# GENETIC EVALUATION STUDIES IN TOMATO (*Solanum lycopersicum* L.)

*Thesis*

**by**

**SUMIT B PATIL**
**(H-2015-110-M)**

**Submitted to**

**Dr. YASHWANT SINGH PARMAR UNIVERSITY**
**OF HORTICULTURE AND FORESTRY**
**SOLAN (NAUNI) HP - 173 230 INDIA**

**in**

**Partial fulfilment of the requirements for the degree**

**of**

**MASTER OF SCIENCE**
**(HORTICULTURE)**
**VEGETABLE SCIENCE**
**DEPARTMENT OF VEGETABLE SCIENCE**
**COLLEGE OF HORTICULTURE**

**2017**

**Dr Santosh Kumari**
**(Scientist)**

**Department of Vegetable Science,**
**College of Horticulture,**
**Dr YS Parmar University of Horticulture and Forestry**
**(Nauni) Solan (HP) - 173 230 India**

# CERTIFICATE-I

This is to certify that the thesis titled **"Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)"** submitted in partial fulfilment of the requirements for the award of degree of Master of Science (Horticulture) in the discipline of **Vegetable Science** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 is a bonafide research work carried out by **Mr Sumit B Patil** son of Sh. Basavaraj Patil under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

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

**Place: Nauni, Solan**
**Dated:**

**(Dr Santosh Kumari)**
**Major Advisor**

# CERTIFICATE-II

This is to certify that the thesis titled **"Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)"**, submitted by **Mr Sumit B Patil (H-2015-110-M)** son of Mr Basavaraj Patil to the Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP) - 173 230 India in partial fulfilment of the requirements for the degree of Master of Science (Horticulture) in the discipline of **Vegetable Science** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

**Dr Santosh Kumari**
**(Scientist)**
**Major Advisor**

**Dr R K Dhall**
**(Olericulturist)**
**PAU, Ludhiana**
**External Examiner**

**Dr D P Sharma**
**(Principal Scientist)**
**(Dean's Nominee)**

## Advisory Committee

**Dr H R Sharma**
**(Principal Scientist)**

**Dr R K Dogra**
**(Assistant Professor)**

**Professor and Head**
**Department of Vegetable Science**

**Countersigned**

**Dean**
**College of Horticulture**

# ACKNOWLEDGEMENTS

First and foremost I express my deepest and sincerest gratitude to the omniscient, omnipresent and omnipotent god who enabled me to pursue education in Horticulture discipline and to complete this thesis for the degree of Master of Science in Horticulture (Vegetable Science).

My way in this world paves through the path carved by my grandfather **Mr. Paris Patil** and grandmother **Mrs. Padmavati Patil** whom I wish to idolize throughout my life. No words in this mortal world can suffice to express my feelings towards my beloved parents **Mr. Basavaraj Patil** and **Mrs. Bharati Patil**. My words are inadequate to express my deepest sense of gratitude and profound indebtedness to my brother **Mr. Sanat**. It is my pleasure to thank my whole **Patil** family. First and foremost I express my deepest and sincerest gratitude to the omniscient, omnipresent and omnipotent god who enabled me to pursue education in Horticulture discipline and to complete this thesis for the degree of Master of Science in Horticulture (Vegetable Science).

I would like to put on record of my heartfelt sincere gratitude to chairman of my advisory committee **Dr. Santosh Kumari**, **Scientist**, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan Dist, Himachal Pradesh for her inspiring guidance, constant, everlasting patience, encouragement, intellectual suggestions and disciplined instructions, fueled my efforts to achieve the endeavour. I acknowledge this figure with deep sense of gratitude and I consider myself most fortunate to have worked under her guidance.

With respectful regards and privilege to **Dr. H R Sharma**, Principal Scientist, Department of Vegetable Science, for his invaluable guidance and critical suggestion in my research work. I equally extend my sincere thanks to the revered member of my advisory committee **Dr. R K Dogra**, Assistant Professor (Fruit Science), for giving encouragement and valuable suggestions during my research work.

I gratefully acknowledge **Dr. H S Kanwar** Professor and Head (Vegetable science) and **all the teaching staff** of Vegetable Department, Dr. YS Parmar University of Horticulture and Forestry, Nauni for their guidance. Dr. H D Sharma, Dr.A K Sharma, Dr.Y R Shukla, Dr.D K Mehta, Dr. Ramesh Kumar, Dr. K S Thakur, Dr.S Kansal, Dr. Meenu Gupta, Dr. Seema Thakur and Dr. Amit Vikram, and other supporting staff, Dr. YS Parmar UHF, Nauni, Solan for their timely help during the course of investigation for extending all possible help whenever I approached them and for their kind co-operation and valuable suggestions.

I am also grateful and I thank all my seniors Dr. Adarsh, Dr. Shivaputra, Dr. Omkar, Dr. Rohit, Mr. Azim and Mr. Deepesh and who assisted me during this study and friends for their constant encouragement all these days. I strongly be holding to all my affectionate friends, to mention a few Classmates Shubhrajothi, Manisha, Arushi, Shivendar, Atal sir, Raveena, Kajal, and Pradeep (Solan). I also express my cordial thanks to some of my Karnataka friends Sagar, Omkar, Shridhar, Sujay, Manohar, Manasa, Pooja, Chaitra, Ashwin, and Vinay.

This thesis of mine is dedicated to my parents. They had been a source of great inspiration for me. I feel highly privileged when I award them with the epithet of peerless asset, who revitalized my dream to live and theme to struggle with an eternal touch of dedication.

*"Grattitude can transform common days into thanksgivings, turn routine jobs into joy, and change ordinary opportunities into blessings".*

**Place: Nauni, Solan**
**Date: , 2017** **(Sumit B Patil)**

# CONTENTS

# LIST OF TABLES



# LIST OF PLATES

# LIST OF ABBREVIATIONS USED

| Abbreviation | Meaning |
|---|---|
| % | Per cent |
| (L.) | Linnaeus |
| / | Per |
| ± | Plus or minus |
| $^0$C | Degree Celsius |
| CD | Critical difference |
| Df | Degree of freedom |
| *et al.* | et alia (and others) |
| etc. | et cetera (and rest) |
| FAO | Food and Agriculture Organization of the United Nations |
| g | Gram |
| HP | Himachal Pradesh |
| *i.e.* | Id Est (that is) |
| MT | Metric tones |
| NHB | National horticulture board |
| P | Pages |
| Pp | Particular page |
| RH | Relative humidity |
| var. | Variety |
| *viz.* | Vide licet (namely) |
| w.r.t. | with respect to |

# Chapter 1

# Introduction

## *Chapter-1*

# INTRODUCTION

Tomato is an important vegetable crop grown throughout the world. It is grown in tropical, subtropical and mild cold climatic regions of the world. Tomato is grown for its edible fruit, which is consumed either fresh or cooked and in the form of various processed products like juice, ketch up, sauce, puree, chutney, pickles and soup etc. Tomato being a nutritional crop, is considered as an important source of vitamin A, C and minerals like calcium, phosphorus and magnesium etc. Tomatoes are major contributors of antioxidants such as carotenoids especially, lycopene and β-carotene, phenolics, ascorbic acid with small amounts of vitamin E in daily diets.

In India, tomato is cultivated in different states like Uttar Pradesh, Karnataka, Himachal Pradesh, Maharashtra, Haryana, Punjab and Bihar. In India, it is grown over an area of 791 thousand hectares with an annual production of 17,398 thousand tonnes (NHB, 2015). In Himachal Pradesh, tomato is grown during summer and rainy seasons, as the climatic conditions are congenial for optimum plant growth and yield. Total area under this crop in the state is 10.3 thousand hectares with annual production of 430.79 thousand tonnes (NHB, 2015).

Tomato is most remunerative cash crop of the low and mid hills of Himachal Pradesh, where it is grown for off season vegetable produce and further supply to the markets in neighbouring states. Generally, indeterminate varieties are considered most suitable for growing the crop for commercial markets. Longer harvesting period and off season production of tomato make this crop more suitable for cultivation in mid-hills conditions. In North Indian plains, due to high temperature and rains, the crop is not grown during rainy seasons, thereby giving an opportunity for vegetable growers of Himachal Pradesh to fetch off season prices and good returns. Tomato plays an important role in the economic upliftment of the farmers of hilly areas in form of off season crop in state.

In Himachal Pradesh, growing period of crop coincides with monsoon rains which invites many diseases, insects and pests and ultimately yield is reduced. Productivity of tomato in the region is less because of non-availability of high yielding, disease and insect pest resistant cultivars. Being an important vegetable crop in the state, there is a need to develop tomato varieties suitable to agro-ecological conditions and also for specific end use.

The genetic improvement depends upon the nature and magnitude of variability present in the base population. Wider the genetic variability in the qualitative and quantitative traits, better would be the chances of crop improvement through selection. This vegetable has been under improvement through breeding for desired traits such as faster growth, uniform maturity with higher yields, early maturing varieties, biotic and abiotic stresses. A thorough knowledge regarding the amount of genetic variability existing for various characters in the germplasm is essential. Large number of genotypes should be studied to identify the promising ones. Correlation studies are of great significance as, if significant correlation values are established between yield and other economic traits, improvement could be made through selective plant breeding technique. Path analysis provides important information regarding direct and indirect effects of the characters contributing towards the yield of the plants.

Thus, the performance of thirty five different tomato genotypes collected from different sources were studied under mid hills conditions with the following objectives:

1) To study genetic variability in the germplasm
2) To workout association among yield and horticultural characters

# Chapter 2

# Review of Literature

## *Chapter-2*

# REVIEW OF LITERATURE

The literature available on the present investigation **"Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)"** has been reviewed under the following sub heads:

**2.1 Genetic variability studies**

**2.2 Correlation studies**

**2.3 Path coefficient analysis**

## 2.1 Genetic variability studies

Mittal *et al*. (1996) found high magnitude of genotypic and phenotypic coefficients of variation for number of fruits per plant, marketable yield per plant, number of locules per fruit, average fruit weight, plant height, fruit shape index, pericarp thickness, total soluble solids and days to 50 percent flowering and was lowest for days to first picking.

Singh *et al*. (1997) studied genetic variability in twenty three genotypes of tomato and observed that phenotypic variation was quite large but genotypic variation was low. The phenotypic and genotypic coefficients of variation indicated that selection may be done for fruit weight, number of fruits per plant, number of locules per fruit and fruit yield per hectare. Heritability and genetic advance values showed that effective selection may be made for fruit weight and number of fruits per plant.

Das *et al.* (1998) evaluated twenty three diverse genotypes of tomato for various fruit characters and observed that fruit yield per plant, fruits per plant, fruit weight, fruit diameter, fruit length and locules per fruit had high estimates of genotypic coefficients of variation, heritability and high expected genetic gain, indicating the scope for their improvement through selection.

Kumar and Tewari (1999) evaluated thirty two tomato genotypes of tomato for different processing characters and observed that the genotypic coefficient of variation was higher for all characters except specific gravity and total soluble solids. The characters showing high heritability in the broad sense were yield and ascorbic acid content. Highest genetic advance was observed for juice viscosity.

Brar *et al.* (2000) studied genetic variability in 186 genotypes of tomato and reported high degree of variation for all the characters studied viz., number of fruits per plant, total number of fruits per plant, number of marketable fruits per plant, total yield per plant and marketable yield per plant. The number of fruits per plant, total number of fruits per plant and marketable yield per plant had low or moderate estimates of phenotypic and genotypic coefficients of variation, heritability and genetic advance, hence they will not respond to selection.

Singh *et al.* (2002) studied the variation among 92 tomato genotypes with regard to 13 characters and reported high phenotypic and genotypic coefficients of variation for average fruit weight, shelf life of ripe red fruits, total yield, marketable yield and moderate for days from fruit setting to mature green stage. In all traits, genotypic coefficient of variation was lower than phenotypic coefficient of variation, indicating the role of environment in the expression of these characters. Heritability was high for all characters except days from fruit setting to red ripe stage. The highest genetic advance was predicted for average fruit weight, followed by shelf life of red ripe fruits.

Mariame *et al.* (2003) studied genetic variability in tomato for fruit yield and other yield contributing characters and reported significant genotypic variation among the genotypes. High heritability estimates coupled with high genetic advance as percent of mean were observed for plant height, number of nodes on main stem, number of flowers per cluster, number of fruits per plant and number seeds per fruit.

Joshi *et al.* (2004) conducted an experiment on genetic variability in tomato and found the high phenotypic and genotypic coefficient of variation for shelf life of fruits. Moderate heritability and moderate genetic gain was observed for number of fruits per cluster, fruit length, fruit breadth, stem end scar size, number of locules per fruit, whole fruit firmness, ascorbic acid content and plant height indicating additive gene effects. Low heritability and low genetic gain was observed for pericarp thickness. Moderate heritability and low genetic gain for harvest duration indicated the presence of dominance and epistatic effects. High heritability combined with high genetic gain was observed for shelf life indicating additive gene action

Manivannan *et al*. (2005) reported high phenotypic and genotypic coefficient of variation for number of fruits per plant, fruit weight and fruit yield in tomato.

Ahmed *et al*. (2006) studied genetic variability, heritability and genetic advance for fourteen traits in sixty genotypes of tomato and indicated considerable genetic variability for yield and yield components. High phenotypic and genotypic variances were observed for yield per plant, plant height, average fruit weight, number of fruits per plant, juice to pulp ratio and average fruit weight. High estimates of heritability were recorded for all characters except fruit pH. High heritability with high genetic advance as percent of mean was observed for juice to pulp ratio, yield per plant, average fruit weight, acidity, number of fruits per plant, fruit length, pericarp thickness, plant height and earliness.

Haydar *et al*. (2007) reported high genotypic and phenotypic coefficient of variation for plant height at flowering, number of flowers in three clusters per plant, number of fruits in three cluster per plant, total number of fruits at harvesting period and weight of fruits per plant. High genetic advance as percentage of mean was exhibited for fruit weight per plant followed by number of fruits in three clusters per plant and number of flowers in three clusters per plant.

Kumari *et al.* (2007) conducted an experiment on genetic variability and heritability in tomato and observed high heritability for all the characters like total soluble solids, dry matter content, reducing sugar, titratable acidity, ascorbic acid, lycopene content, days to flowering, days to maturity, number of fruits per bunch, weight per fruit, fruit length, fruit width, number of fruit bearing branches, total number of fruits per plant, plant height, early yield and total yield in tomato.

Asati *et al.* (2008) studied genetic variability in sixteen genotypes of tomato for yield and quality traits. Results revealed that plant height, number of primary branches, number of fruits per plant, fruit diameter, fruit weight, pericarp thickness, number of locules per fruit, number of seeds per fruit, ascorbic acid and yield per plant showed high genotypic coefficient of variation and high heritability along with high genetic advance.

Ara *et al*. (2009) observed significant differences among thirty five genotypes of tomato for growth, yield and quality attributes. The high heritability estimates associated with greater value of genetic gain were observed for juice-pulp ratio, fruit yield per plant, number of primary branches per plant, number of fruits per plant, average fruit weight and titratable acidity.

Ghosh *et al*. (2010) observed very little differences between phenotypic coefficient of variation and genotypic coefficient of variation for days to first flowering, fruit length and fruit diameter. High heritability was observed for all the yield contributing characters except flowers per cluster. High heritability associated with high genetic advance was found for fruit cluster per plant, fruits per plant, fruits per cluster, individual fruit weight and fruit yield per plant.

Sharma *et al.* (2010) observed high genotypic and phenotypic coefficient of variation for average fruit weight followed by number of fruits per plant, fruit yield, number of locules per plant, plant height, pericarp thickness and number of branches per plant, while it was moderate for days to 50% flowering. High heritability coupled with high genetic gain were observed for average fruit weight, number of fruits per plant, fruit yield, plant height, number of locules per fruit, pericarp thickness and number of branches per plant, however days to 50% flowering had high heritability and moderate genetic gain.

Dar and Sharma (2011) reported high values of phenotypic coefficient of variation for yield per hectare, average fruit weight and number of fruits per plant. High heritability was recorded for β-carotene, ascorbic acid and lycopene content.

Kaushik *et al*. (2011) reported that magnitude of genotypic and phenotypic coefficient of variation was higher for number of leaves per plant, fruit length and fruit yield. High values of heritability coupled with high genetic advance were observed for number of leaves at 60 days after transplanting and fruit yield.

Rani and Anita (2011) evaluated eighteen genotypes of tomato for yield and various yield attributing characters and observed that phenotypic coefficient of variation was higher than genotypic coefficient of variation for all traits depicting the influence of environmental effect. Phenotypic coefficient of variation estimates were high for average fruit weight, number of fruits per plant and yield per plant. Heritability estimates were high for average fruit weight, plant height, number of branches per plant and number of fruits per plant.

Ayush *et al*. (2012) observed significant differences among diverse tomato genotypes for yield and yield contributing characters. The phenotypic and genotypic coefficients of variation were highest for number of fruits per plant whereas, the lowest values were for harvest index. High heritability coupled with high genetic advance as percent over mean were observed for number of primary branches per plant, number of fruits per plant, number of fruits per cluster, average fruit weight and fruit yield per plant.

Khan and Samadia (2012) observed that genotypic and phenotypic coefficient of variation were high for fruit weight, number of fruits per plant, plant height and fruit yield per plant. High heritability with high genetic advance as percentage of mean were observed for yield per plant, average fruit weight, number of fruits per plant and plant height indicating the role of additive gene effects and effectiveness of selecting for these traits.

Rahaman *et al*. (2012) evaluated thirty four genotypes of tomato and found that the estimates of phenotypic and genotypic coefficient of variation were high for fruit weight followed by fruit length and lowest for number of flowers per cluster and total acid. High heritability coupled with high genetic advance expressed in percentage of mean was observed for primary and secondary branches, plant height, fruits per plant, fruit length, fruit diameter and fruit weight indicating that these traits were mainly governed by additive gene effect and responsive for further improvement of these traits.

Ahirwar and Prashad (2013) reported significant differences among the genotypes for all the traits and it was found that the phenotypic coefficient of variation was higher than genotypic coefficient of variation for traits like plant height 120 days after transplanting, number of branches 120 days after transplanting, days to flower anthesis, number of fruits per plant, average fruit weight, number of cluster per plant, fruit set, radial diameter, polar diameter, ascorbic acid, total soluble solids, plant height after 120 days after transplanting and days to 50% flowering.

Patel *et al*. (2013) observed high genotypic and phenotypic coefficient of variation for fruit yield per plant. Low genotypic and phenotypic coefficient of variation was noticed for days to first harvest and days to 50% flowering. High heritability and high genetic advance as percent of mean was observed for fruit yield per plant and average fruit weight.

Kumari and Sharma (2013) revealed that phenotypic coefficient of variation was higher than genotypic coefficient for all the traits and high genotypic and phenotypic coefficients of variability were recorded for number of fruits per plant, average fruit weight, fruit yield per plant, number of seeds per fruit and plant height.

Khapte and Jansirani (2014) revealed high heritability for plant height, number of flowers per truss, number of flower trusses per plant, fruit length, fruit diameter, fruit shape index, pericarp thickness, total soluble solids, average fruit weight, fruit firmness, number of fruits per plant and yield per plant.

Singh *et al*. (2014) revealed that genotypic as well as phenotypic coefficient of variation were high for number of cluster per plant, number of flowers per plant, fruit weight per cluster and number of fruits per plant.

Meena and Bahadur (2015) revealed that the magnitude of phenotypic coefficient of variation was higher than genotypic coefficient of variation for all traits under study. The leaf curl incidence and ascorbic acid recorded high genotypic and phenotypic coefficient of variation, indicating higher magnitude of variability for these characters.

Singh *et al.* (2015) reported high amount of genotypic coefficient of variation and phenotypic coefficient of variation for traits like fruit yield per plant, average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant and low for days to 50 percent flowering.

Singh *et al.* (2017) revealed high magnitude of phenotypic as well as genotypic coefficients of variation for fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant. High heritability coupled with high genetic advance were estimated for fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant.

## 2.2 Correlation studies

Barman *et al*. (1996) carried out studies on association among quantitative characters of twenty nine genotypes of tomato and reported positive and significant correlation of number of branches and plant height, days to 50% fruiting and 50% flowering, width and length of fruit, number of locules and number of seeds, number of fruits per plant and number of fruits per branch and yield and length of fruit.

Yadav and Singh (1998) studied phenotypic and genotypic correlation of twelve yield components in twenty eight genotypes of tomato. In general, genotypic correlations were higher than phenotypic ones. Positive correlations of fruits per plant, fruit weight, number of locules and juice percentage with yield were recorded.

Prasad and Rai (1999) worked out component association for nine characters in seventy five exotic genotypes of tomato belonging to both determinate and indeterminate groups. They observed very high and significant positive correlation coefficients between plot yield and fruit weight, fruit length and fruit breadth, number of locules and pulp thickness.

Dhankar *et al.* (2001) carried out studies on correlation in different genotypes of tomato and reported that fruit yield was positively correlated with number of fruits per plant, number of fruits per cluster, percent fruit set and pollen viability and negatively correlated with electrical conductivity (cell membrane injury) and flower drop.

Cuong (2002) found a positive and significant association between number of fruits per cluster and number of fruits per plant.

Harer *et al.* (2002) reported that the number of fruits per cluster and per plant was significantly and positively correlated with fruit yield per plant, whereas the number of branches per plant, fruit weight and ascorbic acid content had negative association with fruit yield in tomato.

Kumar *et al*. (2003) assessed thirty diverse tomato genotypes and revealed that correlation coefficients at the genotypic level were generally higher than the corresponding phenotypic ones. Yield per plant was positively and significantly associated with plant height, fruit number per plant, fruit shape index and pericarp thickness.

Joshi *et al*. (2004) evaluated thirty seven genotypes of tomato and reported that yield per plant was positively and significantly correlated with average fruit weight, fruit length, plant height and harvest duration. The average fruit weight was positively correlated with fruit length, fruit breadth, stem end scar size, pericarp thickness, whole fruit firmness and shelf life of fruits. However, fruit weight was negatively correlated with number of fruits per plant, number of fruits per cluster and ascorbic acid content.

Kant and Mani (2004) studied correlation in nineteen genotypes of tomato and observed that yield had significant and positive correlation with fruits per plant, number of primary branches, plant height and fruits per bunch.

Joshi and Kohli (2005) in their correlation studies revealed that shelf life of tomato fruits was positively and significantly associated with average fruit weight, pericarp thickness, whole fruit firmness and stem-end scar size, but it was negatively and significantly correlated with number of locules per fruit.

Makesh *et al.* (2006) found that yield per plant was positively and significantly correlated with number of fruits per plant, plant height, number of laterals per plant and fruits per cluster and was negatively correlated with number of locules per fruit and flesh thickness in tomato.

Golani *et al.* (2007) reported that the phenotypic and genotypic associations of fruit yield were significant and positive with 10-fruit weight, total soluble solids (at genotypic level) and number of locules per fruit and significant and negative with plant height. However, ten fruit weight had significant and positive correlation with fruit length, fruit girth and number of locules per fruit at both levels.

Hidayatullah *et al.* (2008) reported that fruit weight showed high and positive genotypic and phenotypic correlation with number of pickings and with number of fruits, thus indicating that these traits were the most important yield components.

Mehta and Asati (2008) revealed that fruit yield was positively associated with days to 50% flowering and days to 50% fruiting.

Prashanth *et al.* (2008) indicated the inverse relationship between growth and earliness characters but strong association between growth and yield characters. Total yield per plant was positively and significantly associated with early fruit yield per plant, equatorial diameter of the fruit, fruit volume, average fruit weight, polar diameter of the fruit, number of fruits per plant, percent fruit set, stem girth at 90 days after transplanting, number of locules per fruit, plant height at 60 days after transplanting, pericarp thickness and number of seeds per fruit.

Ara *et al.* (2009) in their correlation studies revealed that the fruit yield per plant exhibited high positive significant correlation with fruit size, plant height, number of fruits per plant and number of primary branches per plant at both phenotypic as well as genotypic levels.

Ghosh *et al.* (2010) observed significant positive genotypic and phenotypic correlation between fruit yield and plant height at first flowering, flowers per plant, fruits per cluster, fruit clusters per plant and fruits per plant.

Rani *et al.* (2010) observed that fruit weight, pericarp thickness, acidity, ascorbic acid and lycopene were positively associated with yield per plant, while number of fruits per plant was negatively associated.

Kumar and Dudi (2011) in their study on correlation analysis revealed that total fruit yield per plant was significantly and positively correlated with number of fruits per plant, fruit weight and total sugar.

Buckseth *et al.* (2012) observed that fruit yield per plant had a highly significant positive correlation with pericarp thickness, shelf life, TSS and fruit shape index. Number of fruits per plant were positively and significantly correlated with yield per plant, while negatively and significantly correlated with average fruit weight.

Khan and Samadia (2012) in their correlation studies revealed that fruit yield had significant positive correlation with fruit weight, fruit length, fruit diameter and number of fruits per plant, both at the genotypic and phenotypic levels, indicating mutual association of these traits. Negative correlation of days to flowering and days to first harvest on yield per plant suggested indirect selection for earliness for yield improvement.

Sharma and Singh (2012) reported that fruit yield was significantly and positively correlated with fruit weight per plant followed by days to 50 percent flowering and non-significantly but positively correlated with average fruit weight and seed yield per plant.

Shashikant *et al.* (2012) revealed that fruit yield had a positive and highly significant association with number of fruits per plant and number of branches per plant. Strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield.

Ahirwar and Prashad (2013) carried out studies on correlation among nineteen genotypes of tomato and observed that traits like plant height 120 DAT, number of branches 120 DAT, days to flower, number of fruits per plant, average fruit weight, number of cluster per plant, fruit set, radial and polar diameter, ascorbic acid and TSS showed positive correlation with fruit yield per hectare. Plant height after 120 DAT, days to 50% flowering, leaf curl incidence and intensity showed negative correlation at both phenotypic and genotypic levels.

Srivastava *et al*. (2013) reported that yield per plant was highly significant and positively correlated with days to 50% flowering, days to 50% fruiting, plant height, number of primary branches per plant, number of fruits per cluster, number of fruits per plant and average fruit weight, which indicated that yield could be increased by improving these traits.

Sherpa *et al.* (2014) found that the genotypic correlations were higher than phenotypic correlations in most of the characters. Out of fifteen yield component characters studied, three characters viz., number of fruits per cluster, number of fruits per plant and fruit weight exhibited significant positive correlation with fruit yield per plant at genotypic and phenotypic levels.

Meena and Bahadur (2015) observed that fruit yield was significantly and positively correlated with number of flowers per plant, number of fruits per plant and fruit weight at genotypic and phenotypic levels. Strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield.

Prajapati *et al.* (2015) reported that fruit yield had positive and significant correlation with average fruit weight, number of secondary branches per plant, days to fruit maturity, plant height, total soluble solids, days to 50% flowering and days to 50% fruit setting.

## 2.3 Path coefficient analysis

Singh (1999) evaluated forty two tomato lines for yield components and observed that plant height exerted maximum positive direct effect on yield.

Verma and Sarnaik (2000) observed that total number of fruits per plant, average weight of fruit, thousand seed weight and number of branches per plant exhibited positive as well as high direct effects on yield.

Harer *et al.* (2002) reported that number of fruits per cluster, average fruit weight and number of fruits per plant had maximum positive direct effect on fruit yield. The total soluble solids content had positive but low direct effect on yield, whereas ascorbic acid content had negative direct effect on fruit yield.

Kumar *et al.* (2003) revealed that the number of fruits per cluster, average fruit weight and number of fruits per plant had maximum direct effects on fruit yield in tomato.

Joshi *et al*. (2004) in their path coefficient analysis revealed that the number of fruits per plant is the most important yield contributing trait followed by fruit length, fruit breadth and plant height in tomato.

Makesh *et al.* (2006) in their path coefficient analysis revealed that the number of fruits per plant followed by plant height and total soluble solids exhibited positive direct effect on yield. Path analysis indicated that the number of fruits per plant, total soluble solids and acidity had positive direct influence on yield, while the number of laterals per plant, number of fruits per cluster and flesh thickness had negative direct effect on yield.

Golani *et al*. (2007) reported that fruit weight had highest positive direct effect followed by number of locules per fruit on fruit yield.

Ramana *et al*. (2007) observed that fruit weight had highest direct and positive effects on fruit yield per plant, followed by total soluble solid content, number of fruiting clusters per plant, number of branches per plant, titratable acidity, plant height and number of days to 50% flowering.

Hidayatullah *et al.* (2008) reported that fruit diameter exhibited the highest direct effect and could be the selection criteria for improving fruit yield per plant.

Mehata and Asati (2008) revealed that plant height, weight of fruit per plant, days to first fruiting and days to 50% fruiting were the major yield contributing traits in tomato.

Prashant *et al*. (2008) observed that early yield and average fruit weight had maximum direct positive effects on total yield in tomato. Hence, direct selection for early yield and average fruit weight is suggested for yield improvement.

Ara *et al*. (2009) reported that days to first picking had the highest positive direct effect on fruit yield followed by harvest duration, number of fruits per plant, average fruit weight, plant height and number of flowers per cluster.

Ghosh *et al.* (2010) reported that fruits per plant showed the highest positive direct effect on fruit yield per plant.

Kumar (2010) revealed that marketable fruits per plant had maximum direct effect on marketable yield per plant followed by average fruit weight and pericarp thickness.

Dar *et al*. (2011) reported that fruit yield per plant had highest positive direct effect on yield per hectare, followed by average fruit weight, number of fruits per plant, lycopene content per fruit and ascorbic acid.

Kumar and Dudi (2011) reported that highest positive direct effect was exerted by number of fruits per plant, towards fruit yield in tomato.

Tiwari and Uphadhyay (2011) reported that fruit weight influenced the fruit yield per plant with high direct effect and therefore, may be included in selection criteria for improvement in fruit yield per plant.

Buckseth *et al*. (2012) reported that shelf life had maximum direct effect followed by average fruit weight and number of fruits per plant towards fruit yield. Among the negative direct effects, pericarp thickness showed highest negative effect on yield per plant followed by fruit shape index.

Sharma and Singh (2012) studied that fruit weight per plant had maximum direct effect on fruit yield followed by number of fruits per plant and flower clusters per plant. Seed vigour index also had maximum direct effect on seed yield.

Shashikanth *et al*. (2012) revealed that number of flowers per cluster and number of branches per plant had the highest positive direct effect on fruit yield.

Kumar *et al*. (2013) observed that fruit weight had the positive direct effect on yield per plant followed by number of fruits per plant, fruit diameter and number of fruits per cluster. So, direct selection on the basis of these characters is reliable for yield improvement in tomato.

Reddy *et al*. (2013) reported that plant height, number of fruits per plant, fruit length, fruit width and ascorbic acid had high positive direct effects on fruit yield per plant.

Srivastava *et al*. (2013) observed that average fruit weight showed the highest positive direct effect on yield per plant followed by number of fruits per plant, day to 50% flowering, number of primary branches per plant and number of fruits per cluster. It indicated that direct selection for these traits might be effective and there is a possibility of improving yield per plant.

Sherpa *et al.* (2014) revealed that number of flower clusters per plant, number of fruits per cluster and fruit weight showed high positive direct effect on fruit yield per plant.

Meena and Bahadur (2015) reported high positive direct effect of fruit weight on fruit yield per plant followed by number of flowers per plant, fruit set per cent, number of fruits per plant, total soluble solids, plant height, radial diameter of fruit, leaf curl incidence per cent and days to 50% flowering

Prajapati *et al.* (2015) revealed that fruit weight recorded high estimate of positive direct effect on fruit yield followed by number of fruits per plant, number of fruiting clusters per plant, days to first flowering, days to fruit maturity, pericarp thickness, number of primary branches, number of flowers per cluster and fruit diameter and suggested that direct selection based on these traits will be effective for improvement in tomato.

Rahaman *et al*. (2015) revealed that number of fruits per cluster had the highest positive direct effect on fruit yield per plant in tomato.

# Chapter 3

# Materials & Methods

## *Chapter-3*

# MATERIALS AND METHODS

The present investigation entitled **"Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)"** was carried out at the experimental farm of the Department of Vegetable Science, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during Kharif season of 2016. The materials used and methods followed during the investigation have been discussed as under:

### 3.1 EXPERIMENTAL SITE

#### 3.1.1 Location

The Experimental Farm of the Department of Vegetable Science is located at an altitude of about 1270 m above mean sea level, lying between $30^0$51' N latitude and $77^0$ 11' E. It falls under the mid hill zone of Himachal Pradesh.

#### 3.1.2 Climate

Climate of the experimental area is generally sub-temperate and semi-humid characterized with mild summers and cool winters. Generally, May and June are the hottest months and December and January are the coldest ones. The annual precipitation ranges between 1100-1300 mm, most of which is received during the monsoon season (June-September). Mean temperature during the crop season varied from $13.5^0$ C to $29.4^0$ C, while the relative humidity varied from 45 to 83 per cent. Agrometeorological data pertaining to temperature, relative humidity and rain fall during the growing season has been tabulated in Appendix I

#### 3.1.3 Soil

The soil structure of the experimental farm is gravelly loam to gravelly clay loam with pH ranging from 6.85-7.04.

### 3.2 EXPERIMENTAL MATERIAL

Experimental material comprised of thirty five genotypes including one check Solan Lalima for conducting the present investigation. The genotypes along with their sources have been presented in table 3.1.

**Table 3.1: List of tomato genotypes used for present study along with their source**

| Genotype | Source | Genotype | Source |
|---|---|---|---|
| BCT-2 | BCKV, West Bengal | EC-36293 | IIVR, Varanasi |
| BCT-4 | BCKV, West Bengal | EC-433607 | IIVR, Varanasi |
| BCT-5 | BCKV, West Bengal | EC-524082 | IIVR, Varanasi |
| BCT-8 | BCKV, West Bengal | LO-2410 | UHF, Nauni, Solan |
| BCT-10 | BCKV, West Bengal | Punjab Gaurav | PAU, Ludhiana |
| BT-10-10 | UHF, Nauni, Solan | Punjab Ratta | PAU, Ludhiana |
| DMT KRCCH-1 | KRCCH, Arabhavi | Punjab Red Cherry | PAU, Ludhiana |
| DMT KRCCH-2 | KRCCH, Arabhavi | Punjab Sarataj | PAU, Ludhiana |
| DMT KRCCH-3 | KRCCH, Arabhavi | S-1001 | UHF, Nauni, Solan |
| DMT KRCCH-4 | KRCCH, Arabhavi | Selection-12 | UHF, Nauni, Solan |
| DMT KRCCH-6 | KRCCH, Arabhavi | Selection-87 | UHF, Nauni, Solan |
| EC-141827 | IIVR, Varanasi | Solan Vajr | UHF, Nauni, Solan |
| EC-15998 | IIVR, Varanasi | UHF-553 | UHF, Nauni, Solan |
| EC-16788 | IIVR, Varanasi | UHF-571 | UHF, Nauni, Solan |
| EC-21132 | IIVR, Varanasi | UHF-90 | UHF, Nauni, Solan |
| EC-29414 | IIVR, Varanasi | UHF-95 | UHF, Nauni, Solan |
| EC-2997 | IIVR, Varanasi | Solan Lalima (check) | UHF, Nauni, Solan |
| EC-3526 | IIVR, Varanasi | | |

## 3.3 SEED SOWING AND RAISING OF SEEDLINGS IN NURSERY

The seed sowing of all the genotypes was carried out in February, 2016 on the raised nursery beds. Recommended cultural practices were followed for raising the healthy nursery.

## 3.4 EXPERIMENTAL LAYOUT

The experimental material was planted in a randomized complete block design with three replications in plot size of 1.8 m × 1.8 m. Twelve plants of each genotype were transplanted in each replication at spacing of 90 cm × 30 cm on 6$^{th}$ April, 2016.

## 3.5 CULTURAL PRACTICES

The standard cultural practices recommended in the Package of Practices of Vegetable Crops were followed for a healthy crop stand (Anonymous, 2013). Besides the application of Farm Yard Manure @ 20 t/ha, chemical fertilizers were applied as per the recommendation of package of practice *i.e* 100 kg N, 75 kg $P_2O_5$ and 50 kg $K_2O$/ha. One third dose of N and full doses of $P_2O_5$ and $K_2O$ were applied at the time of field preparations. Remaining two-third dose N was top dressed in equal amounts after 30 and 45 days of transplanting. Other intercultural operations were carried out in accordance with the package of practice.

## 3.6 OBSERVATIONS RECORDED

Observations with respect to following characters were recorded on ten randomly selected plants from each plot in each replication and their means were worked out for statistical analysis. Detailed observations were recorded for the following characters:

### 3.6.1 Days to 50 percent flowering

Number of days from the date of transplanting to the date when at least 50% of plants flowered were counted and mean values were worked out to estimate the earliness of the genotype.

### 3.6.2 Days to marketable maturity

Numbers of days from transplanting to first picking were noted and mean numbers of days were worked out.

### 3.6.3 Plant height (cm)

Plant height of randomly selected plants was measured from the ground level to the highest tip of the plant, the average was worked out and plant height was expressed in centimeters.

### 3.6.4 Number of fruits per cluster

Number of fruits per cluster in selected plants were counted and average was worked out.

### 3.6.5 Number of fruits per plant

Total number of healthy fruits picked at each harvest from selected plants were added and averaged to work out mean number of fruits per plant.

### 3.6.6 Average fruit weight (g)

Twenty randomly selected fruits were weighed and averaged to obtain average fruit weight.

### 3.6.7 Fruit yield per plant (kg) and per hectare (q)

The picking of marketable fruits was made at half ripe stage. Yield was recorded at every picking from ten plants in grams and added up for all the picking to arrive at the total yield per plant. On the basis of fruit yield per plant, yield per hectare was calculated.

### 3.6.8 Fruit shape index

Polar and equatorial diameter of ten randomly picked fruits was measured with Digital Vernier Calliper. Ratio of polar diameter to equatorial diameter was worked out to calculate fruit shape index. Fruits having index value 1.0 or more were described as oval, between 0.99 to 0.86 as spherical, between 0.85 to 0.71 as flat round and less than 0.70 as flat shaped as per the method suggested by Roy and Choudhary (1972).

### 3.6.9 Pericarp thickness (mm)

Mean value of pericarp thickness of ten randomly picked fruits was worked out after cutting the fruits transversely. Measurement was taken with Digital Vernier Calliper in millimetres.

### 3.6.10 Number of locules per fruit

Locule numbers were counted by cutting a transverse section of the fruit. Average of ten fruits was calculated.

### 3.6.11 Total soluble solids (°B)

Ten ripe fruits were crushed and their juice passed through a double layer of fine mesh cheese cloth. A drop of juice was placed on the plate of hand refractometer (0-32 $^{0}$B, ERMA, JAPAN) and the reading was noted. A mean of ten reading was taken in every plot.

### 3.6.12 Ascorbic acid (mg/100 g)

The ascorbic acid content in the fruit was determined by 2,6-dichlorophenol-indophenol visual titration method as described by Ranganna (1986). Aliquots prepared by macerating fleshy harvested fully ripe tomato fruits in the presence of 3% metaphosphoric acid and titrated against 2,6- dichlorophenol-indophenol dye to pink end point persisting for 15 seconds . The ascorbic acid content was calculated by means of the following formula:

$$\text{mg of ascorbic acid per 100g of fresh tissue} = \frac{\text{Titre} \times \text{Dye factor} \times \text{Volume made up}}{\text{Aliquot of extract for estimation} \times \text{Volume of sample taken for estimation}} \times 100$$

### 3.6.13 Fruit colour

The colour of the freshly harvested fruits at marketable stage was compared with the Royal Horticultural Society (RHS) colours charts and classified into different colour groups.

### 3.6.14 Harvest duration

Total number of days from first fruit picking to final fruit picking were counted and average value was expressed as harvest duration.

### 3.6.15 Incidence of buckeye rot (%)

The incidence of buckeye rot under natural epiphytic conditions in each genotype was recorded periodically by using the following formula:

$$\text{Disease incidence} = \frac{\text{Number of diseased fruits per plant}}{\text{Total number of fruits per plant}} \text{ X } 100$$

The disease reaction was categorized as per the scale given by Dodan, 1995.

| Scale/grade | Disease incidence (%) | Reaction |
|---|---|---|
| **1.** | Nil | Resistant |
| **2.** | 0.1-10.0 | Moderately Resistant (MR) |
| **3.** | 10.1-25.0 | Moderately Susceptible (MS) |
| **4.** | 25.1-45.0 | Susceptible (S) |
| **5.** | 45.1 and above | Highly Susceptible (HS) |

## 3.7 STATISTICAL ANALYSIS

The statistical analysis of the data was carried out using MS-Excel, OPSTAT and SPAR 1.0 packages. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1983) for Randomized Complete Block Design. For estimation of different statistical parameters, following procedure and formulae were adopted:

### 3.7.1 Analysis of variance (ANOVA)

| **Source of variation** | **Degree of freedom** | **Sum of squares** | **Mean sum of squares** | **Variance ratio** |
|---|---|---|---|---|
| Replication (r) | (r-1) | $S_r$ | $S_r/(r-1) = M_r$ | $M_r/M_e$ |
| Genotypes (g) | (g-1) | $S_g$ | $S_g/(g-1) = M_g$ | $M_g/M_e$ |
| Errors (e) | (r-1) (g-1) | $S_e$ | $S_e/(r-1)(g-1) = M_e$ | |

Where,

r = Number of replications

g = Number of genotypes

$S_r$ = Sum of squares due to replications

$S_g$ = Sum of squares due to treatments/genotypes

$S_e$ = Sum of squares due to errors

$M_r$ = Mean sum of squares due to replications

$M_g$ = Mean sum of squares due to treatments/genotypes

$M_e$ = Mean sum of squares due to errors

The calculated F-values were compared with the tabulated F-values. When F-test was found significant, Critical Difference (CD) and Coefficient of Variation (CV) was calculated to find out the superiority of one entry over the others.

The standard error of mean ($SE_m$) and critical difference (CD) for comparing the mean of any two genotypes were computed as follows:

$SE_{(m)} = \pm(M_e/r)^{1/2}$

$SE_{(d)} = \pm(2M_e/r)^{1/2}$

$CD_{(0.05)} = SE_{(d)} \times$ 't' value at error degree of freedom

Where,

$SE_{(m)}$ = Standard error of mean

$SE_{(d)}$ = Standard error of difference

$CD_{(0.05)}$ = Critical difference at 5% level of significance

All the characters which differed significantly among the genotypes were further utilized for estimation of following genetic parameters:

3.7.2 Coefficients of variability (phenotypic and genotypic)
3.7.3 Heritability (broad sense)
3.7.4 Genetic advance (GA)
3.7.5 Genetic gain (GG)
3.7.6 Correlation coefficients
3.7.7 Path coefficient analysis

**3.7.2 Coefficients of variability**

The Genotypic and Phenotypic coefficients of variation were calculated as per the method suggested by Burton and De Vane (1953).

**a) Genotypic Coefficient of Variability (GCV)**

$$\text{GCV (\%)} = \frac{\sqrt{\text{Genotypic Variance (Vg)}}}{\text{General mean of population } (\bar{X})} \times 100$$

**b) Phenotypic Coefficient of Variability (PCV)**

$$\text{PCV (\%)} = \frac{\sqrt{\text{Phenotypic Variance (Vp)}}}{\text{General mean of population } (\bar{X})} \times 100$$

**3.7.3 Heritability:**

Heritability in broad sense was calculated as per the method suggested by Allard (1960).

$$\text{H (\%)} = \frac{Vg}{Vp} \times 100$$

Where,

H = Heritability (%)

Vg = Genotypic variance, [Vg = (Mg – Me) / r]

Vp = Phenotypic variance (Vg + Ve)

### 3.7.4 Genetic advance

The expected genetic advance (GA) resulting from selection of five percent superior individuals was calculated as per Allard (1960).

$$GA = H \times \sigma_p \times K$$

Where,

H = Heritability (%)

$\sigma_p$ = Phenotypic standard deviation

K = Selection differential at 5% selection intensity K = 2.06

### 3.7.5 Genetic gain:

Genetic advance expressed as per cent of population mean was calculated by the formula suggested by Johnson *et al.* (1955).

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance (GA)}}{\text{General mean of the population } (\bar{X})} \times 100$$

For categorizing the magnitude of different parameters, Sharma (1994) suggested the following limits:

| | | | |
|---|---|---|---|
| PCV and GCV | >30% | - | High |
| | 15-30% | - | Moderate |
| | <15% | - | Low |
| Heritability (H) | >80% | - | High |
| | 50-80% | - | Moderate |
| | <50% | - | Low |
| Genetic gain | >50% | - | High |
| | 25-50% | - | Moderate |
| | <25% | - | Low |

### 3.7.6 Correlation coefficient

The genotypic and phenotypic correlation coefficients were calculated as per Al-Jibouri *et al*. (1958) by using analysis of variance and covariance matrix in which total variability has been split into replications, genotypes and errors. All the components of variance were estimated from analysis of co-variance as given below:

#### 3.7.6.1 Analysis of variance and covariance

| Source of variance | Degree of freedom | Mean sum of squares | | Mean sum of products | Variance |
|---|---|---|---|---|---|
| | | X | Y | | |
| Replications | (r-1) | | | | |
| Genotypes | (g-1) | $M_g$ X | $M_g$ Y | $M_g XY = MP_1$ | $MP_1 / MP_2$ |
| Error | (r-1) (g-1) | $M_e$ Y | $M_e$ Y | $M_e XY = MP_2$ | |

Genotypic, phenotypic and environmental co-variances between X and Y characters were worked out as under:

Environmental covariance ($V_e$ XY) $= MP_2$

Genotypic covariance ($V_g$ XY) $= (MP_1 – MP_2) / r$

Phenotypic variance ($V_p$ XY) $= V_g XY + V_e XY$

Where,

$V_e XY$ = Environmental covariance between X and Y

$V_g XY$ = Genetic covariance between X and Y

$V_p XY$ = Phenotypic covariance between X and Y

#### 3.7.6.2 Coefficients of correlation

**a) Phenotypic correlation between characters X and Y:**

$$r_p = Vp\,XY \,/\, \sqrt{Vp\,X \times Vp\,Y}$$

Where,

Vp XY = Phenotypic co-variance between X and Y

Vp X = Phenotypic variance of character X

Vp Y = Phenotypic variance of character Y

**b) Genotypic correlation between characters X and Y:**

$$rg = Vg\ XY \,/\, \sqrt{Vg\ X \times Vg\ Y}$$

Where,

Vg XY = Genotypic co-variance between X and Y

Vg X = Genotypic variance of character X

Vg Y = Genotypic variance of character Y

The calculated correlation coefficients (r) values were compared with ‘r’ tabulated values as given by Fisher and Yates (1963) at (n-2) degrees of freedom to test their significance, where ‘n’ denotes number of genotypes. If calculated ‘r’ value at 5 per cent level of significance was greater than tabulated value of ‘r’, the correlation was said to be significant.

### 3.7.7 Path Coefficient Analysis

The genotypic and phenotypic correlation coefficients were used in finding out their direct and indirect contribution towards yield per plot.

Path coefficient analysis was done to calculate direct and indirect contribution of different characters towards yield. The direct and indirect effects were obtained following Dewey and Lu (1959). The path coefficients were obtained by the simultaneous selection of following equations, which express the basic relationship between genotypic correlation (r) and path coefficient (P).

$$r_{14} = P_{14} + P_{24}r_{12} + P_{34}r_{13}$$

$$r_{24} = P_{14}r_{21} + P_{24} + P_{34}r_{23}$$

$$r_{34} = P_{14}r_{31} + P_{24}r_{32} + P_{34}$$

Where, $r_{14}$, $r_{24}$ and $r_{34}$ are genotypic correlations of component characters with yield (dependent variable) and $r_{12}$, $r_{13}$, $r_{23}$ are genotypic correlations among the component characters (independent variables).

The direct effects were calculated by the following set of equations:

$$P_{14} = C_{11}r_{14} + C_{12}r_{24} + C_{13}r_{34}$$

$$P_{24} = C_{21}r_{14} + C_{22}r_{24} + C_{23}r_{34}$$

$$P_{34} = C_{31}r_{14} + C_{32}r_{24} + C_{33}r_{34}$$

Where, $C_{11}$, $C_{12}$, $C_{23}$ and $C_{33}$ are constants derived by using abbreviated Doulittle's technique as explained by Goulden (1959) and $r_{12}P_{34}$, $r_{13}P_{34}$, $r_{23}P_{34}$, $r_{31}P_{14}$ and $r_{32}P_{24}$ are indirect effects.

**Residual effect:**

The variation in the independent variable remained undetermined by including all the variables was assumed to be due to variable (s) on dependent variable was calculated as follows:

$$I = P^2x_4 + P^2_{14} + P^2_{24} + P^2_{34} + 2P_{14}r_{12}P_{24} + 2P_{14}r_{13}P_{34} + 2P_{24}r_{23}P_{34}$$

# Chapter 4

# Results and Discussion

# *Chapter-4*

# RESULTS AND DISCUSSION

The present investigation entitled, **"Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)"** was conducted at the experimental farm of the Department of Vegetable Science, College of Horticulture, Dr. YS Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh during Kharif season of 2016. Thirty five diverse genotypes of tomato including check variety (Solan Lalima) were evaluated for yield and yield contributing traits. The experimental results obtained are presented under the following sub-heads:

**4.1 Variability studies**

**4.2 Correlation studies**

**4.3 Path coefficient analysis**

## 4.1 Variability studies

### 4.1.1 General performance of genotypes

The analysis of variance indicated highly significant differences among the genotypes for all the trait studied (Appendix-II), which revealed the existence of sufficient variability in the germplasm. The mean performance of all the genotypes for various horticultural traits is described as follows:

#### 4.1.1.1 Days to 50 percent flowering

Genotypes differed significantly from each other for number of days to 50% flowering. Days to 50% flowering varied from 24.67 to 35.67 (Table 4.1) having population mean of 32.24. Out of 25 genotypes, sixteen were earlier in 50% flowering than the population mean. Genotype Punjab Red Cherry (24.67) took minimum days to reach 50% flowering. UHF-95 (35.67) recorded maximum days for 50% flowering and was found statistically at par with seven genotypes viz., EC-15998 (35.00), EC-524082 (34.67), EC-3526 (34.33), UHF-90 (34.33), Selection-12 (33.67) and DMT KRCCH-4 (33.33). Among all the genotypes under study eighteen genotypes took less days to 50 % flowering than check Solan Lalima (32.67 days). Variability for this character was reported by Sharma *et al.*

(2010), Mohamed *et al.* (2012), Ahirwar and Prashad (2013), Reddy *et al*. (2013) and Kumar (2014).

#### 4.1.1.2 Days to marketable maturity

Statistical analysis revealed that genotypes showed significant variation for days to marketable maturity. It ranged from 66.00 to 80.33 days with population mean of 73.02 (Table 4.1). Eighteen genotypes were earlier in maturity than the check Solan Lalima (73.33 days). The mean values for genotypes revealed that Punjab Red Cherry was the earliest (66.00 days) to first picking, which was statistically at par with UHF-553 (67.00 days), UHF-95 (67.67 days), BT-10-10 (67.67 days), BCT-2 (68.00 days), EC-2997 (68.67 days), EC-3526 (68.67 days), EC-21132 (69.00 days), BCT-8 (70.00 days), EC-36293 (70.00 days), UHF-90 (70.33 days), EC- 433607 (70.33 days) and EC-15998 (70.67 days). Punjab Gaurav took maximum days to attain marketable maturity (80.33 days) and found statistically at par with Solan Vajr (80.00), Selection-87 (79.67 days), DMT KRCCH-4 (79.00 days), DMT KRCCH-3 (78.00 days), BCT-5 (77.67 days), DMT KRCCH-6 (77.33 days) S-1001 (77.00 days) and DMT KRCCH-2 (76.33 days). Eighteen genotypes were earlier in maturity than the population mean (73.02 days). Considerable variability regarding this trait was found and which was in accordance with the findings of Buckseth *et al.* (2012), Kumar (2013), Patel *et al*. (2013) and Kumar (2014).

#### 4.1.1.3 Plant height (cm)

Comparison of genotypes revealed that genotypes differed significantly for plant height. The overall mean for the character was 88.13 cm. It ranged from 52.51 to 123.65 cm (Table 4.1). Sixteen genotypes including the check produced maximum plant height than the population mean. Maximum plant height was recorded in Solan Vajr (123.65 cm), which was statistically at par with EC-2997 (121.33 cm) and Solan Lalima (120.32 cm). Minimum plant height was recorded in DMT KRCCH-2 (52.51 cm), which was statistically at par with BCT-5 (55.00 cm). Two genotypes viz., EC-2997 (121.33 cm) and Solan Lalima (120.32 cm) resulted in more plant height than the check Solan Lalima (124.32 cm). Variability regarding plant height was also reported by Bora *et al*. (1993), Ara *et al*. (2009), Buckseth *et al*. (2012), Rahaman *et al.* (2012) and Kumar (2014).

**Table 4.1 Mean performance of tomato genotypes for days to 50 percent flowering, days to marketable maturity, plant height (cm) and number of fruits per cluster**

| Genotypes | Days to 50% flowering | Days to marketable maturity | Plant height (cm) | Number of fruits per cluster |
|---|---|---|---|---|
| **Punjab Sartaj** | 31.67 | 74.67 | 107.44 | 4.92 |
| **Punjab Ratta** | 31.00 | 73.67 | 75.33 | 5.30 |
| **DMT KRCCH-4** | 33.33 | 79.00 | 69.01 | 3.70 |
| **BCT-8** | 32.67 | 70.00 | 69.88 | 4.80 |
| **LO-2410** | 32.00 | 71.67 | 112.39 | 3.10 |
| **DMT KRCCH-1** | 31.67 | 75.00 | 64.41 | 3.00 |
| **Punjab Gaurav** | 31.67 | 80.33 | 105.13 | 5.27 |
| **BCT-10** | 32.00 | 75.33 | 60.53 | 4.99 |
| **BCT-5** | 31.33 | 77.67 | 55.00 | 3.74 |
| **DMT KRCCH-3** | 32.00 | 78.00 | 58.93 | 4.49 |
| **UHF-553** | 33.00 | 67.00 | 93.15 | 3.84 |
| **Punjab Red Cherry** | 24.67 | 66.00 | 85.45 | 15.07 |
| **BCT-2** | 32.67 | 68.00 | 71.67 | 3.80 |
| **BCT-4** | 31.67 | 75.33 | 65.98 | 3.72 |
| **DMT KRCCH-6** | 33.00 | 77.33 | 73.95 | 3.16 |
| **DMT KRCCH-2** | 31.67 | 76.33 | 52.51 | 2.76 |
| **Solan Vajr** | 32.33 | 80.00 | 123.65 | 4.16 |
| **S-1001** | 29.67 | 77.00 | 75.90 | 4.28 |
| **EC-524082** | 34.67 | 72.67 | 116.78 | 3.97 |
| **EC-433607** | 32.67 | 70.33 | 117.24 | 4.20 |
| **EC-21132** | 29.00 | 69.00 | 76.04 | 3.56 |
| **EC-2997** | 31.67 | 68.67 | 121.33 | 3.99 |
| **EC-36293** | 33.00 | 70.00 | 64.61 | 2.79 |
| **EC-141827** | 32.33 | 71.33 | 92.05 | 3.14 |
| **EC-16788** | 32.67 | 72.67 | 77.05 | 3.41 |
| **EC-3526** | 34.33 | 68.67 | 94.78 | 3.24 |
| **EC-15998** | 35.00 | 70.67 | 114.09 | 4.03 |
| **UHF-571** | 31.33 | 74.33 | 94.56 | 3.14 |
| **EC-29414** | 32.67 | 72.00 | 84.35 | 2.83 |
| **UHF-95** | 35.67 | 67.67 | 84.82 | 2.76 |
| **UHF-90** | 34.33 | 70.33 | 85.09 | 2.97 |
| **BT-10-10** | 32.00 | 67.67 | 109.99 | 4.51 |
| **Selection-12** | 33.67 | 74.33 | 104.14 | 3.40 |
| **Selection-87** | 32.67 | 79.67 | 107.20 | 3.49 |
| **Solan Lalima (check)** | 32.67 | 73.33 | 120.32 | 5.00 |
| **Mean** | 32.24 | 73.02 | 88.13 | 4.12 |
| **$CD_{(0.05)}$** | 2.62 | 4.77 | 3.57 | 0.27 |

#### 4.1.1.4 Number of fruits per cluster

Data recorded on number of fruits per cluster showed significant variation among genotypes. Its value ranged from 2.76 to 15.07 with population mean of 4.12. Three genotypes resulted in more number of fruits per cluster than check Solan Lalima (5.00). Comparison of mean values of the genotypes depicted maximum number of fruits per cluster (15.07) in Punjab Red Cherry. Genotypes DMT KRCCH-2 (2.76) and UHF-95 (2.76) bear minimum number of fruits per cluster and were found statistically at par with genotypes viz., EC-36293 (2.79), EC-29414 (2.83), UHF-90 (2.97) and DMT KRCCH-1 (3.00). Twelve genotypes including check had more number of fruits per cluster than population mean. Variability with respect to this trait was reported by Haydar *et al.* (2007), Ara *et al*. (2009), Ghosh *et al.*(2010), Kumar *et al*. (2013) and Reddy *et al*. (2013).

#### 4.1.1.5 Number of fruits per plant

Data recorded on number of fruits per plant (table 4.2) showed significant variation among genotypes. The number of fruits per plant ranged from 11.25 to 70.02. Comparison of mean values of the genotypes depicted maximum number of fruits per plant (70.02) in Punjab Red Cherry, which was statistically superior over all other genotypes and check variety. However, minimum numbers of fruits per plant were recorded in DMT KRCCH-1 (11.25). Check variety Solan Lalima recorded 26.37 fruits per plant. Considerable variability regarding this trait was found and was in accordance with the findings of Buckseth *et al*. (2012), Khan and Samadia (2012), Kumar *et al*. (2013), Reddy *et al*. (2013) and Kumar (2014).

#### 4.1.1.6 Average fruit weight (g)

Range of data recorded for this trait was between 10.53 to 84.00 g with population mean of 56.17 g. Data presented in table 4.2, revealed that the maximum average fruit weight (84.00 g) was observed in Punjab Sartaj, which was statistically superior than all other genotypes. Minimum value for average fruit weight was recorded in the genotype Punjab Red Cherry (10.53 g). Check variety Solan Lalima recorded average fruit weight of 65.00 g. Twelve genotypes recorded more average fruit weight than check Solan Lalima. Wide genetic variation with respect to this character was also reported by Asati *et al.* (2008), Ara *et al*. (2009), Ghosh *et al*. (2010), Shashikanth *et al.* (2010), Khan and Samadia (2012), Reddy *et al.* (2013), Kumar *et al.* (2013), Premalakshmi *et al.* (2014) and Sharma and Jaipaul (2014).

**Table 4.2 Mean performance of tomato genotypes for number of fruits per plant, average fruit weight (g), fruit yield per plant (kg) and fruit yield per hectare (q)**

| Genotypes | Number of fruits per plant | Average fruit weight (g) | Fruit yield per plant (kg) | Fruit yield per hectare (q) |
|---|---|---|---|---|
| **Punjab Sartaj** | 22.80 | 84.00 | 1.59 | 471.11 |
| **Punjab Ratta** | 23.27 | 62.73 | 1.42 | 420.74 |
| **DMT KRCCH-4** | 14.80 | 69.07 | 1.02 | 302.22 |
| **BCT-8** | 14.50 | 75.80 | 1.09 | 322.96 |
| **LO-2410** | 18.60 | 42.53 | 0.62 | 183.70 |
| **DMT KRCCH-1** | 11.25 | 62.53 | 0.48 | 142.22 |
| **Punjab Gaurav** | 21.88 | 75.67 | 1.53 | 453.33 |
| **BCT-10** | 12.72 | 78.80 | 1.00 | 296.30 |
| **BCT-5** | 13.25 | 74.73 | 0.98 | 290.37 |
| **DMT KRCCH-3** | 15.00 | 62.53 | 0.93 | 275.55 |
| **UHF-553** | 23.80 | 65.00 | 1.20 | 355.55 |
| **Punjab Red Cherry** | 70.02 | 10.53 | 0.70 | 207.40 |
| **BCT-2** | 14.20 | 70.00 | 0.99 | 293.33 |
| **BCT-4** | 13.50 | 74.20 | 1.00 | 296.29 |
| **DMT KRCCH-6** | 14.00 | 63.93 | 0.83 | 245.92 |
| **DMT KRCCH-2** | 13.20 | 73.93 | 0.73 | 216.29 |
| **Solan Vajr** | 21.83 | 71.00 | 1.23 | 364.44 |
| **S-1001** | 22.33 | 70.15 | 1.32 | 391.11 |
| **EC-524082** | 23.07 | 37.67 | 0.87 | 257.77 |
| **EC-433607** | 20.00 | 38.73 | 0.77 | 228.14 |
| **EC-21132** | 18.51 | 43.00 | 0.60 | 177.77 |
| **EC-2997** | 21.57 | 57.01 | 0.93 | 275.55 |
| **EC-36293** | 16.33 | 42.60 | 0.41 | 121.48 |
| **EC-141827** | 17.60 | 47.87 | 0.48 | 142.22 |
| **EC-16788** | 18.00 | 43.57 | 0.48 | 142.22 |
| **EC-3526** | 19.39 | 34.63 | 0.65 | 192.59 |
| **EC-15998** | 20.94 | 66.50 | 0.84 | 248.88 |
| **UHF-571** | 22.48 | 55.69 | 0.97 | 287.40 |
| **EC-29414** | 17.34 | 36.08 | 0.44 | 130.37 |
| **UHF-95** | 16.40 | 37.09 | 0.43 | 127.40 |
| **UHF-90** | 18.30 | 31.13 | 0.53 | 157.03 |
| **BT-10-10** | 24.53 | 45.58 | 1.11 | 328.88 |
| **Selection-12** | 23.80 | 45.74 | 1.08 | 320.00 |
| **Selection-87** | 24.13 | 51.00 | 1.22 | 361.48 |
| **Solan Lalima (check)** | 26.37 | 65.00 | 1.54 | 456.29 |
| **Mean** | 20.27 | 56.17 | 0.91 | 271.00 |
| **CD $_{(0.05)}$** | 1.32 | 2.42 | 0.04 | 11.90 |

#### 4.1.1.7 Fruit yield per plant (kg) and per hectare (q)

Data recorded on fruit yield per plant has been presented in table 4.2. Maximum fruit yield per plant was recorded in Punjab Sartaj (1.59 kg). Whereas, minimum fruit yield per plant was recorded in EC-36293 (0.41 kg) and was found to be statistically at par with the genotypes UHF-95 (0.43) and EC-29414 (0.44 kg). Check 'Solan Lalima' recorded 1.54 kg fruit yield per plant. General mean for this observation was 0.91 kg.

Similarly, observation on fruit yield per hectare showed that maximum fruit yield per hectare was recorded by Punjab Sartaj (471.11 q/ha). Whereas, minimum yield per hectare was observed in genotype EC-36293 (121.48 q/ha) and was statistically at par with genotypes UHF-95 (127.40 q/ha) and EC-29414 (130.37 q/ha). Check Solan Lalima recorded fruit yield per hectare of about 456.29 q. Population mean for this character was 271.00. Wide variation with respect to this character was reported by Asati *et al*. (2008), Ara *et al*. (2009), Ghosh *et al*.(2010), Shashikanth *et al*. (2010), Khan and Samadia (2012), Reddy *et al.* (2013), Kumar *et al.* (2013), Singh *et al.* (2014), Premalakshmi *et al.* (2014) and Kumar (2014).

#### 4.1.1.8 Fruit shape index

Significant differences were observed for fruit shape index. The mean performance of genotypes showed maximum fruit shape index value in DMT KRCCH-1 (1.19), which was statistically at par with DMT KRCCH-4 (1.17) and BT-10-10 (1.13) whereas, minimum value was observed in DMT KRCCH-6 (0.79), which was statistically at par with ten genotypes viz., DMT KRCCH-2 (0.82), EC-21132 (0.85), Selection-87 (0.86), Selection-12 (0.87), UHF-95 (0.87), EC-3526 (0.87), EC-141827 (0.88), BCT-8 (0.88), LO-2410 (0.89) and BCT-10 (0.89). Index values for all the genotypes have been presented in table 4.3. Seven genotypes were found to have oval shape with an index value one and above, while twenty four genotypes fall under spherical group and four under flat round group. Similarly, tomato genotypes were also classified into oval, spherical and flat round categories by Buckseth *et al.* (2012), Kumar (2014) and Kharshandi (2015) as per the method suggested by Roy and Choudhary (1972).

**Table 4.3 Categories of genotypes on the basis of fruit shape index values**

| Fruit shape index values | Shapes | Genotypes |
|---|---|---|
| **1 or more** | **Oval** | Punjab Ratta, DMT KRCCH-4, DMT KRCCH-1, Punjab Red Cherry, S-1001, EC-29414, BT-10-10 |
| **0.86-0.99** | **Spherical** | Punjab Sartaj, BCT-8, LO-2410, Punjab Gaurav, BCT-10, BCT-5, DMT KRCCH-3, UHF-553, BCT-2, BCT-4, Solan Vajr, EC-524082, EC-433607, EC-2997, EC-36293, EC-141827, EC-16788, EC-3526, EC-15998, UHF-571, UHF-95, UHF-90, Selection-12, Solan Lalima (check) |
| **0.71-0.85** | **Flat round** | DMT KRCCH-6, DMT KRCCH-2, EC-21132, Selection-87 |

#### 4.1.1.9 Pericarp thickness (mm)

Significant variation for pericarp thickness was obtained among all the genotypes studied. The data presented in table 4.4 revealed that pericarp thickness varied from 2.12 to 6.13 mm. The overall mean value of the population was 4.25. Six genotypes had more pericarp thickness than the check Solan Lalima (5.20 mm). Maximum pericarp thickness (6.13 mm) was observed in S-1001. Whereas, minimum pericarp thickness (2.12 mm) was recorded in Punjab Red Cherry. Considerable variability regarding this trait was found and was in accordance with the findings of Kumar *et al*. (2004), Prashanth *et al*. (2008), Dar *et al.* (2011), Buckseth *et al.* (2012), Khapte and Jansirani (2014) and Kumar (2014).

#### 4.1.1.10 Number of locules per fruit

Range of data recorded for this trait lies between 2.50 to 5.00 (table 4.4). The mean values of different genotypes for number of locules per fruit revealed that EC-29414 (2.50) and UHF-90 (2.50) had the lowest number of locules per fruit, which was statistically at par with fourteen genotypes viz., Punjab Red Cherry (2.53), EC-524082 (2.69), BCT-5 (2.73), UHF-571 (2.80), BCT-10 (2.87), Solan Vajr (2.92), BCT-2 (2.93), S-1001 (2.93), check Solan Lalima (2.99), EC-21132 (3.00), BT-10-10 (3.03), EC-2997 (3.07), Selection-87 (3.20)

**Table 4.4 Mean performance of tomato genotypes for fruit shape index, pericarp thickness (mm), number of locules per fruit and total soluble solids (°B)**

| Genotypes | Fruit shape index | Pericarp thickness (mm) | Number of locules per fruit | Total soluble solids (°B) |
|---|---|---|---|---|
| **Punjab Sartaj** | 0.98 | 4.48 | 3.47 | 3.32 |
| **Punjab Ratta** | 1.03 | 5.22 | 3.33 | 3.77 |
| **DMT KRCCH-4** | 1.17 | 4.54 | 3.47 | 3.31 |
| **BCT-8** | 0.88 | 5.30 | 3.20 | 3.66 |
| **LO-2410** | 0.89 | 4.08 | 3.93 | 4.53 |
| **DMT KRCCH-1** | 1.19 | 4.28 | 3.40 | 3.52 |
| **Punjab Gaurav** | 0.99 | 5.45 | 3.53 | 3.49 |
| **BCT-10** | 0.89 | 4.16 | 2.87 | 4.97 |
| **BCT-5** | 0.96 | 4.53 | 2.73 | 4.21 |
| **DMT KRCCH-3** | 0.93 | 4.20 | 3.80 | 3.27 |
| **UHF-553** | 0.91 | 4.50 | 5.00 | 4.44 |
| **Punjab Red Cherry** | 1.03 | 2.12 | 2.53 | 6.04 |
| **BCT-2** | 0.94 | 4.52 | 2.93 | 3.74 |
| **BCT-4** | 0.99 | 5.32 | 3.47 | 3.31 |
| **DMT KRCCH-6** | 0.79 | 3.54 | 3.93 | 3.53 |
| **DMT KRCCH-2** | 0.82 | 5.46 | 3.87 | 3.41 |
| **Solan Vajr** | 0.96 | 5.18 | 2.92 | 3.67 |
| **S-1001** | 1.02 | 6.13 | 2.93 | 3.89 |
| **EC-524082** | 0.96 | 3.24 | 2.69 | 4.35 |
| **EC-433607** | 0.98 | 3.67 | 4.00 | 5.97 |
| **EC-21132** | 0.85 | 3.37 | 3.00 | 6.32 |
| **EC-2997** | 0.91 | 3.98 | 3.07 | 4.95 |
| **EC-36293** | 0.98 | 4.54 | 4.03 | 5.71 |
| **EC-141827** | 0.88 | 3.24 | 3.63 | 5.93 |
| **EC-16788** | 0.90 | 3.63 | 4.40 | 5.54 |
| **EC-3526** | 0.87 | 3.10 | 3.67 | 4.84 |
| **EC-15998** | 0.93 | 4.18 | 3.73 | 4.43 |
| **UHF-571** | 0.91 | 4.31 | 2.80 | 5.15 |
| **EC-29414** | 1.02 | 3.37 | 2.50 | 5.19 |
| **UHF-95** | 0.87 | 3.59 | 3.47 | 4.40 |
| **UHF-90** | 0.98 | 3.34 | 2.50 | 5.33 |
| **BT-10-10** | 1.13 | 4.54 | 3.03 | 4.68 |
| **Selection-12** | 0.87 | 4.31 | 3.37 | 5.12 |
| **Selection-87** | 0.86 | 4.25 | 3.20 | 4.65 |
| **Solan Lalima (check)** | 0.94 | 5.20 | 2.99 | 4.94 |
| **Mean** | 0.95 | 4.25 | 3.35 | 4.50 |
| **$CD_{(0.05)}$** | 0.10 | 0.50 | 0.79 | 0.83 |

and BCT-8 (3.20). Maximum number of locules per fruit were recorded in UHF-553 (5.00) which was statistically at par with EC-16788 (4.40). Variation with respect to this character was reported by Joshi *et al.* (2004), Manna and Paul (2012), Buckseth *et al.* (2012) and Kumar (2014).

#### 4.1.1.11 Total soluble solids ($^0$B)

The mean values of the genotypes presented in table 4.4 showed that all the genotypes were significant for total soluble solids. It ranged from 3.27 to 6.32 $^0$B with population mean of 4.50. Seventeen genotypes recorded maximum value for total soluble solids than population mean. Maximum total soluble solids (6.32 $^0$B) were recorded in EC-21132, which was statistically at par with EC-16788 (5.54 $^0$B), EC-36293 (5.71 $^0$B), EC-141827 (5.93 $^0$B), EC-433607 (5.97 $^0$B) and Punjab Red Cherry (6.04 $^0$B). Minimum total soluble solids (3.27 $^0$B) were observed in DMT KRCCH-3 and was statistically at par with twelve genotypes viz., DMT KRCCH-4 (3.31 $^0$B), BCT-4 (3.31 $^0$B), Punjab Sartaj (3.32 $^0$B), DMT KRCCH-2 (3.41 $^0$B), Punjab Gaurav (3.49 $^0$B), DMT KRCCH-1 (3.52 $^0$B), DMT KRCCH-6 (3.53 $^0$B), BCT-8 (3.66 $^0$B), Solan Vajr (3.67 $^0$B), BCT-2 (3.74 $^0$B), Punjab Ratta (3.77 $^0$B) and S-1001 (3.89 $^0$B). Twelve genotypes recorded maximum value for total soluble solids than the check Solan Lalima (4.94 $^0$B). Considerable variability regarding this trait was found and was in accordance with the findings of Buckseth *et al.* (2012) and Kumar (2014).

#### 4.1.1.12 Ascorbic acid (mg/100 g)

The data recorded for ascorbic acid content showed significant differences among the genotypes. It ranged from 14.49 to 36.55 mg/100 g (table 4.5) with population mean of 26.83. Fifteen genotypes recorded maximum value for ascorbic acid content than the population mean. Genotype DMT KRCCH-2 had maximum ascorbic acid content (36.55 mg/100 g) which was statistically at par with DMT KRCCH-1 (35.39 mg/100 g), EC-524082 (36.32 mg/100 g) and DMT KRCCH-6 (36.51 mg/100 g). Minimum value for this trait was found in UHF-95 (14.49 mg/100 g). Nineteen genotypes recorded maximum value for total soluble solids than the check Solan Lalima (25.60 mg/100 g). Considerable variability with respect to this trait was reported by Dar and Sharma (2011), Reddy *et al.* (2013) and Kumar (2014).

**Table 4.5 Mean performance of tomato genotypes for ascorbic acid (mg/100 g), harvest duration and incidence of buckeye rot (%)**

| Genotypes | Ascorbic acid (mg/100 g) | Harvest duration (days) | Incidence of buckeye rot (%) |
|---|---|---|---|
| **Punjab Sartaj** | 23.74 | 40.33 | 37.19 (37.21) |
| **Punjab Ratta** | 33.18 | 39.67 | 43.05 (40.83) |
| **DMT KRCCH-4** | 31.63 | 28.67 | 29.57 (32.65) |
| **BCT-8** | 29.29 | 29.67 | 31.00 (33.78) |
| **LO-2410** | 33.03 | 35.33 | 29.15 (32.38) |
| **DMT KRCCH-1** | 35.39 | 29.67 | 36.81 (37.29) |
| **Punjab Gaurav** | 21.48 | 41.67 | 37.80 (37.67) |
| **BCT-10** | 29.99 | 31.33 | 35.70 (36.51) |
| **BCT-5** | 29.84 | 27.67 | 29.37 (32.67) |
| **DMT KRCCH-3** | 18.62 | 27.00 | 44.21 (41.67) |
| **UHF-553** | 26.58 | 37.00 | 36.09 (36.74) |
| **Punjab Red Cherry** | 28.42 | 28.33 | 22.39 (27.42) |
| **BCT-2** | 23.52 | 31.00 | 43.70 (40.94) |
| **BCT-4** | 26.55 | 36.00 | 42.56 (40.66) |
| **DMT KRCCH-6** | 36.51 | 35.33 | 34.63 (35.75) |
| **DMT KRCCH-2** | 36.55 | 28.33 | 38.17 (38.11) |
| **Solan Vajr** | 24.88 | 39.67 | 34.87 (36.18) |
| **S-1001** | 29.67 | 36.67 | 22.19 (18.82) |
| **EC-524082** | 36.32 | 42.00 | 21.49 (27.55) |
| **EC-433607** | 26.65 | 40.00 | 29.22 (32.68) |
| **EC-21132** | 25.16 | 35.33 | 29.29 (32.76) |
| **EC-2997** | 19.77 | 42.00 | 29.34 (32.77) |
| **EC-36293** | 33.21 | 32.00 | 30.21 (33.33) |
| **EC-141827** | 18.20 | 34.33 | 10.57 (18.92) |
| **EC-16788** | 23.49 | 32.00 | 27.97 (31.92) |
| **EC-3526** | 26.43 | 39.00 | 18.15 (25.19) |
| **EC-15998** | 19.83 | 39.67 | 43.19 (41.08) |
| **UHF-571** | 23.25 | 36.00 | 25.00 (29.99) |
| **EC-29414** | 28.49 | 35.33 | 8.63 (16.99) |
| **UHF-95** | 14.49 | 33.33 | 26.11 (30.62) |
| **UHF-90** | 16.50 | 38.33 | 26.22 (30.64) |
| **BT-10-10** | 23.47 | 41.67 | 14.25 (21.94) |
| **Selection-12** | 24.85 | 40.33 | 18.12 (25.07) |
| **Selection-87** | 26.49 | 39.00 | 25.89 (30.49) |
| **Solan Lalima (check)** | 25.60 | 42.67 | 26.74 (31.11) |
| **Mean** | 26.60 | 35.60 | 32.30 |
| **$CD_{(0.05)}$** | 1.84 | 1.43 | 10.36 |

Figures in parenthesis are arc sine transformed values.

#### 4.1.1.13 Harvest duration (days)

Statistical analysis revealed that genotypes showed significant variation for harvest duration. Its observation varied between 27.00 to 42.67 with population mean of 35.60. Maximum harvest duration (42.67 days) was recorded in genotype Solan Lalima, which was statistically at par with EC-2997 (42.00 days), EC-524082 (42.00 days), Punjab Gaurav (41.67 days) and BT-10-10 (41.67 days). Minimum harvest duration was recorded in DMT KRCCH-3 (27.00 days), and was statistically at par with BCT-5 (27.67 days), Punjab Red Cherry (28.33 days), DMT KRCCH-2 (28.33 days), DMT KRCCH-4 (28.67 days), BCT-8 (29.67 days), DMT KRCCH-1 (29.67 days) and BCT-2 (31.00 days). Eighteen genotypes including check were found to had more harvest duration than population mean. Considerable variability regarding this trait was found and similar findings were observed by Ara *et al*. (2009), Sharma and Jaipaul (2014), Kumar (2014) and Rai *et al*. (2016).

#### 4.1.1.14 Incidence of buckeye rot (%)

The data on disease incidence of buckeye rot under field conditions exhibited significant variation among different genotypes (table 4.5). Disease incidence varied from 8.63 % to 44.21 % with population mean of 32.30 %. Minimum buckeye rot incidence (8.63 %) was observed in EC-29414 and was statistically at par with EC-141827 (10.57 %), BT-10-10 (14.25 %), Selection-12 (18.12 %), EC-3526 (18.15 %) and S-1001 (22.19 %). Buckeye rot incidence was maximum in DMT KRCCH-3 (44.21 %), which was statistically at par with twenty two genotypes. Twelve genotypes recorded less incidence of buckeye rot than the check Solan Lalima (26.74 %). Wide genetic variation with respect to this character was reported by Buckseth *et al*. (2012), Kumar (2014) and Rai (2015).

#### 4.1.1.14 Fruit colour

It is evident from table 4.6 that, one genotype BCT-10 fall under orange red group, whereas all other genotypes fall under red group including check Solan Lalima.

### 4.1.2 PARAMETERS OF VARIABILITY

The parameters of variability viz., mean, range, coefficients of variation (genotypic and phenotypic), heritability (broad sense), genetic advance and genetic gain were worked out for various characters and are presented in table 4.7.

**Table 4.6 Fruit colour of tomato genotypes at marketable stage**

| Genotypes | Fruit colour |
|---|---|
| **Punjab Sartaj** | Red group (44 A) |
| **Punjab Ratta** | Red group (43 A) |
| **DMT KRCCH-4** | Red group (45 A) |
| **BCT-8** | Red group (45 B) |
| **LO-2410** | Red group (45 A) |
| **DMT KRCCH-1** | Red group (46 B) |
| **Punjab Gaurav** | Red group (42 A) |
| **BCT-10** | Orange Red group (35 B) |
| **BCT-5** | Red group (45 B) |
| **DMT KRCCH-3** | Red group (44 A) |
| **UHF-553** | Red group (45 A) |
| **Punjab Red Cherry** | Red group (46 A) |
| **BCT-2** | Red group (43 B) |
| **BCT-4** | Red group (45 B) |
| **DMT KRCCH-6** | Red group (46 B) |
| **DMT KRCCH-2** | Red group (44 B) |
| **Solan Vajr** | Red group (46 B) |
| **S-1001** | Red group (42 B) |
| **EC-524082** | Red group (42 B) |
| **EC-433607** | Red group (45 A) |
| **EC-21132** | Red group (46 A) |
| **EC-2997** | Red group (46 A) |
| **EC-36293** | Red group (45 A) |
| **EC-141827** | Red group (45 A) |
| **EC-16788** | Red group (45 A) |
| **EC-3526** | Red group (45 A) |
| **EC-15998** | Red group (45 A) |
| **UHF-571** | Red group (45 A) |
| **EC-29414** | Red group (45 A) |
| **UHF-95** | Red group (46 A) |
| **UHF-90** | Red group (45 A) |
| **BT-10-10** | Red group (45 A) |
| **Selection-87** | Red group (46 B) |
| **Selection-12** | Red group (45 A) |
| **Solan Lalima (check)** | Red group (40 B) |

**Table 4.7. Estimation of phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for various traits in tomato**

| Characters | Mean | Range | Coefficient of variability (%) | | Heritability (Broad sense) (%) | Genetic advance | Genetic gain (%) |
|---|---|---|---|---|---|---|---|
| | | | Phenotypic | Genotypic | | | |
| **Days to 50% flowerings** | 32.24 | 24.67 - 35.67 | 6.15 | 5.65 | 84.40 | 3.45 | 10.70 |
| **Days to marketable maturity** | 73.02 | 66.00 - 80.33 | 5.91 | 5.38 | 82.99 | 7.37 | 10.10 |
| **Plant height (cm)** | 88.13 | 52.51 - 123.65 | 24.38 | 24.26 | 98.96 | 43.81 | 49.71 |
| **Numbers of fruits per cluster** | 4.12 | 2.76 - 15.07 | 49.66 | 49.50 | 99.33 | 4.19 | 101.63 |
| **Numbers of fruits per plant** | 20.39 | 11.25 - 70.02 | 46.28 | 46.11 | 99.28 | 19.56 | 94.66 |
| **Average fruit weight (g)** | 56.17 | 10.53 - 84.00 | 30.39 | 30.29 | 99.35 | 34.93 | 62.19 |
| **Fruit yield/plant (Kg)** | 0.92 | 0.41 - 1.61 | 38.13 | 38.04 | 99.52 | 0.72 | 78.18 |
| **Fruit shape index** | 0.95 | 0.79 - 1.19 | 19.84 | 19.69 | 98.50 | 1.71 | 40.26 |
| **Pericarp thickness (mm)** | 4.25 | 2.12 - 6.13 | 16.90 | 16.70 | 97.71 | 1.14 | 34.02 |
| **Number of locules per fruit** | 3.35 | 2.50 - 5.00 | 20.28 | 20.11 | 98.33 | 1.85 | 41.09 |
| **Total soluble solids ($^0$B)** | 4.50 | 3.27 - 6.32 | 21.73 | 21.59 | 98.73 | 11.76 | 44.21 |
| **Ascorbic acid (mg/100g)** | 26.60 | 14.49 - 36.55 | 13.65 | 13.43 | 96.72 | 9.69 | 27.21 |
| **Harvest duration (days)** | 35.60 | 27.00 - 42.67 | 9.66 | 9.33 | 93.37 | 0.17 | 18.58 |

#### 4.1.2.1 Coefficients of variation

For all the characters studied, phenotypic coefficients of variation were higher in magnitude than the corresponding genotypic coefficients of variation, though the difference was less in majority of cases thus, indicating that environmental factors have played less influence on the expression of these characters. Coefficients of variation varied in magnitude *i.e.* either low or moderate or high, indicating that there was a great diversity in the experimental material used.

For determining the magnitude of phenotypic and genotypic variation, the phenotypic coefficient of variation and genotypic coefficient of variation were calculated. The investigation showed marked extent of variation for all the characters studied. The phenotypic and genotypic coefficients of variation were higher for number of fruits per cluster (49.66 % and 49.50 %), number of fruits per plant (46.28 % and 46.11 %), fruit yield per plant (38.13 % and 38.04 %) and average fruit weight (30.39 % and 30.29 %). Ghosh *et al.* (2010) and Kumar *et al*. (2013) reported high phenotypic and genotypic coefficients of variation for number of fruits per cluster, number of fruits per plant and average fruit weight. High phenotypic and genotypic coefficients of variation were reported for fruit yield per plant and number of fruits per plant by Shashikanth *et al.* (2010). Similarly high amount of phenotypic and genotypic coefficients of variation for fruit yield per plant, number of fruits per plant and average fruit weight was also observed by Khan and Samadia (2012).

Moderate phenotypic and genotypic coefficients of variation were observed for plant height (24.38 % and 24.26 %), total soluble solids (21.73 % and 21.59 %), number of locules (20.28 % and 20.11 %), fruit shape index (19.84 % and 19.69 %) and pericarp thickness (16.90 % and 16.70 %). For plant height, moderate phenotypic and genotypic coefficients of variation were reported by Reddy *et al.* (2013). Patel *et al*. (2013) reported moderate phenotypic and genotypic coefficients of variation for total soluble solids and number of locules per fruit. Dar *et al.* (2012) recorded moderate phenotypic and genotypic coefficients of variation for characters like pericarp thickness and number of locules per fruit. Kumar *et al*. (2012) also reported moderate phenotypic and genotypic coefficient of variation for total soluble solids and pericarp thickness.

Low values of phenotypic and genotypic coefficient of variation were observed for ascorbic acid (13.65 % and 13.43 %), harvest duration (9.66 % and 9.33 %), days to

50 % flowering (6.15 % and 5.65 %) and days to marketable maturity (5.91 % and 5.38 %). Reddy *et al.* (2013) reported low phenotypic and genotypic coefficients of variation for harvest duration, days to 50 % flowering and days to marketable maturity. Similarly low amount of phenotypic and genotypic coefficients of variation for harvest duration and days to marketable maturity were also observed by Ara *et al*. (2009) and Patel *et al*. (2013). Kumar (2014) and Singh *et al.* (2015) reported low phenotypic and genotypic coefficients of variation for days to 50 % flowering.

#### 4.1.2.2 Heritability

Heritability (broad sense) estimates ranged from 82.99 percent to 99.52 percent. High heritability was recorded for fruit yield per plant (99.52 %), average fruit weight (99.35 %), number of fruits per cluster (99.33 %), number of fruits per plant (99.22 %), harvest duration (98.96 %), total soluble solids (98.73 %), fruit shape index (98.50 %), number of locules per fruit (98.33 %), plant height (97.93 %), pericarp thickness (97.71 %), ascorbic acid (96.72 %), days to 50 % flowering (84.40 %) and days to marketable maturity (82.99 %). High heritability estimates for the characters number of fruits per plant, number of fruits per cluster and pericarp thickness were reported by Kumar *et al*. (2012). Khan and Samadia (2012) observed high heritability estimates for the characters fruit yield per plant and plant height. Similar results to present study were also reported by Premalakshmi *et al*. (2014) and Rai *et al*. (2016) who recorded high heritability for number of fruits per plant and average fruit weight. Meena and Bahudur (2014) and Hasan *et al.* (2016) noted high heritability estimates for plant height, days to 50 % flowering, number of fruits per plant, harvest duration, fruit yield per plant, average fruit weight, total soluble solids and ascorbic acid.

#### 4.1.2.3 Genetic advance and genetic gain

The genetic gain (genetic advance expressed as per cent of population mean) was low to high in nature and ranged from 10.10 to 101.63 percent (table 4.7). High genetic gain was recorded for number of fruits per cluster (101.63 %), fruit yield per plant (78.18 %), number of fruits per plant (94.66 %) and average fruit weight (62.19%). High genetic gain recorded for number of fruits per cluster, average fruit weight, number of fruits per plant and fruit yield per plant was in accordance with the findings of Kumar *et al*. (2013) and Basavaraj *et al.* (2015).

Genetic gain was moderate for plant height (49.71 %), total soluble solids (44.21%), number of locules per fruit (41.09%), fruit shape index (40.26 %), pericarp thickness (34.02 %) and ascorbic acid (27.21%). Moderate genetic gain for total soluble solids was observed by Reddy *et al*. (2013) and Basavaraj *et al*. (2015), for pericarp thickness, plant height and number of locules per fruit by Kingsley (2015) and for ascorbic acid by Reddy *et al*. (2013).

Low genetic gain was observed for harvest duration (18.58%), days to 50% flowering (10.70%) and days to marketable maturity (10.10%). Low values of genetic gain for harvest duration were also observed by Ara *et al.* (2009) and Patel *et al*. (2013), for days to 50% flowering and days to marketable maturity by Mehta and Asati (2008), Patel *et al*. (2013) and Kumar *et al.* (2014).

High heritability along with high estimates of genetic gain were observed for number of fruits per cluster (99.33 % and 101.63 %), number of fruits per plant (99.28 % and 94.66 %), fruit yield per plant (99.52 % and 78.18 %) and average fruit weight (99.35% and 62.19 %). Khan and Samadia (2012) reported high heritability along with high estimates of genetic gain for characters like number of fruits per plant and average fruit weight. Basavaraj *et al.* (2015) reported high heritability along with high estimates of genetic gain for number of fruits per cluster and number of fruits per plant. Singh *et al.* (2015) and Rai *et al*. (2016) observed high heritability and high estimates of genetic gain for fruit yield per plant.

High heritability along with high genetic gain were noticed for number of fruits per cluster, number of fruits per plant, fruit yield per plant and average fruit weight which might be assigned to additive gene effect governing their inheritance and phenotypic selection for their improvement could be achieved by simple method like pure line or mass selection or bulk or single seed descent method following hybridization and selection in early generations.

High heritability along with moderate genetic gain was observed for plant height (98.96 % and 49.71 %), total soluble solids (98.73 % and 44.21 %), number of locules per fruit (98.33 % and 41.09 %), fruit shape index (98.50 % and 40.26 %), pericarp thickness (97.71 % and 34.02 %) and ascorbic acid (96.72 % and 27.21 %). High heritability coupled with moderate genetic gain for pericarp thickness was noted by Kumar *et al*. (2013) and for ascorbic acid content by Reddy *et al.* (2013). Singh *et al.* (2015) observed high heritability and moderate genetic gain for total soluble solids and number of locules per fruit. Kumar *et al.* (2012) recorded high heritability and moderate gain for plant height, pericarp thickness and total soluble solids.

High heritability along with low genetic gain was observed for harvest duration (93.37 % and 18.58 %), days to 50 % flowering (84.40 % and 10.70 %) and days to marketable maturity (82.99 % and 10.10 %).

## 4.2 Correlation studies

The correlation coefficients among different characters were worked out at phenotypic and genotypic levels and have been presented in table 4.8. In general, the genotypic correlation coefficients were high in magnitude than phenotypic correlation coefficients.

### 4.2.1 Genotypic correlation coefficients

Genotypic correlation coefficients among thirteen characters (table 4.8) depicted that fruit yield per plant had positive and significant association with days to marketable maturity (0.430), plant height (0.215), number of fruits per cluster (0.200), average fruit weight (0.655), pericarp thickness (0.608) and harvest duration (0.360). However, it showed significant negative correlation with total soluble solids (-0.441). Positive and significant association of fruit yield per plant with days to marketable maturity, average fruit weight, pericarp thickness and harvest duration has been reported by Khan and Samadia (2012) and Kingsley (2015). Positive and significant association of average fruit weight and pericarp thickness with fruit yield per plant was also observed by Mahapatra *et al.* (2013) and Kumar (2014). Prashant *et al.* (2008) noted positive and significant association of fruit yield per plant with number of fruits per cluster and Joshi *et al.* (2004) with harvest duration. Negative and significant association of total soluble solids with fruit yield per plant, was in accordance with the findings of Aysh *et al.* (2012).

Days to 50% flowering exhibited positive and highly significant association with number of locules per fruit (0.268) and harvest duration (0.256) and had negative and significant association with number of fruits per cluster (-0.757), number of fruits per plant (-0.667), fruit shape index (-0.242), total soluble solids (-0.199) and ascorbic acid (-0.217). Positive and significant association of days to 50% flowering with number of locules per fruit and harvest duration and negative and significant correlation with number of fruits per cluster was in accordance with Kumar (2014), whereas, negative and significant correlation of total soluble solids with days to 50% flowering was observed by Khan and Samadia (2012).

Days to marketable maturity was positively and significantly correlated with average fruit weight (0.576), pericarp thickness (0.496) and ascorbic acid (0.240), while negatively and significantly with number of fruits per cluster (-0.225), number of fruits per plant (-0.315) and total soluble solids (-0.594). Kumar (2014) also reported positive and significant correlation of days to marketable maturity with average fruit weight, pericarp thickness and ascorbic acid.

Plant height exhibited positive and significant association with number of fruits per plant (0.287), total soluble solids (0.234) and harvest duration (0.832), while negative and significant association with average fruit weight (-0.235) and ascorbic acid (-0.312). Kumar (2010), Rai (2015), Joshi *et al.* (2004) and Khan and Samadia (2012) also observed positive and significant association of plant height with harvest duration.

Number of fruits per cluster had positive and significant correlation with number of fruits per plant (0.919) and fruit shape index (0.216) and had negative and significant correlation with average fruit weight (-0.258), pericarp thickness (-0.254) and number of locules per fruit (-0.286). Positive and significant association of number of fruits per cluster with number of fruits per plant was in accordance with Kumar (2014), Kumari and Sharma (2013) and Rai (2015) and negative and significant correlation with average fruit weight and number of locules per fruit was noted by Rai (2015).

Number of fruits per plant were positively and significantly correlated with total soluble solids (0.367) and negatively and significantly correlated with average fruit weight (-0.450), pericarp thickness (-0.362) and number of locules per fruit (-0.282). Negative and significant association of number of fruits per plant with average fruit weight and pericarp thickness has been reported by Joshi *et al.* (2004), Singh (2009), Manna and Paul (2012), Kumar (2014) and Rai (2015).

Average fruit weight showed positive and significant association with pericarp thickness (0.778), while negative and significant correlation with total soluble solids (-0.734). Buckseth (2010), Rai (2015), Joshi *et al*. (2004), and Sharma *et al.* (2010) also proposed significant and positive association of average fruit weight with pericarp thickness.

## Table 4.8. Genotypic and Phenotypic coefficients of correlation among different traits in tomato

| Characters | | Days to marketable maturity | Plant height (cm) | Numbers of fruits per cluster | Numbers of fruits per plant | Average fruit weight (g) | Fruit Shape Index | Pericarp thickness (mm) | Number of locules per fruit | Total soluble solids ($^0$B) | Ascorbic acid (mg/100 g) | Harvest duration | Fruit yield/plant (kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days to 50% flowerings** | **G** | -0.043 | 0.191 | -0.757** | -0.667** | 0.077 | -0.242* | 0.017 | 0.268** | -0.199* | -0.217* | 0.256** | -0.141 |
| | **P** | 0.126 | 0.214* | -0.670** | -0.586** | 0.100 | -0.114 | 0.063 | 0.302** | -0.132 | -0.155 | 0.303** | -0.103 |
| **Days to marketable maturity** | **G** | | -0.169 | -0.225* | -0.315** | 0.576** | 0.029 | 0.496** | -0.071 | -0.594** | 0.240* | -0.094 | 0.430** |
| | **P** | | -0.113 | -0.179 | -0.258** | 0.554** | 0.131 | 0.498** | -0.004 | -0.485** | 0.263** | -0.010 | 0.418** |
| **Plant height (cm)** | **G** | | | 0.057 | 0.287** | -0.235* | -0.053 | -0.131 | -0.057 | 0.234* | -0.312** | 0.832** | 0.215* |
| | **P** | | | 0.063 | 0.291** | -0.226* | -0.025 | -0.118 | -0.042 | 0.243* | -0.297** | 0.832** | 0.220* |
| **Numbers of fruits per cluster** | **G** | | | | 0.919** | -0.258** | 0.216* | -0.254** | -0.286** | 0.165 | 0.025 | -0.136 | 0.200* |
| | **P** | | | | 0.919** | -0.252** | 0.225* | -0.245* | -0.273** | 0.172 | 0.032 | -0.122 | 0.203* |
| **Numbers of fruits per plant** | **G** | | | | | -0.450** | 0.127 | -0.362** | -0.282** | 0.367** | -0.039 | 0.097 | 0.154 |
| | **P** | | | | | -0.443** | 0.140 | -0.351** | -0.268** | 0.372** | -0.031 | 0.107 | 0.157 |
| **Average fruit weight (g)** | **G** | | | | | | 0.001 | 0.778** | 0.128 | -0.734** | 0.134 | -0.088 | 0.655** |
| | **P** | | | | | | 0.020 | 0.779** | 0.137 | -0.717** | 0.141 | -0.073 | 0.657** |
| **Fruit Shape Index** | **G** | | | | | | | 0.140 | -0.262** | -0.205* | 0.134 | -0.057 | 0.071 |
| | **P** | | | | | | | 0.165 | -0.213* | -0.164 | 0.157 | -0.008 | 0.085 |
| **Pericarp thickness (mm)** | **G** | | | | | | | | 0.092 | -0.631** | 0.167 | 0.070 | 0.608** |
| | **P** | | | | | | | | 0.109 | -0.606** | 0.178 | 0.090 | 0.610** |
| **Number of locules per fruit** | **G** | | | | | | | | | -0.114 | 0.057 | -0.076 | -0.132 |
| | **P** | | | | | | | | | -0.093 | 0.073 | -0.047 | -0.120 |
| **Total soluble solids ($^0$B)** | **G** | | | | | | | | | | -0.243* | 0.129 | -0.441** |
| | **P** | | | | | | | | | | -0.226* | 0.149 | -0.429** |
| **Ascorbic acid (mg/100 g)** | **G** | | | | | | | | | | | -0.242* | 0.031 |
| | **P** | | | | | | | | | | | -0.217* | 0.038 |
| **Harvest duration** | **G** | | | | | | | | | | | | 0.360** |
| | **P** | | | | | | | | | | | | 0.365** |

*Significant at 5% level of significance

**Significant at 1% level of significance

Fruit shape index showed negative and significant correlation with number of locules per fruit (-0.262) and total soluble solids (-0.205) which was in accordance with the findings of Kumar (2014).

Pericarp thickness exhibited negative and significant correlation with total soluble solids (-0.631).

Total soluble solids had negative and significant correlation with ascorbic acid (-0.243).

Ascorbic acid had negative and significant correlation with harvest duration (-0.242).

### 4.2.2 Phenotypic correlation coefficients

The nature of phenotypic correlation was similar to genotypic correlation. But in some cases, the magnitude of phenotypic correlation was considerably lower and was statistically non significant while they were found significant at genotypic level.

## 4.3 Path coefficient analysis

Path coefficient analysis method was devised by Dewey and Lu (1959) which helps in partitioning the correlation coefficient under direct and indirect effects which permit a critical examination of the relative importance of each trait. In order to understand such effects of different independent characters or in combination with other characters on yield, the estimates of direct and indirect effects were computed through path coefficient analysis in the present investigation. Perusal of data from table 4.9 indicated that maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight (0.877), followed by days to 50% flowering (0.619), number of fruits per cluster (0.611) and harvest duration (0.559). The other characters which showed positive direct effect were number of fruits per plant (0.462), total soluble solids (0.461), days to marketable maturity (0.370), pericarp thickness (0.242), fruit shape index (0.083) and ascorbic acid (0.057). Plant height (-0.320) and number of locules per fruit (-0.006) had negative direct effect on fruit yield per plant.

Days to marketable maturity (0.213) and pericarp thickness (0.188) recorded maximum positive indirect effect via average fruit weight on fruit yield. Harvest duration (0.143) exerted maximum positive indirect effect via days to 50 % flowering. Number of

**Table 4.9. Estimates of direct and indirect effects of different traits on yield in tomato**

| Characters | Days to 50% flowerings | Days to marketable maturity | Plant height (cm) | Numbers of fruits per cluster | Numbers of fruits per plant | Average fruit weight (g) | Fruit Shape index | Pericarp thickness (mm) | Number of locules per fruit | Total soluble solids ($^0$B) | Ascorbic acid (mg/100 g) | Harvest duration (days) | GCCFYPP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Days to 50% flowerings** | **0.619** | -0.015 | -0.061 | -0.462 | -0.308 | 0.067 | -0.020 | 0.004 | -0.001 | -0.091 | -0.012 | 0.143 | -0.141 |
| **Days to marketable maturity** | -0.026 | **0.370** | 0.054 | -0.137 | -0.145 | 0.505 | 0.002 | 0.120 | 0.0004 | -0.274 | 0.013 | -0.052 | 0.430 |
| **Plant height (cm)** | 0.118 | -0.062 | **-0.320** | 0.034 | 0.132 | -0.206 | -0.004 | -0.031 | 0.0003 | 0.107 | -0.018 | 0.465 | 0.215 |
| **Numbers of fruits per cluster** | -0.468 | -0.083 | -0.018 | **0.611** | 0.424 | -0.226 | 0.018 | -0.061 | 0.001 | 0.076 | 0.001 | -0.075 | 0.200 |
| **Numbers of fruits per plant** | -0.413 | -0.116 | -0.091 | 0.561 | **0.462** | -0.395 | 0.010 | -0.087 | 0.001 | 0.169 | -0.002 | 0.054 | 0.154 |
| **Average fruit weight (g)** | 0.047 | 0.213 | 0.075 | -0.157 | -0.208 | **0.877** | 0.0001 | 0.188 | -0.0008 | -0.339 | 0.007 | -0.049 | 0.655 |
| **Fruit shape index** | -0.149 | 0.010 | 0.016 | 0.132 | 0.058 | 0.001 | **0.083** | 0.034 | 0.001 | -0.094 | 0.007 | -0.031 | 0.071 |
| **Pericarp thickness (mm)** | 0.010 | 0.183 | 0.042 | -0.155 | -0.167 | 0.682 | 0.011 | **0.242** | -0.0006 | -0.291 | 0.009 | 0.039 | 0.608 |
| **Number of locules per fruit** | 0.166 | -0.026 | 0.018 | -0.174 | -0.130 | 0.112 | -0.022 | 0.022 | **-0.006** | -0.052 | 0.003 | -0.042 | -0.132 |
| **Total soluble solids ($^0$B)** | -0.123 | -0.220 | -0.075 | 0.100 | 0.169 | -0.644 | -0.017 | -0.152 | 0.0007 | **0.461** | -0.014 | 0.072 | -0.441 |
| **Ascorbic acid (mg/100 g)** | -0.134 | 0.089 | 0.100 | 0.015 | -0.018 | 0.118 | 0.011 | 0.040 | -0.0004 | -0.112 | **0.057** | -0.135 | 0.031 |
| **Harvest duration (days)** | 0.158 | -0.034 | -0.266 | -0.082 | 0.045 | -0.077 | -0.004 | 0.017 | 0.0004 | 0.059 | -0.013 | **0.559** | 0.360 |

At genotypic level, the residual effect was recorded to be 0.07

fruits per plant (0.424) exerted maximum positive indirect effect via number of fruits per cluster and days to 50% flowering (0.158) recorded maximum positive indirect effect via harvest duration. At genotypic level, the residual effect was recorded to be 0.07.

Golani *et al*. (2007), Ramana *et al.* (2007), Tiwari and Uphadhyay (2011), Sharma and Singh (2012), Kumar *et al.* (2013), Srivastava *et al.* (2013), Meena & Bahadur (2015) and Prajapati *et al*. (2015) reported highest positive direct effect of average fruit weight on fruit yield per plant. Srivastava *et al.* (2013) and Meena and Bahadur (2015) noted positive direct effect of days to 50% flowering. Harer *et al.* (2002) and Kumar (2003) also observed high positive direct effect of average fruit weight and number of fruits per cluster on fruit yield per plant. Ara *et al.* (2009) proposed positive direct effect of harvest duration. Kumar (2010), Buckseth *et al*. (2012), Manna and Paul (2012), Kumar *et al*. (2013), Reddy *et al*. (2013), Khapte and Jansirani (2014), Premalakshmi *et al.*(2014) and Menna and Bahadur (2015) also noted positive direct effect of number of fruits per plant. Harer *et al*. (2002), Makesh *et al.* (2006) and Ramana *et al*. (2007) observed positive direct effect of total soluble solids. Positive direct effect of days to marketable maturity was noted by Prajapati *et al*. (2015). Positive direct effect of pericarp thickness has been proposed by Manna and Paul (2012) and Kumar *et al.* (2014). Ara *et al*. (2009) and Saleem *et al*. (2013) reported negative and direct effect of number of locules per fruit.

**Plate 1. View of Experimental Area**

# Chapter 5

# Summary and Conclusion

## *Chapter-5*

# SUMMARY AND CONCLUSION

The present investigation entitled "Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)" was carried out at the experimental farm of the Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) on diverse group of thirty five genotypes to ascertain the extent of variability, correlation and path analysis. The experiment was laid out in randomized complete block design with three replications during kharif season of 2016. The characters studied during the evaluation of germplasm were days to 50 % flowering, days to marketable maturity, plant height (cm), number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg) and per hectare, fruit shape index, pericarp thickness (mm), number of locules per fruit, total soluble solids (°B), ascorbic acid (mg/100 g), fruit colour, harvest duration and incidence of buckeye rot (%).

Parameters of variability and correlation were estimated for different traits and path coefficient analysis was carried out for yield per plant with other horticultural traits. Analysis of variance showed highly significant variation among genotypes for all the traits. Genotype Punjab Red Cherry took minimum days (24.67) to reach 50% flowering, followed by EC-21132 (29.00) and S-1001 (29.67). Genotype Punjab Red Cherry was earliest in maturity and took 66.00 days to first harvesting, followed by UHF-553 (67.00), BT-10-10 (67.67) and UHF-95 (67.67). Genotype Solan Vajr observed maximum Plant height (123.65 cm) and next best genotypes were EC-2997 (121.33 cm) and check variety Solan Lalima (120.32 cm). Maximum number of fruits per cluster (15.07) were recorded in Punjab Red Cherry followed by Punjab Ratta (5.30) and Punjab Gaurav (5.27). Genotype Punjab Red Cherry recorded maximum number of fruits per plant (70.02), whereas, minimum fruits were found in DMT KRCCH-1 (11.25). Genotype Punjab Sartaj produced biggest sized fruit of 84.00 g and next best genotypes were BCT-10 (78.80 g) and BCT-8 (75.80 g). Maximum fruit yield per plant (1.59 kg) and maximum fruit yield per hectare (471.11 q/ha) was recorded by Punjab Sartaj. Genotype DMT KRCCH-1 depicted maximum fruit shape index value (1.19). Maximum pericarp thickness of 6.13 mm was observed in S-1001 followed by DMT KRCCH-2 (5.46 mm) and Punjab Gaurav (5.45 mm). Minimum number of locules per fruit were observed in UHF-90 (2.50) and EC-29414 (2.50). The maximum value for total soluble solids (6.32 $^{0}$B) was recorded in EC-21132 followed by Punjab Red Cherry (6.04) and EC-141827 (5.93). Genotype DMT KRCCH-2 recoded maximum ascorbic acid content (36.55 mg/100 g), while minimum was found in DMT KRCCH-3 (18.62 mg/100 g). In case of fruit color, thirty five genotypes fall under red group and one genotype under orange red group. Maximum harvest duration (42.67 days) was recorded in check variety Solan Lalima, followed by EC-2997 (42.00 days) and EC-524082 (42.00 days). Minimum buckeye rot incidence (8.63 %) was observed in EC-29414, followed by EC-141827 (10.57 %) and BT-10-10 (14.25 %).

**Parameters of Variability**

Among various parameters of variability, high coefficients of variation (phenotypic and genotypic) were found for number of fruits per cluster, fruit yield per plant, number of fruits per plant and average fruit weight. The differences between phenotypic and genotypic coefficients were very less. Further, high estimates of heritability and genetic gain were recorded for number of fruits per cluster**,** fruit yield per plant**,** number of fruits per plant and average fruit weight, there by suggesting that straight selection for these traits may bring worthwhile improvement in identifying superior genotypes in tomato. High heritability coupled with moderate genetic gain was observed for plant height, ascorbic acid, total soluble solids, fruit shape index, pericarp thickness and number of locules per fruit. These characters also show some scope for improvement through selection.

**Correlation Studies**

In general, correlation coefficients were high at genotypic level than phenotypic level. Results indicated that fruit yield per plant had positive and significant association with days to marketable maturity, plant height, number of fruits per cluster, average fruit weight, pericarp thickness and harvest duration. Hence, there is ample scope of selection for these traits. However, it showed negative and significant correlation with total soluble solids.

**Path coefficient analysis**

The path coefficient analysis revealed that maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight followed by days to 50 % flowering, number of fruits per cluster and harvest duration thus, indicating direct selection for these traits as a criteria for improvement in tomato.

**CONCLUSION:**

- From the present investigation, it can be concluded that among all genotypes, Punjab Sartaj was found promising for yield and yield contributing traits.
- High phenotypic and genotypic coefficients of variation were recorded for number of fruits per cluster, fruit yield per plant, number of fruits per plant and average fruit weight. High heritability coupled with high genetic gain was recorded for number of fruits per cluster, fruit yield per plant, number of fruits per plant and average fruit weight. Hence, selection for these traits can prove effective for improvement in yield. High heritability coupled with moderate genetic gain was observed for plant height, ascorbic acid content, total soluble solids, fruit shape index, pericarp thickness and number of locules per fruit. These characters also show some scope for improvement through selection.
- A highly positive and significant genotypic correlation of fruit yield per plant was observed with days to marketable maturity, plant height, number of fruits per cluster, average fruit weight, pericarp thickness and harvest duration.
- Maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight followed by days to 50 % flowering, number of fruits per cluster and harvest duration.

**Table 5.1 Best three genotypes with respect to different traits in tomato**

| Characters | Genotypes | Mean |
|---|---|---|
| Days to 50% flowering (days) | Punjab Red Cherry | 24.67 |
| | EC-21132 | 29.00 |
| | S-1001 | 29.67 |
| Days to marketable maturity (days) | Punjab Red Cherry | 66.00 |
| | UHF-553 | 67.00 |
| | BT-10-10 | 67.67 |
| Plant height (cm) | Solan Vajr | 123.65 |
| | EC-2997 | 121.33 |
| | Solan Lalima | 120.32 |
| Number of fruits per cluster | Punjab Red Cherry | 15.07 |
| | Punjab Ratta | 5.30 |
| | Punjab Gaurav | 5.27 |
| Number of fruits per plant | Punjab Red Cherry | 70.02 |
| | Solan Lalima | 26.37 |
| | BT-10-10 | 24.53 |
| Average fruit weight (g) | Punjab Sartaj | 84.00 |
| | BCT-10 | 78.80 |
| | BCT-8 | 75.80 |
| Fruit yield per plant (kg) | Punjab Sartaj | 1.59 |
| | Solan Lalima | 1.54 |
| | Punjab Gaurav | 1.53 |
| Fruit yield per hectare (q/ha) | Punjab Sartaj | 471.11 |
| | Solan Lalima | 456.29 |
| | Punjab Gaurav | 453.33 |
| Fruit shape index | DMT KRCCH-1 | 1.19 |
| | DMT KRCCH-4 | 1.17 |
| | BT-10-10 | 1.13 |
| Pericarp thickness (mm) | S-1001 | 6.13 |
| | DMT KRCCH-2 | 5.46 |
| | Punjab Gaurav | 5.45 |
| Number of locules per fruit | EC-29414 | 2.50 |
| | UHF-90 | 2.50 |
| | Punjab Red Cherry | 2.53 |
| Total soluble solids ($^0$B) | EC-21132 | 6.32 |
| | Punjab Red Cherry | 6.04 |
| | EC-141827 | 5.93 |
| Ascorbic acid (mg/100 g) | DMT KRCCH-2 | 36.55 |
| | DMT KRCCH-6 | 36.51 |
| | DMT KRCCH-1 | 35.39 |
| Harvest duration (days) | Solan Lalima | 42.67 |
| | EC-2997 | 42.00 |
| | EC-524082 | 42.00 |
| Incidence of buckeye rot (%) | EC-29414 | 8.63 |
| | EC-141827 | 10.57 |
| | BT-10-10 | 14.25 |

# Abstract

**Dr. Y. S. Parmar University of Horticulture & Forestry**
**Nauni, Solan-173230 (HP)**
**Department of Vegetable Science**

| | | |
|---|---|---|
| **Title of Thesis** | : | **"Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)"** |
| **Name of the Student** | : | Sumit B Patil |
| **Admission Number** | : | H-2015-110-M |
| **Major Advisor** | : | Dr. Santosh Kumari |
| **Major Field** | : | Vegetable Science |
| **Minor Field** | : | i) Genetics and Plant Breeding<br>ii) Plant Pathology |
| **Degree Awarded** | : | M.Sc. (Horticulture) Vegetable Science |
| **Year of Award of Degree** | : | 2017 |
| **No. of Pages in Thesis** | : | 61 + iii |
| **No. of words in Abstract** | : | 429 |

## ABSTRACT

The present investigation entitled "Genetic evaluation studies in tomato (*Solanum lycopersicum* L.)" was carried out at Vegetable Research Farm, Department of Vegetable Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during *kharif* season, 2016. The experiment was laid out in RCBD with three replications comprising of thirty five diverse genotypes of tomato including Solan Lalima as check variety. The characters studied during the present study were days to 50 % flowering, days to marketable maturity, plant height (cm), number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit yield per plant (kg) and per hectare (q), fruit shape index, pericarp thickness (mm), number of locules per fruit, total soluble solids (°B), ascorbic acid (mg/100 g), fruit color, harvest duration and incidence of buckeye rot (%). Analysis of variance revealed highly significant differences among genotypes for all the characters under study. Among all genotypes, Punjab Sartaj was found promising for yield and yield contributing traits. High phenotypic and genotypic coefficients of variation were recorded for number of fruits per cluster, fruit yield per plant, number of fruits per plant and average fruit weight. High heritability coupled with high genetic gain was recorded for number of fruits per cluster**,** fruit yield per plant**,** number of fruits per plant and average fruit weight. Hence, selection for these traits can prove effective for improvement in fruit yield. A highly positive and significant correlation of fruit yield per plant with days to marketable maturity, plant height, number of fruits per cluster, average fruit weight, pericarp thickness and harvest duration was observed, however it showed negative and significant correlation with total soluble solids. Maximum positive direct effect towards fruit yield per plant was exerted by average fruit weight followed by days to 50 % flowering, number of fruits per cluster and harvest duration.

**Signature of Major Advisor** **Signature of Student**

**Countersigned**

**Professor and Head**
**Department of Vegetable Science**
**Dr Y S Parmar University of Horticulture and Forestry**
**Nauni, Solan, Himachal Pradesh – 173 230**

# Appendices

## APPENDIX-I

### Agro-meteorological data during growing period (2016)

| Month | Temperature (°C) | | | Relative humidity (%) | Rainfall (mm) |
|---|---|---|---|---|---|
| | 2016 | | Mean | 2016 | 2016 |
| | Max | Min | | | |
| **March** | 24.2 | 9.1 | 16.65 | 55.00 | 87.50 |
| **April** | 29.4 | 13.5 | 21.5 | 45 | 25.6 |
| **May** | 30.5 | 16.6 | 23.6 | 46 | 115.0 |
| **June** | 29.6 | 19.2 | 24.4 | 69 | 118.9 |
| **July** | 27.4 | 20.6 | 24.0 | 82 | 151.9 |
| **August** | 26.9 | 19.9 | 23.4 | 83 | 164.1 |

**Source:** Meteorological Observatory, Department of Environmental Science, Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan HP 173 230

## APPENDIX-II (A)

**Analysis of variance for various horticultural characters in tomato**

| Character / Source | df | Mean Sum of Squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering | Days to marketable maturity | Plant height (cm) | Number of fruits per cluster | Number of fruits per plant | Average fruit weight (g) | Fruit yield per plant (kg) | Fruit yield per plant (q/ha) |
| **Replication** | 2 | 0.49 | 1.55 | 31.25 | 0.55 | 0.39 | 11.71 | 0.001 | 472.47 |
| **Treatment** | 34 | 10.59* | 49.54* | 1,376.34* | 12.59* | 228.08* | 870.42* | 0.43* | 37,947.97* |
| **Error** | 68 | 2.58 | 8.53 | 11.14 | 0.37 | 0.70 | 9.79 | 0.001 | 88.80 |

* Significant at 5% level of significance

## APPENDIX-II (B)

**Analysis of variance for various horticultural characters in tomato**

| Character / Source | df | Mean Sum of Squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | **Fruit shape index** | **Pericarp thickness (mm)** | **Number of locules per fruit** | **Total soluble solids ($^0$B)** | **Ascorbic acid (mg/100 g)** | **Harvest duration (days)** | **Incidence of buckeye rot (%)** |
| **Replication** | 2 | 0.003 | 0.12 | 1.09 | 0.01 | 7.41 | 6.66 | 229.80 |
| **Treatment** | 34 | 0.02* | 2.11* | 0.94* | 2.47* | 99.48* | 69.40* | 214.94* |
| **Error** | 68 | 0.004 | 0.09 | 0.23 | 0.26 | 1.27 | 7.47 | 116.32 |

* Significant at 5% level of significance

# BRIEF BIO-DATA

---

**Name** : Sumit B Patil

**Father's Name** : Sri Basavaraj Patil

**Mother's Name** : Smt. Bharati Patil

**Date of Birth** : 25 th August, 1993

**Permanent Address** : S/O Basavaraj Patil, House no. 547, Basavan galli, killa, Gokak, Dist.- Belagavi, Karnataka- 591307.

**Educational Qualifications** :

| **Certificate/ degree** | **University/ Board** | **Year** | **Marks (%)** | **Division** |
|---|---|---|---|---|
| Matriculation/ Secondary | Karnataka Secondary Education Examination Board | 2009 | 71.52% | First |
| Higher Secondary | Karnataka Pre-University Board | 2011 | 50.33% | Second |
| Graduation | University of Horticulture Sciences, Bagalkot, Karnataka | 2015 | 7.55 | Second |

Scholarship/ Stipend/ Fellowship, any Other financial assistance received during the study period : Post matric scholarship schemes minorities, Karnataka

**(Sumit B Patil)**