ represents the correlation coefficient between the characters and ‘p’ indicates the effects of various characters on the dependent variable (the yield in this case).

### 3.6.9.2 Calculation of indirect effect:

The indirect effect can be calculated by multiplying the value of coefficient to the correlation coefficient or respective rows and column as per the formula given below.

Indirect effect = rij x Pij

i = 1…………n

j = 1…………n

pij = $P_{1y}P_{2y}$ ……Pny

### 3.6.9.3 Calculation of residual effect:

The residual effects were calculated by the following formula:

Residual effects = $1 - R^2$

Where,

$$R^2 = P_1y.r_1y + P_2y.r_2y + \ldots\ldots Pny. Rny$$

## Chapter IV

# EXPERIMENTAL FINDINGS

The present investigation entitled **“Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)”** was carried out at Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University, Lucknow (U.P.) during the summer season of 2014-15 and 2015-16. In this chapter the results obtained from this investigation are being presented in tables and described under the following heads:

4.1 Analysis of variance of Line x Tester (12 female and 3 male) for the 16 characters of tomato

4.2 Mean performance of parents for 16 characters of tomato

4.3 Analysis of variance (ANOVA) for combining ability and their effects

4.4 Estimation of heterosis, heterobeltiosis and inbreeding depression

4.5 Genetic variability, heritability and genetic advance of parents and their crosses

4.6 Genotypic and phenotypic correlation coefficient of parents and hybrids

## 4.1 ANALYSIS OF VARIANCE:

Analysis of variance (ANOVA) for the sixteen characters is given in Table-4.1. The variances for different characters were divided in to replications, treatments, parents, hybrids and error. The variances due to parents were further divided in female, male and females vs. males variance due to parents and hybrids were also worked out.

Variance due to lines (female) was highly significant for all the characters except plant height(cm) and vitamin C (mg/100g).Variance due to testers (males) was also highly significant for all the characters except plant height, clusters per plant, fruits per plant, average fruit weight and fruit width . Whereas, variances due to parents vs. hybrids were highly significant for days to 50% flowering, clusters per plant, flowers per cluster, fruits per cluster, fruits per plant, average fruit weight (g), locules per fruit, pericarp thickness (mm), fruit length (cm), fruit width (cm), ridges on fruit except vitamin C (mg/100g) , plant height (cm), number of branches per plant fruit and yield per plant (kg) were non-significant under study.

## 4.2 MEAN PERFORMANCE OF PARENTS AND HYBRIDS:

Mean value of parents and their crosses in respect to various characters are presented in Table-4.2 and 4.3.a, 4.3.b respectively.

## Table -4.1: Analysis of variance for the 16 characters of tomato

| S. No | Source of variation | D. F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| **1.** | Replication | 2 | 1.03 | 0.04 | 1.65 | 0.04 | 0.14 | 0.10 | 1.56 | 9.66 | 0.08 | 0.09 | 0.12 | 0.01 | 0.00 | 0.01 | 0.09 | 5.62* |
| **2.** | Parents | 14 | 25.80 | 1.07** | 2.68** | 1.02** | 2.08** | 1.29** | 16.75** | 131.26** | 0.64** | 0.62** | 0.32** | 0.26** | 0.45** | 0.21** | 0.48** | 2.00 |
| **3.** | Female | 11 | 27.65 | 1.11** | 2.81** | 1.24** | 1.68** | 1.23** | 15.23** | 161.97** | 0.65** | 0.51** | 0.37** | 0.31** | 0.45** | 0.23** | 0.44** | 1.58 |
| **4.** | Male | 2 | 26.48 | 0.60* | 3.17* | 0.31 | 3.60** | 0.80** | 10.42 | 8.11 | 0.65** | 0.88** | 0.21* | 0.06 | 0.63** | 0.08** | 0.23* | 5.00* |
| **5.** | Female vs. male | 1 | 4.00 | 1.58** | 0.25 | 0.03 | 3.47** | 2.94** | 46.22** | 39.72 | 0.49* | 1.35** | 0.01 | 0.13 | 0.07* | 0.26** | 1.47** | 0.56 |
| **6.** | Hybrids | 35 | 11.57 | 0.61 | 2.94** | 0.39** | 0.42** | 0.59** | 29.71** | 56.55** | 0.25** | 0.38** | 0.28** | 0.25** | 0.14** | 0.12** | 0.26** | 4.22** |
| **7.** | Parents vs. hybrids | 1 | 31.82 | 0.07 | 16.12** | 5.93** | 91.20** | 18.33** | 34.26** | 529.29** | 1.41** | 4.17** | 3.09** | 10.78** | 1.25** | 0.00 | 3.74** | 1.84 |
| **8.** | Error | 100 | 1.74 | 0.18 | 0.91 | 0.16 | 0.21 | 0.11 | 3.69 | 16.63 | 0.11 | 0.05 | 0.07 | 0.08 | 0.02 | 0.01 | 0.06 | 1.53 |

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

## Table -4.2: Mean performance of 15 parents for 16 characters of tomato

| Parents | Symbol | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lines (Female)** | | | | | | | | | | | | | | | | | |
| IIVR-Sel.-1 | $L_1$ | 59.80 | 5.01 | 59.52 | 4.53 | 5.41 | 4.42 | 21.52 | 31.34 | 4.25 | 3.78 | 3.69 | 3.92 | 1.21 | 0.74 | 4.28 | 23.26 |
| G-3 | $L_2$ | 63.65 | 4.55 | 60.13 | 6.11 | 8.02 | 6.10 | 25.06 | 29.77 | 3.25 | 3.92 | 3.52 | 4.18 | 1.56 | 0.62 | 4.10 | 23.93 |
| S. Naveen | $L_3$ | 60.74 | 3.90 | 59.24 | 4.80 | 6.35 | 5.63 | 18.00 | 48.36 | 3.52 | 4.48 | 3.76 | 4.55 | 1.15 | 1.40 | 3.71 | 25.04 |
| DVRT-2 | $L_4$ | 56.13 | 4.05 | 61.44 | 3.99 | 6.48 | 4.83 | 20.48 | 26.98 | 3.70 | 3.97 | 3.62 | 4.42 | 1.12 | 0.87 | 4.46 | 24.51 |
| H-24 | $L_5$ | 60.12 | 4.21 | 61.80 | 4.28 | 6.46 | 5.32 | 22.30 | 47.26 | 3.07 | 3.85 | 4.02 | 3.93 | 1.81 | 1.15 | 4.75 | 23.89 |
| H-86 | $L_6$ | 54.62 | 3.27 | 60.22 | 5.11 | 6.21 | 4.75 | 20.03 | 28.02 | 3.15 | 3.86 | 3.79 | 3.61 | 2.29 | 0.63 | 3.84 | 24.16 |
| H-88 | $L_7$ | 57.92 | 4.23 | 60.66 | 4.67 | 5.73 | 4.37 | 21.52 | 39.40 | 2.57 | 4.76 | 4.55 | 4.61 | 1.28 | 0.88 | 4.63 | 22.70 |
| Pusa Sheetal | $L_8$ | 53.49 | 3.76 | 59.44 | 4.97 | 5.39 | 4.30 | 21.59 | 28.95 | 3.65 | 4.33 | 4.33 | 4.32 | 1.45 | 1.26 | 4.56 | 23.23 |
| FLA 7171 | $L_9$ | 55.18 | 5.38 | 60.50 | 4.63 | 5.16 | 3.87 | 18.89 | 27.87 | 3.93 | 3.77 | 3.91 | 4.07 | 1.66 | 0.74 | 4.78 | 24.74 |
| Hisar Arun | $L_{10}$ | 59.21 | 3.78 | 62.36 | 3.58 | 6.30 | 5.38 | 20.73 | 36.85 | 3.39 | 4.40 | 4.21 | 4.05 | 1.58 | 0.93 | 3.71 | 23.83 |
| Sel.-32 | $L_{11}$ | 61.21 | 3.46 | 61.14 | 4.33 | 6.02 | 4.93 | 17.55 | 32.59 | 3.69 | 3.19 | 3.33 | 3.70 | 0.79 | 0.59 | 4.41 | 25.01 |
| Flora Dode | $L_{12}$ | 59.26 | 4.41 | 60.41 | 5.20 | 6.47 | 5.33 | 17.20 | 34.96 | 4.04 | 4.01 | 3.93 | 4.41 | 1.37 | 0.56 | 4.17 | 24.19 |
| Mean of female | | 58.44 | 4.17 | 60.57 | 4.68 | 6.17 | 4.94 | 20.41 | 34.36 | 3.52 | 4.03 | 3.89 | 4.15 | 1.44 | 0.86 | 4.28 | 24.04 |
| **Testers (Male)** | | | | | | | | | | | | | | | | | |
| Pusa Sadabahar | $T_1$ | 61.66 | 4.50 | 61.54 | 4.95 | 6.58 | 4.89 | 16.97 | 33.41 | 3.30 | 4.18 | 3.95 | 4.25 | 1.45 | 0.53 | 3.73 | 25.49 |
| Kashi Vishesh | $T_2$ | 55.89 | 5.13 | 60.06 | 4.91 | 4.39 | 4.00 | 20.02 | 32.43 | 3.80 | 3.49 | 3.64 | 4.17 | 1.73 | 0.64 | 4.15 | 24.53 |
| Kashi Amrit | $T_3$ | 60.02 | 4.27 | 59.56 | 4.37 | 5.45 | 4.00 | 16.64 | 30.20 | 4.23 | 3.11 | 4.17 | 4.43 | 0.84 | 0.85 | 3.62 | 22.94 |
| Mean of male | | 59.19 | 4.63 | 60.39 | 4.74 | 5.47 | 4.30 | 17.88 | 32.01 | 3.78 | 3.59 | 3.92 | 4.28 | 1.34 | 0.67 | 3.83 | 24.32 |
| SEM | | 0.78 | 0.24 | 0.57 | 0.24 | 0.29 | 0.25 | 0.88 | 3.42 | 0.20 | 0.17 | 0.21 | 0.16 | 0.08 | 0.05 | 0.13 | 0.55 |
| CD at 5% | | 2.27 | 0.71 | 1.66 | 0.68 | 0.84 | 0.73 | 2.55 | 9.89 | 0.57 | 0.49 | 0.61 | 0.47 | 0.24 | 0.15 | 0.39 | 1.58 |
| **(SV)**<br>Pusa Rohini | | 62.17 | 5.95 | 57.56 | 6.34 | 8.19 | 7.45 | 21.26 | 39.56 | 5.33 | 5.47 | 4.57 | 4.99 | 1.56 | 1.68 | 4.77 | 24.25 |

# Table-4.3 a: Mean performance of 36 $F_1$ hybrids for 8 characters of tomato

| S. No. | Crosses | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | 60.16 | 4.69 | 58.60 | 3.81 | 5.12 | 3.52 | 23.68 | 33.59 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | 60.92 | 4.18 | 58.97 | 4.50 | 5.20 | 4.33 | 20.60 | 33.14 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | 59.26 | 4.11 | 60.16 | 3.96 | 4.10 | 3.79 | 27.26 | 44.76 |
| 4 | G-3 x Pusa Sadabahar | 60.85 | 3.75 | 58.92 | 3.99 | 5.02 | 3.79 | 32.52 | 36.48 |
| 5 | G-3 x Kashi Vishesh | 61.45 | 4.26 | 60.25 | 3.91 | 5.05 | 4.00 | 26.17 | 42.15 |
| 6 | G-3 x Kashi Amrit | 60.74 | 4.52 | 60.67 | 4.19 | 5.17 | 4.07 | 25.10 | 45.00 |
| 7 | S. Naveen x Pusa Sadabahar | 56.79 | 4.33 | 57.06 | 4.07 | 4.67 | 4.13 | 21.86 | 40.55 |
| 8 | S. Naveenx Kashi Vishesh | 59.69 | 4.93 | 60.54 | 4.85 | 4.27 | 3.48 | 28.24 | 37.62 |
| 9 | S. Naveen x Kashi Amrit | 56.86 | 4.41 | 58.77 | 3.93 | 4.12 | 2.94 | 22.19 | 35.34 |
| 10 | DVRT-2 x Pusa Sadabahar | 59.29 | 4.32 | 59.74 | 4.76 | 5.41 | 4.15 | 25.53 | 40.91 |
| 11 | DVRT-2 x Kashi Vishesh | 55.49 | 4.98 | 60.08 | 4.18 | 5.02 | 3.64 | 16.35 | 38.32 |
| 12 | DVRT-2 x Kashi Amrit | 56.99 | 4.50 | 60.81 | 4.56 | 4.65 | 4.05 | 18.86 | 35.94 |
| 13 | H-24 x Pusa Sadabahar | 58.37 | 4.25 | 60.06 | 4.04 | 4.89 | 3.96 | 16.09 | 42.84 |
| 14 | H-24 x Kashi Vishesh | 60.36 | 4.79 | 60.38 | 4.66 | 3.84 | 3.09 | 21.94 | 36.71 |
| 15 | H-24 x Kashi Amrit | 59.80 | 4.44 | 57.38 | 4.52 | 5.50 | 3.80 | 21.33 | 35.99 |
| 16 | H-86 x Pusa Sadabahar | 62.62 | 4.73 | 59.75 | 4.72 | 4.27 | 3.23 | 20.42 | 43.31 |
| 17 | H-86 x Kashi Vishesh | 57.22 | 4.92 | 60.60 | 4.74 | 4.21 | 3.70 | 28.00 | 42.60 |
| 18 | H-86 x Kashi Amrit | 59.01 | 4.44 | 59.37 | 5.20 | 4.66 | 3.18 | 34.14 | 35.14 |
| 19 | H-88 x Pusa Sadabahar | 60.94 | 4.79 | 59.99 | 4.31 | 4.82 | 3.38 | 25.84 | 42.83 |
| 20 | H-88 x Kashi Vishesh | 57.66 | 4.51 | 59.28 | 4.60 | 4.53 | 2.97 | 22.39 | 52.59 |
| 21 | H-88 x Kashi Amrit | 57.97 | 5.32 | 59.32 | 4.81 | 4.52 | 3.25 | 22.95 | 42.30 |
| 22 | Pusa Sheetal x Pusa Sadabahar | 60.37 | 5.05 | 59.95 | 3.79 | 4.46 | 3.11 | 18.86 | 34.13 |
| 23 | Pusa Sheetal x Kashi Vishesh | 60.68 | 5.08 | 59.98 | 4.40 | 4.08 | 3.04 | 18.97 | 36.20 |
| 24 | Pusa Sheetal x Kashi Amrit | 61.06 | 5.45 | 59.58 | 4.93 | 4.43 | 3.37 | 13.99 | 44.98 |
| 25 | FLA 7171 x Pusa Sadabahar | 62.55 | 5.11 | 58.45 | 4.73 | 6.70 | 5.16 | 14.60 | 40.32 |
| 26 | FLA 7171 x Kashi Vishesh | 59.20 | 4.94 | 60.49 | 4.54 | 4.76 | 3.52 | 16.34 | 34.68 |
| 27 | FLA 7171 x Kashi Amrit | 60.70 | 4.63 | 61.14 | 4.69 | 4.30 | 3.30 | 18.38 | 38.86 |
| 28 | Hisar Arun x Pusa Sadabahar | 60.75 | 4.37 | 60.45 | 4.31 | 4.81 | 3.43 | 18.88 | 31.18 |
| 29 | Hisar Arun x Kashi Vishesh | 61.14 | 4.67 | 59.46 | 4.12 | 4.82 | 4.23 | 23.23 | 35.75 |
| 30 | Hisar Arun x Kashi Amrit | 60.63 | 5.13 | 58.83 | 3.87 | 5.68 | 4.08 | 21.53 | 39.54 |
| 31 | Sel.-32 x Pusa Sadabahar | 61.73 | 4.25 | 60.74 | 3.97 | 5.61 | 3.36 | 21.98 | 38.92 |
| 32 | Sel.-32 x Kashi Vishesh | 62.41 | 5.06 | 59.58 | 4.72 | 4.59 | 3.49 | 21.48 | 38.60 |
| 33 | Sel.-32 x Kashi Amrit | 60.45 | 4.76 | 60.11 | 3.93 | 4.84 | 3.63 | 25.92 | 46.70 |
| 34 | Flora Dode x Pusa Sadabahar | 59.11 | 4.70 | 55.80 | 4.83 | 4.47 | 3.46 | 25.62 | 26.78 |
| 35 | Flora Dode x Kashi Vishesh | 60.69 | 4.68 | 59.70 | 4.80 | 4.66 | 4.44 | 26.70 | 36.85 |
| 36 | Flora Dode x Kashi Amrit | 59.51 | 4.85 | 57.77 | 5.10 | 4.62 | 4.52 | 25.02 | 39.61 |
| **General mean** |  | 59.82 | 4.66 | 59.52 | 4.42 | 4.77 | 3.68 | 22.58 | 38.92 |
| **Mean of parents** |  | 58.81 | 4.40 | 60.48 | 4.71 | 5.82 | 4.62 | 19.14 | 33.18 |
| **Mean of hybrids** |  | 59.35 | 4.32 | 59.92 | 4.41 | 4.84 | 4.30 | 20.94 | 36.95 |

## Table-4.3 b: Mean performance of 36 $F_1$ hybrids for 8 characters of tomato

| S. No. | Crosses | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | 3.61 | 3.71 | 3.78 | 4.20 | 1.22 | 0.71 | 4.17 | 21.71 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | 3.59 | 2.73 | 3.65 | 3.70 | 1.23 | 0.62 | 3.99 | 25.29 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | 3.69 | 4.27 | 4.16 | 4.11 | 1.16 | 1.43 | 4.24 | 22.51 |
| 4 | G-3 x Pusa Sadabahar | 2.85 | 3.31 | 4.12 | 3.55 | 0.87 | 0.87 | 3.70 | 23.12 |
| 5 | G-3 x Kashi Vishesh | 3.43 | 4.00 | 3.33 | 4.02 | 1.36 | 1.18 | 4.21 | 24.40 |
| 6 | G-3 x Kashi Amrit | 2.96 | 3.74 | 3.72 | 3.47 | 1.76 | 0.62 | 3.71 | 23.38 |
| 7 | S. Naveen x Pusa Sadabahar | 3.16 | 4.04 | 4.32 | 4.18 | 1.01 | 0.89 | 4.61 | 21.95 |
| 8 | S. Naveenx Kashi Vishesh | 3.30 | 3.90 | 3.86 | 4.33 | 1.18 | 1.30 | 4.34 | 22.41 |
| 9 | S. Naveen x Kashi Amrit | 3.00 | 3.37 | 3.37 | 3.44 | 1.13 | 0.70 | 4.41 | 22.47 |
| 10 | DVRT-2 x Pusa Sadabahar | 3.16 | 3.91 | 4.24 | 4.02 | 1.07 | 0.95 | 4.02 | 23.92 |
| 11 | DVRT-2 x Kashi Vishesh | 3.63 | 3.28 | 3.37 | 3.72 | 0.96 | 0.60 | 3.99 | 26.60 |
| 12 | DVRT-2 x Kashi Amrit | 3.83 | 3.58 | 3.83 | 4.00 | 1.09 | 0.58 | 4.29 | 23.19 |
| 13 | H-24 x Pusa Sadabahar | 4.09 | 4.21 | 3.86 | 4.36 | 0.88 | 0.53 | 4.07 | 26.92 |
| 14 | H-24 x Kashi Vishesh | 3.11 | 3.75 | 3.63 | 4.07 | 0.73 | 0.66 | 3.62 | 28.10 |
| 15 | H-24 x Kashi Amrit | 3.28 | 3.67 | 4.08 | 3.96 | 0.94 | 0.97 | 3.90 | 29.39 |
| 16 | H-86 x Pusa Sadabahar | 3.23 | 3.69 | 4.24 | 3.62 | 1.40 | 0.85 | 4.04 | 25.38 |
| 17 | H-86 x Kashi Vishesh | 4.46 | 3.97 | 4.02 | 4.20 | 0.99 | 0.79 | 3.93 | 25.36 |
| 18 | H-86 x Kashi Amrit | 3.53 | 2.72 | 3.69 | 4.10 | 1.01 | 1.20 | 3.80 | 24.72 |
| 19 | H-88 x Pusa Sadabahar | 3.27 | 4.33 | 3.83 | 3.76 | 0.96 | 0.85 | 4.15 | 23.44 |
| 20 | H-88 x Kashi Vishesh | 3.36 | 3.26 | 3.71 | 3.83 | 0.95 | 0.85 | 4.04 | 26.20 |
| 21 | H-88 x Kashi Amrit | 3.73 | 4.17 | 3.82 | 4.09 | 0.92 | 0.72 | 4.25 | 28.05 |
| 22 | Pusa Sheetal x Pusa Sadabahar | 2.86 | 3.70 | 3.09 | 3.76 | 0.89 | 0.55 | 3.93 | 24.35 |
| 23 | Pusa Sheetal x Kashi Vishesh | 3.80 | 4.07 | 3.41 | 3.61 | 0.87 | 0.55 | 3.93 | 28.86 |
| 24 | Pusa Sheetal x Kashi Amrit | 4.12 | 3.83 | 4.38 | 3.90 | 0.82 | 0.58 | 4.38 | 24.43 |
| 25 | FLA 7171 x Pusa Sadabahar | 3.15 | 3.35 | 3.37 | 3.37 | 1.01 | 0.77 | 3.65 | 26.17 |
| 26 | FLA 7171 x Kashi Vishesh | 4.01 | 3.94 | 3.34 | 3.75 | 1.32 | 0.68 | 4.29 | 26.62 |
| 27 | FLA 7171 x Kashi Amrit | 4.34 | 3.27 | 3.75 | 4.30 | 1.11 | 0.86 | 3.92 | 28.83 |
| 28 | Hisar Arun x Pusa Sadabahar | 3.12 | 3.59 | 3.94 | 3.78 | 1.03 | 1.24 | 3.89 | 24.36 |
| 29 | Hisar Arun x Kashi Vishesh | 3.69 | 4.23 | 3.76 | 4.02 | 1.04 | 0.88 | 4.29 | 23.64 |
| 30 | Hisar Arun x Kashi Amrit | 3.52 | 3.94 | 3.81 | 3.07 | 1.05 | 0.95 | 4.17 | 22.09 |
| 31 | Sel.-32 x Pusa Sadabahar | 3.32 | 3.27 | 3.89 | 4.08 | 0.84 | 1.01 | 3.76 | 24.42 |
| 32 | Sel.-32 x Kashi Vishesh | 2.71 | 3.80 | 3.63 | 3.69 | 1.07 | 0.71 | 3.73 | 27.62 |
| 33 | Sel.-32 x Kashi Amrit | 2.81 | 3.24 | 3.87 | 3.05 | 0.97 | 1.05 | 3.46 | 23.94 |
| 34 | Flora Dode x Pusa Sadabahar | 3.14 | 3.76 | 3.60 | 3.35 | 0.75 | 1.00 | 3.77 | 25.21 |
| 35 | Flora Dode x Kashi Vishesh | 3.66 | 3.62 | 3.78 | 3.30 | 0.91 | 0.78 | 3.76 | 24.67 |
| 36 | Flora Dode x Kashi Amrit | 3.48 | 3.06 | 3.13 | 3.61 | 0.83 | 0.78 | 3.63 | 26.23 |
| **General mean** | | 3.44 | 3.67 | 3.76 | 3.82 | 1.04 | 0.84 | 4.00 | 25.00 |
| **Mean of parents** | | 3.65 | 3.81 | 3.90 | 4.21 | 1.39 | 0.76 | 4.05 | 24.18 |
| **Mean of hybrids** | | 3.43 | 3.70 | 3.69 | 3.77 | 1.28 | 0.84 | 3.95 | 24.35 |

## 1. Plant height:

The highest plant height was recorded from G-3 (63.65 cm) followed by Pusa Sadabahar (61.66 cm) and Sel.-32 (61.21 cm) among the parents, lowest in Pusa Sheetal (53.49 cm). Among the crosses, plant height were recorded high in crosses H-86 x Pusa Sadabahar (62.62 cm ) followed by FLA 7171 x Pusa Sadabahar (62.55cm ) and Sel.-32 x Kashi Vishesh (62.41cm ), lowest in DVRT-2 x Kashi Vishesh (55.49 cm ).

## 2. Number of branches per plant:

The maximum number of number of branches per plant was recorded in parents FLA 7171 (5.38 ), Kashi Vishesh (5.13 ) and IIVR-Sel.-1 (5.01 ), minimum in H-86 ( 3.27) whereas, among the crosses it was maximum in cross combinations Pusa Sheetal x Kashi Amrit (5.45 ), H-88 x Kashi Amrit (5.32 ) and Hisar Arun x Kashi Amrit (5.13) and minimum in G-3 x Pusa Sadabahar (3.75).

## 3. Days to 50 per cent flowering:

The parents, S. Naveen (59.24 days) was the minimum days to 50% flowering followed by Pusa Sheetal (59.44 days) and IIVR-Sel.-1 (59.52 days), although, parent Hisar Arun (62.36 days) was maximum days to 50% flowering. While, in crosses Flora Dode x Pusa Sadabahar (55.80 days) was the minimum days to 50% flowering followed by S. Naveen x Pusa Sadabahar (57.06 days) and H-24 x Kashi Amrit (57.38 days).

## 4. Number of clusters per plant:

Among the sixteen parents, highest clusters per plant were recorded for parent G-3 (6.11) followed by Flora Dode (5.20) minimum recorded in Hisar Arun (3.58 ) while, in cross combinations, it highest clusters per plant were recorded for H-86 x Kashi Amrit (5.20) followed by Flora Dode x Kashi Amrit (5.10) and minimum for Pusa Sheetal x Pusa Sadabahar (3.79 ).

Plate-4: A general view of tomato crop at vegetative stage

Plate-5: A general view of tomato crop at flowering stage

**Plate-6: A general view of tomato crop at fruiting stage**

**Plate-7: A general view of Vitamin- C estimation in tomato fruit under laboratory condition**

### 5. Number of flowers per cluster:

The maximum number of flowers per cluster was recorded in parents G-3 (8.02), Pusa Sadabahar (6.58) and DVRT-2 (6.48) and minimum in Kashi Vishesh (4.39) whereas, among the crosses it was maximum in cross combinations FLA 7171 x Pusa Sadabahar (6.70), Hisar Arun x Kashi Amrit (5.68) and Sel.-32 x Pusa Sadabahar (5.61) and minimum in H-24 x Kashi Vishesh (3.84 ) .

### 6. Number of fruits per cluster:

Maximum number of fruits per cluster was recorded in parents G-3 (6.10 ), S. Naveen (5.63 ) and Hisar Arun (5.38), and minimum in FLA 7171 (3.87 ) whereas, among the crosses it was maximum in cross combinations FLA 7171 x Pusa Sadabahar (5.16), Flora Dode x Kashi Amrit (4.52 ) and Flora Dode x Kashi Vishesh (4.44) but it was minimum in S. Naveen x Kashi Amrit (2.94) .

### 7. Number of fruits per plant:

Maximum number of fruits per plant was noted in parents G-3 (25.06), H-24 (22.30) and Pusa Sheetal (21.59) and minimum in Kashi Amrit (16.64) whereas, among the crosses it was maximum in cross combinations H-86 x Kashi Amrit (34.14), G-3 x Pusa Sadabahar (32.52) and S. Naveenx Kashi Vishesh (28.24) but it was minimum in FLA 7171 x Pusa Sadabahar (14.60).

### 8. Average fruit weight (g):

Among the sixteen parents, maximum fruit weight were recorded for parent S. Naveen (48.36 g) followed by H-24 (47.26 g) and H-8 (39.40 g) but it was minimum recorded in DVRT-2 (26.98 g)while, in cross combinations, it highest fruit weight were recorded for H-88 x Kashi Vishesh (52.59 g) followed by Sel.-32 x Kashi Amrit (46.70 g) , G-3 x Kashi Amrit (45.00 g) and minimum for Flora Dode x Pusa Sadabahar (26.78 g).

### 9. Number of locules per fruit:

Maximum locules per fruit was recorded from IIVR Sel.-1(4.25) followed by Kashi Amrit (4.23) and Flora Dode (4.04) between the parents and minimum was recorded in H-88 (2.57). Between the crosses, maximum number of locules per fruit were recorded in H-86 x Kashi Vishesh (4.46) followed by FLA 7171 x Kashi Amrit (4.34), Pusa Sheetal x Kashi Amrit (4.12) and minimum number of locules per fruit were recorded in Sel.-32 x Kashi Vishesh (2.71).

### 10. Pericarp thickness (mm):

Pericarp thickness exhibited variation among parents which ranged from (3.11 mm to 4.76 mm). Among the parents, H-88 recorded the highest value for pericarp thickness (4.76 mm) followed by S. Naveen (4.48mm) , Hisar Arun ( 4.40 mm), while Kashi Amrit recorded the lowest value for the same character (3.11 mm). Among the hybrids evaluated, the maximum value for pericarp thickness was noticed in cross combination H-88 x Pusa Sadabahar (4.33 mm) followed by IIVR-Sel.-1 x Kashi Amrit (4.27mm), Hisar Arun x Kashi Vishesh (4.23mm). The minimum value for the same trait was recorded in H-86 x Kashi Amrit (2.72 mm).

### 11. Fruit length (cm):

Fruit lenghth varied from Sel.-32 (3.33 cm) to H-88 (4.55 cm) among the parents and crosses, it ranged from Pusa Sheetal x Pusa Sadabahar (3.09 cm) to Pusa Sheetal x Kashi Amrit (4.38 cm). Cross combination Pusa Sheetal x Kashi Amrit (4.38 cm) was showed maximum length of fruit followed by S. Naveen x Pusa Sadabahar (4.32 cm) and DVRT-2 x Pusa Sadabahar (4.24 cm).

### 12. Fruit width (cm):

Fruit width varied from H-86 (3.61cm) to H-88 (4.61cm) between the parents and crosses, it ranged from Hisar Arun x Kashi Amrit (3.07 cm) to H-24 x Pusa Sadabahar (4.36 cm). Cross combination H-24 x Pusa Sadabahar (4.36 cm) was showed maximum fruit width followed by S. Naveenx Kashi Vishesh (4.33 cm) and FLA 7171 x Kashi Amrit (4.30 cm).

### 13. Number of ridges on fruit:

Maximum ridges on fruit were noted from H-86 (2.29) followed by H-24 (1.81) and Pusa Sadabahar (1.45) among the parents and minimum was recorded in Sel.-32

(0.79). Crosses, maximum ridges on fruit were noted in G-3 x Kashi Amrit (1.76) followed by H-86 x Pusa Sadabahar (1.40), G-3 x Kashi Vishesh (1.36) and minimum number of ridges on fruit were noted in H-24 x Kashi Vishesh (0.73).

### 14. Fruit yield per plant (kg):

High yielding parent was S. Naveen (1.40 kg) followed by Pusa Sheetal (1.26 kg) and H-24 (1.15kg), While, lowest fruit yield per plant was recorded in Pusa Sadabahar (0.53kg). Between the hybrids, cross IIVR-Sel.-1 x Kashi Amrit was the high yielding hybrids with (1.43kg) fruit yield per plant followed by S. Naveen x Kashi Vishesh (1.30kg) and Hisar Arun x Pusa Sadabahar (1.24 kg), whereas, cross H-24 x Pusa Sadabahar (0.53kg) gave the low yielding per plant.

### 15. TSS (°Brix):

Maximum TSS (°Brix) parent was FLA 7171 (4.78) followed by H-24 (4.75) and H-88 (4.63), whereas, minimum TSS was observed in Kashi Amrit (3.62). Between the crosses S. Naveen x Pusa Sadabahar was the maximum TSS (4.61) fruit yield per plant followed by S. Naveen x Kashi Amrit (4.41) and Pusa Sheetal x Kashi Amrit (4.38), while, Sel.-32 x Kashi Amrit gave the minimum TSS (3.46 ) per plant.

### 16. Vitamin C (mg/100g ):

The maximum vitamin C parent was Pusa Sadabahar (25.49) followed by S. Naveen (25.04) and Sel.-32 (25.01), While, minimum vitamin C was observed in H-88 (22.70). Between the hybrids, cross H-24 x Kashi Amrit was the maximum vitamin C hybrids with (29.39) followed by Pusa Sheetal x Kashi Vishesh (28.86) and H-24 x Kashi Vishesh (28.10), whereas, IIVR-Sel.-1 x Pusa Sadabahar gave the minimum vitamin C (21.71).

## 4.3 COMBINING ABILITY VARIANCE AND THEIR EFFECTS:

The analysis of variance for combining ability for all the sixteen characters is showed in Table-4.4.a & 4.4.b. respectively. The treatment mean of square were partitioned in to lines, testers and lines vs. tester. The mean sum of square due to line was significant for plant height , fruits per plant and vitamin C non significant for remaining characters In case of tester, it was non significant for all characters except vitamin C significant . Due to line vs. tester were reveal significant for all of the characters except vitamin C was non significant.

### 4.3.1. GENERAL AND SPECIFIC COMBINING ABILITY EFFECTS:

The assessment of general combining ability effects for parents and specific combining ability effects for crosses are given in Table-4.5.a, 4.5.b, 4.6.a and 4.6.b. The result description of general and specific combining ability effects for different traits are given below:

### 1. Plant height (cm):

In the present lines and testers, positive and significant general combining ability effects were observed for parents Sel.-32 (1.71) followed by G-3 (1.20). While, negative and significant general combining ability effects were recorded for DVRT-2 (-2.56) followed by S. Naveen (-2.04) indicating that these parents are desirable general combiners for plant height as the negative general combining ability effects is good for dwarf plant type. While, significant and positive specific combining ability effects were observed for cross combinations H-86 x Pusa Sadabahar (2.53) followed by S. Naveen x Kashi Vishesh (1.99). The negative and significant specific combining ability effects were observed for cross combinations H-86 x Kashi Vishesh (-2.32) and IIVR-Sel.-1 x Kashi Amrit (-0.45).

## Table -4.4.a: Analysis of variance for the 8 characters of combining ability

| S. No. | Source of variation | D. F. | Characters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) |
| 1. | Replication | 2 | 1.11 | 0.04 | 0.72 | 0.03 | 0.08 | 0.05 | 4.70 | 2.66 |
| 2. | Lines | 11 | 27.15** | 0.75 | 3.54 | 0.37 | 0.34 | 0.91 | 64.27** | 56.60 |
| 3. | Testers | 2 | 4.38 | 0.07 | 2.09 | 0.26 | 0.63 | 0.08 | 3.35 | 7.35 |
| 4. | Lines x testers | 22 | 4.43** | 0.59** | 2.71** | 0.41** | 0.44** | 0.47** | 14.83** | 61.00** |
| 5. | Errors | 70 | 1.72 | 0.18 | 0.90 | 0.16 | 0.19 | 0.09 | 3.69 | 9.67 |

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

## Table -4.4.b: Analysis of variance for the 8 characters of combining ability

| S. No | Source of variation | D. F. | Characters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| 1. | Replication | 2 | 0.07 | 0.07 | 0.06 | 0.01 | 0.00 | 0.00 | 0.07 | 2.28 |
| 2. | Lines | 11 | 0.26 | 0.27 | 0.13 | 0.12 | 0.14 | 0.09 | 0.28 | 8.85** |
| 3. | Testers | 2 | 0.34 | 0.16 | 0.01 | 0.17 | 0.02 | 0.07 | 0.13 | 6.30* |
| 4. | Lines x testers | 22 | 0.23** | 0.46** | 0.38** | 0.32** | 0.16** | 0.14** | 0.27** | 1.71 |
| 5. | Errors | 70 | 0.11 | 0.04 | 0.06 | 0.09 | 0.02 | 0.01 | 0.07 | 1.75 |

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

## Table -4. 5.a : Estimation of general combining ability (GCA) effect of 15 parents for 8 characters of tomato

| Parents | Symbol | Characters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Line (Female) | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) |
| IIVR-Sel.-1 | $L_1$ | 0.30 | 0.34* | -0.28 | -0.33* | 0.04 | 0.20 | 1.26* | -1.76 |
| G-3 | $L_2$ | 1.20* | -0.49** | 0.43 | -0.39** | 0.31* | 0.27* | 5.35** | 2.29 |
| S. Naveen | $L_3$ | -2.04** | -0.10 | -0.73* | -0.13 | -0.42** | -0.17 | 1.52** | -1.09 |
| DVRT-2 | $L_4$ | -2.56** | -0.06 | 0.69* | 0.08 | 0.25 | 0.26* | -2.33** | -0.54 |
| H-24 | $L_5$ | -0.31 | -0.17* | -0.25 | -0.01 | -0.03 | -0.07 | -2.80** | -0.41 |
| H-86 | $L_6$ | -0.20 | 0.03 | 0.39 | 0.47** | -0.39** | -0.31** | 4.94** | 1.42* |
| H-88 | $L_7$ | -0.96 | 0.21 | 0.01 | 0.15 | -0.15 | -0.48** | 1.14* | 6.99** |
| Pusa Sheetal | $L_8$ | 0.88 | 0.53** | 0.32 | -0.04 | -0.45** | -0.51** | -5.31** | -0.48 |
| FLA 7171 | $L_9$ | 1.00 | 0.23 * | 0.51 | 0.23* | 0.48** | 0.31** | -6.14** | -0.97 |
| Hisar Arun | $L_{10}$ | 1.02* | 0.06 | 0.06 | -0.31 | 0.33* | 0.23* | -1.37** | -3.43* |
| Sel.-32 | $L_{11}$ | 1.71** | 0.03 | 0.62 | -0.21 | 0.24 | -0.19 | 0.54 | 2.48 |
| Flora Dode | $L_{12}$ | -0.05 | 0.08 | -1.76** | 0.49** | -0.19 | 0.46** | 3.20** | -4.51** |
| SE±F | | 0.440 | 0.143 | 0.318 | 0.132 | 0.153 | 0.111 | 0.640 | 1.359 |
| CD (5%) F | | 0.877 | 0.286 | 0.633 | 0.263 | 0.306 | 0.221 | 1.277 | 2.711 |
| **Testers** | | | | | | | | | |
| Pusa Sadabahar | $T_1$ | 0.48 | -0.14 | -0.39* | -0.14* | 0.25** | 0.04 | -0.43 | -1.27 |
| Kashi Vishesh | $T_2$ | -0.08 | 0.09 | 0.42* | 0.08 | -0.19** | -0.02 | -0.05 | -0.15 |
| Kashi Amrit | $T_3$ | -0.40 | 0.05 | -0.03 | 0.06 | -0.06 | -0.02 | 0.47 | 1.42* |
| S.E.(gii) ±M | | 0.220 | 0.072 | 0.159 | 0.066 | 0.077 | 0.055 | 0.320 | 0.680 |
| CD (5%) M | | 0.438 | 0.143 | 0.317 | 0.132 | 0.153 | 0.110 | 0.639 | 1.356 |

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

## Table -4.5.b: Estimation of general combining ability (GCA) effect of 15 parents for 8 characters of tomato

| Parents | Symbol | Characters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Line (Female) | | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| IIVR-Sel.-1 | $L_1$ | 0.18 | -0.11 | 0.10* | 0.19 | 0.17** | 0.08 | 0.13 | -1.83** |
| G-3 | $L_2$ | -0.36** | 0.01 | -0.04 | -0.14 | 0.30** | 0.05 | -0.13 | -1.37* |
| S. Naveen | $L_3$ | -0.29** | 0.10 | 0.09 | 0.17 | 0.07 | 0.12* | 0.45** | -2.72** |
| DVRT-2 | $L_4$ | 0.10 | -0.08 | 0.05 | 0.10 | 0.00 | -0.13* | 0.10 | -0.43 |
| H-24 | $L_5$ | 0.05 | 0.20* | 0.10 | 0.31** | -0.19** | -0.12* | -0.14 | 3.14** |
| H-86 | $L_6$ | 0.30** | -0.22* | 0.22* | 0.16 | 0.10** | 0.10 | -0.08 | 0.15 |
| H-88 | $L_7$ | 0.01 | 0.24* | 0.03 | 0.08* | -0.09* | -0.03 | 0.14* | 0.90 |
| Pusa Sheetal | $L_8$ | 0.15 | 0.19 | -0.13 | -0.06 | -0.18** | -0.28** | 0.08 | 0.88 |
| FLA 7171 | $L_9$ | 0.39** | -0.15 | -0.27* | -0.01 | 0.11** | -0.07 | -0.05 | 2.21** |
| Hisar Arun | $L_{10}$ | 0.00 | 0.25* | 0.08* | -0.19 | 0.00 | 0.18** | 0.11 | -1.63** |
| Sel.-32 | $L_{11}$ | -0.50** | -0.24* | 0.04 | 0.21* * | -0.08* | 0.09 | 0.35** | 0.33 |
| Flora Dode | $L_{12}$ | -0.02 | -0.20* | -0.26* | -0.39** | -0.21** | 0.01* | -0.28** | 0.37 |
| SE±F | | 0.109 | 0.075 | 0.086 | 0.096 | 0.044 | 0.035 | 0.084 | 0.412 |
| CD (5%) F | | 0.217 | 0.149 | 0.171 | 0.191 | 0.088 | 0.069 | 0.167 | 0.822 |
| **Testers** | | | | | | | | | |
| Pusa Sadabahar | $T_1$ | -0.20** | 0.06 | 0.10 | 0.02 | -0.04* | 0.01 | -0.02 | -0.75* |
| Kashi Vishesh | $T_2$ | 0.12* | 0.04 | -0.14* | 0.04 | 0.01 | -0.04 | 0.01 | 0.82** |
| Kashi Amrit | $T_3$ | 0.08 | -0.10* | 0.04 | -0.06 | 0.03 | 0.03 | 0.01 | -0.06 |
| S.E.(gii) ±M | | 0.054 | 0.037 | 0.043 | 0.048 | 0.022 | 0.017 | 0.042 | 0.206 |
| CD (5%) M | | 0.109 | 0.075 | 0.085 | 0.095 | 0.044 | 0.035 | 0.083 | 0.411 |

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

## Table-4.6 a: Estimation of specific combining ability (SCA) effect for the 8 characters of tomato

| S. No. | Crosses | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -0.43 | 0.50 | -0.25 | -0.14 | 0.07 | -0.40* | 0.26 | -2.30 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | 0.88 | -0.23 | -0.69 | 0.32 | 0.58 | 0.47* | -3.20** | -3.87 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -0.45 * | -0.27 | 0.94 | -0.19 | -0.65 | -0.07 | 2.94** | 6.17* |
| 4 | G-3 x Pusa Sadabahar | -0.64 | -0.29 | -0.63 | 0.10 | -0.31 | -0.21 | 5.01** | -3.46 |
| 5 | G-3 x Kashi Vishesh | 0.51 | -0.01 | -0.12 | -0.21 | 0.15 | 0.07 | -1.71 | 1.09 |
| 6 | G-3 x Kashi Amrit | 0.13* | 0.29 | 0.76 | 0.11 | 0.15 | 0.14 | -3.30** | 2.37 |
| 7 | S. Naveen x Pusa Sadabahar | -1.46 | -0.09* | -1.33* | -0.07 | 0.07 | 0.57** | -1.81* | 3.98 |
| 8 | S. Naveenx Kashi Vishesh | 1.99* | 0.29 | 1.33* | 0.48* | 0.10 | -0.01 | 4.19** | -0.06 |
| 9 | S. Naveen x Kashi Amrit | -0.52 | -0.20 | 0.01 | -0.41 | -0.18 | -0.56** | -2.38** | -3.92 |
| 10 | DVRT-2 x Pusa Sadabahar | 1.56 | -0.15 | -0.07 | 0.40 | 0.14 | 0.16 | 5.71** | 3.79 |
| 11 | DVRT-2 x Kashi Vishesh | -1.69 | 0.30 | -0.55 | -0.41 | 0.18 | -0.29 | -3.85** | 0.08 |
| 12 | DVRT-2 x Kashi Amrit | 0.13 | -0.15 | 0.63 | 0.01 | -0.32 | 0.12 | -1.86* | -3.87 |
| 13 | H-24 x Pusa Sadabahar | -1.62 | -0.11 | 1.18* | -0.23 | -0.10 | 0.30 | -3.27** | 5.59* |
| 14 | H-24 x Kashi Vishesh | 0.93 | 0.21 | 0.68 | 0.17* | -0.71** | -0.50* | 2.21* | -1.65 |
| 15 | H-24 x Kashi Amrit | 0.69 | -0.10 | -1.87** | 0.06 | 0.81** | 0.20 | 1.07 | -3.95 |
| 16 | H-86 x Pusa Sadabahar | 2.53`* | 0.17 | 0.24 | -0.03 | -0.36 | -0.18 | -6.67** | 4.23 |
| 17 | H-86 x Kashi Vishesh | -2.32* | 0.14 | 0.27 | -0.23 | 0.02 | 0.35 | 0.53 | 2.41 |
| 18 | H-86 x Kashi Amrit | -0.20 | -0.31 | -0.51 | 0.26 | 0.34 | -0.17 | 6.14** | -6.63** |
| 19 | H-88 x Pusa Sadabahar | 1.61 | 0.05 | 0.86 | -0.12 | -0.05 | 0.14 | 2.54** | -1.81 |
| 20 | H-88 x Kashi Vishesh | -1.12 | -0.45 | -0.68 | -0.06 | 0.09 | -0.21 | -1.29 | 6.84** |
| 21 | H-88 x Kashi Amrit | -0.48 | 0.40* | -0.18 | 0.18 | -0.04 | 0.07 | -1.25 | -5.03 |
| 22 | Pusa Sheetal x Pusa Sadabahar | -0.81 | -0.01 | 0.51 | -0.44 | -0.11 | -0.11 | 2.01 | -3.04 |
| 23 | Pusa Sheetal x Kashi Vishesh | 0.05 | -0.20 | -0.28 | -0.06 | -0.05 | -0.11 | 1.74 | -2.08 |
| 24 | Pusa Sheetal x Kashi Amrit | 0.76 | 0.21 | -0.23 | 0.50* | 0.17 | 0.22 | -3.75 | 5.12 |
| 25 | FLA 7171 x Pusa Sadabahar | 1.26 | 0.36* | -1.18* | 0.22 | 1.20** | 1.13** | -1.41 | 3.64 |
| 26 | FLA 7171 x Kashi Vishesh | -1.54 | -0.04 | 0.04 | -0.19 | -0.30 | -0.45* | -0.05 | -3.12 |
| 27 | FLA 7171 x Kashi Amrit | 0.29 | -0.32 * | 1.14 | -0.02 | -0.90** | -0.68** | 1.46 | -0.52 |
| 28 | Hisar Arun x Pusa Sadabahar | -0.57 | -0.22 | 1.26* | 0.35 | -0.54* | -0.52 | -1.91 | -3.04 |
| 29 | Hisar Arun x Kashi Vishesh | 0.38 | -0.14 | -0.54 | -0.06 | -0.09 | 0.34 | 2.07 | 0.42 |
| 30 | Hisar Arun x Kashi Amrit | 0.19 | 0.36 | -0.72 | -0.29 | 0.63** | 0.18 | -0.16 | 2.62 |
| 31 | Sel.-32 x Pusa Sadabahar | -0.28 | -0.31 | 0.99 | -0.09 | 0.35 | -0.17 | -0.72 | -1.21 |
| 32 | Sel.-32 x Kashi Vishesh | 0.96 | 0.29* | -0.98 | 0.43 | -0.23 | 0.02 | -1.60 | -2.65 |
| 33 | Sel.-32 x Kashi Amrit | -0.68 | 0.02* | -0.01 | -0.34 | -0.12 | 0.15 | 2.32 | 3.87 |
| 34 | Flora Dode x Pusa Sadabahar | -1.14 | 0.09 | -1.56** | 0.06 | -0.36 | -0.72 | 0.26 | -6.36 |
| 35 | Flora Dode x Kashi Vishesh | 0.99 | -0.15 | 1.53* | -0.19* | 0.27 | 0.32 | 0.97 | 2.59 |
| 36 | Flora Dode x Kashi Amrit | 0.15 | 0.06 | 0.04 | 0.13 | 0.10 | 0.40 | -1.23 | 3.77 |
| S.E ±M | | 0.762 | 0.248 | 0.550 | 0.229 | 0.266 | 0.192 | 1.109 | 2.354 |
| CD (5%) | | 1.519 | 0.495 | 1.097 | 0.456 | 0.530 | 0.383 | 2.212 | 4.696 |

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

## Table-4.6.b: Estimation of specific combining ability (SCA) effect for the 8 characters of tomato

| S. No. | Crosses | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (mg/100g) |
|---|---|---|---|---|---|---|---|---|---|
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | 0.17 | 0.07 | -0.18 | 0.18 | 0.06 | -0.22* | 0.06 | -0.71 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -0.16 | -0.88** | -0.08 | -0.34 | 0.01 | -0.26** | -0.16 | 1.31 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -0.02 | 0.81** | 0.26 | 0.16 | -0.07 | 0.48** | 0.10 | -0.60 |
| 4 | G-3 x Pusa Sadabahar | -0.03 | -0.44* | 0.30 | -0.15 | -0.42** | -0.03 | -0.15 | 0.24 |
| 5 | G-3 x Kashi Vishesh | 0.23 | 0.28 | -0.26 | 0.30 | 0.02 | 0.33** | 0.33* | -0.05 |
| 6 | G-3 x Kashi Amrit | -0.20 | 0.16 | -0.04 | -0.15 | 0.40** | -0.30** | -0.17 | -0.19 |
| 7 | S. Naveen x Pusa Sadabahar | 0.21 | 0.20 | 0.37 | 0.17 | -0.05 | -0.08 | 0.18 | 0.43 |
| 8 | S. Naveenx Kashi Vishesh | 0.03 | 0.09 | 0.15 | 0.31 | 0.06 | 0.38** | -0.12 | -0.68 |
| 9 | S. Naveen x Kashi Amrit | -0.23 | -0.30 | 0.52* | -0.49** | -0.01 | -0.29* | -0.06 | 0.25 |
| 10 | DVRT-2 x Pusa Sadabahar | -0.19 | 0.25 | 0.33* | 0.08 | 0.07 | 0.23* | -0.06 | 0.10 |
| 11 | DVRT-2 x Kashi Vishesh | -0.03 | -0.35* | -0.30 | -0.23 | -0.09 | -0.07 | -0.11 | 1.22 |
| 12 | DVRT-2 x Kashi Amrit | 0.21 | 0.09 | -0.03 | 0.15 | 0.02 | -0.16 | 0.18 | -1.31 * |
| 13 | H-24 x Pusa Sadabahar | 0.80** | 0.27 | -0.09 | 0.21 | 0.07 | -0.20* | 0.23 | -0.46 |
| 14 | H-24 x Kashi Vishesh | -0.50** | -0.16 | -0.09 | -0.10 | -0.13* | -0.02 | -0.25 | -0.85 |
| 15 | H-24 x Kashi Amrit | -0.30 | -0.10 | 0.18 | -0.11 | 0.06 | 0.22* | 0.03 | 1.32 |
| 16 | H-86 x Pusa Sadabahar | -0.31 | 0.17 | 0.16 | 0.38* | 0.31** | -0.11 | 0.13 | 0.98 |
| 17 | H-86 x Kashi Vishesh | 0.60** | 0.47** | 0.17* | 0.19 | -0.16* | -0.12 | 0.00 | -0.61 |
| 18 | H-86 x Kashi Amrit | -0.29 | -0.64** | -0.33 | 0.18 | -0.15* | 0.22* | -0.13 | -0.37 |
| 19 | H-88 x Pusa Sadabahar | 0.02 | 0.34* | -0.05 | -0.15 | 0.06 | 0.03 | 0.02 | -1.70 |
| 20 | H-88 x Kashi Vishesh | -0.21 | -0.70** | 0.06 | -0.10 | -0.01 | 0.09 | -0.11 | -0.51 |
| 21 | H-88 x Kashi Amrit | 0.20 | 0.36 | -0.01 | 0.25* | -0.05 | -0.12 | 0.09 | 2.22* |
| 22 | Pusa Sheetal x Pusa Sadabahar | -0.54 | -0.23 | -0.63 | -0.02 | 0.07 | -0.02 | -0.13 | -0.78 |
| 23 | Pusa Sheetal x Kashi Vishesh | 0.09 | 0.17 | -0.08 | -0.19 | -0.01 | 0.03 | -0.16 | 2.17* |
| 24 | Pusa Sheetal x Kashi Amrit | 0.45 | 0.06 | 0.71 | 0.20 | -0.07 | -0.01 | 0.29* | -1.39 |
| 25 | FLA 7171 x Pusa Sadabahar | -0.48 | -0.23 | -0.21 | -0.45 | -0.09 | -0.01 | -0.28* | -0.28 |
| 26 | FLA 7171 x Kashi Vishesh | 0.06 | 0.38 | -0.01 | -0.10 | 0.16* | -0.05 | 0.32* | -1.40 |
| 27 | FLA 7171 x Kashi Amrit | 0.42* | -0.15 | 0.22 | 0.55* | -0.07 | 0.06 | -0.04 | 1.68* |
| 28 | Hisar Arun x Pusa Sadabahar | -0.13 | -0.39 | 0.01 | 0.14 | 0.03 | 0.21* | -0.20 | 1.75 |
| 29 | Hisar Arun x Kashi Vishesh | 0.13 | 0.27 | 0.06 | 0.36 | -0.01 | -0.10 | 0.16 | -0.54 |
| 30 | Hisar Arun x Kashi Amrit | 0.00 | 0.12 | -0.06 | -0.50 | -0.02 | -0.10 | 0.04 | -1.21 |
| 31 | Sel.-32 x Pusa Sadabahar | 0.57 | -0.23 | 0.00 | 0.45 | -0.08 | 0.08 | 0.14 | -0.15 |
| 32 | Sel.-32 x Kashi Vishesh | -0.36 | 0.32 | -0.03 | 0.05 | 0.10 | -0.17 | 0.07 | 1.48 |
| 33 | Sel.-32 x Kashi Amrit | -0.21 | -0.09 | 0.03 | -0.50 | -0.02 | 0.10 | -0.20 | -1.32 |
| 34 | Flora Dode x Pusa Sadabahar | -0.09 | 0.22 | 0.00 | -0.09 | -0.04 | 0.13 | 0.07 | 0.59 |
| 35 | Flora Dode x Kashi Vishesh | 0.11 | 0.10 | 0.41 | -0.16 | 0.07 | -0.03 | 0.03 | -1.51 |
| 36 | Flora Dode x Kashi Amrit | -0.02 | -0.32 | -0.41* | 0.25 | -0.03 | -0.10 | -0.10 | 0.93 |
| S.E ±M | | 0.189 | 0.129 | 0.148 | 0.166 | 0.077 | 0.060 | 0.145 | 0.714 |
| CD (5%) | | 0.376 | 0.258 | 0.296 | 0.331 | 0.153 | 0.120 | 0.289 | 1.424 |

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

## Table – 4.7: Ranking of three desirable parents on the basis of *per se* performance and GCA effect for the 16 character of tomato

| S. No. | Characters | Best general combiners | Desirable parents based on *per se* performance | Best parents based on *per se* performance and GCA effects |
|---|---|---|---|---|
| 1 | Plant height (cm) | Sel.-32 | G-3 | G-3 |
| | | G-3 | Pusa Sadabahar | Sel.-32 |
| | | Hisar Arun | Sel.-32 | - |
| 2 | Branches per plant | Pusa Sheetal | FLA 7171 | IIVR-Sel.-1 |
| | | IIVR-Sel.-1 | Kashi Vishesh | FLA 7171 |
| | | FLA 7171 | IIVR-Sel.-1 | - |
| 3 | Days to 50% flowering | S. Naveen | Pusa Sheetal | S. Naveen |
| | | Flora Dode | S. Naveen | - |
| | | Pusa Sadabahar | IIVR-Sel.-1 | - |
| 4 | Clusters per plant | Flora Dode | G-3 | Flora Dode |
| | | H-86 | Flora Dode | - |
| | | FLA 7171 | Pusa Sheetal | - |
| 5 | Flowers per cluster | FLA 7171 | DVRT-2 | - |
| | | Hisar Arun | G-3 | G-3 |
| | | G-3 | DVRT-2 | - |
| 6 | Fruits per cluster | FLA 7171 | G-3 | G-3 |
| | | Flora Dode | S. Naveen | - |
| | | G-3 | Hisar Arun | - |
| 7 | Fruits per plant | G-3 | G-3 | G-3 |
| | | H-86 | H-24 | - |
| | | Flora Dode | Pusa Sheetal | - |

| | | | | |
|---|---|---|---|---|
| 8 | Average fruit weight (g) | H-88 | S. Naveen | H-88 |
| | | Kashi Amrit | H-24 | - |
| | | H-86 | H-88 | - |
| 9 | Locules per fruit | Kashi Vishesh | IIVR-Sel.-1 | - |
| | | FLA 7171 | Kashi Amrit | - |
| | | H-86 | Flora Dode | - |
| 10 | Pericarp thickness (mm) | Hisar Arun | Kashi Amrit | H-88 |
| | | H-88 | Sel.-32 | - |
| | | H-24 | FLA 7171 | - |
| 11 | Fruit length (cm) | FLA 7171 | H-88 | - |
| | | Flora Dode | Pusa Sheetal | - |
| | | Hisar Arun | Kashi Amrit | - |
| 12 | Fruit width (cm) | H-24 | S. Naveen | H-88 |
| | | Sel.-32 | H-88 | - |
| | | H-88 | DVRT-2 | - |
| 13 | Ridges on fruit | G-3 | Sel.-32 | - |
| | | IIVR-Sel.-1 | Kashi Amrit | - |
| | | FLA 7171 | DVRT-2 | - |
| 14 | Fruit yield per plant (kg) | Hisar Arun | S. Naveen | S. Naveen |
| | | S. Naveen | Pusa Sheetal | - |
| | | Flora Dode | H-24 | - |
| 15 | TSS (°Brix) | S. Naveen | FLA 7171 | - |
| | | Sel.-32 | H-24 | - |
| | | H-88 | DVRT-2 | - |
| 16 | Vit. C (Mg/100g) | H-24 | Pusa Sadabahar | - |
| | | FLA 7171 | S. Naveen | - |
| | | Kashi Vishesh | Sel.-32 | - |

## Table – 4.8: Ranking of three desirable parents on the basis of *per se* performance and SCA effect for the 16 character of tomato

| S. No. | Characters | Best general combiners | Desirable parents based on *per se* performance | Best parents based on *per se* performance and SCA effects |
|---|---|---|---|---|
| 1 | Plant height (cm) | H-86 x Pusa Sadabahar | FLA 7171 x Pusa Sadabahar | H-86 x Pusa Sadabahar |
| | | S. Naveen x Kashi Vishesh | H-86 x Pusa Sadabahar | - |
| | | G-3 x Kashi Amrit | Sel.-32 x Kashi Vishesh | - |
| 2 | Branches per plant | FLA 7171 x Pusa Sadabahar | Pusa Sheetal x Kashi Amrit | H-88 x Kashi Amrit |
| | | H-88 x Kashi Amrit | H-88 x Kashi Amrit | - |
| | | Sel.-32 x Kashi Amrit | Hisar Arun x Kashi Amrit | - |
| 3 | Days to 50% flowering | H-24 x Kashi Amrit | Flora Dode x Pusa Sadabahar | H-24 x Kashi Amrit |
| | | Flora Dode x Pusa Sadabahar | S. Naveen x Pusa Sadabahar | Flora Dode x Pusa Sadabahar |
| | | S. Naveen x Pusa Sadabahar | H-24 x Kashi Amrit | S. Naveen x Pusa Sadabahar |
| 4 | Clusters per plant | Pusa Sheetal x Kashi Amrit | H-86 x Kashi Amrit | S. Naveenx Kashi Vishesh |
| | | S. Naveenx Kashi Vishesh | Flora Dode x Kashi Amrit | - |
| | | H-24 x Kashi Vishesh | S. Naveenx Kashi Vishesh | - |
| 5 | Flowers per cluster | FLA 7171 x Pusa Sadabahar | FLA 7171 x Pusa Sadabahar | FLA 7171 x Pusa Sadabahar |
| | | H-24 x Kashi Amrit | Hisar Arun x Kashi Amrit | Hisar Arun x Kashi Amrit |
| | | Hisar Arun x Kashi Amrit | Sel.-32 x Pusa Sadabahar | - |
| 6 | Fruits per cluster | FLA 7171 x Pusa Sadabahar | FLA 7171 x Pusa Sadabahar | FLA 7171 x Pusa Sadabahar |
| | | S. Naveen x Pusa Sadabahar | Flora Dode x Kashi Amrit | - |
| | | IIVR-Sel. 1 x Kashi Vishesh | Flora Dode x Kashi Vishesh | - |
| 7 | Fruits per plant | H-86 x Kashi Amrit | H-86 x Kashi Amrit | H-86 x Kashi Amrit |
| | | G-3 x Pusa Sadabahar | G-3 x Pusa Sadabahar | G-3 x Pusa Sadabahar |
| | | DVRT-2 x Pusa Sadabahar | S. Naveenx Kashi Vishesh | - |
| 8 | Average fruit weight (g) | H-88 x Kashi Vishesh | H-88 x Kashi Vishesh | H-88 x Kashi Vishesh |

| | | | | |
|---|---|---|---|---|
| | | IIVR-Sel.-1 x Kashi Amrit | G-3 x Kashi Amrit | - |
| | | H-24 x Pusa Sadabahar | Sel.-32 x Kashi Amrit | - |
| 9 | Locules per fruit | H-24 x Pusa Sadabahar | H-86 x Kashi Vishesh | H-86 x Kashi Vishesh |
| | | H-86 x Kashi Vishesh | FLA 7171 x Kashi Amrit | FLA 7171 x Kashi Amrit |
| | | FLA 7171 x Kashi Amrit | Pusa Sheetal x Kashi Amrit | - |
| 10 | Pericarp thickness (mm) | IIVR-Sel. 1 x Kashi Vishesh | H-86 x Kashi Amrit | H-86 x Kashi Amrit |
| | | H-88 x Kashi Vishesh | IIVR-Sel. 1 x Kashi Vishesh | IIVR-Sel. 1 x Kashi Vishesh |
| | | H-86 x Kashi Amrit | Flora Dode x Kashi Amrit | - |
| 11 | Fruit length (cm) | S. Naveen x Kashi Amrit | Pusa Sheetal x Kashi Amrit | - |
| | | DVRT-2 x Pusa Sadabahar | S. Naveen x Pusa Sadabahar | - |
| | | H-86 x Kashi Vishesh | H-24 x Kashi Amrit | - |
| 12 | Fruit width (cm) | H-86 x Pusa Sadabahar | H-24 x Pusa Sadabahar | - |
| | | FLA 7171 x Kashi Amrit | S. Naveenx Kashi Vishesh | - |
| | | H-88 x Kashi Amrit | IIVR-Sel.-1 x Pusa Sadabahar | - |
| 13 | Ridges on fruit | G-3 x Kashi Amrit | G-3 x Kashi Amrit | G-3 x Kashi Amrit |
| | | H-86 x Pusa Sadabahar | H-86 x Pusa Sadabahar | H-86 x Pusa Sadabahar |
| | | FLA 7171 x Kashi Vishesh | FLA 7171 x Kashi Vishesh | FLA 7171 x Kashi Vishesh |
| 14 | Fruit yield per plant (kg) | S. Naveenx Kashi Vishesh | IIVR-Sel.-1 x Kashi Amrit | IIVR-Sel.-1 x Kashi Amrit |
| | | G-3 x Kashi Vishesh | S. Naveenx Kashi Vishesh | S. Naveenx Kashi Vishesh |
| | | IIVR-Sel.-1 x Kashi Amrit | Hisar Arun x Pusa Sadabahar | - |
| 15 | TSS (°Brix) | G-3 x Kashi Vishesh | S. Naveen x Pusa Sadabahar | FLA 7171 x Kashi Vishesh |
| | | FLA 7171 x Kashi Vishesh | S. Naveenx Kashi Vishesh | - |
| | | Pusa Sheetal x Kashi Amrit | FLA 7171 x Kashi Vishesh | - |
| 16 | Vit. C (Mg/100g) | H-88 x Kashi Amrit | H-24 x Kashi Amrit | Pusa Sheetal x Kashi Vishesh |
| | | Pusa Sheetal x Kashi Vishesh | Pusa Sheetal x Kashi Vishesh | FLA 7171 x Kashi Amrit |
| | | FLA 7171 x Kashi Amrit | FLA 7171 x Kashi Amrit | - |

### 2. Number of branches per plant:

The significant and negative general combining ability are good for number of branches per plant was revealed for G-3 (-0.49) followed by H-24 (-0.17). While, positive and significant general combining ability were revealed for parents Pusa Sheetal (0.53) followed by IIVR-Sel.-1 (0.34). The significant and negative estimates for specific combining ability effects showing the earliness, which is considered to be good for number of branches per plant was observed for FLA 7171 x Kashi Amrit (-0.32) followed by S. Naveen x Pusa Sadabahar (-0.09). While, significant and positive specific combining ability effects was recorded for cross FLA 7171 x Pusa Sadabahar (0.36) followed by Sel.-32 x Kashi Vishesh (0.29).

### 3. Days to 50 per cent flowering:

In the present lines and testers, significant and positive general combining ability effects were revealed for parents DVRT-2 (0.69) followed by Kashi Vishesh (0.42). While, significant and negative general combining ability effects were recorded for Flora Dode (-1.76) followed by S. Naveen (-0.73) indicating that these parents are desirable general combiners for days to 50% flowering as the negative general combining ability effects is good for this characters. While, positive and significant specific combining ability effects were revealed for cross combinations in Flora Dode x Kashi Vishesh (1.53), Hisar Arun x Pusa Sadabahar (1.26) and H-24 x Pusa Sadabahar (1.18).Whereas, significant and negative specific combining ability effects were recorded for cross combinations H-24 x Kashi Amrit (-1.87), S. Naveen x Pusa Sadabahar (-1.33) and FLA 7171 x Pusa Sadabahar (-1.18).

### 4. Number of clusters per plant:

The significant and negative general combining ability effects were observed for the parents G-3 (-0.39) and IIVR-Sel.-1 (-0.33). While, significant and Positive general combining ability effects were recorded for parents Flora Dode (0.49) followed by H-86 (0.47). Among the cross combinations Flora Dode x Kashi Vishesh (-0.19) showed negative and significant desirable specific combining effects. Whereas, Pusa Sheetal x Kashi Amrit (0.50) and S. Naveen x Kashi Vishesh (0.48) showed significant and positive specific combining ability effects.

### 5. Number of flowers per cluster:

Significant and Positive general combining ability are good for flowers per cluster were showed by the parents FLA-7171 (0.48) followed by Hisar Arun (0.33) and Pusa Sadabahar (0.25) among the lines. Whereas, significant and negative general combining ability were observed for parents Pusa Sheetal (-0.45) followed by S. Naveen (-0.42) and H-86 (-0.39). Whereas, highly positive significant were observed for cross combinations FLA-7171 x Pusa Sadabahar (1.20) followed by H-24 x Kashi Amrit (0.81) and Hisar Arun x Kashi Amrit (0.63). Significant and negative specific combining ability effects were observed in FLA 7171 x Kashi Amrit (-0.90) and H-24 x Kashi Vishesh (-0.71).

### 6. Number of fruits per cluster:

Positive and significant value of general combining ability effect as well as specific combining effect is good for this trait. Flora Dode (0.46), FLA-7171 (0.31) and G-3 (0.27) were labeled as good general combiners for number of fruits per cluster due to significant and positive general combining effects,whereas, negative significant general combining ability effects were revealed by parents Pusa Sheetal (-0.51) and H-88 (-0.48). In cross combination crosses FLA-7171 x Pusa Sadabahar (1.13), S. Naveen x Pusa Sadabahar (0.57) showed positive and significant SCA effects, whereas FLA-7171 x Kashi Amrit (-0.68), S. Naveen x Kashi Amrit (-0.56) and FLA-7171 x Kashi Vishesh (-0.45) were observed significant and negative SCA effects for fruits per cluster.

### 7. Number of fruits per plant:

Significant and positive general combining ability effects were found for fruits per plant in G-3 (5.35), H-86 (4.94) and Flora Dode (3.20), while, negative significant general combining ability effects were observed in FLA-7171 (-6.14), Pusa Sheetal (-5.31) and H-24 (-2.80). Among the cross combination H-86 x Kashi Amrit (6.14), DVRT-2 x Pusa Sadabahar (5.71), G-3 x Pusa Sadabahar (5.01) and S. Naveenx Kashi Vishesh (4.19) were observed significant and positive SCA and H-86 x Pusa Sadabahar (-6.67), DVRT-2 x Kashi Vishesh (-3.85) and G-3 x Kashi Amrit (-3.30) were revealed significant and negative SCA effect.

### 8. Average fruit weight (g):

The significant and positive value of general combining ability and specific combining ability effects are good for this trait. H-88 (6.99) and Kashi Amrit (1.42) showed significantly positive general combining ability effects, whereas, Flora Dode (-4.51) and Hisar Arun (-3.43) recorded negative significant general combining ability effects for this character. Highly significant and positive specific combining ability effects were recorded in number of cross combinations namely, H-88 x Kashi Vishesh (6.84), IIVR-Sel.-1 x Kashi Amrit (6.17) and H-24 x Pusa Sadabahar (5.59), while, significant negative specific combining ability effect was found in cross combination H-86 x Kashi Amrit (-6.63) for average fruit weight.

### 9. Number of locules per fruit:

Among the parents, FLA-7171 (0.39), H-86 (0.30) and Kashi Vishesh (0.12) were showed positive and significant GCA, while Sel.-32 (-0.50), G-3 (-0.36) and S. Naveen (-0.29) showed negative and significant GCA. Among the cross combination H-24 x Pusa Sadabahar (0.80) and H-86 x Kashi Vishesh (0.60) were showed positive and significant SCA and H-24 x Kashi Vishesh (-0.50) was showed negative and significant SCA effect.

### 10. Pericarp thickness (mm):

The positive and significant value of general combining ability and specific combining ability effects are good for this trait. Hisar Arun (0.25) and H-88 (0.24) showed positive significant general combining ability effects, whereas, Sel.-32 (-0.24) and H-86 (-0.22) observed negative significant general combining ability effects for this character. Highly significant and positive specific combining ability effects, were showed in number of cross combinations IIVR Sel.-1 x Kashi Amrit (0.81) and H-86 x Kashi Vishesh (0.47), while, negative significant specific combining ability effect was found in cross combination IIVR-Sel. 1 x Kashi Vishesh (-0.88) and H-88 x Kashi Vishesh (-0.70) for pericarp thickness.

### 11. Fruit length (cm):

The Parents, H-86 (0.22) and IIVR-Sel.-1 (0.10) were observed as desirable general combiners for length of fruits due to expression of significant and positive combining ability effects, while, negative significant and general combining ability effects were observed for parents FLA-7171 (-0.27), Flora Dode (-0.26) and Kashi Vishesh (-0.14). Cross combinations S. Naveen x Kashi Amrit(0.52) recorded positive and significant specific combining ability effects for length of fruit. While cross Flora Dode x Kashi Amrit (-0.41) was showed negative and significant SCA effects for fruit length.

### 12. Fruit width (cm):

For this trait, H-24 (0.31) and Sel.-32 (0.21) recorded highly positive significant general combining ability effects except IIVR Sel.-1, S. Naveen, DVRT-2, H-86 and H-88 showed non-significant positive general combining ability effects. The lines Flora Dode (-0.39) showed highly negative significant general combining ability effects.Cross combinations H-86 x Pusa Sadabahar(0.38) recorded highly significant positive specific combining ability effects, whereas, highly negative significant specific combining ability effects was noted in cross combination S. Naveen x Kashi Amrit(-0.49) for fruit width.

### 13. Number of ridges on fruit:

The positive and highly significant value of general combining ability effects were showed for ridges on fruit in G-3 (0.30) and IIVR-Sel.-1 (0.17 ), while, negative and significant general combining ability effects were observed for Flora Dode (-0.21) and H-24 (-0.19). In cross combinations G-3 x Kashi Amrit(0.40) and H-86 x Pusa Sadabahar (0.31) showed positive and significant specific combining ability effects, whereas, G-3 x Pusa Sadabahar(-0.42), H-86 x Kashi Vishesh(-0.16) and H-86 x Kashi Amrit(-0.15) showed negative and significant SCA effects for ridges on fruit.

### 14. Fruit yield per plant (Kg):

Significant and positive value of general combining ability effect as well as specific combining effect is desirable for this trait. Hisar Arun (0.18), S. Naveen

(0.12) and Pusa Sadabahar (0.01) were identified as good general combiners for fruit yield due to positive and significant general combining effects, while, undesirable and negative significant general combining ability effects were showed by parents Pusa Sheetal (-0.28),DVRT-2 (-0.13)and H-24 (-0.12). In cross combinations IIVR-Sel.-1 x Kashi Amrit(0.48), S. Naveenx Kashi Vishesh(0.38) and G-3 x Kashi Vishesh(0.33) showed positive and significant specific combining ability effects, whereas, G-3 x Kashi Amrit(-0.30) and S. Naveen x Kashi Amrit(-0.29) recorded negative and significant SCA effects for number of fruits per plant.

### 15. TSS (°Brix):

Among parents,the maximum positive and significant general combining abilityeffectwasobservedin S. Naveen (0.45) and Sel.-32 (0.35) were identified as good general combiners for TSS.While, undesirable and negative significant general combining ability effects were observed by parents Flora Dode (-0.28). In cross combination crosses G-3 x Kashi Vishesh (0.33), FLA-7171 x Kashi Vishesh (0.32) showed positive and significant SCA effects, whereas FLA-7171 x Pusa Sadabahar (-0.28) was observed negative and significant SCA effects for TSS.

### 16. Vitamin C (mg/100g ):

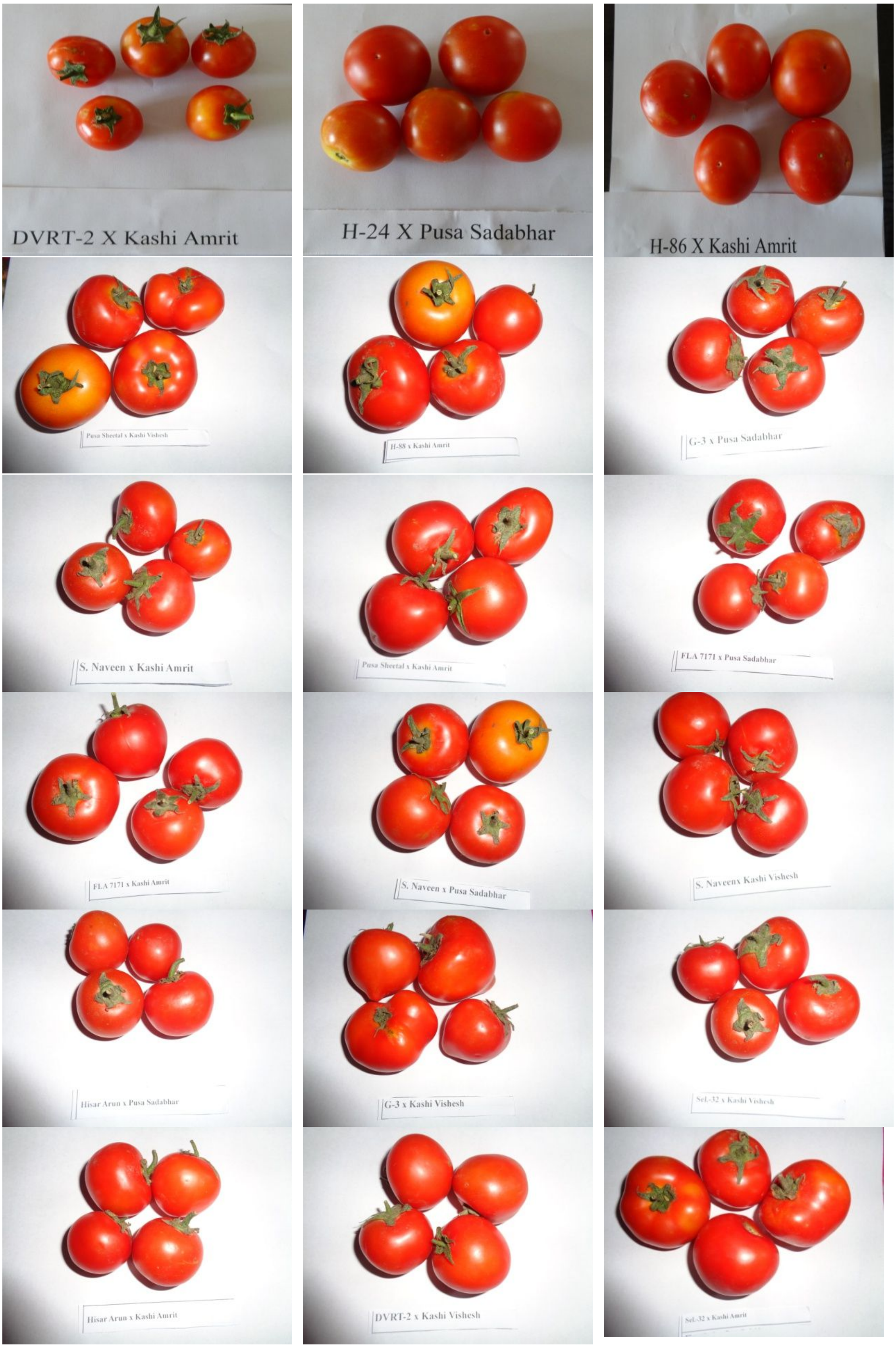
Positive and significant value of general combining ability effect as well as specific combining effect is desirable for this trait. Parents H-24 (3.14), FLA-7171 (2.21) and Kashi Vishesh (0.82) were identified as good general combiners for vitamin C due to positive and significant general combining effects.While, negative significant general combining ability effects were recorded by parents S. Naveen (-2.72) and IIVR-Sel.-1 (-1.83). In cross combinations crosses H-88 x Kashi Amrit(2.22) and Pusa Sheetal x Kashi Vishesh (2.17) were recorded positive and highly significant specific combining ability effects. While, DVRT-2 x Kashi Amrit (-1.31) was showed negative and significant specific combining ability effects for vitamin C.

## Plate-8: A general view of Parents (12 lines and 3testers) of tomato

### 12 LINES

### 3 TESTERS

## Plate-9: A general view of cross combinations of tomato



## Plate-10: A general view of cross combinations of tomato

### 4.3.2 Genetic component and combining ability variance:

The estimation of genetic component of variance (additive and dominance), combining ability variance (GCA and SCA), degree of dominance and predictability ratio for sixteen characters of tomato are given in Table 4.9.

**1. Plant height (cm):**

The estimated genetic component of variance for dominance (3.585) was showed higher than the additive variance (2.493) along with degree of dominance greater the one (1.199). Specific combining variance (0.896) was also found to be greater than the general combining ability variance (0.624) along with predictability ratio of less than one (0.582) for plant height.It indicated that over dominance effect is playing role for plant height due to non-additive gene action.

**Table – 4.9: Estimation of genetic components of variance (additive & dominance variance), degree of dominance, combining ability variance (GCA & SCA) and predictability ratio for 16 character of tomato.**

| S. No. | Characters | Genetic components of variance | | Degree of dominance | Combining ability variance | | Predictability ratio |
|---|---|---|---|---|---|---|---|
| | | Additive | Dominance | | GCA variance | SCA variance | |
| 1 | Plant height (cm) | 2.493 | 3.585 | 1.199 | 0.624** | 0.896** | 0.582 |
| 2 | Branches per plant | 0.040 | 0.544 | 3.667 | 0.010 | 0.136** | 0.130 |
| 3 | Days to 50% flowering | 0.339 | 2.402 | 2.660 | 0.085 | 0.600** | 0.220 |
| 4 | Clusters per plant | 0.028 | 0.342 | 3.495 | 0.007 | 0.085** | 0.141 |
| 5 | Flowers per cluster | 0.048 | 0.301 | 2.496 | 0.012 | 0.075* | 0.244 |
| 6 | Fruits per cluster | 0.069 | 0.484 | 2.655 | 0.017 | 0.121** | 0.222 |
| 7 | Fruits per plant | 5.354 | 14.855 | 1.666 | 1.339** | 3.714** | 0.419 |
| 8 | Average fruit weight (g) | 2.728 | 59.155 | 4.657 | 0.682 | 14.789** | 0.084 |
| 9 | Locules per fruit | 0.034 | 0.168 | 2.228 | 0.008* | 0.042** | 0.287 |
| 10 | Pericarp thickness (mm) | 0.029 | 0.546 | 4.343 | 0.007 | 0.137** | 0.096 |
| 11 | Fruit length (cm) | 0.008 | 0.424 | 34.538 | 0.002 | 0.106** | 0.056 |
| 12 | Fruit width (cm) | 0.011 | 0.315 | 5.407 | 0.003 | 0.079** | 0.064 |
| 13 | Ridges on fruit | 0.011 | 0.185 | 4.051 | 0.003 | 0.046** | 0.109 |
| 14 | Fruit yield per plant (kg) | 0.012 | 0.175 | 3.827 | 0.003 | 0.044** | 0.120 |
| 15 | TSS (°Brix) | 0.025 | 0.272 | 3.276 | 0.006 | 0.068** | 0.157 |
| 16 | Vit C mg/100g | 1.075 | 0.245 | 0.477 | 0.269** | 0.061 | 0.898 |

## 2. Number of branches per plant:

The estimated dominance variance (0.544) was recorded maximum than the additive variance (0.040) along with degree of dominance greater than one (3.667). The specific combining ability variance (0.136) was also found greater than general combining ability variance (0.010) with predictability ratio of less than one (0.130) for number of branches per plant.

## 3. Days to 50 per cent flowering:

The value of genetic component of variance for dominance resulted in maximum value (2.402) than the its respective additive variance (0.339) along with degree of dominance greater than one (2.660) degree of dominance. The variance for specific combining ability (0.600) was also found maximum value than the general combining ability variance (0.085) with predictability ratio of less than one (0.220) for days to 50% flowering.

## 4. Number of clusters per plant:

The estimated dominance variance (0.342) was recorded highest than the additive variance (0.028) along with degree of dominance greater than one (3.495). The specific combining ability variance (0.085) was also found greater than general combining ability variance (0.007) with predictability ratio of less than one (0.141) for clusters per plant.

## 5. Number of flowers per cluster:

The value of dominance variance exhibited higher value (0.301) than the corresponding additive variance (0.048) with higer than one (2.496) degree of dominance. The variance for specific combining ability (0.075) was also reflected maximum value than general combining ability variance (0.012) along with predictability ratio of less than one (0.244) for flowers per cluster.

## 6. Number of fruits per cluster:

The estimated genetic component of variance for dominance (0.484) was showed higher than the additive variance (0.069) with the degree of dominance greater than one (2.655). The specific combining ability variance (0.121) was recorded to be higher than the general combining ability variance (0.017) with predictability ratio of less than one (0.222) for fruits per cluster.

### 7. Number of fruits per plant:

The value of dominance variance (14.855) was showed higher than the additive variance (5.354) along with degree of dominance was found to be greater than one (1.666). The specific combining ability (3.714) was found to be greater than the general combining ability (1.339) along with predictability ratio less than one (0.419) for fruits per plant.

### 8. Average fruit weight (g):

The estimated genetic component of variance for dominance (59.155) was recorded higher than the additive variance (2.728) along with degree of dominance greater than one (4.657). Marked increase was exhibited by specific combining ability variance (14.789) over than the general combining ability variance (0.682) with predictability ratio of less than one (0.084) for average fruit weight.

### 9. Number of locules per fruit:

The value of dominance variance (0.168) was showed higher than the additive variance (0.034) along with degree of dominance was found to be greater than one (2.228). The specific combining ability (0.042) was found to be greater than the general combining ability (0.008) along with predictability ratio less than one (0.287) for locules per fruit.

### 10. Pericarp thickness (mm):

The estimated genetic component of variance for dominance recorded higher value (0.546) than the corresponding additive variance (0.029) along with greater than one (4.343) degree of dominance. The variance for specific combining ability (0.137) was recorded to be greater than the general combining ability variance (0.007) with predictability ratio of less than one (0.096) for pericarp thickness.

### 11. Fruit length (cm):

The value of dominance variance (0.424) was recorded higher than the additive variance (0.008) along with degree of dominance was found to be greater than one (34.538). The specific combining ability (0.106) was found to be greater than the general combining ability (0.002) along with predictability ratio less than one (0.056) for fruit length.

### 12. Fruit width (cm):

The estimated genetic component of variance for dominance (0.315) was showed grater than the additive variance (0.011) with the degree of dominance greater than one (5.407). The specific combining ability variance (0.079) was recorded to be graterer than the general combining ability variance (0.003) with predictability ratio of less than one (0.064) for fruit width.

### 13. Number of ridges on fruit:

The value of genetic component of variance for dominance resulted in grater value (0.185) than the its respective additive variance (0.011) along with degree of dominance higher than one (4.051). The variance for specific combining ability (0.046) was also found higher value than the general combining ability variance (0.003) with predictability ratio of less than one (0.109) for ridges on fruit.

### 14. Fruit yield per plant (kg):

The estimated genetic component of variance for dominance (0.175) was recorded grater than the additive variance (0.012) with the degree of dominance higher than one (3.827). The specific combining ability variance (0.044) was recorded to be grater than the general combining ability variance (0.003) with predictability ratio of less than one (0.120) for fruit yield per plant.

### 15. TSS (°Brix):

The value of dominance variance (0.272) was recorded grater than the additive variance (0.025) along with degree of dominance was found to be greater than one

(3.276). The specific combining ability (0.068) was found to be higher than the general combining ability (0.006) along with predictability ratio less than one (0.157) for TSS.

**16. Vitamin C (mg/100g ):**

The estimated genetic component of variance for dominance (0.245) was recorded lower than the additive variance (1.075) with the degree of dominance lower than one (0.477). The specific combining ability variance (0.061) was showed to be lower than the general combining ability variance (0.269) with predictability ratio of less than one (0.898) for vitamin C.

## 4.4 HETEROSIS AND INBREEDING DEPRESSION:

Heterosis was estimated as percent increases or decreases of $F_1$ value over standard variety (SV) and better parent (BP) and inbreeding depression (expressed as the reduction of $F_2$ mean from $F_1$ mean) in $F_2$ population for all the characters under study and its presented in Table-4.10.a, 4.10.b, 4.10.c, 4.10.d, 4.10.e, 4.10.f, 4.10.g, 4.10.h and 4.11.

**1. Plant height (cm):**

The positive and significant heterosis for plant height is desirable. The heterosis value ranged from -9.26 % (DVRT-2 x Pusa Sadabahar) to 9.90 % (DVRT-2 x Kashi Vishesh) over standard variety and -8.75 % (DVRT-2 x Pusa Sadabahar) to 8.67% (FLA 7171 x Kashi Vishesh) over better parents. Cross combinations DVRT-2 x Kashi Vishesh, H-88 x Kashi Amrit and Pusa Sheetal x Kashi Amrit over standard variety and FLA 7171 x Kashi Vishesh, H-86 x Kashi Amrit and Hisar Arun x Kashi Vishesh over better parents showed positive and significant heterosis. In case of inbreeding depression ranged from -6.62% (S. Naveen x Kashi Amrit) to 7.03% (H-88 x Pusa Sadabahar). Cross combinations H-88 x Pusa Sadabahar, Sel.-32 x Kashi Vishesh and DVRT-2 x Pusa Sadabaharrecorded positive and highly significant inbreeding depression whereas, four cross combinations recorded negative and significant inbreeding depression in $F_2$ population for plant height.

## Table-4.10 a: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for plant height (cm) and branches per plant of tomato

| S. No. | Crosses | Plant height (cm) | | | Branches per plant | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -3.75 * | -3.21 | 0.80 | -18.90** | -9.72 | 3.62 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -2.48 | 1.12 | 0.75 | 13.52* | -6.10 | -15.22 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -4.98** | -1.83 | 0.58 | -28.05** | 19.91* | 2.51 |
| 4 | G-3 x Pusa Sadabahar | -0.95 | -3.51* | -0.94 | -30.02** | -14.29 | -3.91 |
| 5 | G-3 x Kashi Vishesh | -0.06 | -2.65 | -0.84 | -23.98** | -17.47 | 0.47 |
| 6 | G-3 x Kashi Amrit | -1.85 | -4.39* | -0.20 | 18.78** | -0.51 | -0.15 |
| 7 | S. Naveen x Pusa Sadabahar | -5.02** | -4.48* | -3.70 | -24.64** | -6.74 | 3.08* |
| 8 | S. Naveenx Kashi Vishesh | -3.71* | -1.71 | -0.02 | -27.99** | -21.82** | 18.65 |
| 9 | S. Naveen x Kashi Amrit | -2.23 | -0.19 | -6.62** | -18.06** | 6.95 | -3.47 |
| 10 | DVRT-2 x Pusa Sadabahar | -9.26** | -8.75** | 5.11** | -36.24** | -21.10** | 17.68 |
| 11 | DVRT-2 x Kashi Vishesh | 9.90** | -0.46 | -0.68 | -24.22** | -17.73 | 15.25 |
| 12 | DVRT-2 x Kashi Amrit | -6.62** | -3.53 | -1.60 | -37.80** | -18.81 | 23.02 |
| 13 | H-24 x Pusa Sadabahar | -2.55 | -2.00 | -3.52 | -33.49** | -17.69 | 12.72 |
| 14 | H-24 x Kashi Vishesh | 0.19 | 3.33 | -2.93* | -22.97** | -16.36* | 10.43 |
| 15 | H-24 x Kashi Amrit | -0.15 | 2.98 | -3.54 | 40.07** | -21.78** | 24.83 |
| 16 | H-86 x Pusa Sadabahar | -2.22 | -1.67 | 3.18 | -8.13** | 13.69 | -8.25 |
| 17 | H-86 x Kashi Vishesh | -7.84** | 2.24 | 0.12 | -18.36** | -11.36 | 7.58* |
| 18 | H-86 x Kashi Amrit | -8.71** | 5.69** | 4.08 | -22.85** | 0.70 | 3.23 |
| 19 | H-88 x Pusa Sadabahar | -8.62** | -8.11** | 7.03** | -19.62** | -0.52 | 6.41 |
| 20 | H-88 x Kashi Vishesh | -4.98** | 1.73 | -2.19 | -36.54** | 31.10** | 21.58 |
| 21 | H-88 x Kashi Amrit | 7.82** | -4.76** | 1.40 | -14.23** | 11.94 | 10.21 |
| 22 | Pusa Sheetal x Pusa Sadabahar | -3.74* | -3.19 | 1.13 | -25.78** | -8.14 | 18.03 |
| 23 | Pusa Sheetal x Kashi Vishesh | -7.63** | 2.47 | 5.61 | -22.73** | -16.10 | 15.17 |
| 24 | Pusa Sheetal x Kashi Amrit | 7.06** | -3.98* | 5.62 | -18.12** | 6.87 | 16.32 |
| 25 | FLA 7171 x Pusa Sadabahar | 0.44 | 1.01 | 0.44 | -10.29** | -7.01 | 2.15 |
| 26 | FLA 7171 x Kashi Vishesh | -2.04 | 8.67** | -2.60* | -29.84** | -27.28** | 20.80 |
| 27 | FLA 7171 x Kashi Amrit | -0.96 | 2.33 | -1.17 | -26.56** | -23.87** | 11.53 |
| 28 | Hisar Arun x Pusa Sadabahar | 2.62 | 3.20 | -4.75* | -20.81** | -2.00 | -1.07 |
| 29 | Hisar Arun x Kashi Vishesh | -0.84 | 3.83* | -0.56 | -22.97** | -16.36 | 8.00 |
| 30 | Hisar Arun x Kashi Amrit | -3.05 | 0.16 | 0.85 | -9.39** | 18.27 | 1.62 |
| 31 | Sel.-32 x Pusa Sadabahar | -0.71 | -0.15 | 0.26 | -22.79** | -4.44 | -1.34 |
| 32 | Sel.-32 x Kashi Vishesh | -5.06** | -3.82* | 5.68** | -10.47** | -2.79 | 1.45 |
| 33 | Sel.-32 x Kashi Amrit | -2.32 | -1.05 | -0.20 | -22.85** | 0.70 | 9.66 |
| 34 | Flora Dode x Pusa Sadabahar | -5.16** | -4.62* | 0.50 | -11.78** | 9.18 | -4.68 |
| 35 | Flora Dode x Kashi Vishesh | -6.67** | -2.35 | 4.64 | -19.98** | -13.12 | 4.70 |
| 36 | Flora Dode x Kashi Amrit | -4.34* | -1.17 | 0.34 | -25.18** | -5.44 | 14.08 |

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

## 2. Number of branches per plant:

The positive and significant heterosis for number of branches per plant is good because it is directly associated with increase fruit yield per plant. The heterosis value ranged from -36.54% (H-88 x Kashi Vishesh) to 40.07% (H-24 x Kashi Amrit) over standard variety and -27.28 % (FLA 7171 x Kashi Vishesh) to 31.10 % (H-88 x Kashi Vishesh) over better parents. Cross combinations (H-24 x Kashi Amrit), (G-3 x Kashi Amrit) and (IIVR-Sel. 1 x Kashi Vishesh) showed positive and significant heterosis over standard variety and cross combinations (H-88 x Kashi Vishesh) and (IIVR-Sel.-1 x Kashi Amrit) showed positive and significant heterosis over better parents for number of branches per plant. In case of inbreeding depression 3.08 % (S. Naveen x Pusa Sadabahar) to 7.58% ( H-86 x Kashi Vishesh). Thirty four crosses exhibited non significant in $F_2$ populations for number of branches per plant.

## 3. Days to 50 per cent flowering:

The extent of heterosis for days fifty percent flowering ranged from -12.02% (DVRT-2 x Kashi Vishesh) to 13.38%(Sel.-32 x Pusa Sadabahar) over standard variety. Negative and significant heterosis is desirable for days to fifty percent flowering. Out of thirty six crosses, twenty four crosses recorded positive and significant heterosis over standard variety for this characters and -5.97 (S. Naveen x Pusa Sadabahar) to 0.65 (FLA 7171 x Kashi Vishesh) over better parents, only one crosses showed positive and significant heterosis, whereas, eleven crosses showed negative and significant heterosis over better parents. Cross combinations Sel.-32 x Pusa Sadabahar, and H-24 x Kashi Vishesh positive and significant heterosis over standard variety and S. Naveen x Pusa Sadabahar over better parent recorded early 50%flowering. The magnitude of inbreeding depression ranged from -5.08% (Flora Dode x Pusa Sadabahar) to 1.75% (IIVR-Sel.-1 x Kashi Amrit). Eleven $F_2$ population showed early days to 50% flowering.

## Table-4.10 b: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for days to fifty percent flowering and cluster per plant of tomato

| S. No. | Crosses | Days to 50% flowering | | | Clusters per plant | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | 7.78** | -4.83** | 0.07 | -23.47** | -15.75* | -9.44 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | 7.31** | -2.92 | 1.12 | -14.91** | -5.56 | -3.11 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | 8.77** | -0.76 | 1.75 | -25.55** | -10.44 | -2.53 |
| 4 | G-3 x Pusa Sadabahar | 9.08** | -3.68** | -0.60 | -26.65** | 34.50** | -0.34 |
| 5 | G-3 x Kashi Vishesh | 8.42** | -2.02 | 2.21 | -24.82 | -32.86** | -4.95 |
| 6 | G-3 x Kashi Amrit | 11.23** | 0.52 | 0.38 | -15.10** | -24.18 | -10.41 |
| 7 | S. Naveen x Pusa Sadabahar | 6.49** | -5.97** | -1.40 | -25.86 | -18.37* | 0.65 |
| 8 | S. Naveenx Kashi Vishesh | 9.45** | -0.99 | 1.76 | -19.62** | -10.79 | 9.68 |
| 9 | S. Naveen x Kashi Amrit | 9.50** | -0.10 | -1.25 | -21.03 | -10.28 | -9.49 |
| 10 | DVRT-2 x Pusa Sadabahar | 8.91** | -3.84** | 0.94 | -30.50** | -23.49 | 20.32 |
| 11 | DVRT-2 x Kashi Vishesh | -12.02** | -0.93 | -1.32 | -21.82 | -13.23* | -2.08 |
| 12 | DVRT-2 x Kashi Amrit | 12.77** | -0.27 | -0.77 | -22.49** | -3.35 | 7.38 |
| 13 | H-24 x Pusa Sadabahar | 10.72** | -2.65 | -0.17 | 32.76** | -25.98 | 9.17 |
| 14 | H-24 x Kashi Vishesh | 13.02** | -0.62 | -1.72 | -24.33 | -16.01* | 11.45 |
| 15 | H-24 x Kashi Amrit | 10.52** | -2.82 | -4.67* | -18.46** | 1.68 | 1.70 |
| 16 | H-86 x Pusa Sadabahar | 9.23** | -3.55** | 0.67 | -13.94** | -8.09 | 0.56 |
| 17 | H-86 x Kashi Vishesh | 9.53** | -1.17 | 1.80 | -24.82* | -19.71 | 13.50 |
| 18 | H-86 x Kashi Amrit | 10.93** | 0.09 | -1.52 | -13.75 | -7.90 | 9.55 |
| 19 | H-88 x Pusa Sadabahar | -11.01** | -1.98* | -0.54 | -37.78** | -31.49 | 21.27 |
| 20 | H-88 x Kashi Vishesh | 11.00 | -0.57 | -1.75 | -24.51 | -16.21* | 10.51 |
| 21 | H-88 x Kashi Amrit | 10.40** | -1.10 | -1.12 | -23.72 | -10.86 | 13.45 |
| 22 | Pusa Sheetal x Pusa Sadabahar | 9.91 | -2.95 | 0.38 | -29.77** | -22.68 | -0.97 |
| 23 | Pusa Sheetal x Kashi Vishesh | 12.23 | 1.53 | -1.67 | -23.35 | -14.93 | 5.00 |
| 24 | Pusa Sheetal x Kashi Amrit | 9.64** | 0.03 | 0.01 | -22.00 | -13.32** | 13.72 |
| 25 | FLA 7171 x Pusa Sadabahar | 9.54 | -3.28* | -1.82 | -14.36 | -5.72 | 1.20 |
| 26 | FLA 7171 x Kashi Vishesh | 12.07** | 0.65* | -0.66 | -32.15** | -24.69 | 18.56 |
| 27 | FLA 7171 x Kashi Amrit | 12.09 | 0.67 | 0.38 | -10.09 | 5.98 | -4.62 |
| 28 | Hisar Arun x Pusa Sadabahar | 12.13 | -2.30 | -0.79 | -7.58** | 1.75 | -16.85 |
| 29 | Hisar Arun x Kashi Vishesh | 11.80** | -2.59 | -2.16 | -16.69 | -7.53 | -10.19 |
| 30 | Hisar Arun x Kashi Amrit | 8.13 | -5.78** | 0.12 | -21.70 | -2.36 | -10.24 |
| 31 | Sel.-32 x Pusa Sadabahar | 13.38** | 0.11 | -1.43 | -22.68** | -14.87** | -6.12 |
| 32 | Sel.-32 x Kashi Vishesh | 8.05 | -3.97** | 1.45 | -17.48 | -8.41 | 4.73 |
| 33 | Sel.-32 x Kashi Amrit | 9.88 | -2.34 | 0.67 | -18.58** | 1.52 | -12.98* |
| 34 | Flora Dode x Pusa Sadabahar | 7.90** | -4.72** | -5.08* | -13.75 | -9.61 | 2.55 |
| 35 | Flora Dode x Kashi Vishesh | 11.78 | 0.54 | -1.73 | -21.64 | -17.87** | 10.97 |
| 36 | Flora Dode x Kashi Amrit | 6.80** | -3.94** | -0.46 | -30.07** | -26.71** | 25.23* |

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

## 4. Number of clusters per plant:

Increase in the clusters per plant is an important trait which contributes to the yield enhancement, hence positive and significant heterotic effect would be highly good. The cross H-24 x Pusa Sadabaharshowed heighest (32.76 %) significant positive heterosis over the standard variety. Eighteen crosses showed negative and significant heterosis. The ranged of heterosis over standard variety was from -37.78% (H-88 x Pusa Sadabahar) to 32.76% (H-24 x Pusa Sadabahar) and -32.86% (G-3 x Kashi Vishesh) to 34.50% (G-3 x Pusa Sadabahar) over better parents. The hybrid combinations H-24 x Pusa Sadabahar over standard variety and G-3 x Pusa Sadabahar over better parents showed heighest positive and highly significant heterosis for clusters per plant. Inbreeding depression ranged from -12.98% (Sel.-32 x Kashi Amrit) to 25.23% (Flora Dode x Kashi Amrit).

## 5. Number of flowers per cluster:

The positive and significant heterosis for flowers per cluster is desirable. The heterosis value ranged from -36.69% (H-86 x Pusa Sadabahar) to 33.43% (Flora Dode x Kashi Vishesh) over standard variety and -46.86% (H-86 x Pusa Sadabahar) to 45.74% (G-3 x Kashi Amrit) over better parents. Cross combinations IIVR-Sel.-1 x Pusa Sadabahar, Pusa Sheetal x Kashi Visheshand S. Naveen x Kashi Amrit over standard variety and Flora Dode x Kashi Vishesh, IIVR Sel.-1 x Pusa Sadabaharand FLA-7171 x Pusa Sadabaharover better parents recorded negative and significant heterosis. In case of inbreeding depression ranged from -28.30% (H-24 x Kashi Vishesh) to 39.68% (FLA-7171 x Pusa Sadabahar). Cross combinations IIVR Sel.-1 x Pusa Sadabahar, DVRT-2 x Pusa Sadabaharand Sel.-32 x Pusa Sadabaharsrecorded positive and highly significant inbreeding depression whereas, three cross combinations, showed negative and significant inbreeding depression in $F_2$ population for flowers per cluster.

## Table-4.10 c: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for flower per cluster and fruit per cluster of tomato

| S. No. | Crosses | Flowers per cluster | | | `Fruits per cluster | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -31.08** | -42.15** | 25.70* | -30.23** | -18.87** | -12.78 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -8.93 | -7.08 | 3.33 | -12.13 | 13.21 | -15.47 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -23.96** | -22.89 | -2.36 | -15.93 | 8.30 | -26.10** |
| 4 | G-3 x Pusa Sadabahar | -12.25 | -39.54** | 3.52 | -24.78** | 29.80** | -13.03 |
| 5 | G-3 x Kashi Vishesh | -21.91** | -46.20 | 14.53 | -18.10* | -23.56** | -16.60* |
| 6 | G-3 x Kashi Amrit | -21.24 | 45.74** | 15.91* | -22.38** | -27.56** | -8.43 |
| 7 | S. Naveen x Pusa Sadabahar | -20.82** | -33.54 | 6.42 | -25.31** | -24.56 | -2.91 |
| 8 | S. Naveenx Kashi Vishesh | -17.38 | -28.14 | -6.95 | -31.52** | -30.83** | -11.97 |
| 9 | S. Naveen x Kashi Amrit | -27.10** | -36.59** | 2.19 | -33.86 | -33.20** | -28.15* |
| 10 | DVRT-2 x Pusa Sadabahar | -19.98 | -32.83** | 18.35* | -21.97** | -9.26 | -7.07 |
| 11 | DVRT-2 x Kashi Vishesh | -16.29** | -28.62 | -7.84* | -30.52** | -18.21 | -8.71 |
| 12 | DVRT-2 x Kashi Amrit | -16.54 | -28.82 | 0.79 | -17.63 | -3.03 | -15.62* |
| 13 | H-24 x Pusa Sadabahar | -22.39** | -34.85** | 12.34 | -22.14 | -16.68** | -11.96 |
| 14 | H-24 x Kashi Vishesh | -10.80 | -23.70 | -28.30* | -40.60** | -36.43 | -9.27 |
| 15 | H-24 x Kashi Amrit | -9.29** | -22.41 | 8.85 | -31.46** | -26.65 | -2.72 |
| 16 | H-86 x Pusa Sadabahar | -36.69** | -46.86** | 18.18 | 27.12** | -15.26 | -28.51** |
| 17 | H-86 x Kashi Vishesh | -18.83 | -27.84 | -6.49* | -19.51 | -3.58 | -23.67* |
| 18 | H-86 x Kashi Amrit | -10.50** | -20.44 | -6.00 | -37.84** | -25.54** | -11.10 |
| 19 | H-88 x Pusa Sadabahar | -23.11** | -35.46** | 11.83 | -34.68** | -24.05 | -9.85 |
| 20 | H-88 x Kashi Vishesh | -23.30** | -26.06** | 6.41 | -36.91 | -17.79 | -21.01* |
| 21 | H-88 x Kashi Amrit | -15.57 | -18.62 | -3.17 | -42.65** | -25.27** | -0.41 |
| 22 | Pusa Sheetal x Pusa Sadabahar | -25.23** | -37.23** | 7.47 | -36.67** | -26.36 | -15.99 |
| 23 | Pusa Sheetal x Kashi Vishesh | -29.03** | -27.32 | 4.00 | -40.07** | -20.70 | -12.30 |
| 24 | Pusa Sheetal x Kashi Amrit | -21.00 | -19.89 | 1.58 | -29.00 | -6.05 | -19.76 |
| 25 | FLA 7171 x Pusa Sadabahar | -26.80** | -38.55** | 39.68** | -18.51 | -5.25 | 10.14 |
| 26 | FLA 7171 x Kashi Vishesh | -27.76 | -22.62 | 16.24* | -38.96** | -13.24** | 1.23 |
| 27 | FLA 7171 x Kashi Amrit | -18.29 | -17.14 | -4.96 | -31.93 | -3.09 | -17.49 |
| 28 | Hisar Arun x Pusa Sadabahar | -23.60** | -35.87 | 12.27 | -27.30 | -23.16** | -20.49 |
| 29 | Hisar Arun x Kashi Vishesh | -24.74 | -34.02** | 13.82 | -20.50** | -15.98 | -6.85 |
| 30 | Hisar Arun x Kashi Amrit | -17.02 | -27.25 | 19.26 | -28.65 | -24.58 | 0.57 |
| 31 | Sel.-32 x Pusa Sadabahar | -17.14** | -30.45 | 18.37* | -36.26** | -26.49** | -7.83 |
| 32 | Sel.-32 x Kashi Vishesh | -30.60 | -36.29 | 16.48 | -32.10** | -21.69** | -10.70 |
| 33 | Sel.-32 x Kashi Amrit | -27.88 | -33.80** | 17.64 | -33.92 | -23.78 | -3.58 |
| 34 | Flora Dode x Pusa Sadabahar | -25.77** | -37.69 | 8.21 | -32.40** | -27.88 | -11.28 |
| 35 | Flora Dode x Kashi Vishesh | 33.43** | -43.17** | 21.10 | -22.79 | -17.63** | 1.05 |
| 36 | Flora Dode x Kashi Amrit | -19.67** | -31.43 | 4.04 | -31.87** | -27.31** | 14.30 |

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

### 6. Number of fruits per cluster:

The positive and significant heterosis for fruits per cluster is good because it is directly associated with increase of fruit yield. The heterosis value ranged from -42.65% (H-88 x Kashi Amrit), to 27.12% (H-86 x Pusa Sadabahar) over standard variety and -33.20% (S. Naveen x Kashi Amrit) to 29.80% (G-3 x Pusa Sadabahar) over better parents. Cross combinations (H-24 x Kashi Vishesh), (Pusa Sheetal x Kashi Vishesh), (FLA 7171 x Kashi Vishesh) over standard variety and (S. Naveenx Kashi Vishesh), (G-3 x Kashi Amrit) and (Flora Dode x Kashi Amrit) showed negative and significant heterosis over better parents, respectively. The inbreeding depression ranged from -28.51% (H-86 x Pusa Sadabahar) to -15.62% (DVRT-2 x Kashi Amrit) showed highly negative and significant inbreeding depression.

### 7. Number of fruits per plant:

The significant and positive heterosis is good for this charater. The heterosis value ranged from -55.62% (H-24 x Pusa Sadabahar) to 27.43% (G-3 x Pusa Sadabahar) over standard variety and -27.37% (H-24 x Pusa Sadabahar) to 42.03% (H-86 x Kashi Amrit) over better parents. Cross combinations Sel.-32 x Kashi Amrit, FLA-7171 x Kashi Vishesh and FLA-7171 x Kashi Amrit over standard variety recorded negative and significant heterosis. Whereas, H-86 x Kashi Vishesh, Flora Dode x Kashi Amrit and S. Naveenx Kashi Vishesh over better parents revealed significant and positive heterosis. In case of inbreeding depression ranged from -29.19% (FLA-7171 x Pusa Sadabahar) to 36.70% (Sel.-32 x Kashi Amrit). Cross combinations Flora Dode x Pusa Sadabahar, Flora Dode x Kashi Vishesh and G-3 x Pusa Sadabahar recorded significant and positive inbreeding depression. Seven crosses exhibited positive and significant in $F_2$ populations for this character.

# Table-4.10.d: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for fruits per plant and average fruit weight (g) of tomato

| S. No. | Crosses | Fruits per plant | | | Average fruit weight (g) | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -38.52** | 4.23 | 5.28 | -27.03** | 0.16 | 0.37 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -37.72** | 5.58 | -10.33 | -31.42** | -2.99 | 5.09 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -35.69 | 9.01 | 13.92 | 1.56 | 48.63** | -4.07 |
| 4 | G-3 x Pusa Sadabahar | 27.43** | 5.67 | 18.58** | -30.82** | -5.04 | 13.03 |
| 5 | G-3 x Kashi Vishesh | -34.49 | -4.60 | 8.66 | -3.26 | 36.84** | -5.27 |
| 6 | G-3 x Kashi Amrit | -38.15** | -9.94 | 10.08 | 22.94** | 17.02 | 21.47** |
| 7 | S. Naveen x Pusa Sadabahar | -40.54** | 20.50* | 0.78 | -11.76 | -16.31 | 0.19 |
| 8 | S. Naveenx Kashi Vishesh | -32.62 | 22.81** | 12.94 | -27.43 | -31.17** | 11.51* |
| 9 | S. Naveen x Kashi Amrit | -40.50** | 20.59 | 2.18 | -29.32** | -32.97** | 8.27 |
| 10 | DVRT-2 x Pusa Sadabahar | -36.57 | 12.99 | 9.36 | -15.25 | 16.33 | 4.99 |
| 11 | DVRT-2 x Kashi Vishesh | -53.54 | -17.25 | -3.65 | -20.52 | 12.43 | 4.85 |
| 12 | DVRT-2 x Kashi Amrit | -53.79** | -17.69 | 10.59 | -22.71** | 17.37 | 1.35 |
| 13 | H-24 x Pusa Sadabahar | -55.62** | -27.37** | -0.66 | -15.06 | -17.57** | 9.06 |
| 14 | H-24 x Kashi Vishesh | -42.50** | -5.91 | 4.39 | -24.51 | -26.74** | 5.68 |
| 15 | H-24 x Kashi Amrit | -47.98 | -14.88** | 11.00 | -26.38** | -28.56** | 6.19 |
| 16 | H-86 x Pusa Sadabahar | -41.28** | 6.96 | -4.93 | -17.41 | 13.38 | 12.52* |
| 17 | H-86 x Kashi Vishesh | -30.48 | 26.62** | 9.40 | -19.27** | 14.19 | 13.08 |
| 18 | H-86 x Kashi Amrit | -22.02 | 42.03** | 16.65** | -10.94 | 35.25** | -16.26 |
| 19 | H-88 x Pusa Sadabahar | -28.28 | 21.59** | -1.26 | -18.72 | -5.39 | 12.96* |
| 20 | H-88 x Kashi Vishesh | -36.57** | 7.54 | -3.38 | 5.71 | 23.05** | 7.81* |
| 21 | H-88 x Kashi Amrit | -37.57 | 5.86** | 0.76 | -15.34 | -1.46 | 8.21 |
| 22 | Pusa Sheetal x Pusa Sadabahar | -48.13** | -12.35 | -0.34 | -18.70** | 11.60 | -9.26 |
| 23 | Pusa Sheetal x Kashi Vishesh | -41.25** | -0.73 | -13.02 | -23.48** | 8.23 | 3.06 |
| 24 | Pusa Sheetal x Kashi Amrit | -51.07** | -17.32 | -27.58 | -15.78 | 27.90 | 14.12 |
| 25 | FLA 7171 x Pusa Sadabahar | -48.29 | -0.12 | -29.19** | -13.73 | 18.43 | 1.86 |
| 26 | FLA 7171 x Kashi Vishesh | -54.38** | -16.84** | -1.86 | -22.69** | 9.35 | -2.25 |
| 27 | FLA 7171 x Kashi Amrit | -51.70** | -6.71 | 4.12 | -19.11 | 22.85 | 4.51 |
| 28 | Hisar Arun x Pusa Sadabahar | -50.62** | -13.09** | 4.56 | -23.54 | -4.82 | -12.48 |
| 29 | Hisar Arun x Kashi Vishesh | -39.41 | 6.64 | 4.84 | -23.47** | -4.74 | 1.82 |
| 30 | Hisar Arun x Kashi Amrit | -44.50 | -2.32 | 5.93 | -20.20 | -0.66 | 7.42 |
| 31 | Sel.-32 x Pusa Sadabahar | -48.31** | 7.46** | 14.18** | -11.50 | 21.49 | -4.29 |
| 32 | Sel.-32 x Kashi Vishesh | -49.75 | -8.41 | 14.65 | -13.15 | 22.21 | -3.20 |
| 33 | Sel.-32 x Kashi Amrit | -55.03** | -6.51** | 36.70** | -17.17 | 16.57 | 18.64 |
| 34 | Flora Dode x Pusa Sadabahar | -51.22 | 3.47 | 30.51** | -12.67** | 14.59 | -49.56** |
| 35 | Flora Dode x Kashi Vishesh | -47.34 | -4.01 | 28.03** | 10.19 | 44.58** | -37.14** |
| 36 | Flora Dode x Kashi Amrit | -41.19** | 24.72** | 14.24* | -11.56 | 16.05 | -2.42 |

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

**8. Average fruit weight:**

The significant and positive Heterosis is good for average fruit weight. The heterosis value ranged from -31.42% (IIVR-Sel. 1 x Kashi Vishesh) to 22.94% (G-3 x Kashi Amrit) over standard variety and -32.97% (S. Naveen x Kashi Amrit) to 48.63 (IIVR-Sel.-1 x Kashi Amrit) over better parents for average fruit weight. Cross combinations G-3 x Pusa Sadabahar, S. Naveen x Kashi Amrit and IIVR-Sel.-1 x Pusa Sadabahar over standard variety recorded significant and negative heterosis and Flora Dode x Kashi Vishesh, G-3 x Kashi Vishesh and H-86 x Kashi Amrit over better parents recorded highly significant and positive heterosis for average fruit weight. Inbreeding depression ranged from -49.56% (Flora Dode x Pusa Sadabahar) to 21.47% (G-3 x Kashi Amrit) and cross combinations H-88 x Pusa Sadabahar, H-86 x Pusa Sadabahar and S. Naveen x Kashi Vishesh recorded highly significant and positive inbreeding depression. Such combination of high heterosis and high inbreeding depression would be very effective for commercial $F_1$ hybrid development. Only two crosses showed negative and significant inbreeding depression for this character.

**9. Number of locules per fruit:**

Heterosis ranged from -27.36% (S. Naveen x Pusa Sadabahar) to 25.10% (H-88 x Kashi Vishesh) over standard variety and -28.82% (G-3 x Kashi Amrit) to 26.54% (Hisar Arun x Kashi Amrit) over better parents for locules per fruit. In cross combinations Pusa Sheetal x Pusa Sadabahar, Flora Dode x Kashi Amrit and Sel.-32 x Kashi Vishesh over standard variety and Flora Dode x Kashi Amrit, IIVR Sel. 1 x Kashi Vishesh and FLA-7171 x Kashi Amrit over better parents recorded highly significant and negative heterosis for locules per fruit. Cross combinations FLA-7171 x Kashi Amrit and Pusa Sheetal x Kashi Vishesh recorded highly significant and positive inbreeding depression whereas, ranged from -39.93 %( Sel.-32 x Kashi Amrit) to 24.60% (FLA-7171 x Kashi Amrit) inbreeding depression while, fourteen cross combination noted non significant and negative inbreeding depression in $F_2$ population for locules per fruit.

## Table-4.10. e: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for locules per fruit and pericarp thickness (mm) of tomato

| S. No. | Crosses | Locules per fruit | | | Pericarp thickness (mm) | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -12.80 | -18.27 | 3.70 | -22.19** | -20.02** | 9.80 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -22.51** | -27.37** | 14.02 | -34.37** | -25.33** | -3.42 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -9.96 | -15.61 | 2.80 | -5.66 | 7.33 | 5.15 |
| 4 | G-3 x Pusa Sadabahar | -26.03** | -10.80 | -3.27 | -24.44** | -22.33** | 1.91 |
| 5 | G-3 x Kashi Vishesh | -20.50** | -16.59 | 7.68 | -10.01 | -1.28 | 3.33 |
| 6 | G-3 x Kashi Amrit | -24.35** | -28.82** | -1.69 | -15.28 | -7.06 | 2.59 |
| 7 | S. Naveen x Pusa Sadabahar | -27.36** | -17.80 | 8.54 | -9.31 | -12.96 | 3.47 |
| 8 | S. Naveenx Kashi Vishesh | -16.82 | -12.73 | -0.51 | -12.96 | -16.46 | 4.18 |
| 9 | S. Naveen x Kashi Amrit | -14.23 | -19.29** | -14.01 | -21.57** | -24.72** | 0.00 |
| 10 | DVRT-2 x Pusa Sadabahar | -18.58** | -12.42 | -2.64 | -12.26 | -9.81 | 3.58 |
| 11 | DVRT-2 x Kashi Vishesh | -11.13 | -6.76 | 2.57 | -21.80** | -15.37 | -2.44 |
| 12 | DVRT-2 x Kashi Amrit | -10.04 | -15.35 | 6.52 | -12.96 | -5.79 | -4.37 |
| 13 | H-24 x Pusa Sadabahar | -5.86 | 13.52 | 8.39 | -3.34 | -0.64 | 1.27 |
| 14 | H-24 x Kashi Vishesh | -18.24** | -14.22 | -4.71 | -20.17** | -10.83 | 8.62 |
| 15 | H-24 x Kashi Amrit | -5.10 | -10.71 | -15.36 | -19.08 | -9.62 | 5.27 |
| 16 | H-86 x Pusa Sadabahar | -14.98 | 2.52 | -4.74 | -19.08 | -16.83 | 5.78 |
| 17 | H-86 x Kashi Vishesh | -0.50 | 4.39 | 11.14 | -1.94 | 9.06 | -6.22 |
| 18 | H-86 x Kashi Amrit | -12.72 | -17.87** | 1.51 | -26.69** | -18.46 | -15.95* |
| 19 | H-88 x Pusa Sadabahar | -22.43** | -6.46 | 5.50 | -11.48 | -20.04 | 12.09* |
| 20 | H-88 x Kashi Vishesh | 25.10** | -21.42** | 11.12 | -22.89** | 30.34** | -1.74 |
| 21 | H-88 x Kashi Amrit | -12.64 | -17.80** | 6.62 | -7.21 | -16.19 | 4.47 |
| 22 | Pusa Sheetal x Pusa Sadabahar | -25.94** | -19.10 | -3.27 | 23.89** | -24.54** | 11.54* |
| 23 | Pusa Sheetal x Kashi Vishesh | -16.07 | -11.94 | 12.10* | -8.30 | -9.08 | 3.19 |
| 24 | Pusa Sheetal x Kashi Amrit | -10.29 | -15.59 | 13.34 | -6.83 | -7.62 | -4.62 |
| 25 | FLA 7171 x Pusa Sadabahar | -19.16 | -18.07** | -2.11 | -27.77** | -25.76** | 7.45 |
| 26 | FLA 7171 x Kashi Vishesh | -8.95 | -7.72 | 9.56 | -7.06 | 5.83 | -1.27 |
| 27 | FLA 7171 x Kashi Amrit | -17.91** | -22.76** | 24.60* | -11.48 | 0.80 | -16.31 |
| 28 | Hisar Arun x Pusa Sadabahar | -11.7 | 3.84 | -12.83 | -21.64** | -23.54** | 6.22 |
| 29 | Hisar Arun x Kashi Vishesh | -6.61 | -2.02 | -0.81 | -8.07 | -10.30 | 6.69 |
| 30 | Hisar Arun x Kashi Amrit | -21.92** | 26.54** | 11.56 | -15.90 | -17.94 | 8.21 |
| 31 | Sel.-32 x Pusa Sadabahar | -14.98** | -8.22 | -1.90 | -27.08** | -25.04** | 4.18 |
| 32 | Sel.-32 x Kashi Vishesh | -23.43** | -19.67** | -12.55 | -26.61** | -9.65 | 17.02** |
| 33 | Sel.-32 x Kashi Amrit | -1.17 | -7.01 | -39.93** | -29.71** | -5.23 | 6.89 |
| 34 | Flora Dode x Pusa Sadabahar | -20.59** | -21.64** | -0.64 | -18.77 | -16.51 | 7.18 |
| 35 | Flora Dode x Kashi Vishesh | -10.38 | -11.56 | 2.46 | -11.25 | -4.90 | -5.44 |
| 36 | Flora Dode x Kashi Amrit | -23.51** | -28.03** | 12.54 | -23.82** | -18.37** | -6.97* |

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

### 10. Pericarp thickness (mm):

The significant and negative heterosis is good for pericarp thickness. The heterosis ranged from -34.37% (IIVR Sel. 1 x Kashi Vishesh) to 23.89% (Pusa Sheetal x Pusa Sadabahar) over standard variety and -25.76% (FLA-7171 x Pusa Sadabahar) to 30.34% (H-88 x Kashi Vishesh) over better parents. Cross combinations Sel.-32 x Kashi Amrit , FLA-7171 x Pusa Sadabahar and H-86 x Kashi Amrit recorded significant and negative heterosis over standard variety, while, cross combinations Sel.-32 x Pusa Sadabahar, IIVR Sel. 1 x Kashi Vishesh and S. Naveen x Kashi Amrit showed significant and negative heterosis over better parents for this trait. In case of inbreeding depression cross combinations Sel.-32 x Kashi Vishesh, H-88 x Pusa Sadabahar and Pusa Sheetal x Pusa Sadabahar recorded significant and positive inbreeding depression, whereas, eight crosses showed negative and non significant inbreeding depression in $F_2$ population for this trait.

### 11. Fruit length (cm):

The cross combinations S. Naveen x Kashi Amrit, FLA-7171 x Pusa Sadabahar and Sel.-32 x Kashi Amrit over standard variety and IIVR Sel. 1 x Kashi Vishesh, Pusa Sheetal x Pusa Sadabahar and Sel.-32 x Kashi Amrit over better parents recorded significant and negative heterosis for highest length of fruit. Heterosis ranged from -32.92% (IIVR Sel. 1 x Kashi Vishesh) to 22.65% (H-86 x Kashi Amrit) over standard variety and -26.57% (H-88 x Kashi Vishesh) to 29.84% (S. Naveen x Kashi Amrit) over better parents for length of fruit. In case of inbreeding depression ranged from -13.39% (FLA-7171 x Kashi Vishesh) to 21.28% (IIVR Sel. 1 x Kashi Vishesh). Cross combinations G-3 x Pusa Sadabahar, H-86 x Pusa Sadabahar and Sel.-32 x Kashi Amrit recorded significant and positive inbreeding depression in $F_2$ population for length of fruit.

## Table-4.10.f: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for fruit length (cm) and fruit width (cm) of tomato

| S. No. | Crosses | Fruit length (cm) | | | Fruit width (cm) | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -5.99 | 1.94 | -6.52 | -11.73 | 16.22** | 15.23 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -32.92** | -22.06** | 21.28** | -16.76** | -19.36 | 9.19 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -9.42 | -6.88 | 6.66 | -3.14 | -11.80 | 4.79 |
| 4 | G-3 x Pusa Sadabahar | -22.65** | -16.12 | 19.58** | 1.73 | -3.45 | -15.68 |
| 5 | G-3 x Kashi Vishesh | -13.54 | 1.83 | -11.21 | -6.03 | -9.25 | 5.56 |
| 6 | G-3 x Kashi Amrit | -12.45 | -10.00 | -0.72 | -23.37** | -30.23** | 10.94 |
| 7 | S. Naveen x Pusa Sadabahar | -10.35 | -2.78 | 11.18 | -11.89 | -21.83 | 14.85 |
| 8 | S. Naveenx Kashi Vishesh | -15.64 | -3.99 | 6.39 | -19.16 | -28.28** | 24.69* |
| 9 | S. Naveen x Kashi Amrit | -31.75** | 29.84** | 13.25 | -19.74 | -28.79** | 5.72 |
| 10 | DVRT-2 x Pusa Sadabahar | -19.53 | -12.74 | 18.78 | -6.19 | -14.39 | 5.73 |
| 11 | DVRT-2 x Kashi Vishesh | -19.92 | -5.68 | -1.68 | -21.39** | -28.26** | 14.62 |
| 12 | DVRT-2 x Kashi Amrit | -20.31 | -18.08 | 10.80 | -4.46 | -13.01 | 3.66 |
| 13 | H-24 x Pusa Sadabahar | -5.29 | 1.00 | -5.00 | 1.49 | -3.68 | 6.04 |
| 14 | H-24 x Kashi Vishesh | -18.37 | -12.95 | 3.67 | -24.19** | -26.56** | 24.82* |
| 15 | H-24 x Kashi Amrit | -16.89 | -14.56 | 12.67 | -6.94 | -15.26 | 5.14 |
| 16 | H-86 x Pusa Sadabahar | -16.81 | -9.79 | 16.03** | -20.73** | -24.76** | 11.52 |
| 17 | H-86 x Kashi Vishesh | -1.09 | 11.69 | -5.48 | -5.20 | -8.16 | 8.89 |
| 18 | H-86 x Kashi Amrit | 22.65** | -20.48** | 10.21 | -8.34 | -16.54 | 9.76* |
| 19 | H-88 x Pusa Sadabahar | -13.00 | -18.16 | 2.78 | -8.59 | -19.90 | 1.86 |
| 20 | H-88 x Kashi Vishesh | -21.95** | -26.57** | 9.96 | -12.80** | -23.59** | 8.17 |
| 21 | H-88 x Kashi Amrit | -10.89 | -16.18 | 0.09 | -4.05 | -15.92 | 5.30 |
| 22 | Pusa Sheetal x Pusa Sadabahar | -22.02** | -22.86** | -7.97 | -9.25 | -15.20 | 2.66 |
| 23 | Pusa Sheetal x Kashi Vishesh | -12.22 | -13.16 | -10.26 | -12.80 | -18.52 | 2.49 |
| 24 | Pusa Sheetal x Kashi Amrit | -3.50 | -4.54 | 5.56 | 2.48 | -6.69 | -5.98 |
| 25 | FLA 7171 x Pusa Sadabahar | -25.37** | -19.07** | 5.24 | -16.93 | -21.16** | 0.59 |
| 26 | FLA 7171 x Kashi Vishesh | -11.67 | -3.16 | -13.39** | -9.66 | -12.48 | 2.67 |
| 27 | FLA 7171 x Kashi Amrit | -11.60 | -9.12 | -0.98 | -18.74** | -26.02** | 23.72* |
| 28 | Hisar Arun x Pusa Sadabahar | -19.77** | -18.37** | 12.85 | -10.07 | -14.66 | 4.05 |
| 29 | Hisar Arun x Kashi Vishesh | -9.81 | -8.23 | -2.84 | -3.72 | -6.72 | 3.40 |
| 30 | Hisar Arun x Kashi Amrit | -14.09 | -12.59 | 3.50 | 20.97** | -28.05** | -3.79 |
| 31 | Sel.-32 x Pusa Sadabahar | -20.93** | -14.26** | 13.02 | -6.03 | -10.82 | 7.10 |
| 32 | Sel.-32 x Kashi Vishesh | -20.86** | -6.78 | 6.70 | -9.17 | -12.00 | 0.72 |
| 33 | Sel.-32 x Kashi Amrit | -22.96** | -20.80** | 14.66** | -12.80 | -20.60** | -15.28 |
| 34 | Flora Dode x Pusa Sadabahar | -18.44 | -11.56 | 3.05 | -13.05 | -20.41 | -4.67 |
| 35 | Flora Dode x Kashi Vishesh | -13.85 | -6.11 | 2.38 | -11.07 | -18.59 | -8.79 |
| 36 | Flora Dode x Kashi Amrit | -20.70** | -18.48** | -8.52 | -12.55** | -20.38** | 2.31 |

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

## 12. Fruit width (cm):

Heterosis ranged from -24.19% (H-24 x Kashi Vishesh) to 20.97% (Hisar Arun x Kashi Amrit) over standard variety and -30.23% (G-3 x Kashi Amrit) to 16.22% (IIVR Sel.-1 x Pusa Sadabahar) over better parents for fruit width. In cross combinations G-3 x Kashi Amrit, DVRT-2 x Kashi Vishesh and H-86 x Pusa Sadabahar over standard variety and S. Naveen x Kashi Amrit, S. Naveenx Kashi Vishesh and DVRT-2 x Kashi Vishesh over better parents recorded highly significant and negative heterosis for fruit width. Cross combinations H-24 x Kashi Vishesh, S. Naveen x Kashi Vishesh and FLA-7171 x Kashi Amrit observed highly significant and positive inbreeding depression whereas, ranged from 9.76% (H-86 x Kashi Amrit) to 24.82% (H-24 x Kashi Vishesh) inbreeding depression while, five cross combination recorded non significant and negative inbreeding depression in $F_2$ population for fruit width.

## 13. Number of ridges on fruit:

The significant and positive heterosis is good for ridges on fruit. Heterosis ranged from -26.28% (DVRT-2 x Kashi Vishesh) to 73.73% (G-3 x Kashi Amrit) over standard variety and -51.82 % ( H-86 x Kashi Vishesh) to 54.18% (Sel.-32 x Kashi Amrit) over better parents for ridges on fruit. In cross combinations G-3 x Kashi Vishesh, Sel.-32 x Pusa Sadabahar and Pusa Sheetal x Pusa Sadabahar over standard variety and G-3 x Kashi Amrit, S. Naveen x Kashi Amrit and IIVR-Sel. 1 x Kashi Vishesh over better parents revealed significant and positive heterosis for ridges on fruit. Cross combinations H-24 x Kashi Vishesh and Pusa Sheetal x Pusa Sadabahar recorded significant and negative inbreeding depression whereas, ranged from -70.09% ( Flora Dode x Pusa Sadabahar) to -16.25% (G-3 x Kashi Amrit) inbreeding depression while, eighteen cross combination showed non significant and negative inbreeding depression in $F_2$ population for ridges on fruit.

## Table-4.10.g: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for Ridges on fruit and fruit yield per plant (kg) of tomato

| S. No. | Crosses | Ridges on fruit | | | Fruit yield per plant (kg) | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | 3.11 | -16.28 | 0.27 | -40.93** | -3.59 | -0.47 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | 18.64 | 19.23** | -13.82 | -50.27** | -18.83 | 2.16 |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -0.28 | -3.02 | -1.73 | 15.66 | 64.45** | 1.64 |
| 4 | G-3 x Pusa Sadabahar | -15.54 | -36.25** | -14.11 | -27.75 | 40.64** | -1.15 |
| 5 | G-3 x Kashi Vishesh | 33.90** | -8.85 | -15.89 | -3.85 | 82.29** | 1.13 |
| 6 | G-3 x Kashi Amrit | 73.73** | 31.13** | -16.25** | -48.35** | -26.56 | -0.53 |
| 7 | S. Naveen x Pusa Sadabahar | -2.54 | -20.87 | -14.24 | -26.37** | -36.04** | -0.37 |
| 8 | S. Naveenx Kashi Vishesh | 10.17 | -25.00** | -10.48 | 5.49 | -8.35 | 1.54 |
| 9 | S. Naveen x Kashi Amrit | 18.08 | 21.16** | -23.68 | -40.66** | -48.45** | -3.35 |
| 10 | DVRT-2 x Pusa Sadabahar | 12.43 | -8.72 | -24.37 | -22.53** | 8.46 | 1.40 |
| 11 | DVRT-2 x Kashi Vishesh | -26.28** | -49.81** | 9.06 | -51.10** | -31.54** | 1.11 |
| 12 | DVRT-2 x Kashi Amrit | 4.24 | 9.82 | -13.19 | -52.75** | -33.85 | 1.15 |
| 13 | H-24 x Pusa Sadabahar | -1.41 | -35.73** | -32.70** | -56.32** | -54.05** | 0.00 |
| 14 | H-24 x Kashi Vishesh | 4.52 | -31.86 | -68.95** | -46.43** | -43.64** | 2.01 |
| 15 | H-24 x Kashi Amrit | -25.14** | -51.20** | 6.03 | -24.73 | -20.81 | 5.52 |
| 16 | H-86 x Pusa Sadabahar | 18.93 | -38.72** | -0.48 | 40.93** | 13.76 | 15.35 |
| 17 | H-86 x Kashi Vishesh | -6.50 | -51.82** | -11.82 | -37.91** | 17.71 | 4.64 |
| 18 | H-86 x Kashi Amrit | 1.98 | -47.45** | -19.14 | 25.55** | 5.86 | 24.51 |
| 19 | H-88 x Pusa Sadabahar | -10.73 | -27.52 | -10.10 | -6.59 | 28.79* | -33.33* |
| 20 | H-88 x Kashi Vishesh | -17.51 | -43.85** | -2.10 | -28.57** | -1.52 | -1.56 |
| 21 | H-88 x Kashi Amrit | 6.21 | -1.83 | -35.74 | -22.53 | 6.82 | -30.56* |
| 22 | Pusa Sheetal x Pusa Sadabahar | 23.73** | 0.46 | -64.66** | -51.37** | -53.05** | -7.93 |
| 23 | Pusa Sheetal x Kashi Vishesh | 3.11 | -29.81** | -40.38** | -40.66** | -42.71** | -30.12 |
| 24 | Pusa Sheetal x Kashi Amrit | 1.41 | -17.28 | -45.93 | -23.63 | -26.26 | -60.69** |
| 25 | FLA 7171 x Pusa Sadabahar | -1.98 | -30.46** | -14.14 | -39.01** | 0.00 | 3.48 |
| 26 | FLA 7171 x Kashi Vishesh | 12.43 | -23.46 | -0.25 | -33.52 | 9.01 | -18.63 |
| 27 | FLA 7171 x Kashi Amrit | -16.10 | -40.48** | 10.81 | -39.56 | -14.06 | 15.06 |
| 28 | Hisar Arun x Pusa Sadabahar | 7.06 | -20.21 | -23.06 | -26.65** | -4.30 | 28.03 |
| 29 | Hisar Arun x Kashi Vishesh | 20.90 | -17.69 | -37.18** | -43.41** | -26.16 | 21.67** |
| 30 | Hisar Arun x Kashi Amrit | -3.67 | -28.21** | -8.60 | -36.26** | -16.85 | 18.31 |
| 31 | Sel.-32 x Pusa Sadabahar | 26.27** | -40.14** | -3.98 | 20.88* | 62.71** | 5.26 |
| 32 | Sel.-32 x Kashi Vishesh | 3.95 | -29.23 | -14.64 | -40.93** | 11.98 | -0.47 |
| 33 | Sel.-32 x Kashi Amrit | 9.32 | 54.18** | -32.99 | -9.89 | 28.12 | -4.13 |
| 34 | Flora Dode x Pusa Sadabahar | 7.63 | -12.61 | -70.09** | -34.62** | 40.83** | 20.40 |
| 35 | Flora Dode x Kashi Vishesh | -3.95 | -34.62** | -24.55 | -39.29 | 15.10 | 5.56 |
| 36 | Flora Dode x Kashi Amrit | -11.30 | -23.79 | -26.10 | 21.43** | 11.72 | -22.75* |

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

## 14. Fruit Yield per Plant (kg):

Significant and positive heterosis value for yield per plant is good for this character. Fifteen crosses recorded significant and negative heterosis out of thirty six crosses and two crosses Positive significant, whereas, four crosses showed highly significant and positive heterosis over better parents. The heterosis value ranged from -56.32% (H-24 x Pusa Sadabahar) to 40.93% (H-86 x Pusa Sadabahar) and -54.05% (H-24 x Pusa Sadabahar) to 82.29% (G-3 x Kashi Vishesh) over standard variety and better parents of this character. The cross combinations H-86 x Kashi Amrit, Flora Dode x Kashi Amrit and Sel.-32 x Pusa Sadabahar over standard variety significant and positive heterosis for total yield per plant. The cross combinations IIVR Sel.-1 x Kashi Amrit, Sel.-32 x Pusa Sadabahar and Flora Dode x Pusa Sadabahar over better parents recorded maximum significant and positive heterosis for total yield per plant. Inbreeding depression ranged from -60.69% (Pusa Sheetal x Kashi Amrit) to 21.67% (Hisar Arun x Kashi Vishesh). Cross combinations H-88 x Pusa Sadabahar, H-88 x Kashi Amrit and Flora Dode x Kashi Amrit recorded significant and negative inbreeding depression, whereas, all the crosses recorded non significant heterosis except five crosses in $F_2$ population for yield per plant.

## 15. TSS (°Brix):

Heterosis ranged from -27.10% (IIVR Sel. 1 x Kashi Vishesh) to 14.37% (DVRT-2 x Pusa Sadabahar) over standard variety and -30.45% (IIVR Sel. 1 x Kashi Vishesh) to 18.60% (H-24 x Pusa Sadabahar) over better parents for TSS. In cross combinations G-3 x Pusa Sadabahar, DVRT-2 x Kashi Amrit and H-86 x Kashi Amrit over standard variety and DVRT-2 x Kashi Amrit, G-3 x Pusa Sadabahar and DVRT-2 x Pusa Sadabahar over better parents recorded highly significant and negative heterosis for TSS. Cross combinations IIVR Sel. 1 x Kashi Vishesh, S. Naveen x Pusa Sadabahar and DVRT-2 x Pusa Sadabahar revealed highly significant and positive inbreeding depression whereas, ranged from -13.31% (Sel.-32 x Kashi Amrit) to 25.74% (DVRT-2 x Kashi Amrit) inbreeding depression while, nine cross combination recorded negative and non significant inbreeding depression in $F_2$ population for TSS.

## Table-4.10.h: Estimation of heterosis and inbreeding depression of 36 $F_1$ hybrids for TSS and Vit. C (Mg/100g) of tomato

| S. No. | Crosses | TSS (°Brix) | | | Vit. C (Mg/100g ) | | |
|---|---|---|---|---|---|---|---|
| | | SV% | BP% | ID% | SV% | BP% | ID% |
| 1 | IIVR-Sel.-1 x Pusa Sadabahar | -2.69 | -7.17 | 4.79 | -24.05** | -14.40** | -0.54 |
| 2 | IIVR-Sel. 1 x Kashi Vishesh | -27.10** | -30.45** | 25.33** | -15.13 | -0.58 | 3.57* |
| 3 | IIVR-Sel.-1 x Kashi Amrit | -2.37 | -6.85 | 6.05 | -17.40** | 2.02 | -5.45 |
| 4 | G-3 x Pusa Sadabahar | -26.53** | -26.89** | 18.92 | 23.09** | -13.31** | 4.40 |
| 5 | G-3 x Kashi Vishesh | -1.14 | -2.65 | 4.04 | -23.03** | -9.84 | 9.36 |
| 6 | G-3 x Kashi Amrit | -8.33 | -8.77 | -0.90 | -17.32 | -0.71 | -1.60 |
| 7 | S. Naveen x Pusa Sadabahar | -10.45* | -1.88 | 20.74** | 21.67** | 11.72** | -2.52 |
| 8 | S. Naveenx Kashi Vishesh | -1.14 | -2.65 | 7.06 | -20.61** | -8.91 | -1.77 |
| 9 | S. Naveen x Kashi Amrit | 3.84 | 14.29 | 3.78 | -17.85 | -5.74 | -5.04 |
| 10 | DVRT-2 x Pusa Sadabahar | 14.37** | -21.66** | 12.95** | -17.03 | -6.49 | 0.32 |
| 11 | DVRT-2 x Kashi Vishesh | -4.73 | -12.85 | 2.59 | -18.31** | -4.31 | 11.77 |
| 12 | DVRT-2 x Kashi Amrit | -22.04** | -28.68** | 25.74** | -17.56 | -3.35 | -2.13 |
| 13 | H-24 x Pusa Sadabahar | -5.31 | 18.60** | 5.00 | -8.91** | 2.67 | 2.76 |
| 14 | H-24 x Kashi Vishesh | -4.90 | -18.25 | -7.27 | -13.14 | 1.74 | 11.18 |
| 15 | H-24 x Kashi Amrit | -8.57 | -21.40 | 4.36 | -8.94 | 9.52* | 10.98* |
| 16 | H-86 x Pusa Sadabahar | -3.02 | 3.04 | 1.90 | -18.20** | -7.81 | 7.39 |
| 17 | H-86 x Kashi Vishesh | -5.22 | -6.67 | 1.53 | -11.30 | 3.90 | -0.51 |
| 18 | H-86 x Kashi Amrit | -12.49* | -7.03 | 6.05 | -11.74 | 4.98 | -2.59 |
| 19 | H-88 x Pusa Sadabahar | -0.24 | -11.96** | 1.77 | -14.44* | -3.57 | -4.88 |
| 20 | H-88 x Kashi Vishesh | -4.98 | -16.14 | 4.04 | -9.98 | 5.45 | 1.28 |
| 21 | H-88 x Kashi Amrit | -1.96 | -13.47 | 5.73 | 13.47** | 8.40 | 11.36 |
| 22 | Pusa Sheetal x PusaSadabahar | -3.59 | -13.73 | -0.26 | -16.29 | -5.65 | 1.20 |
| 23 | Pusa Sheetal x Kashi Vishesh | -6.20 | -16.07 | 2.46 | -11.09 | 4.14 | 11.49 |
| 24 | Pusa Sheetal x Kashi Amrit | 1.14 | -9.50 | 5.64 | -15.93** | 3.99 | 1.11 |
| 25 | FLA 7171 x Pusa Sadabahar | -8.49 | -21.77** | -2.37 | -14.18 | -3.27 | 5.78 |
| 26 | FLA 7171 x Kashi Vishesh | 4.16 | -10.96 | 0.78 | -6.81 | 8.23* | -0.58 |
| 27 | FLA 7171 x Kashi Amrit | -0.33 | -14.79 | -3.74 | -12.41 | 1.72 | 12.71 |
| 28 | Hisar Arun x Pusa Sadabahar | -4.08 | 5.10 | -0.60 | -13.83 | -2.88 | -1.63 |
| 29 | Hisar Arun x Kashi Vishesh | 3.92 | 2.33 | 1.01 | -12.69 | 2.27 | -6.10 |
| 30 | Hisar Arun x Kashi Amrit | -3.27 | 6.37 | 5.20 | -15.37 | 2.03* | -10.08** |
| 31 | Sel.-32 x Pusa Sadabahar | -4.57 | -11.71 | -3.54 | 19.41** | -9.17 | 5.17 |
| 32 | Sel.-32 x Kashi Vishesh | -2.78 | -10.05 | -6.53 | -12.99 | -0.04 | 9.49* |
| 33 | Sel.-32 x Kashi Amrit | -4.08 | -11.25 | -13.31* | -14.92* | -2.25 | -2.12 |
| 34 | Flora Dode x Pusa Sadabahar | -4.41 | -6.47 | -3.54 | -12.10 | -0.93 | -0.20 |
| 35 | Flora Dode x Kashi Vishesh | -2.29 | -4.39 | -6.12 | -14.55 | 0.10 | 0.49 |
| 36 | Flora Dode x Kashi Amrit | -6.29 | -8.31 | -5.32 | -15.07** | 0.90 | 6.98 |

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

## 16. Vitamin C (Mg/100g) :

Heterosis ranged from -24.05% (IIVR-Sel.-1 x Pusa Sadabahar) to 23.09% (G-3 x Pusa Sadabahar) over standard variety and -14.40% (IIVR-Sel.-1 x Pusa Sadabahar) to 23.09% (G-3 x Pusa Sadabahar) over better parents for vitamin C. In cross combinations S. Naveen x Pusa Sadabahar, Sel.-32 x Pusa Sadabahar and H-88 x Kashi Amrit over standard variety and H-24 x Kashi Amrit, FLA 7171 x Kashi Vishesh and Hisar Arun x Kashi Amrit over better parents recorded positive and significant heterosis for vitamin C. Cross combinations Sel.-32 x Kashi Vishesh and IIVR-Sel. 1 x Kashi Vishesh revealed significant and positive inbreeding depression whereas, ranged from -10.08%( Hisar Arun x Kashi Amrit) to 10.98% (H-24 x Kashi Amrit) inbreeding depression while, fifteen cross combination identified significant and non negative inbreeding depression in $F_2$ population for vitamin C.

## Table – 4.11: Range and mean performance of parents, $F_1$ and $F_2$ for 16 characters of tomato

| S. No. | Characters | Parents | | | $F_1$ hybrids | | | $F_2$ | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | Mean | Min. | Max. | Mean | Min. | Max. | Mean |
| 1 | Plant height (cm) | 53.49 | 63.65 | 58.59 | 59.52 | 62.73 | 61.13 | 59.35 | 63.22 | 61.29 |
| 2 | Branches per plant | 3.27 | 5.37 | 4.26 | 4.58 | 5.26 | 4.92 | 4.32 | 5.00 | 4.66 |
| 3 | Days to 50% flowering | 59.24 | 62.36 | 60.53 | 59.71 | 61.74 | 60.73 | 59.92 | 61.78 | 60.85 |
| 4 | Clusters per plant | 3.58 | 6.10 | 4.69 | 4.52 | 5.21 | 4.87 | 4.41 | 5.07 | 4.74 |
| 5 | Flowers per cluster | 4.39 | 8.01 | 6.02 | 5.15 | 6.67 | 5.91 | 4.84 | 6.51 | 5.68 |
| 6 | Fruits per cluster | 3.87 | 6.09 | 4.80 | 4.05 | 5.47 | 4.76 | 4.30 | 5.41 | 4.86 |
| 7 | Fruits per plant | 16.63 | 25.05 | 19.90 | 22.07 | 30.97 | 26.52 | 20.94 | 27.23 | 24.09 |
| 8 | Average fruit weight (g) | 26.98 | 48.36 | 33.89 | 37.71 | 47.14 | 42.43 | 36.95 | 44.85 | 40.9 |
| 9 | Locules per fruit | 2.57 | 4.25 | 3.56 | 3.50 | 4.23 | 3.87 | 3.43 | 3.86 | 3.65 |
| 10 | Pericarp thickness (mm) | 3.11 | 4.75 | 3.93 | 3.76 | 4.45 | 4.11 | 3.70 | 4.42 | 4.06 |
| 11 | Fruit length (cm) | 3.33 | 4.55 | 3.89 | 3.81 | 4.14 | 3.98 | 3.69 | 4.19 | 3.94 |
| 12 | Fruit width (cm) | 3.60 | 4.60 | 4.17 | 3.94 | 4.44 | 4.19 | 3.77 | 4.34 | 4.06 |
| 13 | Ridges on fruit | 0.78 | 2.29 | 1.42 | 1.16 | 1.77 | 1.47 | 1.28 | 1.79 | 1.54 |
| 14 | Fruit yield per plant (kg) | 0.53 | 1.39 | 0.82 | 0.85 | 1.27 | 1.06 | 0.84 | 1.23 | 1.04 |
| 15 | TSS (°Brix) | 3.62 | 4.77 | 4.19 | 4.05 | 4.51 | 4.28 | 3.95 | 4.49 | 4.22 |
| 16 | Vit C (mg/100g ) | 22.70 | 25.49 | 24.09 | 24.80 | 26.92 | 25.86 | 24.35 | 25.68 | 25.02 |

## 4.5 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE OF PARENTS AND THEIR CROSSES:

### 4.5.1: ANALYSIS OF VARIANCE FOR 15 PARENTS OF TOMATO

Analysis of variance for sixteen characters of parents of tomato is showed (Table-4.12). The variance of different characters was divided into replication, treatment and error. The mean sum of square due treatment was highly significant for all the traits.

### I. Genetic variability:

The coefficient of variation value is presented in Table 4.13. The phenotypic coefficient of variation (PCV) was higher than their respective genotypic coefficient of variation (GCV) for all the characters.

The widest range was revealed for average fruit weight (26.98-48.36 ) followed by plant height (53.49-63.65), fruits per plant (16.63 -25.05), flowers per cluster (4.39-8.01), days to 50% flowering(59.24-62.36), vitamin C (22.70-25.49 ), clusters per plant(3.58-6.10 ), fruits per cluster (3.87-6.09),number of branches per plant (3.27-5.37), locules per fruit(2.57- 4.25),while lowest range were recorded in fruit yield per plant (0.53-1.39).

Phenotypic coefficient of variation was maximum for fruit yield per plant (33.17%) followed by ridges on fruit (28.38%), average fruit weight (24.16%) and number of branches per plant (16.23%), while, it was moderate for fruits per cluster (15.53%) followed by flowers per cluster (15.39%), locules per fruit (15.03%) and clusters per plant (14.31%) and low was showed for fruits per plant (13.42%) followed by pericarp thickness (13.08%) and fruit length (11.34%) and it was minimum revealed for days to 50% flowering (2.06%).

## Table -4.12: Analysis of variance for the 15 parents of tomato

| S. No | Source of variation | D. F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| 1. | Replication | 2 | 0.39 | 0.12 | 1.23 | 0.09 | 0.35 | 0.35 | 0.72 | 0.30 | 0.36 | 1.12 | 0.97 | 0.04 | 0.50 | 1.82 | 0.25 | 6.81 |
| 2. | Treatments | 14 | 13.99** | 5.97** | 2.73* | 6.13** | 8.28** | 6.74** | 7.20** | 3.75** | 5.57** | 7.29** | 2.38** | 3.42** | 22.21** | 25.39** | 8.82** | 2.24* |
| 3. | Errors | 28 | 1.84 | 0.18 | 0.98 | 0.17 | 0.25 | 0.19 | 2.33 | 34.99 | 0.11 | 0.09 | 0.13 | 0.08 | 0.02 | 0.01 | 0.05 | 0.89 |

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

### Table – 4.13: Estimation of range, mean, genotypic coefficient of variance (GCV), phenotypic coefficient of variance (PCV), heritability, genetic advance and genetic gain of 15 parents for 16 characters of tomato

| S. No. | Character | Range | | Mean | Variance | | PCV (%) | GCV (%) | $h^2$ (%) | Genetic Advance | GA % of mean |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | | Phenotypic | Genotypic | | | | | |
| 1. | Plant height (cm) | 53.49 | 63.65 | 58.59 | 9.83 | 7.98 | 5.35 | 4.82 | 81 | 5.25 | 8.95 |
| 2. | Branches per plant | 3.27 | 5.37 | 4.26 | 0.48 | 0.30 | 16.23 | 12.82 | 62 | 0.89 | 20.85 |
| 3. | Days to 50% flowering | 59.24 | 62.36 | 60.53 | 1.55 | 0.57 | 2.06 | 1.24 | 37 | 0.94 | 1.55 |
| 4. | Clusters per plant | 3.58 | 6.10 | 4.69 | 0.45 | 0.28 | 14.31 | 11.36 | 63 | 0.87 | 18.59 |
| 5. | Flowers per cluster | 4.39 | 8.01 | 6.02 | 0.86 | 0.61 | 15.39 | 12.95 | 71 | 1.35 | 22.45 |
| 6. | Fruits per cluster | 3.87 | 6.09 | 4.80 | 0.56 | 0.37 | 15.53 | 12.58 | 66 | 1.01 | 21.01 |
| 7. | Fruits per plant | 16.63 | 25.05 | 19.90 | 7.14 | 4.81 | 13.42 | 11.02 | 67 | 3.71 | 18.63 |
| 8. | Average fruit weight (g) | 26.98 | 48.36 | 33.89 | 67.08 | 32.09 | 24.16 | 16.71 | 48 | 8.07 | 23.81 |
| 9. | Locules per fruit | 2.57 | 4.25 | 3.56 | 0.29 | 0.17 | 15.03 | 11.68 | 60 | 0.67 | 18.69 |
| 10. | Pericarp thickness (mm) | 3.11 | 4.75 | 3.93 | 0.27 | 0.18 | 13.08 | 10.76 | 68 | 0.72 | 18.24 |
| 11. | Fruit length (cm) | 3.33 | 4.55 | 3.89 | 0.19 | 0.06 | 11.34 | 6.37 | 32 | 0.29 | 7.38 |
| 12. | Fruit width (cm) | 3.60 | 4.60 | 4.17 | 0.14 | 0.06 | 8.95 | 5.98 | 45 | 0.34 | 8.23 |
| 13. | Ridges on fruit | 0.78 | 2.29 | 1.42 | 0.16 | 0.14 | 28.38 | 26.56 | 88 | 0.73 | 51.21 |
| 14. | Fruit yield per plant (kg) | 0.53 | 1.39 | 0.82 | 0.08 | 0.07 | 33.17 | 31.30 | 89 | 0.50 | 60.84 |
| 15. | TSS (°Brix) | 3.62 | 4.77 | 4.19 | 0.20 | 0.14 | 10.57 | 8.99 | 72 | 0.66 | 15.74 |
| 16. | Vit C mg/100g | 22.70 | 25.49 | 24.09 | 1.26 | 0.37 | 4.66 | 2.52 | 29 | 0.68 | 2.80 |

Maximum genotypic coefficient of variation was recorded for fruit yield per plant (31.30%), ridges on fruit (26.56%), flowers per cluster (12.95%) and number of branches per plant (12.82%) and it was moderate for fruits per cluster (12.58%) followed by locules per fruit (11.68%), clusters per plant (11.36%) and fruits per plant ( 11.02%), whereas, it was recorded low rate for pericarp thickness (10.76%) followed by TSS (8.99%), fruit length (6.37%) and minimum was recorded for fruit width (5.98%).

**Heritability:**

Heritability value in broad sense is showed in Table-4.13. The maximum heritability was observeded for fruit yield per plant (89%) followed by ridges on fruit (88%), plant height (81%), TSS (72%), flowers per cluster (71%), pericarp thickness ( 68%), fruits per plant (67%), fruits per cluster (66%), clusters per plant (63%) and number of branches per plant (62%), while, lowest was observeded for vitamin C (29%).

**Genetic gain:**

The genetic advance (%) was revealed for fruit yield per plant (60.84%) followed by ridges on fruit (51.21%), average fruit weight (23.81%), flowers per cluster (22.45%), fruits per cluster (21.01%), number of branches per plant (20.85%), locules per fruit (18.69%), fruits per plant (18.63%), clusters per plant (18.59%), pericarp thickness (18.24%), TSS (15.74%), while, lowest was recorded for days to 50% flowering (1.55%).

### 4.5.2 ANALYSIS OF VARIANCE FOR 36 CROSSES OF TOMATO:

The analyses of variance of 36 $F_1$ crosses for sixteen characters are given in Table-4.14. The variance of different characters was partitioned into replication, treatment and error. The mean sums of square due to treatment were highly significant for all the characters.

## Table -4.14: Analysis of variance for the 36 $F_1$ hybrids of tomato

| S. No | Source of variation | D.F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| 1. | Replication | 2 | 1.11 | 0.04 | 0.72 | 0.03 | 0.08 | 0.05 | 4.70 | 2.66 | 0.07 | 0.07 | 0.06 | 0.01 | 0.00 | 0.00 | 0.07 | 2.28 |
| 2. | Treatments | 35 | 11.57** | 0.61** | 2.94** | 0.39** | 0.42** | 0.59** | 29.71** | 56.55** | 0.25** | 0.38** | 0.28** | 0.25** | 0.14** | 0.12** | 0.26** | 4.22** |
| 3. | Errors | 70 | 1.72 | 0.18 | 0.90 | 0.16 | 0.19 | 0.09 | 3.69 | 9.67 | 0.11 | 0.04 | 0.06 | 0.09 | 0.02 | 0.01 | 0.07 | 1.75 |

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

## Table – 4.15: Estimation of range, mean, genotypic coefficient of variance (GCV), phenotypic coefficient variance (PCV), heritability, genetic advance and genetic gain for 36 $F_1$ hybrids for 16 characters of tomato

| S. No. | Characters | Range | | Grand mean | GCV | PCV | Heritability | Genetic advance | Genetic gain |
|---|---|---|---|---|---|---|---|---|---|
| | | Min. | Max. | | | | | | |
| 1 | Plant height (cm) | 59.52 | 62.73 | 61.13 | 3.38 | 4.36 | 60 | 3.21 | 5.38 |
| 2 | Branches per plant | 4.58 | 5.26 | 4.92 | 10.02 | 13.80 | 53 | 0.69 | 14.98 |
| 3 | Days to 50% flowering | 59.71 | 61.74 | 60.73 | 2.12 | 2.72 | 61 | 2.03 | 3.40 |
| 4 | Clusters per plant | 4.52 | 5.21 | 4.87 | 9.82 | 13.18 | 56 | 0.68 | 15.08 |
| 5 | Flowers per cluster | 5.15 | 6.67 | 5.91 | 15.96 | 17.76 | 81 | 1.52 | 29.54 |
| 6 | Fruits per cluster | 4.05 | 5.47 | 4.76 | 18.66 | 20.39 | 84 | 1.42 | 35.18 |
| 7 | Fruits per plant | 22.07 | 30.97 | 26.52 | 20.67 | 21.82 | 90 | 8.90 | 40.32 |
| 8 | Average fruit weight (g) | 37.71 | 47.14 | 42.43 | 14.97 | 18.48 | 66 | 9.43 | 25.00 |
| 9 | Locules per fruit | 3.50 | 4.23 | 3.87 | 12.16 | 14.59 | 70 | 0.73 | 20.89 |
| 10 | Pericarp thickness (mm) | 3.76 | 4.45 | 4.11 | 10.81 | 13.27 | 66 | 0.68 | 18.14 |
| 11 | Fruit length (cm) | 3.81 | 4.14 | 3.98 | 6.96 | 11.49 | 37 | 0.33 | 8.69 |
| 12 | Fruit width (cm) | 3.94 | 4.44 | 4.19 | 8.46 | 11.42 | 55 | 0.51 | 12.90 |
| 13 | Ridges on fruit | 1.16 | 1.77 | 1.47 | 27.55 | 29.58 | 87 | 0.61 | 52.87 |
| 14 | Fruit yield per plant (kg) | 0.85 | 1.27 | 1.06 | 28.53 | 34.40 | 69 | 0.42 | 48.73 |
| 15 | TSS (°Brix) | 4.05 | 4.51 | 4.28 | 7.20 | 9.31 | 60 | 0.47 | 11.49 |
| 16 | Vit C mg/100g | 24.80 | 26.92 | 25.86 | 6.36 | 9.76 | 42 | 2.12 | 8.54 |

**Genetic variability:**

The coefficient of variation value is presented in Table 4.15. The phenotypic coefficient of variation (PCV) was higher than their respective genotypic coefficient of variation (GCV) for all the traits under study.

Phenotypic coefficient of variation was higher for fruit yield per plant (34.40%) followed by ridges on fruit (29.58%), fruits per plant (21.82%), fruits per cluster (20.39%), average fruit weight (18.48%) and flowers per cluster (17.76%), whereas, it was moderate for locules per fruit (14.59%) followed by number of branches per plant (13.80%) and pericarp thickness (13.27%), low was recorded for clusters per plant (13.18%) followed by fruit length (11.49%), fruit width (11.42%), vitamin C (9.76%), TSS (9.31%) and it was lowest recorded for plant height (4.36%) followed by days to 50% flowering(2.72%).

Highest genotypic coefficient of variation was observed for fruit yield per plant (28.53%) followed by ridges on fruit (27.55%), fruits per plant (20.67%) and fruits per cluster (18.66%), whereas moderate for flowers per cluster (15.96%), average fruit weight (14.97%) and locules per fruit (12.16%) and low was recorded for pericarp thickness (10.81%), number of branches per plant (10.02%), clusters per plant (9.82%) and lowest for days to 50% flowering (2.12%).

**Heritability:**

Heritability value in broad sense is presented in Table-4.15. The highest heritability was recorded for fruits per plant (90%) and ridges on fruit (87%) followed by fruits per cluster (84%), flowers per cluster (81%), locules per fruit (70%), fruit yield per plant (69%), pericarp thickness (66%), days to 50% flowering (61%), plant height (60%) and clusters per plant (56%). whereas, minimum was recorded for fruit length (37%).

**Genetic gain:**

The maximum genetic gain (%) was recorded for ridges on fruit (52.87%) followed by fruit yield per plant (48.73%), fruits per plant (40.32%), fruits per cluster

(35.18%), flowers per cluster (29.54%), average fruit weight (25.00%), locules per fruit (20.89%), pericarp thickness (18.14%), clusters per plant (15.08%), number of branches per plant (14.98%), fruit width (12.90%), TSS (11.49%), fruit length (8.69%), vitamin C (8.54%), plant height (5.38%), whereas, minimum was recorded for days to 50% flowering (3.40%).

### 4.6.1 CORRELATION COEFFICIENT OF PARENTS:

The genotypic and phenotypic correlation coefficient of parent for sixteen characters of tomato is presented in Table- 4.16. Yield is considered to be the most important trait, on the basis of yield potential of parents are included in breeding programme to developed inbred line /hybrids.

#### I. Genotypic Correlation:

The correlation coefficient at genotypic level are presented in Table-4.16 it was observed that fruit yield per plant had positive and significant genotypic correlation coefficient with average fruit weight (0.632) followed by fruits per plant (0.173). However, negative and significant correlations were recorded for fruit yield per plant with clusters per plant (-0.337). Ridges on fruit showed positive and significant correlation with locules per fruit (0.434) and length of fruit (0.107). Fruit width had positive and significant correlation with pericarp thickness (0.429). Fruit length had negative and significant correlation with fruits per plant (-0.436). The pericarp thickness had negative and significant correlation with number of branches per plant (-0.198). Locules per fruit had negative and significant correlation with flowers per cluster (-0.523). Fruits per plant had positive and significant correlation with clusters per plant (0.365). Flowers per cluster had positive and significant correlation with days to 50% flowering (0.361). Days to 50% flowering had positive and significant correlation with plant height (0.166). Whereas, TSS, vitamin C, average fruit weight, fruits per cluster, clusters per plant and number of branches per plant showed negative and non significant correlation.

## Table -4.16: Genotypic (G) and Phenotypic (P) correlation coefficient for different pairs of characters in 15 parents of tomato

| Character | Symbol | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Vit. C (Mg/100g) | TSS (°Brix) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | G | 0.048 | 0.166** | 0.212 | 0.676 | 0.716 | 0.011 | 0.498 | -0.087 | -0.119 | -0.346 | 0.019 | -0.392 | 0.256 | -0.401 | -0.171 |
|  | P | 0.018 | 0.155 | 0.130 | 0.519** | 0.526** | -0.068 | 0.268 | -0.040 | -0.080 | -0.248 | 0.085 | -0.399** | -0.147 | -0.285 | 0.086 |
| Branches per plant | G |  | -0.293 | 0.285 | -0.328 | -0.358 | 0.069 | -0.115 | 0.556 | -0.198** | -0.137 | 0.338 | 0.042 | 0.117 | 0.281 | -0.283 |
|  | P |  | -0.071 | 0.097 | -0.333* | -0.352* | 0.075 | -0.167 | 0.148 | -0.109 | -0.016 | 0.047 | 0.037 | -0.264 | 0.194 | -0.055 |
| Days to 50% flowering | G |  |  | -0.639 | 0.361* | 0.463 | 0.078 | 0.350 | -0.570 | 0.170 | 0.163 | -0.435 | 0.169 | 0.395 | 0.177 | -0.222 |
|  | P |  |  | -0.388** | 0.248 | 0.089 | 0.001 | -0.027 | -0.247 | 0.078 | -0.026 | -0.086 | 0.137 | -0.172 | 0.062 | 0.192 |
| Clusters per plant | G |  |  |  | 0.402 | 0.301 | 0.365* | -0.260 | -0.199 | 0.124 | -0.163 | 0.194 | 0.309 | 0.137 | -0.099 | -0.337** |
|  | P |  |  |  | 0.274 | 0.200 | 0.091 | -0.076 | -0.017 | -0.080 | -0.283 | -0.062 | 0.253 | -0.252 | -0.033 | 0.014 |
| Flowers per cluster | G |  |  |  |  | 0.920 | 0.340 | 0.225 | -0.523* | 0.255 | -0.348 | -0.065 | 0.059 | 0.201 | -0.221 | -0.064 |
|  | P |  |  |  |  | 0.843** | 0.259 | 0.074 | -0.227 | 0.255 | -0.105 | 0.096 | 0.027 | -0.085 | -0.182 | 0.163 |
| Fruits per cluster | G |  |  |  |  |  | 0.332 | 0.543 | -0.452 | 0.310 | -0.436* | -0.068 | 0.105 | 0.244 | -0.289 | 0.129 |
|  | P |  |  |  |  |  | 0.215 | 0.321* | -0.217 | 0.308* | -0.156 | 0.040 | -0.002 | 0.067 | -0.225 | 0.288 |
| Fruits per plant | G |  |  |  |  |  |  | 0.020 | -0.498 | 0.338 | 0.002 | -0.181 | 0.416 | -0.620 | 0.449 | 0.173* |
|  | P |  |  |  |  |  |  | -0.053 | -0.340* | 0.237 | 0.052 | -0.075 | 0.347* | 0.181 | 0.303 | -0.272 |
| Average fruit weight (g) | G |  |  |  |  |  |  |  | -0.524 | 0.478 | 0.444 | 0.229 | -0.045 | 0.021 | -0.066 | 0.632** |
|  | P |  |  |  |  |  |  |  | -0.275 | 0.312* | 0.055 | 0.219 | -0.024 | 0.500 | -0.010 | 0.086 |
| Locules per fruit | G |  |  |  |  |  |  |  |  | -0.697 | -0.395 | -0.067 | 0.434** | 0.103 | -0.146 | -0.201 |
|  | P |  |  |  |  |  |  |  |  | -0.466** | -0.280 | 0.038 | -0.351* | -0.089 | -0.111 | 0.015 |
| Pericarp thickness (mm) | G |  |  |  |  |  |  |  |  |  | 0.579 | 0.429* | 0.249 | -0.188 | 0.056 | 0.488 |
|  | P |  |  |  |  |  |  |  |  |  | 0.541** | 0.493** | 0.161 | 0.358 | 0.022 | -0.060 |
| Fruit length (cm) | G |  |  |  |  |  |  |  |  |  |  | 0.541 | 0.107* | -0.912 | 0.118 | 0.577 |
|  | P |  |  |  |  |  |  |  |  |  |  | 0.396** | 0.073 | 0.245 | 0.016 | -0.423** |
| Fruit width (cm) | G |  |  |  |  |  |  |  |  |  |  |  | -0.519 | -0.334 | -0.141 | 0.449 |
|  | P |  |  |  |  |  |  |  |  |  |  |  | -0.319* | 0.252 | -0.006 | -0.107 |
| Ridges on fruit | G |  |  |  |  |  |  |  |  |  |  |  |  | 0.143 | 0.053 | -0.108 |
|  | P |  |  |  |  |  |  |  |  |  |  |  |  | -0.089 | 0.044 | 0.001 |
| Vit C mg/100g | G |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.114 | 0.113 |
|  | P |  |  |  |  |  |  |  |  |  |  |  |  |  | 0.107 | -0.172 |
| TSS (°Brix) | G |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.321 |
|  | P |  |  |  |  |  |  |  |  |  |  |  |  |  |  | -0.152 |

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

### II. Phenotypic correlation:

At the phenotypic level are presented in Table-4.16, it was observed that fruit yield per plant had negative and significant correlation with fruit length (-0.423). Ridges on fruit had positive and significant correlation with fruits per plant (0.347) except negative and significant correlation with plant height (-0.399), locules per fruit (-0.351) and fruit width (-0.319). Fruit width had positively and significantly correlated with pericarp thickness (0.493) and fruit length (0.396). Fruit Length showed positive and significant correlation with pericarp thickness (0.541). Pericarp thickness had positively and significantly correlated with average fruit weight (0.312) followed by fruits per cluster (0.308) except negative and significant correlation with locules per fruit (-0.466). Locules per fruit had negative and significant correlation with fruits per plant (-0.340). Average fruit weight had positively and significantly correlated with fruits per cluster (0.321). Fruits per cluster had positively and significantly correlated with flowers per cluster (0.843) followed by plant height (0.526) except negative and significant correlation with number of branches per plant (-0.352). Flowers per cluster had positively and significantly correlated with plant height (0.519) except negative and significant correlation with number of branches per plant (-0.333). Clusters per plant had negatively and significantly correlated with days to 50% flowering (-0.388). Whereas, TSS, vitamin C, fruits per plant, days to 50% flowering and number of branches per plant showed negative and non-significant correlation.

### 4.6.2 PATH COEFFICIENT ANALYSIS OF PARENTS:

The path coefficient analysis was obtained for clear understanding of association of the genotypic correlation coefficient of yield with contributing components. The genotypic correlation coefficient was partitioned into direct and indirect effects through path coefficient analysis of parents. The results of path coefficient for parent are presented in Table-4.17. At genotypic level, highest positive direct and indirect effect towards yield per plant was showed by average fruit weight (0.365) followed by fruits per plant (0.307), pericarp thickness (0.196), locules per fruit (0.170), flowers per cluster (0.102), fruit width (0.070), plant height (0.039) and vitamin C (0.006), while, highest negative effect towards fruit yield per plant was showed by days to 50% flowering (-0.214) followed by number of branches per plant (-0.185), fruits per cluster (-0.166), fruit length (-0.094), clusters per plant (-0.077), ridges on fruit (-0.028) and TSS (-0.007).

From the estimate of correlation coefficient and direct and indirect effect of fruit yield attributing traits, it is clear that for bring out designed improvement towards fruit yield in future of tomato average fruit weight and fruits per plant can be used as direct selection parameters.

## Table -4.17: Genotypic path coefficient analysis (direct and indirect effect) of yield contributing characters in 15 parents of tomato

| Character | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Vit. C (Mg/100g) | TSS (°Brix) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | **0.039** | 0.002 | -0.002 | 0.006 | 0.001 | 0.007 | -0.001 | 0.004 | -0.002 | -0.007 | -0.007 | -0.005 | -0.006 | 0.004 | -0.006 |
| Branches per plant | -0.008 | **-0.185** | 0.053 | -0.040 | 0.024 | 0.007 | -0.034 | 0.010 | -0.014 | 0.015 | 0.000 | 0.015 | -0.013 | -0.002 | -0.026 |
| Days to 50% flowering | 0.011 | 0.061 | **-0.214** | 0.029 | -0.040 | 0.024 | 0.085 | 0.040 | 0.001 | -0.007 | 0.010 | -0.008 | -0.018 | 0.015 | -0.027 |
| Clusters per plant | -0.012 | -0.017 | 0.010 | **-0.077** | -0.026 | -0.024 | -0.003 | 0.006 | -0.009 | -0.003 | -0.001 | -0.009 | -0.020 | -0.010 | -0.009 |
| Flowers per cluster | 0.003 | -0.013 | 0.019 | 0.034 | **0.102** | 0.067 | 0.007 | -0.024 | 0.011 | 0.034 | 0.022 | 0.053 | 0.018 | 0.003 | 0.013 |
| Fruits per cluster | -0.031 | 0.006 | 0.019 | -0.052 | -0.108 | **-0.166** | -0.028 | -0.009 | -0.020 | -0.065 | -0.030 | -0.057 | -0.032 | -0.006 | 0.001 |
| Fruits per plant | -0.005 | 0.057 | -0.122 | 0.012 | 0.020 | 0.052 | **0.307** | 0.024 | -0.033 | 0.042 | 0.025 | 0.003 | 0.023 | 0.024 | -0.024 |
| Average fruit weight (g) | 0.037 | -0.020 | -0.068 | -0.029 | -0.085 | 0.021 | 0.029 | **0.365** | -0.058 | 0.041 | 0.011 | -0.015 | -0.053 | 0.059 | -0.005 |
| Locules per fruit | -0.010 | 0.012 | -0.001 | 0.019 | 0.018 | 0.021 | -0.018 | -0.027 | **0.170** | 0.014 | 0.024 | 0.036 | -0.024 | 0.028 | 0.019 |
| Pericarp thickness (mm) | -0.036 | -0.015 | 0.006 | 0.008 | 0.065 | 0.077 | 0.027 | 0.022 | 0.017 | **0.196** | 0.146 | 0.092 | 0.037 | 0.022 | 0.055 |
| Fruit length (cm) | 0.018 | 0.000 | 0.004 | -0.002 | -0.020 | -0.017 | -0.008 | -0.003 | -0.013 | -0.070 | **-0.094** | -0.042 | -0.012 | -0.003 | -0.028 |
| Fruit width (cm) | -0.009 | -0.005 | 0.003 | 0.008 | 0.036 | 0.024 | 0.001 | -0.003 | 0.015 | 0.033 | 0.031 | **0.070** | 0.000 | 0.001 | 0.012 |
| Ridges on fruit | 0.004 | -0.002 | -0.002 | -0.008 | -0.005 | -0.005 | -0.002 | 0.004 | 0.004 | -0.005 | -0.004 | 0.000 | **-0.028** | 0.001 | -0.004 |
| Vit C (mg/100g) | -0.024 | 0.023 | 0.020 | 0.019 | 0.021 | -0.001 | -0.012 | -0.002 | 0.018 | 0.045 | 0.048 | 0.027 | 0.024 | **0.006** | 0.161 |
| TSS (°Brix) | -0.017 | -0.002 | 0.012 | -0.024 | -0.006 | -0.006 | -0.014 | -0.029 | -0.030 | -0.020 | -0.005 | -0.003 | 0.007 | -0.179 | **-0.007** |
| Fruit yield per plant (kg) | -0.041 | -0.100 | -0.264 | -0.096 | -0.002 | 0.080 | 0.335 | 0.379 | 0.056 | 0.241 | 0.175 | 0.159 | -0.097 | 0.124 | -0.037 |

**Residual effect = 0.781**

**Bold value show direct effect.**

### 4.6.3 CORRELATION COEFFICIENT OF CROSSES:

The genotypic and phenotypic correlation coefficient of hybrids for sixteen characters of tomato are presented in Table–4.18. Yield is considered to be the most important character, on the basis yield ability of crosses are included in breeding programme to developed inbred line/hybrids.

#### I. Genotypic correlation:

As table 4.18 revealed that fruit yield per plant had positive and significant genotypic correlation coefficient with fruit length (0.576) followed by average fruit weight (0.393). However, negative and significant correlations were recorded for fruit yield per plant with fruit width (-0.316) followed by flowers per cluster (-0.005). Vitamin C showed positive and significant correlation with number of branches per plant (0.496). Ridges on fruit had positive and significant correlation with fruits per plant (0.064) except negative and significant correlation with average fruit weight (-0.092).Fruit width had positive and significant correlation with pericarp thickness (0.469). Fruit length had positive and significant correlation with fruits per cluster (0.190) and clusters per plant (0.164). The pericarp thickness had positive and significant correlation with number of branches per plant (0.018). Locules per fruit had positive and significant correlation with fruits per cluster (0.110). Fruits per plant had positive and significant correlation with number of branches per plant (0.081). Flowers per cluster had positive and significant correlation with days to 50% flowering (0.190). Days to 50% flowering had negative and significant correlation with plant height (-0.172 ).Whereas, number of branches per plant, clusters per plant, fruits per cluster and average fruit weight showed negative and non significant correlation.

## Table -4.18: Genotypic (G) and Phenotypic (P) correlation coefficient for different pairs of characters in 36 $F_1$ hybrids of tomato

| Character | Symbol | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Vit. C (Mg/100g) | TSS (°Brix) | Fruit yield per plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | G | 0.255 | -0.172 * | 0.092 | 0.173 | 0.157 | 0.149 | 0.377 | -0.140 | -0.048 | -0.076 | -0.212 | -0.195 | 0.241 | -0.517 | 0.092 |
| | P | 0.170 | -0.034 | 0.087 | 0.154 | 0.123 | 0.126 | 0.197 | -0.112 | -0.092 | -0.088 | -0.108 | -0.195 | 0.104 | -0.345 | 0.111 |
| Branches per plant | G | | -0.462 | 0.344 | -0.397 | -0.274 | 0.081 ** | 0.321 | 0.363 | 0.018 ** | -0.128 | -0.089 | -0.141 | 0.496 * | -0.083 | -0.062 |
| | P | | -0.267 | 0.185* | -0.262 | -0.209 | 0.099 | 0.154 | 0.212 | 0.050 | -0.069 | -0.068 | -0.081 | 0.194 | -0.040 | -0.027 |
| Days to 50% flowering | G | | | -0.327 | 0.190** | 0.032 | -0.426 | -0.159 | -0.069 | 0.102 | -0.090 | 0.122 | 0.182 | -0.241 | 0.256 | -0.355 |
| | P | | | -0.203 | 0.117 | -0.014 | -0.304 | -0.104 ** | -0.039 | -0.001 | -0.068 | 0.086 | 0.145 | -0.085 | 0.160 | -0.239 |
| Clusters per plant | G | | | | 0.270 | 0.417 | 0.216 | -0.081 | 0.238 | 0.090 | 0.164 ** | 0.365 | 0.320 | 0.469 | -0.136 | 0.064 |
| | P | | | | 0.194 | 0.262 | 0.097 | -0.019 | 0.213 * | -0.026 | 0.034 ** | 0.168 | 0.220 | 0.163 | -0.083 | 0.033 |
| Flowers per cluster | G | | | | | 0.864 | -0.186 | -0.194 | -0.111 | 0.205 | 0.104 | 0.221 | 0.451 | -0.187 | 0.020 | -0.005 * |
| | P | | | | | 0.814 | -0.150 | -0.163 ** | -0.032 | 0.166 | 0.044 | 0.195 * | 0.384 | -0.122 | 0.030 | 0.015 |
| Fruits per cluster | G | | | | | | -0.025 | -0.040 | 0.110* | 0.321 | 0.190 * | 0.318 | 0.522 | -0.170 | 0.020 | 0.150 |
| | P | | | | | | -0.022 * | -0.035 | 0.108 | 0.272 ** | 0.080 | 0.238 ** | 0.430 | -0.079 | -0.007 | 0.129 |
| Fruits per plant | G | | | | | | | 0.269 | -0.122 | -0.010 | 0.237 | 0.007 | 0.064 ** | -0.175 | -0.208 | 0.602 |
| | P | | | | | | | 0.189 ** | -0.105 | 0.012 | 0.130 | -0.020 | 0.056 | -0.100 | -0.174 | 0.478 * |
| Average fruit weight (g) | G | | | | | | | | -0.020 | 0.167 | 0.327 | -0.034 | -0.092* | 0.198 | -0.175 | 0.393 ** |
| | P | | | | | | | | -0.025 | 0.163 | 0.161 | 0.039 | -0.042 | 0.131 | -0.116 | 0.260 |
| Locules per fruit | G | | | | | | | | | 0.055 | 0.165 | 0.453 | 0.002 | 0.341 | 0.136 | -0.040 |
| | P | | | | | | | | | 0.002 | -0.009 | 0.333 | 0.002 | 0.117 | 0.094 | 0.032 |
| Pericarp thickness (mm) | G | | | | | | | | | | 0.4913 | 0.469* | 0.326 | -0.124 | 0.382 * | 0.269 |
| | P | | | | | | | | | | 0.349 | 0.361 | 0.243 | -0.047 | 0.209 | 0.158 |
| Fruit length (cm) | G | | | | | | | | | | | 0.501 | 0.253 | -0.354 | 0.200 | 0.576 ** |
| | P | | | | | | | | | | | 0.336 | 0.146 | -0.140 | 0.121 | 0.227 |
| Fruit width (cm) | G | | | | | | | | | | | | 0.209 | 0.014 | 0.349 | -0.316 ** |
| | P | | | | | | | | | | | | 0.164 | 0.035 | 0.172 | 0.178 |
| Ridges on fruit | G | | | | | | | | | | | | | -0.219 | 0.227 | 0.131 |
| | P | | | | | | | | | | | | | -0.120 | 0.148 | 0.067 |
| Vit C mg/100g | G | | | | | | | | | | | | | | -0.511 | -0.046 |
| | P | | | | | | | | | | | | | | -0.222 | -0.035 |
| TSS (°Brix) | G | | | | | | | | | | | | | | | -0.086 |
| | P | | | | | | | | | | | | | | | -0.164 |

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

### II. Phenotypic correlation:

At the phenotypic level are presented in (Table-4.18.), it was observed that fruit yield per plant had positive and significantly correlation with fruits per plant (0.478). Ridges on fruit had negative and significant correlation with average fruit weight (-0.092). Fruit width had positively and significantly correlated with fruits per cluster (0.238) and Flowers per cluster (0.195). Fruit Length showed positive and significant correlation with clusters per plant (0.034). Pericarp thickness had positive and significantly correlated with fruits per cluster (0.272). Locules per fruit had positive and significant correlation with clusters per plant (0.213). Average fruit weight had positively and significantly correlated with fruits per Plant (0.189) except negative and significant correlation with flowers per cluster (-0.163) and days to 50% flowering (-0.104).Fruits per plant had negative and significantly correlated with fruits per cluster (-0.022). Clusters per plant had positive and significantly correlated with number of branches per plant (0.185). Whereas, TSS, vitamin C, fruits per Cluster, flowers per cluster, days to 50% flowering and number of branches per plant showed negative and non significant correlation.

### 4.5.4 PATH COEFFICIENT ANALYSIS OF CROSSES:

The path coefficient analysis was obtained for clear understanding of association of the genotypic correlation coefficient of yield with contributing components. The genotypic correlation coefficient was partitioned into direct and indirect effects through path coefficient analysis in hybrids are presented in table-4.19. Highest positive direct and indirect effect towards yield per plant was showed by fruits per plant (0.393) followed by average fruit weight (0.166), fruit width (0.132), plant height (0.101), locules per fruit (0.079), fruits per cluster (0.068), fruit length (0.054), pericarp thickness (0.042), TSS (0.030) and ridges on fruit(0.020). Whereas, highest negative and direct effect towards fruit yield per vine was exhibited by days to 50% flowering (-0.159) followed by number of branches per plant (-0.112), clusters per plant (-0.055), flowers per cluster (-0.027) and vitamin C (-0.006).

**Table -4.19: Genotypic path coefficient analysis (direct and indirect effect) of yield contributing characters in 36 $F_1$ hybrids of tomato**

| Character | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Vit. C (Mg/100g) | TSS (°Brix) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height (cm) | **0.101** | 0.017 | -0.003 | 0.009 | 0.016 | 0.012 | 0.013 | 0.020 | -0.011 | -0.009 | -0.009 | -0.011 | -0.020 | 0.011 | -0.035 |
| Branches per plant | -0.019 | **-0.112** | 0.030 | -0.021 | 0.029 | 0.023 | -0.011 | -0.017 | -0.024 | -0.006 | 0.008 | 0.008 | 0.009 | -0.022 | 0.004 |
| Days to 50% flowering | 0.005 | 0.042 | **-0.159** | 0.032 | -0.019 | 0.002 | 0.048 | 0.017 | 0.006 | 0.000 | 0.011 | -0.014 | -0.023 | 0.013 | -0.025 |
| Clusters per plant | -0.005 | -0.010 | 0.011 | **-0.055** | -0.011 | -0.014 | -0.005 | 0.001 | -0.012 | 0.001 | -0.002 | -0.009 | -0.012 | -0.009 | 0.005 |
| Flowers per cluster | -0.004 | 0.007 | -0.003 | -0.005 | **-0.027** | -0.022 | 0.004 | 0.004 | 0.001 | -0.005 | -0.001 | -0.005 | -0.010 | 0.003 | -0.001 |
| Fruits per cluster | 0.008 | -0.014 | -0.001 | 0.018 | 0.055 | **0.068** | -0.001 | -0.002 | 0.007 | 0.018 | 0.005 | 0.016 | 0.029 | -0.005 | 0.000 |
| Fruits per plant | 0.050 | 0.039 | -0.120 | 0.038 | -0.059 | -0.009 | **0.393** | 0.074 | -0.041 | 0.005 | 0.051 | -0.008 | 0.022 | -0.039 | -0.068 |
| Average fruit weight (g) | 0.033 | 0.026 | -0.017 | -0.003 | -0.027 | -0.006 | 0.031 | **0.166** | -0.004 | 0.027 | 0.027 | 0.006 | -0.007 | 0.022 | -0.019 |
| Locules per fruit | -0.009 | 0.017 | -0.003 | 0.017 | -0.003 | 0.009 | -0.008 | -0.002 | **0.079** | 0.000 | -0.001 | 0.026 | 0.000 | 0.009 | 0.007 |
| Pericarp thickness (mm) | -0.004 | 0.002 | 0.000 | -0.001 | 0.007 | 0.011 | 0.000 | 0.007 | 0.000 | **0.042** | 0.015 | 0.015 | 0.010 | -0.002 | 0.009 |
| Fruit length (cm) | -0.005 | -0.004 | -0.004 | 0.002 | 0.002 | 0.004 | 0.007 | 0.009 | 0.000 | 0.019 | **0.054** | 0.018 | 0.008 | -0.008 | 0.007 |
| Fruit width (cm) | -0.014 | -0.009 | 0.011 | 0.022 | 0.026 | 0.031 | -0.003 | 0.005 | 0.044 | 0.048 | 0.044 | **0.132** | 0.022 | 0.005 | 0.023 |
| Ridges on fruit | -0.004 | -0.002 | 0.003 | 0.004 | 0.008 | 0.008 | 0.001 | -0.001 | 0.000 | 0.005 | 0.003 | 0.003 | **0.020** | -0.002 | 0.003 |
| Vit C (mg/100g) | -0.009 | -0.001 | 0.004 | -0.002 | 0.001 | 0.000 | -0.005 | -0.003 | 0.003 | 0.006 | 0.003 | 0.005 | 0.004 | **-0.006** | 0.027 |
| TSS (°Brix) | -0.014 | -0.026 | 0.011 | -0.022 | 0.016 | 0.011 | 0.013 | -0.017 | -0.016 | 0.006 | 0.019 | -0.005 | 0.016 | -0.134 | **0.030** |
| Fruit yield per plant (kg) | 0.111 | -0.027 | -0.239 | 0.033 | 0.015 | 0.129 | 0.478 | 0.260 | 0.032 | 0.158 | 0.227 | 0.178 | 0.067 | -0.164 | -0.035 |

**Residual effect =0.357**

**Bold value show direct effect.**

# Chapter V

# DISCUSSION

The importance of heterosis to breeding programme was recognized by early workers, **Kolreuter (1766), Knight (1979), Shull (1910), East (1912)** and others. Though the heterosis is a general phenomenon in tomato, the success of heterosis breeding depends mainly on the choice of the parents for hybridization and the information on nature and magnitude of gene action and combining ability of different parents.

Heterosis breeding is an effective method for crop improvement. The present investigation entitled **"Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)"** was carried out at Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow- 226025 (U.P.), India, during the summer season of 2014-15 and 2015-16. The conclusive findings of the present investigation have been briefly discussed in succeeding pages citing the past works and possible reasoning of results.

Yield is the most important economic trait for any vegetable crop, major objective of any breeding programme. The genetic improvement for yield can possible be brought about in two ways. First, by manipulating the genetic makeup of the plants through a number of desirable, often mutually compatible genes or characters in single genotype and secondary, by getting rid of the bottleneck genes which inhibit or retard certain pathways that lead to higher productivity.

There is a good scope of exploiting heterosis in tomato because of the fact that it is self pollinated crop in nature but at the same time cross pollination up to the extend of 30-40% also occurs. Considering the above facts, research programme was initiated to estimate heterosis and combining ability using line x tester design developed by Kempthorne (1975). The experimental materials consisted of twelve diverse lines and three male testers. Analysis of combining ability along with *per se* performance parents and their crosses are helpful for the selection of suitable parents and crosses for their use in systematic breeding programme.

The knowledge of genetic variability, heritability and genetic advance are considered to be useful in predicting the response for selection of superior lines and selection of yield attributing component traits showing strong association with yield. The magnitude of correlation and path coefficient analysis based on genotypic factors obviously have important vegetable breeder for providing knowledge about understanding the association between pair of characters. In order to generate additional information, on the important results are discussed as following points:

5.1 Analysis of variance of Line x Tester (12 female and 3 male) for the 16 characters of tomato

5.2 Mean performance of parents for 16 characters of tomato

5.3 Analysis of variance (ANOVA) for combining ability and their effects

5.4 Estimation of heterosis, heterobeltiosis and inbreeding depression

5.5 Genetic variability, heritability and genetic advance of parents and their crosses

5.6 Genotypic and phenotypic correlation coefficient of parents and hybrids

## 5.1 ANALYSIS OF VARIANCE

The analysis of variance for the sixteen characters of the fifteen parents (12 lines and 3 testers) and 36 $F_1$ hybrids are given in Table-4.1. The variance due to parents and hybrids were worked out. The mean sum of square due to parents and hybrids were highly significant for all the characters under the investigation. This indicates the presence of an appreciable amount of variability in the base materials as well as in the generated materials.

## 5.2 MEAN PERFORMACE OF PARENTS AND THEIR CROSSES

Mean value of parents and hybrids with respect to sixteen characters are given in Table-4.2, 4.2b and 4.3a ,4.3b, respectively for all the characters under the investigations, showed non significant value of parent and mean value of hybrids were more or less similar for most of the traits under study.

## 5.3 COMBINING ABILITY VARIANCE AND THEIR EFFECTS

The concept of combining ability analysis has been very useful in hybrid development; it is also helpful in understanding the nature of gene action and genetic variation in the population which is essential to workout appropriate breeding strategy. General combining ability largely involves additive gene effects, while, specific combining ability contains non additive type of gene action. Non additive gene action entails dominance and epitasis interactions. This analysis will be of immerse useful in identifying the best combiners which may be hybridzed either to expoit heterosis .In the ensuing pages, the results of combining ability studies obtained from a line x tester analysis consisting of thirty six hybrids (12 lines x 3 testers) are discussed. The genetic estimates in LxT analysis are derive from half sib and full sib relationships.The success of any breeding programme largely depends upon the selection of superior parents for hybridization programme is as essential step in providing outstanding individual hybrids in any crop.

Analysis of variance for combining ability (Table-4.4.a & 4.4.b) indicates that mean sum of square due to line was highly significant for Plant height , Fruits per plant and vitamin C non significant for Remaining characters while in case of tester, it was non significant for all characters except vitamin C significant . Due to line vs. tester were showed highly significant for all of the characters except vitamin C was non significant. Thus, variation within tester was noteworthy and so was their contribution towards combining ability. The line x tester interaction components also emerging significant for all the characters, emphasizing the contribution of combining ability in the expression of these characters.

### 5.3.1 General combining ability effects

General combining ability effects of twelve female lines and three male testers were estimated separately. The estimates of specific combining ability for crosses were also estimated. Thus, the best general combiners and specific cross combiners are here available for discussion of all the characters of tomato. The general combining ability is primarily a function of additive x additive gene action. The information regarding general combining ability effects of the parents (Table-4.5.a, 4.5.b) is of prime importance, it helps in successful prediction of genetic potentiality of crosses which is desirable in segregating population of cross pollinated crops. The indicates that none of the parent were good general combiner for all the characters. Estimates of general combining ability effect exhibited that is was difficult to choose good combination for all the traits as the combining ability effects were not consistent for all the yield components.

However, it was showed that the top two parents parents proved to be the best general combiners for different characters were Sel.-32 and G-3 for plant height, Pusa Sheetal and IIVR-Sel.-1 for number of branches per plant and S. Naveen and Flora Dode for days to 50% flowering, H-86 and Flora Dode for clusters per plant, FLA 7171 and Hisar Arun for flowers per cluster, Flora Dode and FLA 7171 for fruits per cluster, H-86 and Flora Dode for fruits per plant, H-88 and Kashi Amrit for average fruit weight , FLA 7171 and H-86 for locules per Fruit, Hisar Arun and H-88 for pericarp thickness, FLA 7171 and Flora Dode for fruit length, H-24 and Sel.-32 for fruit width, G-3 and IIVR-Sel.-1 for ridges on fruit. Hisar Arun and S. Naveen for fruit yield per plant, Sel.-32 and S. Naveen for TSS, H-24 and FLA 7171 for vitamin C. Similar findings have been also also noted by **Bhatt *et al.* (2001).**

General combining ability effects together with relative *per se* performance is useful for selecting desirable parent with favourable gene for different component of yield. *Per se* performance of parents and their general combining ability effects for all the traits were in close correspondence which indicates that the *per se* performance of the parent for these characters could be possible take as a selection of parents.

### 5.3.2 Specific general combining ability effects

The specific combining ability is represented the dominance and epistatic component of variation that are non-additive gene action. It can be utilized in generation like developing $F_1$ hybrids. In the present investigation, the thirty six cross manifested consistently high specific combining ability effects for most of the characters. The above results are in accordance with **Dahiya *et al.* (1985).**

In the present study findings (Table 4.6a, 4.6b, and 4.8) revealed that the significant and desirable cross in order of merit were H-86 x Pusa Sadabahar and S. Naveen x Kashi Vishesh for plant height FLA 7171 x Pusa Sadabahar for Number of branches per plant, H-24 x Kashi Amrit for days to 50% flowering, S. Naveenx Kashi Vishesh for clusters per plant, FLA 7171 x Pusa Sadabahar for flowers per cluster, FLA 7171 x Pusa Sadabahar for fruits per cluster, H-86 x Kashi Amrit for fruits per plant, H-88 x Kashi Vishesh for average fruit weight, H-24 x Pusa Sadabahar for locules per fruit, IIVR-Sel.-1 x Kashi Amrit for pericarp thickness, S. Naveen x Kashi Amrit for fruit length, H-86 x Pusa Sadabahar for fruit width,G-3 x Kashi Amrit for ridges On fruit, S. Naveenx Kashi Vishesh for fruit yield per plant, G-3 x Kashi Vishesh for TSS and H-88 x Kashi Amrit for vitamin C were showed significant and desirable specific combiner. Similarly, a critical examination of *per se* performance of best crosses for sixteen characters also reviled that there is no direct relationship between the *per se* of the crosses and their parents similar findings have been also reported by **Brar *et al.* (2005).**

### 5.3.3 Genetic component and combining ability variance

Estimation of genetic component of variance (additive and dominance), combining ability variance general combining ability and specific combining ability, degree of dominance and and predictability ratio for sixteen characters of tomato are presented in Table-4.9. The genetic component of variance for the dominance recorded maximum value than the additive variance for all the characters with value of more than one (>1) degree of dominance except vitamin C. The variance of specific combining ability was also recorded to be higher than the general combining ability variance with the value of less than one (<1) predictability ratio for all the characters except vitamin C under study.

## 5.4 HETEROSIS AND INBREEDING DEPRESSION

Heterosis is a general biological phenomenon, observed in $F_1$ generation which manifests itself by greater vitality, rapid growth and development, higher productivity, resistance, adaptation and uniformity of off springs. In a hybrids programme, breeder's aim is either to develop a commercial hybrid or to have a segregate equivalent to or better than the hybrids *per se*. It is with latter aim for which heterosis breeding in a often cross pollinated vegetable crops like tomato holds importance with the availability of existing variability present in the tomato.

Standard heterosis is usually expressed as an increase of $F_1$ value over the standard or commercial variety, while, increase or decrease of $F_1$ value over the better parent is known as heterobeltiosis. In the present investigation, the relative magnitude of heterosis over standard variety and better parent has been studies for sixteen characters in thirty six hybrids.

The results (Table- 4.10.a, 4.10.b, 4.10.c, 4.10.d, 4.10e, 4.10.f, 4.10.g, 4.10.h and 4.11) suggested that the magnitude of hybrid vigour differ from characters to characters depending upon the hybrids combination. None of the crosses were consistently good for all the characters.

### 5.4.1 Plant height (cm):

The positive and significant heterosis was reported in cross combinations Cross combinations DVRT-2 x Kashi Vishesh, H-88 x Kashi Amrit and Pusa Sheetal x Kashi Amrit over standard variety and FLA 7171 x Kashi Vishesh, H-86 x Kashi Amrit and Hisar Arun x Kashi Vishesh over better parents recorded significant and positive heterosis. Cross combinations H-88 x Pusa Sadabahar, Sel.-32 x Kashi Vishesh and DVRT-2 x Pusa Sadabahar recorded highly significant and positive inbreeding depression while, four cross combinations, revealed significant and negative inbreeding depression in $F_2$ population for plant height. **Thakur and Joshi (2003)**

### 5.4.2 Number of branches per plant:

The significant and positive heterosis for number of branches per plant is good because it is directly associated with increase fruit yield per plant. Cross combinations (H-24 x Kashi Amrit), (G-3 x Kashi Amrit) and (IIVR-Sel. 1 x Kashi Vishesh) recorded significant and positive heterosis over standard variety and cross combinations (H-88 x Kashi Vishesh) and (IIVR-Sel.-1 x Kashi Amrit) showed positive and significant heterosis over better parents for number of branches per plant. Thirty four crosses exhibited non significant in $F_2$ populations for number of branches per plant.

### 5.4.3 Days to 50 per cent flowering:

The positive and significant heterosis was reported in Cross combinations Sel.-32 x Pusa Sadabahar, and H-24 x Kashi Vishesh positive and significant heterosis over standard variety and S. Naveen x Pusa Sadabahar over better parents showed early fifty percent flowering. Only one crosses recorded significant and positive heterosis, while, eleven crosses revealed significant and negative heterosis over better parents. Eleven $F_2$ population showed early days to fifty percent flowering. **Sherif and Hussein (1992).**

### 5.4.4 Number of clusters per plant:

Increase in the clusters per plant is an important character which contributes to the yield enhancement, hence significant and positive heterotic effect would be good. The hybrid combinations H-24 x Pusa Sadabahar over standard variety and G-3 x Pusa Sadabahar over better parents showed maximum positive and highly significant heterosis for clusters per plant. Eighteen crosses showed negative and significant heterosis.

### 5.4.5 Number of flowers per cluster:

The positive and significant heterosis for flowers per cluster is desirable. Cross combinations IIVR-Sel.-1 x Pusa Sadabahar, Pusa Sheetal x Kashi Vishesh and S. Naveen x Kashi Amrit over standard variety and Flora Dode x Kashi Vishesh, IIVR-Sel.-1 x Pusa Sadabahar and FLA 7171 x Pusa Sadabahar over better parents recorded significant and negative heterosis. Cross combinations IIVR-Sel.-1 x Pusa Sadabahar, DVRT-2 x Pusa Sadabahar and Sel.-32 x Pusa Sadabahar revealed highly significant and positive inbreeding depression while, three cross combinations, recorded significant and negative inbreeding depression in $F_2$ population for flowers per cluster. The higher heterosis for number of flowers per cluster was reported by **Padmini and Vadivel (1997).**

### 5.4.6 Number of fruits per cluster:

The significant and positive heterosis for fruits per cluster is good because it is directly associated with increase of fruit yield. Cross combinations (H-24 x Kashi Vishesh), (Pusa Sheetal x Kashi Vishesh), (FLA 7171 x Kashi Vishesh) over standard variety and (S. Naveenx Kashi Vishesh), (G-3 x Kashi Amrit) and (Flora Dode x Kashi Amrit) recorded significant and negative heterosis over better parents.

### 5.4.7 Number of fruits per plant:

The significant and positive heterosis is good for this character. Cross combinations Sel.-32 x Kashi Amrit, FLA 7171 x Kashi Vishesh and FLA 7171 x Kashi Amrit over standard variety recorded significant and negative heterosis. Whereas, H-86 x Kashi Vishesh, Flora Dode x Kashi Amrit and S. Naveenx Kashi Vishesh over better parents revealed significant and positive heterosis. Cross combinations Flora Dode x Pusa Sadabahar, Flora Dode x Kashi Vishesh and G-3 x Pusa Sadabahar recorded highly significant and positive inbreeding depression. Seven crosses showed significant and positive in $F_2$ populations for this character. **(Sharma *et al.*, 2001**)

### 5.4.8 Average fruit weight:

The significant and positive heterosis is good for average fruit weight. Cross combinations G-3 x Pusa Sadabahar, S. Naveen x Kashi Amrit and IIVR-Sel.-1 x Pusa Sadabahar over standard variety revealed highly significant and negative heterosis and Flora Dode x Kashi Vishesh, G-3 x Kashi Vishesh and H-86 x Kashi Amrit over better parents recorded significant and positive heterosis for average fruit weight. Cross combinations H-88 x Pusa Sadabahar, H-86 x Pusa Sadabahar and S. Naveenx Kashi Vishesh showed significant and positive inbreeding depression. Only two crosses recorded significant and negative inbreeding depression for this character.Similar reports were given by **Fageria *et al.* (2001).**

### 5.4.9 Number of locules per fruit:

Significant and negative heterosis is good for locules per fruit. In cross combinations Pusa Sheetal x Pusa Sadabahar, Flora Dode x Kashi Amrit and Sel.-32 x

Kashi Vishesh over standard variety and Flora Dode x Kashi Amrit, IIVR-Sel. 1 x Kashi Vishesh and FLA 7171 x Kashi Amrit over better parents recorded significant and negative heterosis for locules per fruit. Cross combinations FLA 7171 x Kashi Amrit and Pusa Sheetal x Kashi Vishesh revealed highly significant and positive inbreeding depression while, fourteen cross combination identified non significant and negative inbreeding depression in $F_2$ population for locules per fruit. Low magnitude for number of locules per fruit has been reported by **Sundaram *et al.* (1994).**

### 5.4.10 Pericarp thickness (mm):

The significant and negative heterosis is good for pericarp thickness. Cross combinations Sel.-32 x Kashi Amrit, FLA 7171 x Pusa Sadabahar and H-86 x Kashi Amrit revealed significant and negative heterosis over standard variety, while, cross combinations Sel.-32 x Pusa Sadabahar, IIVR-Sel. 1 x Kashi Vishesh and S. Naveen x Kashi Amrit recorded significant and negative heterosis over better parents for this traits. In case of inbreeding depression cross combinations Sel.-32 x Kashi Vishesh, H-88 x Pusa Sadabahar and Pusa Sheetal x Pusa Sadabahar recorded significant and positive inbreeding depression, whereas, eight crosses showed non significant and negative inbreeding depression in $F_2$ population for this traits. **Chattopadhyay and Paul (2012)** who have reported significant heterosis in a few or none of the hybrids evaluated by them.

### 5.4.11 Fruit length (cm):

The significant and negative Heterosis is good for fruit length. Cross combinations S. Naveen x Kashi Amrit, FLA 7171 x Pusa Sadabahar and Sel.-32 x Kashi Amrit over standard variety and IIVR-Sel. 1 x Kashi Vishesh, Pusa Sheetal x Pusa Sadabahar and Sel.-32 x Kashi Amrit over better parents revealed significant and negative heterosis for highest length of fruit. Cross combinations G-3 x Pusa Sadabahar, H-86 x Pusa Sadabahar and Sel.-32 x Kashi Amrit recorded significant and positive inbreeding depression in $F_2$ population for length of fruit.

### 5.4.12 Fruit width (cm):

In cross combinations G-3 x Kashi Amrit, DVRT-2 x Kashi Vishesh and H-86 x Pusa Sadabahar over standard variety and S. Naveen x Kashi Amrit, S. Naveenx Kashi Vishesh and DVRT-2 x Kashi Vishesh over better parents recorded highly significant and negative heterosis for fruit width. Cross combinations H-24 x Kashi Vishesh, S. Naveenx Kashi Vishesh and FLA 7171 x Kashi Amrit revealed highly significant and positive inbreeding depression. Five cross combination recorded non significant and negative inbreeding depression in $F_2$ population for fruit width.

### 5.4.13 Number of ridges on fruit:

The significant and positive heterosis is good for ridges on fruit. In cross combinations G-3 x Kashi Vishesh, Sel.-32 x Pusa Sadabahar and Pusa Sheetal x Pusa Sadabahar over standard variety and G-3 x Kashi Amrit, S. Naveen x Kashi Amrit and IIVR-Sel. 1 x Kashi Vishesh over better parents recorded significant and positive heterosis for ridges on fruit. Cross combinations H-24 x Kashi Vishesh and Pusa Sheetal x Pusa Sadabahar showed significant and negative inbreeding depression whereas, eighteen cross combination recorded negative and non significant inbreeding depression in $F_2$ population for ridges on fruit.

### 5.4.14 Fruit Yield Per Plant (kg):

Significant and positive heterosis value for yield per plant is good for this character. Fifteen crosses revealed highly significant and negative heterosis out of thirty six crosses and two crosses Positive significant, whereas, four crosses recorded highly significant and positive heterosis over better parents. The cross combinations H-86 x Kashi Amrit, Flora Dode x Kashi Amrit and Sel.-32 x Pusa Sadabahar over standard variety significant and positive heterosis for total yield per plant. The cross combinations IIVR-Sel.-1 x Kashi Amrit, Sel.-32 x Pusa Sadabahar and Flora Dode x Pusa Sadabahar over better parents noted maximum significant and positive heterosis for total yield per plant. Cross combinations H-88 x Pusa Sadabahar, H-88 x Kashi Amrit and Flora Dode x Kashi Amrit observed significant and negative inbreeding depression, whereas, all the crosses recorded non significant heterosis except five crosses in $F_2$ population for yield per plant. **Power (1955)**

### 5.4.15 TSS (°Brix):

The significant and negative heterosis is better for TSS. In cross combinations G-3 x Pusa Sadabahar, DVRT-2 x Kashi Amrit and H-86 x Kashi Amrit over standard variety and DVRT-2 x Kashi Amrit, G-3 x Pusa Sadabahar and DVRT-2 x Pusa Sadabahar over better parents recorded highly significant and negative heterosis for TSS. Cross combinations IIVR-Sel. 1 x Kashi Vishesh, S. Naveen x Pusa Sadabahar and DVRT-2 x Pusa Sadabahar revealed highly significant and positive inbreeding depression whereas, nine cross combination observed non significant and negative inbreeding depression in $F_2$ population for TSS. The results were also supported by **Patgaonkar *et al.* (2003).**

### 5.4.16 Vitamin C (Mg/100g):

Significant and positive heterosis value for vitamin C is good for this character. In cross combinations S. Naveen x Pusa Sadabahar, Sel.-32 x Pusa Sadabahar and H-88 x Kashi Amrit over standard variety and H-24 x Kashi Amrit, FLA 7171 x Kashi Vishesh and Hisar Arun x Kashi Amrit over better parents recorded significant and positive heterosis for vitamin C. Cross combinations Sel.-32 x Kashi Vishesh and IIVR-Sel. 1 x Kashi Vishesh showed significant and positive inbreeding depression while, fifteen cross combination revealed negative and non significant inbreeding depression in $F_2$ population for vitamin C. **Kumar *et al.*, (2013)** have also reported significant positive heterosis over BP in 7 crosses out of 30 crosses.

## 5.5 GENETIC VARIABILITY, HERITABILITY AND GENETIC ADVANCE OF PARENTS AND THIER CROSSES

Analysis of variance recorded significant difference among the genotypes for all the traits under study (Table-4.13 and 4.15). The present findings recorded higher value of phenotypic coefficient of variation than their respective genotypic coefficient of variation for all the characters under study, which indicates that the characters studied were influenced by the environmental. The phenotypic coefficient of variation and genotypic coefficient of variation was higher for phenotypic coefficient of variation and genotypic coefficient of variation was higher for fruit yield per plant and number of branches per plant, but was lowest for days to 50% flowering, show that the characters would respond to selection.

The highest value of broad sense heritability was showed for fruit yield per plant followed by ridges on fruit , plant height , TSS , flowers per cluster , pericarp thickness , fruits per plant , fruits per cluster , clusters per plant and number of branches per plant , while, lowest was recorded for vitamin C. It is also measures the genetic relationship between parents and their progenies, hence, it is widely used in determining the degree to which characters may be transmitted from parent to offspring. The above result is in accordance with **(Miller *et al.,* 1958)**.

There is a good genetic variability in tomato which can be utilized for varietals improvement. This variability is of much helpful to the breeders in the evolution of new genotypes for selection. The estimates of genetic variability, heritability and genetic gain decide the breeding for improvement in tomato. For the present investigation, widest range was recorded for average fruit weight followed by plant height.

The genetic advanced is another important selection parameter because it measures the difference between the mean genotypic value of the original population from which these were selection. Thus, it adds an advantage over heritability as a guiding factor to breeding in the selection programme. The maximum genetic advance was recorded for fruit yield per plant followed by ridges on fruit , average fruit weight , flowers per cluster, fruits per cluster, number of branches per plant, locules per fruit, fruits per plant, clusters per plant, pericarp thickness , TSS, whereas, minimum was recorded for days to 50% flowering .

### 5.6 CORRELATION COEFFICIENT AND PATH COEFFICIENT ANALYSIS OF PARENTS AND THEIR CROSSES

The magnitude of association between yield and yield attributing traits is necessary for effective selection in advance generation. Correlation between various characters specially when partitioned into genotypic and phenotypic components can be of great value in planning and evaluating any breeding programmes. **Johnson *et al.,* (1955)** suggested that genotypic correlation coefficient provides a measure of the genotypic association between characters and give indication of the characters that may be useful indicators with this view the genotypic and phenotypic correlation among sixteen characters in tomato genotypes were given in the present investigation.

Positive and significant genotypic correlation coefficient of fruit yield per plant, average fruit weight followed by fruits per plant (Table-4.16 and 4.18). **Grafius (1964a)** observed that there were on way in which could be changed without changing one or more than components. Thus all characters in yield must be accompanied by changed in one or more the components traits. The correlation between yield and its components is indispensable when it is required to amalgamate high yield potential with other desirable traits in single genotypes. The correlation studies revealed higher estimates of genotypic correlation coefficient than the corresponding phenotypic correlation indicating there by an inherent association between the characters and the environmental factor has not played much role in expression phenotypic correlation.

In phenotypic level observed that fruit yield per plant had negative and significant correlation with fruit length. Ridges on fruit had positive and significant correlation with fruits per plant except negative and significant correlation with plant height, locules per fruit and fruit width. Fruit width had positively and significantly correlated with pericarp thickness and fruit length. Fruit Length showed positive and significant correlation with pericarp thickness.

The path coefficient analysis was done to investigate the direct and indirect relative effects; hence, it provides a better selection in comparison to correlation coefficient. Such information provides a realistic basis for allocation of appropriate weight age of various attributes, while, designing a pragmatic breeding programme for improvement of yield. The highest positive direct and indirect effect towards yield per plant was showed by average fruit weight followed by fruits per plant, pericarp thickness, locules per fruit, flowers per cluster, fruit width, plant height and vitamin C, while, highest negative effect towards fruit yield per plant was showed by days to 50% flowering followed by number of branches per plant ,fruits per cluster , fruit length , clusters per plant , ridges on fruit and TSS. (Table-4.17 and 4.19)

Chapter VI

# SUMMARY AND CONCLUSION

Heterosis breeding is an effective method for crop improvement. The present investigation entitled **"Heterosis and Combining Ability Studies in Tomato (*Solanum lycopersicum* L.)"** was carried out at Horticulture Research Farm, Department of Applied Plant Science (Horticulture), Babasaheb Bhimrao Ambedkar University (A Central University), Vidya Vihar, Rae Bareli Road, Lucknow- 226025 (U.P.), India, during the summer season of 2014-15 and 2015-16. The conclusive findings of the present investigation have been briefly discussed in succeeding pages citing the past works and possible reasoning of results.

- To estimate general and specific combining ability variance and their effects.
- To estimate heterobeltiosis and standard heterosis for different characters and inbreeding depression.
- To estimate heritability and genetic advanced.
- To estimate the correlation coefficient and path analysis among the different economic traits, under study.

The experimental material consisted of twelve lines, three testers and 36 $F_1$ hybrids obtained from line x tester mating design. The observation was recorded on five randomly selected plants per replication for each germplasm on sixteen important characters including yield per plant. Observations were recorded like plant height (cm), number of branches per plant, days to 50 percent flowering, number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, average fruit weight, number of locules per fruit, pericarp thickness, fruit length, fruit width, number of ridges on fruit, fruit yield per plant, TSS ($^0$Brix) and vitamin c (mg/100g) were recorded. The data were analyzed as per methods suggested by **Panse and Sukhatme (1967)** for analysis of variance, **Burton (1952)** for variability, **Lush (1949)** for heritability (Broad Sense) and **Johnson *et al.*, (1955)** for genetic advance in per cent of mean.

Variance due to lines (female) was highly significant for all the characters except plant height( cm) and vitamin C (mg/100g).Variance due to testers (males) was also highly significant for all the characters except plant height, clusters per plant, fruits per plant, average fruit weight and fruit width .Whereas, variances due to parents vs. hybrids were highly significant for days to 50% flowering, clusters per plant, flowers per cluster, fruits per cluster, fruits per plant, average fruit weight (g), locules per fruit, pericarp thickness (mm), fruit length (cm), fruit width (cm), ridges on fruit except plant height (cm), branches per plant, fruit yield per plant (kg) and vitamin C (mg/100g) were non-significant under study.

The parental, line S. Naveen, Flora Dode , FLA 7171 , Sel.-32 and H-86 were found to be best general combiners for most of the characters, while, *per se* performance for parental Pusa Sheetal was found good general combiners for yield and its related component traits out of thirty six crosses, H-86 x Pusa Sadabahar for plant height, FLA 7171 x Pusa Sadabahar for number of branches per plant, H-24 x Kashi Amrit for days to 50% flowering, S. Naveenx Kashi Vishesh for clusters per plant, FLA 7171 x Pusa Sadabahar for flowers per cluster, FLA 7171 x Pusa Sadabahar for fruits per cluster, H-86 x Kashi Amrit for fruits per plant, H-88 x Kashi Vishesh for average fruit weight, H-24 x Pusa Sadabahar for locules per fruit, IIVR-Sel.-1 x Kashi Amrit for pericarp thickness, S. Naveen x Kashi Amrit for fruit length, H-86 x Pusa Sadabahar for fruit width,G-3 x Kashi Amrit for ridges on fruit, S. Naveen x Kashi Vishesh for fruit yield per plant, G-3 x Kashi Vishesh for TSS and H-88 x Kashi Amrit for vitamin C were showed significant and desirable specific combiner.

Estimate of genetic component of variance (additive and dominance), combining ability variance general combining ability and specific combining ability, degree of dominance and and predictability ratio for sixteen characters of tomato are presented in table-4.9. The genetic component of variance for the dominance showed higher value than the additive variance for all the characters with value of greater than one (>1) degree of dominance except vitamin C. The variance of specific combining ability was also recorded to be higher than the general combining ability variance with the value of less than one (<1) predictability ratio for all the characters except vitamin C under study.

The range of heterosis over standard variety and better parents for almost all characters were carried out. The best cross combinations DVRT-2 x Kashi Vishesh and H-88 x Kashi Amrit the standard variety and FLA 7171 x Kashi Vishesh over better parents for plant height, cross combinations H-24 x Kashi Amrit and G-3 x Kashi Amrit over the standard variety and H-88 x Kashi Vishesh over better parents respectively for number of branches per plant, Sel.-32 x Pusa Sadabahar, and H-24 x Kashi Vishesh for the standard variety and S. Naveen x Pusa Sadabahar over better parents for days to fifty percent flowering, cross combination H-24 x Pusa Sadabahar over the standard variety and G-3 x Pusa Sadabahar over better parent respectively for clusters per plant.

The best cross combination IIVR-Sel.-1 x Pusa Sadabahar and Pusa Sheetal x Kashi Vishesh over the standard variety and Flora Dode x Kashi Vishesh over the better parent for number of flowers per cluster, cross combination H-24 x Kashi Vishesh and Pusa Sheetal x Kashi Vishesh over the standard variety and S. Naveen x Kashi Vishesh over the better parent for fruits per cluster, cross combination Sel.-32 x Kashi Amrit and FLA 7171 x Kashi Vishesh over the standard variety and H-86 x Kashi Vishesh over the better parent for fruits per plant, cross combination G-3 x Pusa Sadabahar over the standard variety and Flora Dode x Kashi Vishesh over the better parent for for average fruit weight, cross combination Pusa Sheetal x Pusa Sadabahar, and Flora Dode x Kashi Amrit over the standard variety and IIVR-Sel. 1 x Kashi Vishesh over the better parent for number of locules per fruit, cross combination Sel.-32 x Kashi Amrit and FLA 7171 x Pusa Sadabahar over the standard variety and Sel.-32 x Pusa Sadabahar over the better parent for pericarp thickness, cross combination S. Naveen x Kashi Amrit and FLA 7171 x Pusa Sadabahar over the standard variety and IIVR-Sel. 1 x Kashi Vishesh over the better parent for for fruit length.cross combination G-3 x Kashi Amrit and DVRT-2 x Kashi Vishesh over standard variety and S. Naveen x Kashi Amrit over the better parent for fruit width, cross combination G-3 x Kashi Vishesh over standard variety and G-3 x Kashi Amrit over better parent for ridges on fruit, cross combination H-86 x Kashi Amrit and Flora Dode x Kashi Amrit over the standard variety and Sel.-32 x Pusa Sadabahar over the better parent showed significant and desirable standard heterosis and heterobiltiosis for yield per plant.cross combination G-3 x Pusa Sadabahar and DVRT-2 x Kashi Amrit over the standard variety and DVRT-2 x Kashi Amrit over the better parent for TSS. cross combination S. Naveen x Pusa Sadabahar and Sel.-32 x Pusa Sadabahar over standard variety and H-24 x Kashi Amrit over the better parent for vitamin C.

Some of the crosses showed remarkable negative inbreeding depression for different characters such as plant height, days to fifty percent flowering, flowers per cluster and fruits per cluster etc. It is desirable for this trait, whereas most of the yield related component traits exhibited positive inbreeding depression such a length of fruit, average fruit weight, fruits per plant, clusters per plant and number of branches per plant.

The phenotypic coefficient of variation than their respective genotypic coefficient of variation for all the characters under study, which indicates that the characters studied were influenced by the environmental. The phenotypic coefficient of variation and genotypic coefficient of variation was maximum for phenotypic coefficient of variation and genotypic coefficient of variation was higher for fruit yield per plant and Number of branches per plant, but was lowest for days to 50% flowering. The highest value of broad sense heritability was showed for fruit yield per plant followed by ridges on fruit. In genetic variability for the present investigation, widest range was revealed for average fruit weight followed by plant height. The highest genetic advance was recorded for fruit yield per plant followed by ridges on fruit.

Positive and significant genotypic correlation coefficient of fruit yield per plant, average fruit weight followed by fruits per plant. In phenotypic level observed that fruit yield per plant had negative and significant correlation with fruit length. The highest positive direct and indirect effect towards yield per plant was showed by average fruit weight followed by fruits per plant, pericarp thickness, locules per fruit, flowers per cluster, fruit width, plant height and vitamin C, while, highest negative effect towards fruit yield per plant was showed by days to 50% flowering followed by number of branches per plant ,fruits per cluster , fruit length , clusters per plant, ridges on fruit and TSS.

## CONCLUSION

It is briefly concluded from the present investigation the best hybrids for flowers per cluster and fruits per cluster can be obtained from the cross combinations FLA 7171 x Pusa Sadabahar. The maximum plant height was found in the cross combination H-86 x Pusa Sadabahar and fruits per plant were found maximum in the cross combination IIVR-Sel.-1 x Kashi Amrit. The maximum fruit weight were found in the cross combination H-88 x Kashi Vishesh. The minimum Days to 50% flowering was found in the cross combination H-24 x Kashi Amrit .The minimum pericarp thickness was found in the cross combination IIVR-Sel. 1 x Kashi Vishesh. The highest TSS and Vitamin C were found in in the cross combination FLA 7171 x Kashi Vishesh and Pusa Sheetal x Kashi Vishesh.

## Chapter VII

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# Appendix

## MECHANICAL AND CHEMICAL ANALYSIS OF SOIL

Before sowing soil sample were drawn out by random method from different places in the field and a composite sample was prepared and subjected to mechanical and chemical analysis the samples were sieved with 0.55 mm sieves. The mechanical, chemical and physical analysis of soils is given as under:

### Analysis of the soil (Experimental field)

| Constituents | Values(%) |
|---|---|
| Sand | 58.21 |
| Silt | 21.26 |
| Clay | 20.53 |

### Chemical Analysis

| Constituents | | Method |
|---|---|---|
| Total $N_2$% | 0.0380 | Kjeldhal Method |
| Available $P_2O_5$ kg/ha | 18.60 | Olsen Method |
| Available $K_2O$ | 238.00 | Morgan Method |
| Organic Carbon | 0.64 | Black Method |

### Physical Characters

| Items | Values (%) |
|---|---|
| pH | 7.60 |
| EC | 0.30 |
| Bulk Density | 1.48 |
| Particle Density | 2.56 |
| Pore Space | 41.88 |
| Permeability | 5.06 |
| M.E. | 21.20 |

# Appendix-1: Analysis of variance for the 16 characters of tomato

| S. No | Source of variation | D. F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Plant height (cm)** | **Branches per plant** | **Days to 50% flowering** | **Clusters per plant** | **Flowers per cluster** | **Fruits per cluster** | **Fruits per plant** | **Average fruit weight (g)** | **Locules per fruit** | **Pericarp thickness (mm)** | **Fruit length (cm)** | **Fruit width (cm)** | **Ridges on fruit** | **Fruit yield per plant (kg)** | **TSS (°BRIX)** | **Vit. C (Mg/100g)** |
| **1.** | Replication | 2 | 1.03 | 0.04 | 1.65 | 0.04 | 0.14 | 0.10 | 1.56 | 9.66 | 0.08 | 0.09 | 0.12 | 0.01 | 0.00 | 0.01 | 0.09 | 5.62* |
| **2.** | Parents | 14 | 25.80 | 1.07** | 2.68** | 1.02** | 2.08** | 1.29** | 16.75** | 131.26** | 0.64** | 0.62** | 0.32** | 0.26** | 0.45** | 0.21** | 0.48** | 2.00 |
| **3.** | Female | 11 | 27.65 | 1.11** | 2.81** | 1.24** | 1.68** | 1.23** | 15.23** | 161.97** | 0.65** | 0.51** | 0.37** | 0.31** | 0.45** | 0.23** | 0.44** | 1.58 |
| **4.** | Male | 2 | 26.48 | 0.60* | 3.17* | 0.31 | 3.60** | 0.80** | 10.42 | 8.11 | 0.65** | 0.88** | 0.21* | 0.06 | 0.63** | 0.08** | 0.23* | 5.00* |
| **5.** | Female vs. male | 1 | 4.00 | 1.58** | 0.25 | 0.03 | 3.47** | 2.94** | 46.22** | 39.72 | 0.49* | 1.35** | 0.01 | 0.13 | 0.07* | 0.26** | 1.47** | 0.56 |
| **6.** | Hybrids | 35 | 11.57 | 0.61 | 2.94** | 0.39** | 0.42** | 0.59** | 29.71** | 56.55** | 0.25** | 0.38** | 0.28** | 0.25** | 0.14** | 0.12** | 0.26** | 4.22** |
| **7.** | Parents vs. hybrids | 1 | 31.82 | 0.07 | 16.12** | 5.93** | 91.20** | 18.33** | 34.26** | 529.29** | 1.41** | 4.17** | 3.09** | 10.78** | 1.25** | 0.00 | 3.74** | 1.84 |
| **8.** | Error | 100 | 1.74 | 0.18 | 0.91 | 0.16 | 0.21 | 0.11 | 3.69 | 16.63 | 0.11 | 0.05 | 0.07 | 0.08 | 0.02 | 0.01 | 0.06 | 1.53 |

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

# Appendix-2: Analysis of variance for the 16 characters of combining ability

| S. No | Source of variation | D. F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| **1.** | Replication | 2 | 1.11 | 0.04 | 0.72 | 0.03 | 0.08 | 0.05 | 4.70 | 2.66 | 0.07 | 0.07 | 0.06 | 0.01 | 0.00 | 0.00 | 0.07 | 2.28 |
| **2.** | Lines | 11 | 27.15** | 0.75 | 3.54 | 0.37 | 0.34 | 0.91 | 64.27** | 56.60 | 0.26 | 0.27 | 0.13 | 0.12 | 0.14 | 0.09 | 0.28 | 8.85** |
| **3.** | Testers | 2 | 4.38 | 0.07 | 2.09 | 0.26 | 0.63 | 0.08 | 3.35 | 7.35 | 0.34 | 0.16 | 0.01 | 0.17 | 0.02 | 0.07 | 0.13 | 6.30* |
| **4.** | Lines x testers | 22 | 4.43** | 0.59** | 2.71** | 0.41** | 0.44** | 0.47** | 14.83** | 61.00** | 0.23** | 0.46** | 0.38** | 0.32** | 0.16** | 0.14** | 0.27** | 1.71 |
| **5.** | Errors | 70 | 1.72 | 0.18 | 0.90 | 0.16 | 0.19 | 0.09 | 3.69 | 9.67 | 0.11 | 0.04 | 0.06 | 0.09 | 0.02 | 0.01 | 0.07 | 1.75 |

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

## Appendix-3: Analysis of variance for the 15 parents of tomato

| S. No | Source of variation | D. F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| 1. | Replication | 2 | 0.39 | 0.12 | 1.23 | 0.09 | 0.35 | 0.35 | 0.72 | 0.30 | 0.36 | 1.12 | 0.97 | 0.04 | 0.50 | 1.82 | 0.25 | 6.81 |
| 2. | Treatments | 14 | 13.99** | 5.97** | 2.73* | 6.13** | 8.28** | 6.74** | 7.20** | 3.75** | 5.57** | 7.29** | 2.38** | 3.42** | 22.21** | 25.39** | 8.82** | 2.24* |
| 3. | Errors | 28 | 1.84 | 0.18 | 0.98 | 0.17 | 0.25 | 0.19 | 2.33 | 34.99 | 0.11 | 0.09 | 0.13 | 0.08 | 0.02 | 0.01 | 0.05 | 0.89 |

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

## Appendix-4: Analysis of variance for the 36 F1 hybrids of tomato

| S. No | Source of variation | D.F. | Characters | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plant height (cm) | Branches per plant | Days to 50% flowering | Clusters per plant | Flowers per cluster | Fruits per cluster | Fruits per plant | Average fruit weight (g) | Locules per fruit | Pericarp thickness (mm) | Fruit length (cm) | Fruit width (cm) | Ridges on fruit | Fruit yield per plant (kg) | TSS (°Brix) | Vit. C (Mg/100g) |
| 1. | Replication | 2 | 1.11 | 0.04 | 0.72 | 0.03 | 0.08 | 0.05 | 4.70 | 2.66 | 0.07 | 0.07 | 0.06 | 0.01 | 0.00 | 0.00 | 0.07 | 2.28 |
| 2. | Treatments | 35 | 11.57** | 0.61** | 2.94** | 0.39** | 0.42** | 0.59** | 29.71** | 56.55** | 0.25** | 0.38** | 0.28** | 0.25** | 0.14** | 0.12** | 0.26** | 4.22** |
| 3. | Errors | 70 | 1.72 | 0.18 | 0.90 | 0.16 | 0.19 | 0.09 | 3.69 | 9.67 | 0.11 | 0.04 | 0.06 | 0.09 | 0.02 | 0.01 | 0.07 | 1.75 |

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