Studies on Genetic Divergence in Tomato (*Solanum lycopersicum* L.)

Thesis

Submitted to the

VCSG Uttarakhand University of Horticulture & Forestry
Bharsar-246123, Pauri Garhwal (Uttarakhand) INDIA

By

Harish Chandra Badhani

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

Master of Science
Horticulture (Vegetable Science)

July, 2015

Tera Tujhko Aarpan

Kaya Lage Mera

Dr. B. P. Nautiyal
Professor

VCSG Uttarakhand University of Horticulture and Forestry
Bharsar-246123, Pauri Garhwal (Uttarakhand) India

CERTIFICATE

This is to certify that the thesis entitled **"Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Horticulture** with major in **Vegetable Science,** of the College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, Pauri Garhwal (UK), is a record of ***bona fide*** research carried out by **Mr. Harish Chandra Badhani, Id. No. 13123**, under my supervision, and no part of the thesis has been submitted for other degree or diploma.

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

(Dr. B. P. Nautiyal)
Chairman
Advisory Committee

CERTIFICATE

We, the undersigned, members of the Advisory Committee, of **Mr. Harish Chandra Badhani, Id. No. 13123**, a candidate for the degree of **Master of Science in Horticulture** with major in **Vegetable Science,** agree that the thesis entitled **"Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)"** may be submitted in partial fulfillment of the requirements for the degree.

(B. P. Nautiyal)
Chairman
Advisory Committee

(S. Kumar)
Co-advisor

(S. C. Pant)
Member

(A. Paliwal)
Member

(M. Sharma)
Member

ACKNOWLEDGEMENTS

I feel pleasure to express my profound regards, deep sense of gratitude and heartiest thanks to ***Dr. B. P. Nautiyal****, Dean, College of Horticulture Bharsar and* ***Chairman of My Advisory Committee*** *for his Co-operative attitude, help, encouragement and for rendering valuable suggestions about the parameters of this study and providing valuable guidance in the preparation of the manuscript.*

I express my most sincere and heartfelt thanks to ***Dr. Sandeep Kumar, Co-advisor of My Advisory Committee*** *for excellent guidance and suggestions during the investigation and for critically going through this manuscript.*

I also want to express sincere thanks to ***Dr. S. C. Pant, Dr. Ajaya Paliwal*** *and* ***Dr. Manju Sharma****, the* ***Members of My Advisory Committee*** *for their valuable help during investigation and statistical analysis of my research.*

I want to express my sincere thanks to ***Dr. Ganshyam Abrol*** *(Post Harvest Technology),* ***Dr. Sanjeev Verma*** *(Microbiology),* ***Dr. Rajnish Mishra*** *(Entomolgy),* ***Dr. Pankaj Bahuguna (Statistics), Dr Shailja Punetha*** *(Vegetable Science),* ***Gajpal Bisht*** *(Sr. Asst.), and* ***Mr. Reni Lal*** *(Supervisor Vegetable field) and vegetable research farm workers for their regular supports.*

I wish to extent warm thanks to all my classmates and juniors specially ***Tinku K Sharma****, Amit Singh, Pavan, Manish, Vipin, Radhika, Ashiq, Ashok, Naveen, Kulveer, Yeswant, Kaushal, Sunil negi, Ekta, Neema, Beena, Deeplata, Neelam, Sarita, Tanuja, Pragya, Pankaj, Manoj, Nitish, Rakesh, Sunil, Chinmay, Mekap, Anil Rana, Navneet and also to entire batch of M.Sc. 2013-14 for their delighted company at different phases of this research.*

*Loyal thanks from the core of my heart are due to my loving mother (****Dhanuli Devi****), father (****Ganesh Datt Badhani****), sister (****Radha Badhani****) and brother (****Prakash Badhani****) for their immense love, heartiest blessings and continuous moral supports during the course of my study.*

Place: Bharsar
Date: July, 2015

Harish

Harish Chandra Badhani

CONTENTS

Chapter No.	Topic	Page No.
1.	Introduction	1-3
2.	Review of literature	4-28
3.	Materials and methods	29-42
4.	Results	43-62
5.	Discussion	63-74
6.	Summary and conclusion	75-79
7.	Literature cited	80-90
•	Appendices	I-II
•	Abstract	-
•	Vitae	-

LIST OF TABLES

Table No.	Title	Page No.
3.1	List of tomato genotypes used in the study	31
3.2	Allotment of treatments in experiment field under RBD	32
4.1	Performance of tomato genotypes for Days to first fruit harvesting (days), Fruit length (cm), Fruit breadth (cm) and Average fruit weight (gm)	44
4.2	Performance of tomato genotypes for Number of fruit clusters per plant, Number of fruits per cluster, Number of fruits per plant and Harvest duration (days)	46
4.3	Performance of tomato genotypes for marketable yield for per plant (kg), per plot (kg), and per hectare (q)	48
4.4	Performance of tomato genotypes for Shelf life (days), Pericarp thickness (mm), Lycopene content (mg/100 g) and Total soluble solids (^{o}brix)	50
4.5	Performance of tomato genotypes for incidence of buckeye rot and fruit borer	52
4.6	Estimates of phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for different traits in tomato	55
4.7	Phenotypic and genotypic coefficients of correlation among different traits in tomato	57
4.8	Estimates of direct and indirect effects of different traits on marketable fruit yield per plant in tomato	58
4.9	Clustering pattern of 30 genotypes of cucumber on the basis of genetic divergence	60
4.10	Average intra and inter cluster distance (D^2)	60
4.11	Cluster means for different characters in 30 genotypes of tomato	61

LIST OF PLATES

Plate No.	Title	Between Pages
3.1	Different inter-cultural operations during the field experiment	32-33
3.2	Best genotypes identified on the basis of overall performance	78-79

ABBREVIATIONS

%	Per cent
&	And
°C	Degree centigrade
^{0}B	Brix
AVRDC	Asian Vegetable Research and Development Center, Taiwan
CD	Critical difference
cm	Centimeter
et al.	And others
Fig.	Figure
g	Gram
GBPUAT	Govind Ballabh Pant University of Agriculture and Technology
ha	Hectare
IIHR	Indian Institute of Horticultural Research
kg	Kilogram
LC	Local Collection
mm	millimeters
PAU	Punjab Agricultural University
q	Quintal
SEd	Standard error of the difference
UHF	Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan
VCSG	Veer Chandra Singh Garhwali
Viz.	Namely

Chapter-1
Introduction

Chapter-1
Introduction

Tomato (*Solanum lycopersicum* L.) is one of the most popular warm season fruit vegetable crops grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of cuisines in fresh as well as in preserved form. It is mostly considered as "Protective food" based on its nutritive value, antioxidant molecules such as carotenoids, particularly lycopene, ascorbic acid, vitamin E and phenol compounds, particularly flavonoids (Sepat *et al*., 2013). Lycopene has important dietetic properties since it reduces the risk of several types of cancers and heart attacks (Dorgan *et al*., 1998); (Clinton, 2005).

In India, it occupied an area of 8.82 lakh hectares with a production of 18.73 million metric tonnes with an average productivity of 21.23 metric tonne per hectare (NHB 2013- 14). It occupied second position among the vegetable crop in terms of production after potato. Uttarakhand is one of the tomato growing states covering an area of 9.08 thousand hectare with a production of 113.65 thousand metric tonnes and an average productivity of 12.51 metric tonnes per hectares (NHB 2013- 14).

Tomato belongs to the family Solanaceae and is native of Andean region that includes parts of Colombia, Ecuador, Peru, Bolivia and Chile. All tomato wild relatives are native to this area (Rick, 1973); (Taylor, 1986). It is a typical day neutral herbaceous annual plant and is mainly self-pollinated, but a certain percentage of cross-pollination also occurs.

It is widely grown as an off-season vegetable in the hills of Uttarakhand. The crop is becoming popular day by day among hill farmers due to its short duration, high market value and constant demand throughout the year on account of its popularity. Farmers fetch good income after sending their produce in the plains from June to September.

Considering the importance of this crop, there is a need for improvement and to develop varieties suited to specific agro-ecological conditions and also for specific end use. A thorough knowledge regarding the amount of genetic variability existing for various characters is essential for initiating the crop1 improvement programme. With limited

variability much cannot be achieved and the breeder will have to enrich the germplasm or he can resort to create greater variability through hybridization, mutation and polyploidy breeding.

The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and the environment, in which it is growing. Further, the genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance and include dominance and epitasis (non-allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as phenotypic and genotypic coefficient of variation, heritability and genetic advance. Further, genetic advance can be used to predict the efficiency of selection.

Yield is a complex character controlled by a large number of contributing characters and their interactions. A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components. For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The path coefficient technique developed by Wright (1921) helps in estimating direct and indirect contribution of various components in building up the total correlation towards yield. On the basis of these studies the quantum importance of individual characters is marked to facilitate the selection programme for better gains.

Commercial F_1 hybrids are common in tomato and selection of new parents for higher heterosis is a continuous process. Generally diverse plants are expected to give high hybrid vigour (Harrington, 1940). Hence, it necessitates the study of genetic divergence among the existing varieties and germplasm collection for identification of parents for hybridization programme. The information on genetic divergence of various traits particularly of those that contribute to yield and quality would be of most useful in planning the breeding programme. D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude for divergence between two genotypes under comparison. It considers the variation produced by any character and their consequent effect that it bears on other characters. The technique was first used by Mahalanobis in an anthropometric survey of the united province in India.

This technique has been applied in several crops to select genotypes for further breeding programmes Grouping of genotypes based on D^2 analysis will be useful in choosing suitable parental lines for heterosis breeding. Such studies are also useful in selection of parents for hybridization to recover superior transgressive segregants and it can further result into release of improved open pollinated varieties for commercial cultivation.

Therefore, the present investigation "Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)" have been undertaken in 30 genotypes of tomato with the following objectives.

1. To study the nature and extent of genetic variability in tomato germplasm for growth, yield and quality parameters.
2. To study the association of different horticultural traits with the yield.
3. To assess the extent of genetic diversity in the available tomato germplasm.

Chapter-2
Review of literature

Chapter-2
Review of Literature

The information available in the literature pertaining to tomato germplasm for yield and quality traits have been reviewed here under the following sub heads:

2.1 Genetic variability studies
2.2 Correlation and path analysis
2.3 Genetic divergence studies

2.1 GENETIC VARIABILITY STUDIES

Genetic variability is the basis of all crop improvement programmes. Higher the amount of variability in the population, greater is the scope for its improvement by selection. The importance of genetic variability was perceived by Vavilov (1951) for the first time and advocated that wide range of variability provides better scope for selecting a desirable genotype. Knowledge of heritability for different traits seems to be essential for any crop improvement programme because the heritable component is the consequence of genotype and inherited from generation to generation. Wright (1921) reported that heritability comprised of additive and non-additive components and it is the former which respond to selection.

Singh *et al.* (2002a) studied the variation among ninety two tomato genotypes with regard to thirteen 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.

Singh *et al*. (2002b) evaluated 15 tomato cultivars for genetic variation in yield and quality parameters (days to anthesis, days from fruit setting to mature green stage, days from fruit setting to red ripe stage, average fruit weight, total yield, shelf life of mature green fruits and shelf life of ripe red fruits). Phenotypic and genotypic coefficients of variation were high for average fruit weight, shelf life of ripe red fruits, total yield and

marketable yield, but were moderate for days from fruit setting to mature green stage and shelf life of mature green fruits. 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 twenty one genotypes of tomato for fruit yield and other yield contributing characters and reported significant genotypic variation among the genotypes for fruit yield and other yield components in tomato. High heritability estimates coupled with high genetic advance as percent mean were observed for plant height, number of nodes on main stem, number of flowers per cluster, number of fruits per plant and number of seeds per fruit in tomato. The results suggested the existence of high genetic variability among the cultivars for all the characters studied.

Joshi *et al.* (2004) conducted an experiment on genetic variability in tomato and found the highest coefficient of variation (genotypic and phenotypic) 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 which indicated the presence of dominance and epistatic effects. High heritability combined with high genetic gain was observed for shelf life indicating additive gene action.

Singh and Narayan (2004) studied the genetic variability in ten diverse genotypes of tomato for yield and yield attributing traits and observed a wide range of variability along with high estimates of genetic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for plant height, fruit length, number of fruits per plant and number of branches per plant. Moderate to high values of heritability coupled with high GCV and genetic gain were observed for plant height, fruit length, number of fruits per plant, fruit yield and number of branches per plant.

Singh and Cheema (2005) studied the variation and heritability of quality characteristics in tomato raised under normal and high temperature conditions (November and February plantings, respectively). Data were recorded for total soluble solids (TSS),

pericarp thickness, fruit firmness, acidity, lycopene content and dry matter content. There were significant differences among the genotypes under normal conditions, whereas differences were not significant under high temperature conditions. The population mean was higher during November than February planting for all the characters except acid content and TSS. In general, the phenotypic coefficients of variation were higher than genotypic coefficients of variation indicating that the genotypic effect is least influenced by the given environment. Heritability estimates (in the broad sense) were high for all the characters for November planting except for lycopene content.

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 (PCV) and genotypic (GCV) 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, and acidity, number of fruits per plant, fruit length, pericarp thickness, plant height and earliness.

Mahesha *et al.* (2006) observed significant differences among thirty diverse tomato genotypes for all the characters studied. A wide range of variation was observed for plant height, number of branches per plant, fruit weight, fruit length, fruit diameter, number of locules per fruit, fruit set percentage, fruits per plant, fruit yield per plant, ascorbic acid content and total soluble solids. Fruit weight, fruits per plant and plant height exhibited very high heritability values along with high genetic gain.

Singh *et al*. (2006) observed considerable range of genetic variability in nineteen genotypes of tomato for yield, yield components and biochemical characters. Maximum genotypic coefficient of variation was recorded for number of leaves per plant, followed by number of clusters per plant. Heritability estimates were high for ascorbic acid content, average weight of fruits, number of leaves per plant, number of locules per fruit, number of fruits per plant, leaf area and dry matter content. High estimates of heritability with high genetic advance was recorded in case of number of leaves per plant, average weight of fruits, number of fruits per plant and plant height, whereas high heritability with low genetic advance was recorded for number of locules per fruit, dry matter content, pericarp thickness and yield per plant.

Haydar *et al.* (2007) studied genetic variability in different tomato genotypes for yield and yield contributing characters. The genotypes exhibited a wide range of variability for all the traits studied. The traits were also found to be highly heritable. High genetic advance as percentage of mean was exhibited for fruit weight per plant followed by number of fruits in three cluster/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.

Saeed *et al.* (2007) estimated the various parameters of genetic variability for number of flowers per plant, number of fruits per plant, number of days for fruit setting and yield per plant in tomato. The variation between the accessions, on the basis of coefficient of variability was greater in traits like number of fruits per plant (13.92%) followed by number of flowers per plant with coefficient of variability (10.75%) and yield per plant (9.99%). Broad sense heritability was highest for number of fruits per plant (96.56%) followed by number of flowers per plant (93.45%) reflecting the effectiveness of selection in the present germplasm of tomato improvement.

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.

Hidayatullah *et al.* (2008) evaluated thirty six tomato genotypes to estimate the nature and magnitude of genetic variability based on days to first harvest, number of pickings, plant height, number of fruit per plant, fruit weight per plant, fruit size, single fruit weight, number of locules, pericarp thickness, TSS, fruit pH, seeds per fruit and 1000 seed weight. A wide range of variation was observed among the characters studied which have a great interest for tomato breeders. Heritability for (broad sense) ranged from 51.8 to 99.8 %.

Prabuddha *et al*. (2008) conducted an experiment on genetic variability in tomato and observed wide range of variability for most of the characters. Plant height and number of fruits per plant showed high phenotypic and genotypic variance, while titrable acidity and total soluble solids showed low variances. The magnitude of phenotypic coefficient of variance (PCV), genotypic coefficient of variance (GCV), heritability and genetic advance was high for number of fruits per plant and number of clusters per plant.

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 in tomato.

Suarma *et al*. (2009) conducted an experiment on genetic variability for different yield contributing characters in 48 genotypes of tomato. They observed high phenotypic and genotypic coefficients of variation for yield (q/ha), number of branches per plant, number of fruits per plant, plant height and average fruit weight. However high heritability combined with high genetic advance were observed for fruit yield (q/ha), number of fruits per plant, average fruit weight, plant height and number of branches per plant.

Ghosh *et al.* (2010) observed very little differences between phenotypic coefficient of variation and genotypic coefficients 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.

Hazra *et al*. (2010) carried out variability study involving twelve varieties of tomato and observed high heritability coupled with high genetic advance for average fruit weight, and high heritability coupled with low genetic advance for rest of the characters except pericarp thickness.

Rocha *et al*. (2010) studied forty accessions of organically grown cherry tomato and observed variability for colour, shape and number of locules per fruit. Fruit with different colours such as yellow, orange and brown were also observed. Regarding locule number, the presence of fruit with two, three, four and even with seven locules was detected.

Sharma *et al.* (2010) studied the genetic variability in the different genotypes of tomato and observed high genotypic and phenotypic coefficient of variation for average fruit weight followed by number of fruits per plant, fruit yield (q/ha), number of locules per plant, plant height, pericarp thickness and number of branches per plant, while it was moderate for days to 50 per cent 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 per cent flowering had high heritability and moderate genetic gain.

Shashikanth *et al.* (2010) assessed the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PVC), heritability in broad sense (bs) and excepted genetic advance for different traits in thirty tomato genotypes. Higher genotypic coefficient of variation and phenotypic coefficient of variation were recorded for characters like number of branches per plant, number of fruits per plant, fruit yield per plant and number of locules per fruit indicating higher magnitude of variability for these traits. High heritability and high genetic advance were observed for the characters like plant height, number of branches per plant, number of fruits per plant, average fruit weight, number of flowers per cluster, number of clusters per plant, fruit shape index, pericarp thickness and total soluble solids indicating that these traits are controlled by additive gene action which is very useful in selection.

Kaushik *et al*. (2011) evaluated ten genotypes of tomato and reported that maximum variation was observed for fruit yield and minimum was observed for fruit width. The magnitude of genotypic and phenotypic coefficient of variation was higher for number of leaves, fruit length (cm) and fruit yield. High values of heritability coupled with high genetic advance were observed for number of leaves at sixty days after transplanting and fruit yield.

Rani and Anitha (2011) assessed the genetic variability in diverse genotypes of tomato and found that phenotypic coefficient of variation was higher than genotypic coefficient of variation for most of the traits. Genotypic 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.

Tasisa *et al*. (2011) evaluated twenty three tomato genotypes and significant genotypic variability among the test genotypes was observed for all traits studied. Higher values of phenotypic and genotypic coefficients of variation were observed for fruits per plant, seed per fruit, flowers per cluster, unmarketable fruit yield per plot, fruit clusters per plant and plant height.

Vyas *et al.* (2011) assessed twenty genotypes of tomato to assess genetic variability. They observed high genotypic and phenotypic coefficient of variation for fruit yield (q/ha), average fruit weight, storability, number of locules per fruit, number of fruits per plant and number of seeds per fruit. The highest heritability in broad sense was found for all the characters except number of branches per plant. The highest genetic advance coupled with high heritability, phenotypic and genotypic coefficients of variation estimates were recorded for average fruit weight, fruit yield per plant, storability, number of fruits per plant, number of locules per fruit, number of seeds per fruit, plant height and fruit length.

Aysh *et al.* (2012) observed significant differences among diverse tomato genotypes for yield and yield contributing characters. The phenotypic coefficient of variation and genotypic coefficient 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.

Buckseth *et al.* (2012) evaluated forty genotypes of tomato and reported high genotypic coefficient of variation values for number of fruits per plant, average fruit weight, yield per plant, pericarp thickness and thousand seed weight with high heritability indicating that there is ample scope for selection. Further, estimates of heritability and genetic advance provide information about the heritable portion of variance and genetic gain expected in the next generation; hence it is desirable to consider these estimates. High heritability with high genetic gain was observed for number of fruits per plant, average fruit weight, yield per plant and pericarp thickness indicating that most likely the heritability is due to additive gene effects and selection may be effective.

Islam *et al.* (2012) studied the genetic variability in nine traits of eleven cherry tomato and obtained high genotypic and phenotypic coefficients of variation for individual

fruit weight (68.16 and 74.23%, respectively) followed by number of fruits per plant (58.8 and 68.34%, respectively). High estimates of heritability, genetic advance and genotypic coefficient of variation were observed for individual fruit weight, number of fruits and clusters per plant, which indicated the predominant role of additive gene action controlling these traits and so possibility of selection to improve these characters.

Mohamed *et al.* (2012) studied the heritability, genetic advance, genetic advanced as percentage over mean and genetic variability among different plant and fruit characters of thirty tomato genotypes. Analysis of variance showed significant variation among the genotypes for all the characters studied. Fruit weight showed the highest genotypic and phenotypic variance (1642.9 and 1779.1), whereas fruit yield per plant showed the lowest ones (0.17 and 0.39). High genotypic variance was observed for most of the characters indicating more contribution of genetic component for the total variation. Genotypic coefficients of variations (GCV) and phenotypic coefficient of variation (PCV) were highest for fruit weight (0.4885 and 0.4905), whereas the lowest ones were for days to 50 Per cent flowering (0.0552 and 0.0665). Higher GCV and PVC were recorded for most of the characters indicating higher magnitude of variability for these characters. The highest heritability was recorded on plant height (97%), while the lowest was for fruit yield per plant (43%). High heritability (broad senses) estimates were observed for all the tested characters indicating that these characters are controlled by additive genes action which is very useful in selection.

Rahaman *et al.* (2012) evaluated thirty four genotypes of tomato for different genetic parameters *viz.* variability, heritability and genetic advance and observed high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for fruit weight followed by fruit length and lowest for number of flowers per cluster and total acid. Moderate value of PCV and GCV were recorded for fruits per plant. Moderate to low estimates of PCV were recorded for plant height, primary branches per plant, fruits per plant and yield per plant. However, days to first flowering, flowers per cluster, fruits per plant, fruit yield and average fruit weight recorded lower GCV values compared to their respective PCV values. 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.

Iqbal *et al.* (2013) carried out a study to determine the breeding potential ten tomato varieties to develop resistant varieties for fruit borer, fruit cracking, blossom end rot, cat face, sunscald and blotchy ripening. Coefficients of variation, heritability and correlation coefficients were determined for this purpose. Significant varietal difference for all the resistant measured was observed. The coefficients of variability for phenotype were always greater then genotypic and environmental coefficients of variation for all the characters under study. High heritability for fruit borer resistant, cracked resist fruit, blossom end rot resist fruit, cat face resist fruit was observed.

Kumar *et al*. (2013a) evaluated the twenty six genotypes of tomato to determine the nature and magnitude of variability for yield and yield-contributing characters. The analysis of variance revealed highly significant differences among all genotypes for the characters. The genotype 'EC-357838' had the highest mean value for number of fruit per plant, total soluble solids, and yield per plant. High phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV), and heritability estimates, coupled with high genetic gain, were observed for plant height, number of fruit per plant, yield per plant, and fruit weight, indicating that these characters are under additive gene effects and more reliable for effective selection.

Kumar *et al*. (2013b) studied the genetic variability in forty nine genotypes of tomato for various quantitative and quality traits. The material showed wide range of variability for gross yield (116.67-5049.06 g/plant), marketable yield (41.67-4388.59 g/plant), average fruit weight (12.23-82.21g), number of marketable fruits/plant (1.67-177.00), pericarp thickness (0.15-1.05 cm) and total soluble solids (3.40-6.05%). The phenotypic coefficients of variability (PCV) were higher with smaller magnitude than genotypic coefficients of variability (GCV), indicating the apparent variation is not only due to genotypes but also due to influence of environmental factors. The characters like total number of fruits, gross yield (g/plant) and number of marketable fruits showed high genetic advance coupled with high heritability and genotypic coefficient of variability, indicating thereby that selections based on phenotypic performance could be effective for improvement of these characters.

Kumari and Sharma (2013) evaluated fourteen genotypes of tomato for different horticultural and quality traits. High genotypic and phenotypic coefficients of variability were recorded for number of fruits per plant (30.13% and 30.80%), average fruit weight

(34.23% and 34.97%), fruit yield per plant (30.61% and 31.60%), number of seeds per fruit (33.73% and 36.06%) and plant height (30.25% and 31.75%), respectively. This suggested greater phenotypic and genotypic variability in the germplasm and possibility for making further improvement by selection. High heritability coupled with high genetic gain were observed for number of fruits per plant (95.72% and 60.73%), average fruit weight (95.80% and 69.01%), fruit yield per plant (93.90% and 60.5 %), number of seeds per fruit (87.53% and 54.68%) and plant height (90.74% and 58.87%), respectively, 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 SSD method following hybridization and selection in early generations.

Patel *et al*. (2013) studied thirteen tomato genotypes and observed a high degree of significant variation for all the characters studied except pericarp thickness and number of locules. A highest GCV was observed for fruit yield per plant and PCV for fruit yield per plant and number of locules while lowest GCV was noticed for days to first harvest, days to 50 per cent flowering and pericarp thickness and PCV for days to first harvest and days to 50 per cent flowering. High heritability with high genetic advance as per cent of mean was observed for fruit yield per plant and average fruit weight.

Reddy *et al*. (2013) studied the genetic variability, heritability and genetic advance in nineteen genotypes of tomato and observed wide range of variability for all the characters studied. Phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all the characters under study. High heritability combined with high genetic advance was observed for plant height, number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit length, fruit weight, fruit yield per plant, ascorbic acid, acidity, shelf life and TSS. High heritability combined with high genetic advance indicates that additive gene action plays a major role in governing these traits and these traits can be improved by simple selection.

Shushay *et al*. (2013) evaluated thirty six genotypes of tomato and got highest phenotypic and genotypic coefficients of variation were observed for number of matured fruits per plant and fruit set percentage. The highest heritability estimate was recorded for number of matured fruits per plant and the least for number of primary branches.

Agarwal *et al.* (2014) assessed the genetic variability; heritability and genetic advance in thirty one genotypes of tomato for 14 qualitative and quantitative traits.

Significant variations were observed for all the traits under study. Four genotypes exhibited superior values for both TSS (more than 5.0) and dry matter content (more than 6.0) were CLN-2413D, CLN-1314G, DARL Cherry Sel-1 and Punjab Chhuhara, whereas CLN-2264G and CLN-2264H showed superiority for pericarp thickness. High estimates of heritability, genetic coefficient of variation and genetic advance were observed for number of fruits per plant and average fruit weight exhibiting possibility of improvement in these traits through direct selection.

Kumar *et al.* (2014) evaluated fifty genotypes of tomato for yield and various yield attributing characters. High magnitude of phenotypic as well as genotypic coefficients of variation were observed in case of 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 amount of GCV and PCV were observed for all the traits except days to 50 per cent flowering which showed very low variability. High heritability along with high genetic advance in per of mean were estimated for all the traits except days to 50 per cent flowering. Fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant and plant height were the top five traits which showed high level of genetic advance indicating opportunity for better selection response.

Meena and Bahadur (2014) estimated the extent of variability in thirty diverse genotypes of tomato. Analysis of variance revealed significant differences among germplasm for all the traits studied, suggesting sufficient variability for yield and quality characters. The overall values of PCV were higher than those of GCV. Higher magnitude of GCV and PCV, respectively were recorded for leaf curl incidence per cent (35.45 and 35.46), followed by plant height, ascorbic acid and TSS ºBrix. In present study, all the characters showed high heritability the magnitude of heritability ranged from 92 per cent to 100 per cent indicating that these traits are controlled by additive gene action which is very useful in standard selection. The traits like plant height, leaf curl incidence per cent, TSS ºBrix and ascorbic acid with high GCV, PCV, heritability and genetic advance as percentage of mean, indicating that these characters are under additive gene effects and more reliable for effective selection.

Nwosu *et al.* (2014) studied the extent of genetic variability among nineteen accessions of tomato and found high significant differences among the accessions for all attributes studied. Values for genotypic and phenotypic coefficients of variation showed variability among the accessions. Very high genetic advance and heritability estimates for

leaf length, leaf width, days to flower, days to 50 per cent flowering, number of fruits per plant, fruit length, fruit diameter, fruit weight and 1000 seed weight suggest simple inheritance system and thus amenability for these attributes to selection in tomato improvement.

Osekita and Ademiluyi (2014) evaluated five genotypes of tomato for yield and its attributing traits. The analysis of variance was found significant for all the traits under study and the highest coefficient of variation (66.56%) was observed in average fruit weight. The wide differences in phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were recorded in number of fruits per plant (52.40%) and (19.11%), number of cluster per plant (44.08%) and (7.08%), number of locules per plant (27.27%) and (9.64%), the remaining traits did not differ greatly. The estimate of heritability among the genotypes ranged from low to moderate and high as the case may be, number of cluster per plant had the lowest heritability estimate (2.60%) and the highest estimate of heritability (99.68%) were found in days to 50 per cent flowering. The traits showed wide variability hence, they can be exploited by direct selection for improving yield in tomato.

2.3 CORRELATION AND PATH ANALYSIS

Yield is a complex character and selection for yield and yield components deserves considerable attention. A crop breeding programme, aimed at increasing the plant productivity requires consideration not only of yield but also of its components that have direct or indirect bearing on yield. Correlation and path coefficient analysis give an insight into the genetic variability present in populations. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Path analysis splits the correlation coefficients into direct and indirect effects of a set of dependent variables on the independent variable thereby aids in selection of elite genotype.

Galton (1889) gave the concept of correlation for the first time which was later elaborated by Fisher (1918) and Wright (1921). Most of the traits of economic importance are complex, involving several related traits; therefore, the knowledge of degree of phenotypic and genotypic correlations of the trait is important (Robinson *et al.* 1949). The genotypic correlation coefficients include heritability and provide a real association between the characters which is useful in selection, while the phenotypic correlations include both heritability and environmental influences (Johnson *et al.* 1955).

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.

Harer *et al.* (2002) studied the character association in thirty seven tomato genotypes and 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. Path analysis revealed that number of fruits per cluster, average fruit weight and number of fruits per plant had maximum direct effects on fruit yield. The total soluble solid content had positive but low direct effects and positive association with fruit yield, whereas the ascorbic acid content had negative direct effects and association with fruit yield.

Kumar *et al*. (2003) assessed thirty diverse tomato genotypes for correlation and Path coefficient analysis 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. In the mean while, number of fruits per cluster, average fruit weight and number of fruits per plant had direct maximum effects on fruit yield in tomato. The total soluble solid content had positive but low direct effect, whereas, the ascorbic acid content had negative direct effect on fruit yield.

Joshi *et al*. (2004) evaluated 37 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. 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.

Joshi and Kohli (2005) in their correlation studies in seventy three genotypes of tomato 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. Path coefficient analysis revealed that maximum positive direct effect towards shelf life of fruits was contributed by whole fruit firmness followed by average fruit weight in tomato. Average fruit weight exhibited the highest negative indirect effect via stem-end scar size on shelf life of tomato.

Makesh *et al.* (2006) worked out correlation and path coefficient analysis in thirty tomato hybrids and 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. 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.

Haydar *et al.* (2007) assessed the correlation and path analysis in different tomato genotypes for yield and yield contributing characters. Fruit yield had high positive rp and rg with total number of fruits at harvesting period and number of fruits in three clusters per plant. Plant height at flowering, number of flowers in three clusters per plant, days to flowering and total number of fruits at harvesting period also contributed yield directly. The results indicate that for increasing yield, selection should be based on plants bearing more fruits of larger size and weight.

Ramana *et al*. (2007) observed that the genetic correlation coefficients were generally higher than the corresponding phenotypic correlation coefficients. The number of branches per plant showed the greatest correlation with fruit yield per plant, followed by fruit weight, number of fruits per plant and number of fruit clusters per plant. The total soluble solid content, titratable acidity, ascorbic acid and lycopene contents were not significantly correlated with yield. On the other hand, fruit weight had the 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 per cent flowering in tomato.

Hidayatullah *et al.* (2008) reported that fruit weight per plant had high and positive genotypic and phenotypic correlation with number of pickings and with number of fruits

per plant, thus indicating that these traits were the most important yield components. Path analysis concluded that fruit diameter which exhibited the highest direct effect could be the selection criteria for improving fruit yield per plant, whereas other important characters (plant height, fruit length, single fruit weight, TSS and seeds per fruit) those exhibited negative direct effect are suggested to be exploited through high indirect effects.

Prashant *et al.* (2008) in their correlation studies indicated the inverse relationship between earliness, but strong association between growth and yield characters in tomato. Total yield per plant was positively and significantly associated with early yield, equatorial diameter of the fruit, fruit volume, average fruit weight, polar diameter of fruit, number of fruits per plant, per cent fruit set, stem girth at 90 DAT, number of locules per fruit, plant height at 60 DAT, pericarp thickness and number of seeds per fruit. Path coefficient analysis revealed 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) studied the correlation for different traits of tomato and 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. In the mean while, path coefficient analysis studies revealed 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 in tomato.

Islam *et al.* (2010) worked out the correlation and path coefficient in thirty nine exotic tomato genotypes for nine yield contributing characters. Yield per plant was found highly significant and positively correlated with flowers per plant, fruits per plant, fruit length, fruit diameter and individual fruit weight which indicated that yield could be increased by improving a traits. Path coefficient analysis revealed that fruits per plant showed the highest positive direct effect (0.980) on yield per plant followed by individual fruit weight (0.958). On the other hand, the highest negative direct effect on yield per plant showed by days to first flowering (-0.277) followed by fruit length (-0.141). The characters showed high direct effect on yield per plant indicated that direct selection for these traits might be effective and there is a possibility of improving yield per plant through selection based on these characters. Residual effect was considerably low (0.183),

which indicated that characters included in this study explained almost all variability towards yield.

Dar *et al*. (2011) evaluated sixty diverse genotypes of tomato and observed that yield quintals per hectare was positively correlated with lycopene content, fruit pH, total soluble solid, pericarp thickness, number of locules per fruit, number of fruits per plant, fruit yield per plant and average fruit weight at genotypic as well as phenotypic level. However negative correlation was observed with β-carotene, ascorbic acid and polygalacturonase activity at genotypic as well as phenotypic level. Path coefficient analysis indicated that fruit yield per plant had highest positive direct effect on yield quintals per hectare, followed by average fruit weight, number of locules per fruit, lycopene content per fruit and ascorbic acid, while as negative indirect effect on yield quintals per hectare.

Al Aysh *et al*. (2012) evaluated 14 landraces of tomato and observed that average fruit weight and harvest index had positive and highly significant correlation with fruit yield per plant at both phenotypic and genotypic levels. Path coefficient analysis revealed that number of fruits per plant and harvest index had the highest positive direct effects on fruit yield per plant.

Buckseth *et al.* (2012) conducted the correlation and path analysis studies in forty genotypes of tomato and revealed that yield per plant expressed a highly significant positive correlation with pericarp thickness, shelf life, TSS and fruit shape index. Number of fruits per plant was positively and significantly correlated with yield per plant, while negatively but significantly correlated with average fruit weightPath coefficient analysis of different characters contributing toward yield per plant revealed that shelf life had maximum direct effect followed by average fruit weight and number of fruits per plant, indicating that these are the real independent characters and have maximum contribution towards increase in fruit yield.

Madhurina and Paul (2012) studied correlation coefficient in 15 tomato genotypes and revealed that fruit yield per plant was positively and significantly correlated with pericarp thickness, fruit length, fruit weight and number of fruits per plant. The path coefficient analysis revealed that number of locules per fruit, TSS, fruit length, number of fruits per plant, fruit weight, vitamin C content and pericarp thickness had positive direct effect on fruit yield, while fruit width and total acid content had strong negative effects on the fruit yield.

Manna and Paul (2012) reported that number of locules per fruit, TSS, fruit length, number of fruits per plant, fruit weight, vitamin C content and pericarp thickness had positive direct effect on fruit yield, while fruit width and total acid content had strong negative effects on the fruit yield.

Khan and Samadia (2012) studied 12 traits in 23 genotypes of tomato for correlation studies which 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.

Sharma and Singh (2012) evaluated one hundred twenty tomato genotypes and this study revealed that fruit yield was significantly and positively correlated with fruit weight per plant followed by days to 50 per cent flowering and non-significantly but positively correlated with average fruit weight, seed yield per plant. Path analysis study shown 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) carried out the studies on correlation and path analysis in thirty tomato genotypes and reported 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 and it is also suggested that hybridization of genotypes possessing combination of above characters is most useful for obtaining desirable high yielding segregation. Path coefficient analysis revealed that number of flowers per cluster and number of branches per plant had the highest positive direct effect on fruit yield both at genotypic and phenotypic levels and most the fruit related traits contributed of fruit yield mainly through number of branches. Hence, it would be essential to lay stress on these characters in selection programmes aiming at increasing the yield.

Ahirwar *et al*. (2013) carried out studies on correlation among nineteen genotypes of tomato and observed that traits like plant height 120 DAT, number of branches, number of fruits per plant, average fruit weight, number of cluster per plant, fruit set (%), radial and polar diameter (mm), ascorbic acid, TSS (^{o}Brix), showed positive correlation with fruit yield per ha. Plant height after 120 DAT, days to 50 per cent flowering, leaf curl

incidence and intensity showed negative correlation at both phenotypic and genotypic level.

Kumar *et al*. (2013a) evaluated twenty six genotypes of tomato to assess the correlation and path coefficient analysis between yield and yield-contributing characters. Correlation indicated that yield was significantly and positively associated with number of fruit per plant and per cluster. Path analysis at the genotypic level indicated that fruit weight had the most positive direct effect on yield per plant followed by number of fruit per plant, fruit diameter, and number of fruit per cluster. Direct selection on the basis of fruit weight, number of fruit per plant, fruit diameter, and number of fruit per cluster is reliable for yield improvement in tomato.

Kumar *et al*. (2013b) studied the character association in forty nine genotypes of tomato for various quantitative and quality traits, which indicated that total numbers of fruits per plant were significantly and positively correlated with gross yield (g/plant), marketable yield (g/plant), number of marketable fruits per plant, plant height (cm) and total soluble solids (%), whereas plant height was negatively and significantly correlated with fruit shape index. Gross yield (g/plant) was significantly and positively correlated with total number of fruits per plant, number of marketable fruits per plant and marketable yield (g/plant). The estimates of direct and indirect effects showed that marketable yield (g/plant) gave highest positive direct effect on gross yield (0.904), followed by number of marketable fruits/plant (0.845) and total number of fruits per plant (0.796). Maximum indirect contribution towards gross yield (g/plant) was through marketable yield (0.819) via total number of fruits. The present studies revealed considerable scope for improvement in tomato as total number of fruits/plant, average fruit weight (g), number of marketable fruits and plant height (cm) showed a wide range of variability.

Kumari and Sharma (2013) conducted the correlation and path analysis studies in fourteen genotypes of tomato and found that genotypic correlations were higher in magnitude than phenotypic values, indicating predominant role of heritable factors. Positive and significant association of fruit yield per plant with number of fruits per plant, average fruit weight and pericarp thickness was observed. This suggested that improvement in these traits will result in increased fruit yield. In the mean while, path analysis studies revealed that maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight (0.754) followed by number of fruits per plant

(0.744), pericarp thickness (0.417) and number of fruits per cluster (0.440). Therefore, during selection more emphasis should be given on these traits.

Mahapatra *et al.* (2013) studied the correlation and path coefficient for sixty eight genotypes of tomato and found that fruit yield had positive and significant correlation with plant height, number of primary branches per plant, number of flower clusters per plant, number of fruits per plant, fruit length, fruit width, pericarp thickness, number of locules per fruit, average fruit weight and fruit yield per plant. It was observed that with increase in plant height, there was corresponding increase in number of primary branches per plant, days to 50 % flowering and number of flower clusters per plant. The association recorded significant improvement in yield. The traits like number of primary branches per plant, number of flower clusters per plant, number of fruits per plant, fruit length, fruit width, pericarp thickness, average fruit weight and number of seeds per fruit exhibited positive direct effects towards yield and these traits also recorded positive significant correlation with yield. This suggested that direct selection based on these traits will be rewarded for crop improvement.

Rahaman and Bhatt (2013) evaluated thirty four genotypes of tomato and observed that fruit weight showed high and positive genotypic and phenotypic correlation with number of picking and with number of fruits per plant On the basis of performance fourteen genotypes were identified through path analysis for future testing under wide range of environments.

Reddy *et al.* (2013) carried out correlation and path analysis in nineteen tomato genotypes for yield and quality characters. The association studies showed that fruit yield per plant was positively and significantly correlated with number of fruits per plant and fruit width. However, fruit yield per plant was negatively and significantly correlated with days to last fruit harvest and shelf life. Path analysis studies done to study the cause and effect relationship revealed 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. Hence, direct selection for these traits is done for improving fruit yield per plant.

Sharma *et al.* (2013) in their studies on path coefficient analysis revealed appreciable amount of direct effect of number of marketable fruits per plant, fruit shape index, gross yield per plant, plant height, number of flower cluster per plant, number of locules per fruit and TSS content on marketable yield per plant at phenotypic level.

Shushay *et al.* (2013) observed that yield per hectare had highest positive and highly significant phenotypic correlation with weight of fruits per plant, fruits per plant and fruit set percentage, while it showed negative and highly significant phenotypic correlation with days to 50 per cent fruiting and days to maturity.

Khapte and Jansirani (2014) had reported that per cent fruit set, number of primary branches, number of fruits per plant, average fruit weight, total soluble solids, fruit length, fruit firmness, number of flower trusses per plant and pericarp thickness were positively and significantly associated with yield per plant. Path analysis revealed that average fruit weight had the high positive direct effect on yield per plant followed by number of fruits per plant. Traits *viz.*, fruit diameter and fruit shape, fruit index had negative direct effect on fruit yield per plant. Most of the other traits had indirect effect via fruit weight, fruits per plant, fruit diameter and fruit shape index. Hence, these characters should be given more weightage in selection programme of high yielding genotypes in tomato.

Shushay *et al.* (2014) estimated the direct and indirect effects of various characters on fruit yield in tomato and revealed that number of matured fruits per plant (0.798) and average weight of fruits per plant (0.644) had highest positive direct contribution to fruit yield. This indicated direct selection based on these characters will improve fruit yield. On the contrary, fruit set percentage (-0.447) and fruit polar diameter (-0.392) exerted highest negative direct effect on fruit yield per hectare.

Meena and Bahadur (2015) evaluated nineteen indeterminate tomato genotypes to estimate the nature and magnitude of associations of yield and its contributing traits. Estimates of genetic parameters revealed that fruit yield was significantly and positively correlated with number of flowers per plant (0.2894 and 0.2891) followed by number of fruits per plant (0.4480 and 0.4486) and fruit weight (0.6223 and 0.6230) at genotypic and phenotypic level, respectively, strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield. In the mean while, path coefficient analysis revealed that fruit weight had a very high positive direct genotypic and phenotypic effect 0.9566 and 0.9442, respectively on fruit yield per plant followed by number of flowers per plant, fruit set per cent, number of fruits per plant, TSS ^{o}Brix, plant height, radial diameter of fruit, leaf curl incidence per cent and days to 50 per cent flowering. The characters showed high direct effect on yield per plant indicated that direct selection for these traits might be effective and there is a possibility of improving yield per

plant through selection based on these characters. Residual effect was considerably low (0.0611 and 0.0751) which indicated that characters included in this study explained almost all variability towards yield.

Prajapati *et al.* (2015) studied the correlation and path co-efficient analysis for fruits yield and its attributing traits in thirty nine indigenous tomato genotypes and reported that fruit yield had positive and significant correlation with average fruit weight, number of secondary branches per plant, days to first flowering, days to fruit maturity, plant height, T.S.S., days to 50 per cent flowering, and days to 50 per cent fruit setting, it was observed that with increase in plant height, there was corresponding increase in number of primary branches per plant, and number of flowering clusters per plant. path coefficient analysis of different yield and yield contributing traits on fruit yield per plant revealed with average fruit weight per plant, recorded high estimate of positive direct effect followed by number of fruit per plant, number of fruiting cluster per plant, days to first flowering days to fruit maturity, pericarp thickness, number of primary branches, number of flowers per cluster and fruit diameter these characters play a major role in recombination breeding and suggested that direct selection based on these traits will be rewarded for crop improvement of tomato.

2.3 GENETIC DIVERGENCE STUDIES

Mohanty and Prusti (2001) studied genetic diversity among eighteen indigenous and exotic tomato cultivars for five economic characters. They reported considerable variability among the accessions. The genotypes were grouped into five clusters including two solitary groups. Genetic diversity was not associated with geographic distribution. Maximum inter-cluster distance was observed between the clusters I and V. The distance between clusters I and III, III and V, III and IV, and IV and V was moderate. Number of fruits per plant and average fruit weight contributed predominantly towards the total divergence. A multiple crossing programme involving genotypes belonging to clusters I, III and V was suggested to isolate promising high yielding wilt tolerant recombinants with other desirable characters.

Mehta *et al*. (2007) evaluated twenty determinate genotypes of tomato and on the basis of D^2 analysis these were grouped into seven clusters. Cluster I topped with maximum number of genotypes among clusters, while maximum inter cluster distance was noticed between cluster V and VII followed by cluster III and VII. Cluster II and V stepped

as important clusters with respect to ideotypic plant characters including fruit yield which could be utilized for breeding purpose. In the present study, four characters *viz.*, 10-fruits weight, fruit length, number of locules per fruit and fruit yield as a whole contributed 84.23 per cent of total divergence.

Prasanth *et al.* (2008) evaluated sixty-seven tomato genotypes of different geographical origin to know the value and magnitude of genetic divergence using Mahalanobis D^2 statistics. A wide genetic diversity was observed among the genotypes and was grouped into seven clusters. The clustering pattern indicated that the geographic diversity need not necessarily be related to genetic diversity. The maximum inter cluster distance was observed between cluster V and VI (D^2=243.700), closely followed by cluster III and V (D^2=239.740), cluster IV and V (D^2=222.521), cluster IV and VII (D^2=211.82), cluster VI and VII (D^2=209.086) and cluster V and VII (D^2=207.860). The cluster II revealed the least distance relationship with the cluster III (D^2=86.717). Therefore, selection of divergent parents based on these cluster distance is recommended for getting good hybrids or segregants in tomato.

Ara *et al.* (2009) studied the genetic divergence for sixteen growth, yield and quality traits in thirty five tomato genotypes using Mahalanobis D^2 technique. From the D^2 statistics and canonical analysis, the genotypes were grouped into 5 clusters irrespective of geographical diversity, indicating no parallelism between geographic and genetic diversity. Cluster I topped in having maximum of 20 genotypes followed by cluster II (11), cluster III (2), while cluster IV and V were monotypic. The maximum intra-cluster distance was observed in cluster I (743.14) comprising 20 genotypes followed by clusters II and III which were identified genetically divergent whereas clusters IV and V exhibited minimum intra-cluster values indicated limited genetic divergence. The maximum inter-cluster distance was noticed between cluster III and V (19316.55) followed by cluster III and IV (13336.55), cluster II and V (10659.36), cluster I and III (7013.87) and cluster II and IV (6396.41). Among characters studied, fruit per yield plant, number of fruits per plant, plant height and fruit weight, fruit size and number of primary branches per plant contributed maximum to divergence and have a major role in improvement of fruit yield in tomato. Crossing between genotypes belonging to cluster III and V as well as cluster III and IV, and cluster II and V are expected to give maximum heterosis.

Shashikanth *et al*. (2010) studied thirty tomato genotypes and Mahalanobis D^2 statistics helped in grouping the 30 genotypes into 10 diverse clusters. The composition of

clusters of heterogenous geographic origin indicated that the strains were distributed among the different clusters randomly irrespective of their geographical origin. This indicated that there was no parallelism between genetic diversity and geographical divergence in tomato.

Pathak and Kumar (2011) studied genetic divergence among six varieties of tomato. Genetic distances were measured following D^2 statistics and grouped into three distinct constellations. The inter- and intra-constellation distance represents the index of genetic diversity among the constellations. The constellation II showed the highest divergence from constellation III.

Sharma *et al*. (2011) evaluated one hundred and twenty six genotypes of tomato and formed 10 groups or clusters of the exotic gene pool. Cluster I accommodated twenty genotypes, followed by cluster II accommodating 18 genotypes. Cluster III and IV, V and VI and VII and VIII had equal number of genotypes i.e., 16, 12 and 11 respectively. Cluster X contained only three genotypes. Cluster V had genotypes with desirable features of higher average fruit weight, more pericarp thickness and more locules per fruit. Cluster III followed the cluster V in economical features. Based on genetic distance, clusters V and X and VIII and X were more diverse.

Narolia *et al*. (2012) studied fifty five genotypes of tomato and based on D^2 values of 13 characters, genotypes were grouped into 12 highly divergent clusters. Out of that eight clusters viz., III, VI, VII, VIII, IX, X, XI and XII were solitary with one genotype in each cluster and the remaining four clusters were having maximum number of genotypes. Cluster II was biggest with 20 genotypes followed by cluster I (14 genotypes), while the other two clusters IV and V comprised six and seven genotypes, respectively. The maximum genetic divergence was observed between clusters IX and XII followed by between clusters V and IX. The maximum intra-cluster distance was shown by cluster V.

Mulge *et al.* (2012) evaluated sixty seven genotypes of tomato collected from different sources and lines developed through pedigree method of breeding and grouped these genotypes into 7 clusters where, maximum of 44 genotypes entered in cluster I, followed by 11 genotypes in cluster II, 7 genotypes in cluster IV, two genotypes in cluster III and the clusters V, VI and VII had solitary genotype each.

Kumar *et al*. (2013) conducted study on forty genotypes of tomato and observed wide genetic diversity among the genotypes which were grouped into 4 clusters based on

14 important characters. The cluster III was the largest containing 17 genotypes followed by cluster I with11 genotypes. The clustering pattern indicated that the geographic distribution need not necessarily be related to genetic diversity. The maximum inter-cluster distance was observed between cluster III and IV.

Reddy *et al*. (2013) conducted a study on divergence analysis using Mahalanobis D^2 statistics and reported considerable genetic diversity among nineteen genotypes of tomato for all the eighteen quantitative characters which was pertaining to the growth, earliness, yield and quality. Fruit weight, plant height and number of fruits per plant contributed 92.40 per cent to the total divergence. Appreciable diversity within and between the clusters was observed. The characters fruit weight, number of fruits per plant and plant height were the potent factors in differentiating the germplasm of tomato under study. Five clusters were formed from the D^2 analysis using Tocher's method. Cluster II topped with maximum number of genotypes, while maximum inter-cluster distance was observed between cluster III and IV followed by cluster IV and V.

Iqbal *et al.* (2014) carried out the studies on genetic divergence in fourty seven tomato genotypes and cluster analysis grouped all genotypes into five divergent clusters. The genotypes in cluster-II and cluster-V exhibited uniform maturity and higher yield. The D^2 statistics confirmed highest distance between cluster- III and cluster-V, while maximum similarity was observed in cluster-II and cluster-III. It is therefore suggested that crosses between genotypes of cluster-II and cluster-V with those of cluster-I and cluster-III may exhibit heterosis in F_1 for hybrid breeding and for selection of superior genotypes in succeeding generations for cross breeding programmes.

Nalla *et al.* (2014) assessed the genetic diversity for quantitative and qualitative traits in tomato using Mahalanobis D^2 statistics method. All the twenty seven genotypes were grouped into nine clusters, indicating the presence of diversity for different traits. The cluster I had the highest number containing 16 genotypes followed by cluster III and VII, containing three and two genotypes respectively. However, the cluster II, IV, V, VI, VIII and IX were solitary. The maximum intra-cluster distance was recorded within cluster III (10.88) and the maximum inter-cluster distance between cluster VI and VII (20.80), indicating the existence of wide genetic variability. Based on mean performances, the cluster VIII with single genotype ranked first and appeared to contain the potential genotype. The cluster VIII and II registered high plant height. The genotypes included in

clusters V and VIII took less number of days to 50 per cent flowering (29.67). The cluster III registered high fruit yield per plant (1004.60), average fruit weight (38.07), and ascorbic acid (28.7) can be utilized in breeding programmes for enhancing their respective characters. The cluster IX had high number of fruits per plant (40.53). Based on cluster mean analysis these genotypes can be used in crop improvement programme in tomato for above-mentioned characters.

Srivastava *et al.* (2014) tested thirty genotypes of tomato, both indigenous and exotic for the presence of diversity on the basis eighteen yield and quality traits. Mahalanobis's D^2 analysis was employed to estimate the distances between and within the clusters formed from the test genotypes. Ten clusters were formed using Tocher's method. Cluster I, III and X were having 16, 3 and 2 genotypes, respectively, rest of the seven clusters were solitary and having single genotype each. The highest inter-cluster distance was found between clusters IV and X whereas lowest distance was observed between cluster VI and VIII suggested a closer relationship between these clusters and low degree of diversity among the genotypes. The maximum contribution towards divergence was accounted by plant height, seed index and yield per plant (~15% each) followed by fruits per plant, juice-pulp ratio, pericarp thickness and flowers per cluster. Results also revealed that there was no association between clustering pattern and eco-geographical distribution of genotypes. On the basis of the divergence study the genotypes could be selected from the most divergent clusters for hybridization and further selection programme.

Thapa *et al.* (2014) carried out a study on genetic divergence in 30 tomato genotypes using Mahalonabis D^2 statistics. These genotypes were grouped into five clusters based on nineteen characters. Maximum divergence was recorded between clusters III and IV followed by cluster IV and V. Genotype MT-4 (Oval big) of cluster III was found to be best for yield and related traits, like number of primary branches, fruit length, diameter, weight and yield per plant. Similarly, BT-10 of cluster IV was suitable for quality traits, like TSS, ascorbic acid, juice, β-carotene and lycopene content. Genotypes of cluster III and IV can be used for the development of hybrid/varieties having higher yield and better quality attributes.

Chapter-3
Materials and methods

Chapter-3
Materials and Methods

The present investigation entitled "Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)" carried out during 2014. The details of materials, techniques and methods used for studies, experimental design adopted and statistical procedures followed are presented in this chapter.

3.1 Experimental site

The investigations entitled "Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)" was conducted at vegetable research block of College of Horticulture, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar. The soil of research field comprised of medium red clay sandy loam.

3.2 Location and climate

Pauri Garhwal is one of the 13 districts of Uttarakhand, and is located between 29^0 20'-29^0 75' N Latitude and 78^0 10'-78^0 80' E Longitude. The district is the most fascinating segents of Himalaya, stretches from the Ram Ganga River that separates Pauri-Kumaon border in the East, and to the Ganga demarcating the Western border. Almora, Nainital (East), Chamoli, Tehri and Dehradun (North-West) and adjacent plains of Bijnor, Hardwar (South) districts, surround it. Bharsar is situated at about 60 km from the district head quarter (Pauri) in the East-South direction in Pauri-Thalisain-Ram Nagar National High way 121/41.

In general, the climate of the Bharsar represents the mild summer, higher precipitation and colder or severe cold prolonged winter. The climate factors *i.e.* precipitation, temperature, relative humidity and wind, in association with elevation (valleys or mountain range from temperate zone), proximity to Great Himalaya, slope aspects, drainage, vegetation etc. are responsible for the micro-climate of this area. Major output of precipitation is in the form of rain fall, besides occasional occurrence of due, hailstorm, fog, frost, snow fall etc. The South-East monsoon commences towards the end of June while the North-East monsoon causes occasional winter showers during November-February. During winter, snow fall is common in this region. During summer months, the valley has hot climate prevailing for few hours in a day, the maximum

temperature during May-June is recorded between 30°C-35°C however, and nights are cool. December and January are the coldest months; the minimum temperature reaches to 1°C to -4°C. Relative humidity is normally highest during rainy season (July - August), often recorded near to saturation point (92-97%) and it gradually decreases towards December.

3.3 EXPERIMENTAL MATERIAL

Thirty diverse genotypes of tomato, including indigenous and exotic collections along with one check cultivar (Solan Lalima) were used for the present investigations. The genotypes along with their sources are presented in Table 3.1.

3.4 SEED SOWING AND RAISING OF SEEDLINGS IN NURSERY

The seed sowing of all the genotypes was carried out on April 2, 2014 in the raised nursery bed. Recommended cultural practices were followed for raising the healthy nursery.

3.5 EXPERIMENTAL LAYOUT

The healthy seedlings of all the genotypes were planted in a Randomized Complete Block Design with three replications (Table 3.2). Plot size was 1.8 m × 1.8 m. twelve plants of each genotype were transplanted in each replication at spacing of 60 cm × 45 cm on May 5, 2014.

3.6 CULTURAL PRACTICES

The standard cultural practices recommended in the Package of Practices of Vegetable Crops were followed to produce 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 practices *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_2O5 and K_2O were applied at the time of field preparations. Remaining two-third dose of N was top dressed in equal amounts after 30 and 45 days of transplanting. The remaining intercultural operations were carried out in accordance with the recommended package of practices.

3.7 OBSRVATIONS

The observations were recorded from five randomly selected plants in each replication for all characters except for fruit characters for which observations were recorded on ten randomly selected fruits per replication. The characters studied were:

Table 3.1 List of tomato genotypes used in the study

Sr. No.	Genotype	Source
1.	LC-1	Nainital, UK
2.	LC-2	Kotdwara, UK
3.	LC-3	Uttarakashi, UK
4.	LC-4	Tehri Garhwal, UK
5.	LC-5	Almora, UK
6.	LC-6	Solan, HP
7.	LC-7	Sirmour, HP
8.	LC-8	Shimla, HP
9.	LC-9	Bilaspur, HP
10.	LC-10	Kangra, HP
11.	Arka Alok	IIHR, Bengaluru
12.	Arka Abha	IIHR, Bengaluru
13.	Arka Meghali	IIHR, Bengaluru
14.	Arka Vikas	IIHR, Bengaluru
15.	Arka Saurabh	IIHR, Bengaluru
16.	Punjab Chhuhara	PAU, Ludhiana
17.	Pant T-3	GBPUAT, Pantnagar
18.	Roma	IARI, New Delhi
19.	Sioux	IARI , New Delhi
20.	AVTO0201	AVRDC, Taiwan
21.	AVTO9803	AVRDC, Taiwan
22.	AVTO9001	AVRDC, Taiwan
23.	AVTO0101	AVRDC, Taiwan
24.	AVTO1173	AVRDC, Taiwan
25.	AVTO1002	AVRDC, Taiwan
26.	AVTO1130	AVRDC, Taiwan
27.	AVTO1219	AVRDC, Taiwan
28.	AVTO1314	AVRDC, Taiwan
29.	AVTO1315	AVRDC, Taiwan
30.	Solan Lalima (Check)	UHF, Solan, HP

Table 3.2 Allotment of treatments in experiment field under RCBD

North

soil fertility in decreasing order

Replication-1	Replication-2	Replication-3
T-7	T-20	T-26
T-12	T-16	T-11
T-3	T-22	T-10
T-13	T-27	T-6
T-15	T-14	T-7
T-11	T-2	T-8
T-5	T-4	T-9
T-6	T-11	T-13
T-2	T-8	T-14
T-10	T-12	T-24
T-4	T-29	T-3
T-1	T-26	T-2
T-28	T-30	T-29
T-14	T-3	T-5
T-29	T-6	T-15
T-17	T-10	T-18
T-21	T-24	T-17
T-19	T-7	T-30
T-26	T-21	T-27
T-22	T-17	T-28
T-18	T-19	T-22
T-16	T-28	T-20
T-30	T-23	T-25
T-20	T-1	T-12
T-27	T-25	T-23
T-8	T-5	T-1
T-24	T-9	T-19
T-9	T-18	T-21
T-25	T-13	T-4
T-23	T-15	T-16

South

Staking

Transplanting

Raised Nursery

Seed Sowing

Data Recording

Fruits Ready to Harvest

Weeded Plots

Plate 1 : Different inter-cultural operations during the field experiment

3.7.1 Days to first fruit harvesting (Days)

Data on the days to first fruit harvesting in days were recorded from the date of transplanting to the date of first fruit harvest of fruits at breaker stage or turning stage.

3.7.2 Fruit length (cm)

Fruit length was measured in cm from the base of calyx to tip of fruit using measuring scale.

3.7.3 Fruit breadth (cm)

Fruit breadth was measured by using Digital vernier calliper at the widest point of fruit.

3.7.4 Average fruit weight (g)

Total weight of fruits from five randomly selected plants at every picking was recorded and divided by total number of fruits of all the harvests to compute the mean fruit weight in grams.

3.7.5 Number of fruit clusters per plant

Total number of fruit clusters harvested from each selected plant was counted to work out the mean value.

3.7.6 Number of fruits per cluster

Number of fruits in each cluster of five plants was counted to work out mean number of fruits per cluster in each entry.

3.7.7 Number of fruits per plant

The marketable fruits harvested from randomly taken plants were counted and summed up at each harvest and will be averaged to obtain numbers of fruit per plant.

3.7.8 Harvest duration (days)

Number of days was counted between first picking to final harvest of marketable fruits in each entry to record the data on harvest duration.

3.7.9 Marketable fruit yield per plant (kg), per plot (kg), and per hectare (q)

The pickings were made at half ripe stage or breaker stage for recording fruit yield per plant. Fruit yield was recorded at every picking in grams and added up for all the pickings to arrive at the total yield per plant. The total yield per plant was multiplied with

total number of plants per plot to obtain yield per plot in kilograms. The total yield per plot was multiplied with total number of plants accommodated per hectare to obtain yield per hectare.

3.7.10 Shelf life (days)

Shelf life of fruits was estimated by keeping the fruits at ambient room temperature conditions till they shrunk and become unfit for consumption.

3.7.11 Pericarp thickness (mm)

Pericarp thickness of five randomly taken fruits of second harvest in each entry was measured after cutting the fruits transversely. Measurement was done with Digital Vernier Calliper in millimeters and mean value was worked out.

3.7.12 Lycopene content (mg/100 g)

Lycopene content in each tomato sample was calculated according to the absorption measurement procedure of petroleum ether extract of total carotenoids at 503 nm as given by Ranganna (1994).

3.7.13 Total soluble solids (^{o}Brix)

The ripe fruits were crushed and their juice passed through a double layer of fine mesh cheese cloth. Further, a drop of juice was placed on the plate of Hand Refractometer (0-32 ^{o}B, ERMA, JAPAN) and the reading was noted. A mean of five readings was taken in every replication in each entry.

3.7.14 Buckeye rot incidence (%)

The incidence of buckeye rot under natural epiphytotic conditions in each genotype was recorded periodically by using the following formula (Dodan, 1995):

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased fruits per plant}}{\text{Total number of fruits per plant}} \times 100$$

3.7.15 Fruit borer incidence (%)

The incidence of fruit borer under natural epiphytotic conditions in each genotype was recorded from randomly selected five plants in each variety at weekly intervals. Per cent fruit-infestation was calculated by the following formula (Wakil *et al*., 2009):

$$\text{Fruit infestation (\%)} = \frac{\text{Number of damaged fruits per plant}}{\text{Total number of fruits per plant}} \times 100$$

3.8. STATISTICAL ANALYSIS

The statistical analysis was carried out for each observed character under the study 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 Block Design (RBD). For estimation of different statistical parameters, following procedure and formulae were adopted:

3.8.1 Analysis of variance

Source of variance	Degree of freedom	Sum of squares	Mean sum of squares	Variance ratio (V.R.)
Replication (r)	r-1	Sr	Sr/(r-1) = Mr	Mr/Me
Genotypes (g)	g-1	Sg	Sg/(g-1) = Mg	Mg/Me
Error (e)	(r-1) (g-1)	Se	Se/(r-1) (g-1) = Me	

Where,

r = Number of replications
g = Number of genotypes
Sr = Sum of squares due to replications
Sg = Sum of squares due to genotypes
Se = Sum of squares due to error
Mr = Mean sum of squares due to replications
Mg = Mean sum of squares due to genotypes
Me = Mean sum of squares due to error

The calculated F-value was compared with tabulated F-value. When F-test was found significant, critical difference was calculated to find out the superiority of one entry over the others.

The standard error and critical differences were calculated as follows:

$$SE\ (m) \pm = \sqrt{Me/r}$$

$$SE\ (d) \pm = \sqrt{2\ Me/r}$$

$$CD_{0.05} = S.E.\ (d) \times t_{(0.05)}\ (r-1)\ (g-1)\ df$$

Where,

SE (m) ± = Standard error of mean

SE (d) ± = Standard error of difference

$CD_{0.05}$ = Critical difference at 5 per cent level of significance

All the traits, which differed significantly, were utilized further for estimation of following genetic parameters:

3.7.2 Mean performance and genetic variation

3.7.3 Heritability (in broad sense)

3.7.4 Genetic advance (GA)

3.7.5 Genetic gain (GG)

3.7.6 Correlation coefficients

3.7.7 Path analysis

3.7.8 Genetic divergence (D^2 analysis)

3.8.2 Mean performance and genetic variation

The Genotypic and Phenotypic Coefficients of variation were calculated as per formulae given by Burton and De-Vane (1953).

A) Genotypic Coefficient of variation (GCV)

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

B) Phenotypic Coefficient of variation (PCV)

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

3.8.3 Heritability (in broad sense)

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

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

Where,

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

Vp = Phenotypic variance [Vg + Ve]

3.8.4 Genetic advance (GA)

The expected genetic advance (GA) resulting from selection of five per cent superior individuals was worked out as suggested by Allard (1960).

Genetic advance = H x σ p x K

Where,

K = 2.06 (Selection differential at 5 per cent selection index)

σ p = Phenotypic standard deviation

H = Heritability in broad sense

3.8.5 Genetic gain (GG)

Genetic gain expressed as per cent ratio of genetic advance and population mean was calculated by the method given by Johanson *et al.* (1955).

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

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 (GG)
  >50% - High
  25-50% - Moderate
  < 25% - Low

3.8.6 Correlations

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

3.8.6.1 Analysis of Variance and Covariance

Source of variance	Degree of freedom	Mean sum of squares		Mean sum of products	Variance
		X	Y		
Replications (r)	r-1				
Genotypes (g)	g-1	Mg X	Mg Y	Mg XY = MP_1	MP_1/MP_2
Error (e)	(r-1) (g-1)	Me X	Me Y	Me XY = MP_2	

Genotypic, phenotypic and environmental covariances between X and Y characters were worked out as under:

Ve XY = MP_2

Vg XY = $(MP_1-MP_2) / r$

Vp XY = Vg XY + Ve XY

Where,

Ve XY = Environmental covariance between X and Y

Vg XY = Genetic covariance between X and Y

Vp XY = Phenotypic covariance between X and Y

3.8.6.2 Coefficients of correlation

a) Genotypic correlation coefficient between X and Y

$$r_g = \frac{Vg\ XY}{\sqrt{Vg\ X \times Vg\ Y}}$$

Where,

Vg XY	=	Genotypic covariance between X and Y
Vg X	=	Genotypic variance of X
Vg Y	=	Genotypic variance of Y

b) Phenotypic correlation coefficient between X and Y

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

Where,

Vp XY	=	Phenotypic covariance between X and Y
Vp X	=	Phenotypic variance of X
Vp Y	=	Phenotypic variance of Y

Genotypic variance (Vg)	=	(Mg-Me) / r
Phenotypic variance (Vp)	=	(Vg+ve)

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.

3.8.7 Path coefficient analysis

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

The direct and indirect paths were obtained by following Dewey and Lu (1959). The path coefficients were obtained by simultaneous selection of the following equations, which expresses the basic relationship between genotypic correlation 'r' and path coefficients (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} and r_{23} are the genotypic correlations among 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_{22}, C_{23} and C_{33} are constants derived by using abbreviated Doulittle's technique as explained by Goulden (1959).

$r_{12}\, P_{24}$, $r_{13}\, P_{34}$, $r_{21}\, P_{14}$, $r_{23}\, P_{34}$, $r_{31}\, P_{14}$, $r_{32}\, P_{24}$ are indirect effects.

Residual effect

The variation in the dependent variable which remained undetermined by including all the variables was assumed to be due to variable (s) not included in the present investigation. The degree of determination of such variable (s) on dependent variable was calculated as follows:

$$1 = P^2 x_4 + P_{14}^2 + P_{24}^2 + P_{34}^2 + 2P_{14}\, r_{12}\, P_{24} + 2P_{14}\, r_{13}\, P_{34} + 2P_{24}\, r_{23}\, P_{34}$$

3.8.8. Diversity analysis

3.8.8.1 Estimation of genetic divergence

The genetic divergence in 30 tomato genotypes was estimated by Mahalanobis D^2 statistics (Generalized distance as suggested by Rao 1952). Transformation of original means of various characters to uncorrelated varieties as carried out by pivotal condensation method as the common dispersion matrix by using computer. This made D^2 value as simple sum of squares of differences in transformed values for various characters. The D^2 values which determine the statistical distance among various genotypes reflecting their genetic diversity was estimated for each pair of genotypes under study. The calculation of D^2 values involved following steps (Murty and Arunachalam, 1966).

I. A set of uncorrelated linear combination (Y,s) was obtained by pivotal condensation of the common dispersion matrix (Rao 1952) of a set of correlated variables (X,s; the common dispersion matrix was arranged with the help of error mean of squares and sum of products).

II. Using the relationship between Y,s and X,s the mean values of different characters (X1 to Xn) were transformed into the mean values of a set of uncorrelated linear combination (Y1 to Yn).

III. The D^2 values between ith and jth lines for kth character is calculated as under:

$$D^2ij = \Sigma kt=1 \ (Yit - Yjt)$$

i. The 'K' component and D^2 for each combination were ranked in descending order of magnitude.

ii. D-square values over all combinations were obtained.

3.8.8.2 Clustering/Group Constellation

Based on D^2 values (Mahalanobis, 1936) lines were grouped into a number of clusters. D^2 being treated as the square of generalized distance, according to the method described by non-hierarchical Euclidean cluster analysis. Criterion used in clustering by this method is that any line belonging to the same cluster showed, at least on an average, a smaller D^2 value than those belonging to two different clusters. The first step of grouping their genotypes into distinct clusters was to arrange them in order of their relative distance from each other. Two populations having the smallest distance from each other were considered first, to which a third population was added having a smallest average D^2 value but higher than the previous two. Similarly, the next population was added and the process continued till ate average D^2 value increased considerably with the next addition. At certain stage, when it was felt that after adding a particular population, if there was an abrupt increase in their average value this population was not added in that cluster. Similarly, a second cluster was formed. D^2 values of all possible combination of genotypes in one cluster with those in other was computed and its square root was use to represent the statistical distance between two cluster. The cluster mean for each of the characters was calculated by averaging the total mean values of each member belonging to that cluster and inter and intra cluster distances values were also calculated as under:

Average intra-cluster distances ($D=\sqrt{D^2}$)

$$D^2 = \frac{\sum D_i^2}{n}$$

Where,

$\sum D_i^2$ = Sum of distances between all possible combinations of the populations included in a cluster

n = Number of populations in a cluster

Average inter-cluster distances ($D=\sqrt{D^2}$)

$$D^2 = \frac{\sum D_{ij}^2}{n_i \, x \, n_j}$$

Where,

$\sum D_{ij}^2$ = Sum of distances between all possible combinations of the two cluster

n_i = Number of populations in i^{th} cluster

n_j = Number of populations in j^{th} cluster

Chapter-4
Results

Chapter-4

Results

The present investigation entitled "Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)" was carried out on thirty diverse genotypes of tomato including indigenous and exotic collections along with one check cultivar (Solan Lalima), for yield and yield contributing traits. The experimental results so obtained have been presented under the following subheads:

4.1 VARIABILITY STUDIES

4.1.1 Performance of genotypes

The analysis of variance indicated highly significant differences among the genotypes for all the traits studied (Appendix-II), which revealed the existence of good deal of variability in the germplasm. The mean performance of all the genotypes for various traits under study has been described as below:

4.1.1.1 Days to first fruit harvesting (Days)

Significant variations were observed among all the genotypes for days to first fruit harvesting (Appendix-II). The mean performance of the genotypes ranged from 64.00-80.00 days (Table 4.1). General mean for the character was 72.09 days. Fourteen genotypes including check cultivar took lesser days to first fruit harvesting than the population mean. Minimum days to first fruit harvesting (64.00 days) were recorded in the genotype Punjab Chhuhara and it was found statistically at par with LC-9 (65.00 days) and LC-8 (65.33 days), whereas the genotype LC-5 had taken maximum days to first fruit harvesting (80.00 days) and it was found statistically at par with Sioux (79.67 days). Amongst all the genotypes under study, nine genotypes were found earlier than check cultivar Solan Lalima (69.00 days) for days to first fruit harvesting.

4.1.1.2 Fruit length (cm)

All the genotypes studied indicated significant variations for fruit length (Appendix-II). It ranged from 3.10-6.22 cm (Table 4.1). General mean for the character was 4.63 cm. Seventeen genotypes including check cultivar produced longer fruits than population mean. Maximum fruit length was recorded in Roma (6.22 cm) and it was found statistically at par with LC-8 (6.08 cm), while minimum fruit length was observed in LC-2

(3.10 cm) and it was statistically at par with LC-3 (3.14 cm) and AVTO9803 (3.36 cm). Two genotypes *viz.* AVTO0201 (5.32 cm) and LC-9 (5.35 cm) had greater fruit lengths than check cultivar Solan Lalima (5.25 cm).

Table 4.1 Performance of tomato genotypes for Days to first fruit harvesting (days), Fruit length (cm), Fruit breadth (cm) and Average fruit weight (g).

Sr. No.	Genotype	Days to first fruit harvesting (days)	Fruit length (cm)	Fruit breadth (cm)	Average fruit weight (g)
1.	LC-1	76.00	4.01	4.50	43.31
2.	LC-2	68.67	3.10	2.74	22.98
3.	LC-3	70.33	3.14	2.78	25.37
4.	LC-4	73.33	3.65	5.04	44.18
5.	LC-5	80.00	5.03	5.36	64.69
6.	LC-6	74.67	4.95	4.93	58.57
7.	LC-7	68.00	4.15	5.15	51.25
8.	LC-8	65.33	6.08	5.11	71.41
9.	LC-9	65.00	5.35	4.78	66.44
10.	LC-10	77.67	3.87	5.07	47.06
11.	Arka Alok	69.00	4.54	5.09	55.53
12.	Arka Abha	76.67	4.17	5.18	51.80
13.	Arka Meghali	72.33	4.16	5.04	50.42
14.	Arka Vikas	72.00	3.96	5.16	49.10
15.	Arka Saurabh	73.33	4.17	5.31	53.14
16.	Punjab Chhuhara	64.00	5.75	4.29	64.18
17.	Pant T-3	75.33	3.74	4.74	42.50
18.	Roma	70.00	6.22	4.19	62.55
19.	Sioux	79.67	4.98	6.35	75.90
20.	AVTO0201	68.33	5.32	5.42	69.11
21.	AVTO9803	67.67	3.36	3.34	29.41
22.	AVTO9001	68.33	5.23	5.20	65.27
23.	AVTO0101	77.33	4.72	4.69	53.10
24.	AVTO1173	73.67	5.16	5.18	64.11
25.	AVTO1002	75.00	5.06	4.66	56.66
26.	AVTO1130	75.33	5.05	4.61	55.97
27.	AVTO1219	73.67	5.12	5.10	62.89
28.	AVTO1314	68.67	4.69	5.08	57.39
29.	AVTO1315	74.33	5.00	4.55	54.59
30.	Solan Lalima (Check)	69.00	5.25	5.02	63.17
•	**Mean**	**72.09**	**4.63**	**4.79**	**54.40**
•	**± SE(d)**	**1.11**	**0.15**	**0.18**	**3.02**
•	**$CD_{(0.05)}$**	**2.22**	**0.30**	**0.36**	**6.05**

4.1.1.3 Fruit breadth (cm)

Significant variations for fruit breadth were obtained among all the genotypes studied (Appendix-II). It ranged from 2.74 -6.35 cm (Table 4.1). General mean for the character was 4.79 cm. Eighteen genotypes including check cultivar had higher fruit

breadth than population mean. Maximum fruit breadth was observed in Sioux (6.35 cm) and it was found most significant among all the genotypes under study. Minimum fruit breadth was recorded in LC-2 (2.74 cm) and it was found statistically at par with LC-3 (2.78 cm). Sixteen genotypes were found superior than check cultivar Solan Lalima (5.02 cm) for the trait under study.

4.1.1.4 Average fruit weight (g)

Significant differences were observed among all the genotypes for average fruit weight (Appendix-II). It ranged from 22.98- 75.90 g (Table 4.1). General mean for the character was 54.40 g. Seventeen genotypes including the check cultivar had higher average fruit weight than population mean. Maximum average fruit weight was recorded in Sioux (75.90 g) and it was found statistically at par with LC-8 (71.41 g) and AVTO0201 (69.11 g), whereas minimum fruit weight was observed in LC-2 (22.98 g) and it was statistically at par with LC-3 (25.37 g). Eight genotypes gave higher average fruit weight than check cultivar Solan Lalima (63.17 g).

4.1.1.5 Number of fruit cluster per plant

The observations recorded for this trait showed significant differences among all the genotypes (Appendix-II). Number of fruit cluster per plant ranged from 3.53-7.50 (Table 4.2). General mean for the character was 5.62. Twelve genotypes including the checks gave higher number of fruit cluster per plant than population mean. Maximum number of fruit cluster per plant was observed in AVTO9001 (7.50) and it was found statistically at par with AVTO1315 (7.33) and AVTO1314 (7.07). Whereas, minimum number of fruit cluster per plant were recorded in LC-5 (3.53). Amongst all the genotypes under study, twenty three genotypes were found superior over check cultivar (5.20) for number of fruit cluster per plant.

4.1.1.6 Number of fruits per cluster

Significant variations among all the genotypes were observed for number of fruits per cluster (Appendix-II). It ranged from 2.74-5.61 and general mean for the character was 4.19 (Table 4.2). Fourteen genotypes including check cultivar gave higher number of fruits per cluster than population mean. Maximum number of fruits per cluster was observed in Arka Meghali and LC-4 (5.61), which were found statistically at par with AVTO9803 (5.58) and LC-9 (5.14).

Table 4.2 Performance of tomato genotypes for Number of fruit clusters per plant, Number of fruits per cluster, Number of fruits per plant and Harvest duration (days).

Sr. No.	Genotype	Number of fruit clusters per plant	Number of fruits per cluster	Number of fruits per plant	Harvest duration (days)
1.	**LC-1**	5.40	4.73	25.53	39.33
2.	**LC-2**	5.93	3.21	18.87	31.67
3.	**LC-3**	5.07	3.90	19.73	34.00
4.	**LC-4**	5.23	5.61	29.27	42.67
5.	**LC-5**	3.53	4.28	15.10	21.33
6.	**LC-6**	5.27	3.66	19.20	34.33
7.	**LC-7**	5.73	4.64	26.47	40.00
8.	**LC-8**	5.90	4.70	27.70	42.00
9.	**LC-9**	5.60	5.14	28.80	43.33
10.	**LC-10**	5.47	3.53	19.33	34.67
11.	**Arka Alok**	4.17	4.53	18.87	33.33
12.	**Arka Abha**	5.53	3.69	20.27	35.00
13.	**Arka Meghali**	4.50	5.61	25.20	36.67
14.	**Arka Vikas**	5.27	4.99	26.27	38.67
15.	**Arka Saurabh**	4.93	4.93	24.33	39.00
16.	**Punjab Chhuhara**	5.60	4.93	27.60	41.33
17.	**Pant T-3**	5.93	4.25	25.07	39.00
18.	**Roma**	6.10	4.06	24.71	38.67
19.	**Sioux**	4.53	3.75	17.00	25.67
20.	**AVTO0201**	6.40	3.89	24.86	39.00
21.	**AVTO9803**	6.20	5.58	34.61	49.33
22.	**AVTO9001**	7.50	3.95	29.65	43.00
23.	**AVTO0101**	5.53	3.34	18.37	32.67
24.	**AVTO1173**	6.03	3.26	19.63	34.33
25.	**AVTO1002**	6.73	3.03	20.42	31.00
26.	**AVTO1130**	5.53	3.89	21.38	33.00
27.	**AVTO1219**	5.33	3.72	19.76	32.00
28.	**AVTO1314**	7.07	3.17	22.37	35.67
29.	**AVTO1315**	7.33	2.74	20.05	33.33
30.	**Solan Lalima (Check)**	5.20	5.07	26.35	40.00
•	**Mean**	**5.62**	**4.19**	**23.23**	**36.47**
•	**± SE(d)**	**0.30**	**0.27**	**1.24**	**0.89**
•	**$CD_{(0.05)}$**	**0.61**	**0.53**	**2.49**	**1.78**

Whereas, minimum number of fruits per cluster were recorded in AVTO1315 (2.74) and it was found statistically at par with AVTO1002 (3.03), AVTO1314 (3.17), LC-2 (3.21) and AVTO1173 (3.26). Amongst all the genotypes under study, four genotypes *viz.*, LC-9 (5.14), AVTO9803 (5.58), LC-4 (5.61) and Arka Meghali (5.61) were found to have more number of fruits per cluster than Solan Lalima (5.07).

4.1.1.7 Number of fruits per plant

The observations recorded for this trait showed significant differences among all the genotypes (Appendix-II). The mean performance of the genotypes ranged from 15.10-34.61 (Table 4.2). General mean for the character was 23.23. Fifteen genotypes including check cultivar recorded higher number of fruits per plant than the population mean. Significantly higher number of fruits per plant was observed in the genotype AVTO9803 (34.61), while minimum number of fruits per plant were recorded in the genotype LC-5 (15.10) and it was found statistically at par with Sioux (17.00). Amongst all the genotypes under study, seven genotypes were found superior than check cultivar Solan Lalima (26.35) for number of fruits per plant.

4.1.1.8 Harvest duration (days)

Significant variations were observed among all the genotypes for harvest duration (Appendix-II). Harvest duration ranged from 21.33 – 49.33 days (Table 4.2). General mean for the character was 36.47 days. Fifteen genotypes including the check cultivar were found to have more harvest duration than population mean. Maximum harvest duration was recorded in AVTO9803 (49.33 days) and it was found most significant for the trait under study. In the mean while, significantly minimum harvest duration was observed in the genotype LC-5 (21.33 days). Amongst all the genotypes under study, six genotypes were found to have more harvest duration than check cultivar Solan Lalima (40.00 days).

4.1.1.9 Marketable fruit yield per plant (kg)

All the genotypes studied revealed significant variations for this character (Appendix-II). It ranged from 0.43-1.98 kg (Table 4.3). General mean for the character was 1.26 kg. Thirteen genotypes including check cultivar recorded higher marketable fruit yield per plant than the population mean. Maximum marketable fruit yield per plant was recorded in the genotype LC-8 (1.98 kg) and it was found statistically at par with three genotypes *viz.* AVTO9001 (1.94 kg), LC-9 (1.91 kg) and Punjab Chhuhara (1.77 kg). Minimum marketable fruit yield per plant was observed in LC-2 (0.43 kg) and it was found statistically at par with one genotype *viz.* LC-3 (0.50 kg). Amongst all the genotypes under study, five genotypes *viz.* AVTO0201 (1.72 kg), Punjab Chhuhara (1.77 kg), LC-9 (1.91 kg), AVTO9001 (1.94 kg) and LC-8 (1.98 kg) recorded higher marketable fruit yield per plant than check cultivar Solan Lalima (1.67 kg).

Table 4.3 Performance of tomato genotypes for marketable yield for per plant (kg), per plot (kg), and per hectare (q).

Sr. No.	Genotype	Marketable fruit yield		
		per plant (kg)	per plot (kg)	per hectare (q)
1.	LC-1	1.11	13.30	328.45
2.	LC-2	0.43	5.20	128.48
3.	LC-3	0.50	6.00	148.21
4.	LC-4	1.29	15.53	383.36
5.	LC-5	0.98	11.72	289.30
6.	LC-6	1.12	13.47	332.64
7.	LC-7	1.36	16.29	402.14
8.	LC-8	1.98	23.74	586.11
9.	LC-9	1.91	22.96	566.86
10.	LC-10	0.91	10.91	269.41
11.	Arka Alok	1.05	12.61	311.31
12.	Arka Abha	1.05	12.63	311.77
13.	Arka Meghali	1.26	15.18	374.69
14.	Arka Vikas	1.29	15.47	382.05
15.	Arka Saurabh	1.29	15.50	382.79
16.	Punjab Chhuhara	1.77	21.29	525.63
17.	Pant T-3	1.07	12.79	315.70
18.	Roma	1.55	18.58	458.72
19.	Sioux	1.29	15.49	382.39
20.	AVTO0201	1.72	20.62	509.13
21.	AVTO9803	1.02	12.27	302.96
22.	AVTO9001	1.94	23.23	573.47
23.	AVTO0101	0.98	11.71	289.11
24.	AVTO1173	1.26	15.11	373.01
25.	AVTO1002	1.16	13.91	343.49
26.	AVTO1130	1.20	14.35	354.27
27.	AVTO1219	1.25	14.99	370.00
28.	AVTO1314	1.29	15.44	381.15
29.	AVTO1315	1.09	13.14	324.36
30.	Solan Lalima (Check)	1.67	19.99	493.53
•	**Mean**	**1.26**	**15.11**	**373.15**
•	**± SE(d)**	**0.10**	**1.21**	**29.82**
•	**$CD_{(0.05)}$**	**0.20**	**2.42**	**59.69**

4.1.1.10 Marketable fruit yield per plot (kg)

The observations recorded for this trait showed significant differences among all the genotypes (Appendix-II). It ranged from 5.02-23.74 kg (Table 4.3). General mean for the character was 15.11 kg. Thirteen genotypes including check cultivar recorded higher marketable fruit yield per plot than the population mean. Maximum marketable fruit yield per plot was recorded in the genotype LC-8 (23.74 kg) and it was found statistically at par with three genotypes *viz.* AVTO9001 (23.23 kg), LC-9 (22.96 kg) and Punjab Chhuhara

(21.29 kg). Minimum marketable fruit yield per plot was observed in LC-2 (5.20 kg) and it was found statistically at par with one genotype *viz.* LC-3 (6.00 kg). Five genotypes *viz.* AVTO0201 (20.62 kg), Punjab Chhuhara (21.29 kg), LC-9 (22.96 kg), AVTO9001 (23.23 kg) and LC-8 (23.74 kg) were found superior over check cultivar (19.99 kg) for the trait under study.

4.1.1.11 Marketable fruit yield per hectare (q)

Significant variations were observed among all the genotypes for marketable fruit yield per hectare (Appendix-II). It ranged from 128.48-586.11 q (Table 4.3). General mean for the character was 373.15 q. Thirteen genotypes including check cultivar recorded higher marketable fruit yield per hectare than the population mean. Maximum marketable fruit yield per hectare was recorded in the genotype LC-8 (586.11 q) and it was found statistically at par with three genotypes *viz.* AVTO9001 (573.47 q), LC-9 (566.86 q) and Punjab Chhuhara (525.63 q). Minimum marketable fruit yield per hectare was observed in LC-2 (128.48 q) and it was found statistically at par with one genotype *viz.* LC-3 (148.21 q). Five genotypes *viz.* AVTO0201 (509.13 q), Punjab Chhuhara (525.63 q), LC-9 (566.86 q), AVTO9001 (573.47 q) and LC-8 (586.11 q) recorded higher marketable fruit yield per hectare than check cultivar Solan Lalima (493.53 q).

4.1.1.12 Shelf life (days)

The observations recorded for this trait showed significant differences among all the genotypes (Appendix-II). Shelf life ranged from 13.33-31.00 days (Table 4.4). General mean for the character was 18.52 days. Fifteen genotypes including the check cultivar recorded higher shelf life than population mean. Maximum shelf life was observed in the genotype AVTO9803 (31.00 days) and it was found statistically superior over all other genotypes. Whereas, minimum shelf life was observed in LC-3 (13.33 days) and it was found statistically at par with LC-2 (14.00 days), Arka Alok (14.00 days), LC-7 (14.33 days), Arka Meghali (14.67 days), Arka Saurabh (15.00 days), LC-6 (15.33 days) and Pant T-3 (15.33 days). Amongst all the genotypes under study, seven genotypes had more shelf life than check cultivar (20.67 days).

4.1.1.13 Pericarp thickness (mm)

All the genotypes studied revealed significant variations for the trait under study (Appendix-II). Pericarp thickness ranged from 1.59-7.05 mm (Table 4.4). General mean

for the character was 5.35 mm. Seventeen genotypes including the check recorded higher pericarp thickness than population mean. Maximum pericarp thickness was observed in AVTO9803 (7.05 mm) and it was found statistically at par with AVTO0201 (6.76 mm), AVTO9001 (6.57 mm) and Punjab Chhuhara (6.47 mm). In the mean while, minimum pericarp thickness was recorded in LC-3 (1.59 mm) and it was found statistically at par with LC-2 (1.67 mm). Six genotypes were found superior over check cultivar Solan Lalima (6.26 mm) for this trait.

Table 4.4 Performance of tomato genotypes for Shelf life (days), Pericarp thickness (mm), Lycopene content (mg/100 g) and Total soluble solids (^{o}Brix).

Sr. No.	Genotype	Shelf life (days)	Pericarp thickness (mm)	Lycopene content (mg/100 g)	Total soluble solids (^{o}Brix)
1.	**LC-1**	16.67	5.05	6.50	4.60
2.	**LC-2**	14.00	1.67	3.41	4.77
3.	**LC-3**	13.33	1.59	4.89	4.33
4.	**LC-4**	16.67	5.38	7.96	3.32
5.	**LC-5**	18.00	6.21	8.15	3.17
6.	**LC-6**	15.33	4.95	6.34	4.33
7.	**LC-7**	14.33	4.62	4.99	4.77
8.	**LC-8**	21.67	6.37	8.63	5.60
9.	**LC-9**	20.00	6.25	8.54	4.80
10.	**LC-10**	15.67	4.90	5.39	4.33
11.	**Arka Alok**	14.00	4.12	8.87	4.37
12.	**Arka Abha**	17.33	5.10	8.27	4.87
13.	**Arka Meghali**	14.67	4.31	5.42	4.73
14.	**Arka Vikas**	15.67	4.61	4.66	3.87
15.	**Arka Saurabh**	15.00	4.41	5.74	4.17
16.	**Punjab Chhuhara**	22.00	6.47	6.34	4.70
17.	**Pant T-3**	15.33	4.51	4.81	4.67
18.	**Roma**	20.00	5.88	6.39	4.17
19.	**Sioux**	17.33	5.10	9.02	3.70
20.	**AVTO0201**	23.00	6.76	5.18	4.90
21.	**AVTO9803**	31.00	7.05	4.54	5.00
22.	**AVTO9001**	22.33	6.57	4.43	4.50
23.	**AVTO0101**	19.67	5.78	4.71	4.60
24.	**AVTO1173**	21.00	6.18	4.76	4.33
25.	**AVTO1002**	20.67	6.08	6.36	4.50
26.	**AVTO1130**	20.33	6.16	7.58	4.73
27.	**AVTO1219**	19.67	5.96	5.94	4.17
28.	**AVTO1314**	19.00	5.76	5.36	4.50
29.	**AVTO1315**	21.33	6.34	5.25	4.77
30.	**Solan Lalima (Check)**	20.67	6.26	8.55	4.83
•	**Mean**	**18.52**	**5.35**	**6.23**	**4.47**
•	**± SE(d)**	**1.05**	**0.30**	**0.37**	**0.28**
•	**$CD_{(0.05)}$**	**2.10**	**0.60**	**0.74**	**0.55**

4.1.1.14 Lycopene content (mg/100 g)

The observations recorded for this trait showed significant differences among all the genotypes (Appendix-II). Lycopene content ranged from 3.41-9.02 mg/100 g (Table 4.4). General mean for the character was 6.23 mg/100 g. Fourteen genotypes including the check cultivar recorded higher lycopene content than population mean. Maximum lycopene content was observed in Sioux (9.02 mg/100 g) and it was found statistically at par with Arka Alok (8.87 mg/100 g), LC-8 (8.63 mg/100 g), Solan Lalima (8.55 mg/100 g) LC-9 (8.54 mg/100 g) and Arka Abha (8.27 mg/100 g). Whereas, minimum lycopene content was observed in LC-2 (3.41 mg/100 g). Three genotypes *viz.*, LC-8 (8.63 mg/100 g), Arka Alok (8.87 mg/100 g) and Sioux (9.02 mg/100 g) had higher lycopene content than the check cultivar Solan Lalima (8.55 mg/100 g).

4.1.1.15 Total soluble solids (^{o}Brix)

Significant variations were observed among all the genotypes for total soluble solids content (Appendix-II). It ranged from 3.17-5.60 ^{o}B (Table 4.4). General mean for the character was 4.47. Eighteen genotypes including the check cultivar recorded higher total soluble solids than population mean. Significantly higher total soluble solids were observed in LC-8 (5.60 ^{o}B). Whereas, minimum total soluble solids were recorded in LC-5 (3.17 ^{o}B) and it was found statistically at par with LC-4 (3.32 ^{o}B) and Sioux (3.70 ^{o}B). Four genotypes *viz.*, Arka Abha (4.87 ^{o}B), AVTO0201 (4.90 ^{o}B), AVTO9803 (5.00 ^{o}B) and LC-8 (5.60 ^{o}B) were found superior over check cultivar Solan Lalima (4.83 ^{o}B) for total soluble solids.

4.1.1.16 Buckeye rot incidence (%)

The field trial study conducted under natural epiphytotic conditions revealed significant differences for the buckeye rot incidence among different tomato genotypes under study (Appendix-II-B). It ranged from 9.73-32.15% and general mean for the character was 19.05% (Table 4.5). Fifteen genotypes including check cultivar gave less buckeye rot incidence than population mean. Minimum buckeye rot incidence was recorded in the genotype LC-9 (9.73%) and it was found statistically at par with six genotypes *viz.*, LC-1 (10.36%), LC-4 (11.06%), Arka Vikas (13.11%), Solan Lalima (13.15%), Punjab Chhuhara (13.49%) and LC-8 (13.67%).

Table 4.5 Performance of tomato genotypes for incidence of buckeye rot (%) and fruit borer (%)

Sr. No.	Genotype	Buckeye rot incidence (%)	Fruit borer incidence (%)
1.	LC-1	10.36(18.67) *	9.38(17.59)
2.	LC-2	32.15(34.53)	29.79(33.07)
3.	LC-3	30.75(33.67)	28.66(32.35)
4.	LC-4	11.06(19.32)	17.10(24.37)
5.	LC-5	26.95(31.23)	30.69(33.61)
6.	LC-6	19.36(25.95)	26.74(30.99)
7.	LC-7	15.83(23.40)	16.80(24.17)
8.	LC-8	13.67(21.60)	11.07(19.39)
9.	LC-9	9.73(18.15)	15.45(23.02)
10.	LC-10	22.17(28.07)	25.46(30.27)
11.	Arka Alok	26.06(30.65)	22.73(28.46)
12.	Arka Abha	16.33(23.78)	18.70(25.59)
13.	Arka Meghali	20.88(27.15)	25.00(29.98)
14.	Arka Vikas	13.11(21.16)	15.97(23.49)
15.	Arka Saurabh	15.41(23.09)	22.33(28.19)
16.	Punjab Chhuhara	13.49(21.49)	17.01(24.30)
17.	Pant T-3	21.81(27.80)	18.48(25.41)
18.	Roma	13.92(21.80)	24.10(29.35)
19.	Sioux	18.86(25.68)	21.54(27.61)
20.	AVTO0201	15.39(23.06)	13.51(21.47)
21.	AVTO9803	20.50(26.90)	17.46(24.66)
22.	AVTO9001	14.35(22.22)	15.37(23.07)
23.	AVTO0101	30.32(33.37)	29.27(32.71)
24.	AVTO1173	20.18(26.65)	28.92(32.37)
25.	AVTO1002	23.78(29.17)	28.45(32.20)
26.	AVTO1130	18.87(25.69)	19.93(26.50)
27.	AVTO1219	22.28(28.08)	27.21(31.38)
28.	AVTO1314	19.84(26.43)	27.14(31.38)
29.	AVTO1315	20.85(27.06)	30.75(33.63)
30.	Solan Lalima (Check)	13.15(21.16)	11.20(19.51)
•	**Mean**	**19.05(25.57)**	**21.54(27.34)**
•	**± SE(d)**	**1.78**	**1.88**
•	**$CD_{(0.05)}$**	**3.57**	**3.76**

*Figures in the parenthesis are arc sine transformed

In the mean while, maximum incidence of buckeye rot was observed in LC-2 (32.15%) and it was found statistically at par with LC-3 (30.75%), AVTO0101 (30.32%) and LC-5 (26.95%) and Arka Alok (26.06%). Amongst all the genotypes under study, four genotypes *viz.*, LC-9 (9.73%), LC-1 (10.36%), LC-4 (11.06%) and Arka Vikas (13.11%) recorded less incidence of buckeye rot than check cultivar (13.15%).

4.1.1.17 Fruit borer incidence (%)

Significant variations among all the genotypes were observed for fruit borer incidence (Appendix-II). It ranged from 9.38–30.75 % and general mean for the character was 21.54% (Table 4.5). Fourteen genotypes including check cultivar recorded less incidence of fruit borer than population mean. Minimum fruit borer incidence was recorded in the genotype LC-1 (9.38%) and it was found statistically at par with two genotypes *viz.*, LC-8 (11.07%) and Solan Lalima (11.20%). Whereas, maximum fruit borer incidence fruit was observed in the genotype AVTO1315 (30.75%) and it was found statistically at par with twelve other genotypes. Amongst all the genotypes under study, two genotypes LC-1 (9.38%) and LC-8 (11.07%) were less affected from fruit borer as compared to check cultivar Solan Lalima (11.20%).

4.1.2.1 Coefficients of variation

The observed variations in the characters among all the genotypes are due to effect of genotype and environment. Environmental variations are not fixable. For determining the magnitude of genotypic and phenotypic variation, the genotypic and phenotypic coefficients of variation were calculated (Table 4.6).

For all the characters studied, phenotypic coefficients of variation were higher in magnitude than genotypic coefficients of variation, though difference was very less in majority of cases. Thus, these traits are showing that these are less influenced by environmental factors. Coefficients of variation varied in magnitude from character to character, either low or moderate or high. Therefore, it indicated that there is always a great diversity.

The phenotypic coefficients of variation (PCV) were found high for buckeye rot incidence (34.05%), fruit borer incidence (32.49%), marketable fruit yield per plot (30.36%), marketable fruit yield per hectare (30.35%) and marketable fruit yield per plant (30.34%), whereas moderate phenotypic coefficients of variation (PCV) were recorded for lycopene content (26.47%), pericarp thickness (24.81%), average fruit weight (24.09%), shelf life (20.96%), number of fruits per cluster (20.36%), number of fruits per plant (20.16%), fruit length (17.89%), number of fruit clusters per plant (16.37%), fruit breadth (15.92%), harvest duration (15.44%), while phenotypic coefficients of variation (PCV) were recorded low in magnitude for days to first fruit harvesting (6.18%) and total soluble solids (12.63%).

The genotypic coefficients of variation (GCV) were recorded high for buckeye rot incidence (30.44%), whereas moderate phenotypic coefficients of variation (PCV) were observed for marketable fruit yield per plot (28.74%), marketable fruit yield per hectare (28.73%), marketable fruit yield per plant (28.72%), fruit borer incidence (28.67%), lycopene content (25.45%), pericarp thickness (23.83%), average fruit weight (23.12%), shelf life (19.79%), number of fruits per cluster (18.81%), number of fruits per plant (19.07%), fruit length (17.44%), number of fruit clusters per plant (15.01%), fruit breadth (15.24%) and harvest duration (15.14%), while phenotypic coefficients of variation (PCV) were recorded low in magnitude for days to first fruit harvesting (5.89%) and total soluble solids (10.09%).

4.1.2.2 Heritability

The estimates of heritability (broad sense) varied from 63.90-96.20% for different characters under study (Table 4.6). It was found high for the characters *viz.,* harvest duration (96.20%), fruit length (95.10%), lycopene content (92.40%), pericarp thickness (92.30%), average fruit weight (92.00%), days to first fruit harvesting (90.70%), fruit breadth (91.60%), marketable fruit yield per plant (89.60%), marketable fruit yield per plot (89.60%), marketable fruit yield per hectare (89.60%), number of fruits per plant (89.40%), shelf life (89.10%), number of fruits per cluster (85.40%), number of fruit clusters per plant (83.60%) and buckeye rot incidence (80.00%), whereas moderate heritability was observed for fruit borer incidence (77.80%) and total soluble solids (63.90%).

4.1.2.3 Genetic advance and genetic gain

Genetic gain (expressed as per cent of population mean) was low to high in nature and ranged from 11.54-56.35% for different characters under study (Table 4.6). It was found high for the characters *viz.,* marketable fruit yield per plant (56.35%), buckeye rot incidence (56.12%), marketable fruit yield per plot (56.06%), marketable fruit yield per hectare (56.02%), fruit borer incidence (52.09%) and lycopene content (50.40%). Moderate genetic gain was observed for pericarp thickness (47.10%), average fruit weight (45.66%), shelf life (38.50%), number of fruits per plant (37.15%), number of fruits per cluster (35.80%), fruit length (34.99%), harvest duration (30.60%), fruit breadth (30.06%) and number of fruit clusters per plant (28.11%), whereas it was recorded low for days to first fruit harvesting (11.54%) and total soluble solids (16.55%).

Table 4.6 Estimates of phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for different traits in tomato

Sr. No.	Characters	Range	Mean ± SE(d)	Coefficients of variation (%)		Heritability (%)	Genetic advance	Genetic gain (%)
				Phenotypic	Genotypic			
1.	Days to first fruit harvesting (Days)	64.00-80.00	72.09±1.11	6.18	5.89	90.70	8.32	11.54
2.	Fruit length (cm)	3.10-6.22	4.63±0.15	17.89	17.44	95.10	1.62	34.99
3.	Fruit breadth (cm)	2.74-6.35	4.79±0.18	15.92	15.24	91.60	1.44	30.06
4.	Average fruit weight (g)	22.98-75.90	54.40±3.02	24.09	23.12	92.00	24.84	45.66
5.	Number of fruit clusters per plant	3.53-7.50	5.62±0.30	16.37	15.01	83.60	1.58	28.11
6.	Number of fruits per cluster	2.74-5.61	4.19±0.27	20.36	18.81	85.40	1.50	35.80
7.	Number of fruits per plant	15.10-34.61	23.23±1.24	20.16	19.07	89.40	8.63	37.15
8.	Harvest duration (days)	21.33-49.33	36.47±0.89	15.44	15.14	96.20	11.16	30.60
9.	Marketable fruit yield per plant (kg)	0.43-1.98	1.26±0.10	30.34	28.72	89.60	0.71	56.35
10.	Marketable fruit yield per plot (kg)	5.20-23.74	15.11±1.21	30.36	28.74	89.60	8.47	56.06
11.	Marketable fruit yield per hectare (q)	128.48-586.11	373.15±29.82	30.35	28.73	89.60	209.05	56.02
12.	Shelf life (days)	13.33-31.00	18.52±1.05	20.96	19.79	89.10	7.13	38.50
13.	Pericarp thickness (mm)	1.59-7.05	5.35±0.30	24.81	23.83	92.30	2.52	47.10
14.	Lycopene content (mg/100g)	3.41-9.02	6.23±0.37	26.47	25.45	92.40	3.14	50.40
15.	Total soluble solids (^{o}Brix)	3.17-5.60	4.47±0.28	12.63	10.09	63.90	0.74	16.55
16.	Buckeye rot incidence (%)	9.73-32.15	19.05±1.78	34.05	30.44	80.00	10.69	56.12
17.	Fruit borer incidence (%)	9.38-30.75	21.54±1.88	32.49	28.67	77.80	11.22	52.09

4.2 Correlation studies

The correlation coefficients among the different characters were worked out at phenotypic and genotypic levels (Table 4.7). In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients.

The phenotypic and genotypic correlation coefficients among different characters showed that marketable yield per plant had positive and significant association with fruit length (0.735 and 0.743), fruit breadth (0.492 and 0.482), average fruit weight (0.752 and 0.748), number of fruit clusters per plant (0.249 and 0.263), number of fruits per cluster (0.354 and 0.346), number of fruits per plant (0.570 and 0.561), harvest duration (0.487 and 0.497), shelf life (0.412 and 0.453), pericarp thickness (0.638 and 0.698), lycopene content (0.314 and 0.347) and total soluble solids (0.231 and 0.262), while significant and negative correlations were observed with days to first fruit harvesting (-0.497 and -0.505), buckeye rot incidence (-0.704 and -0.814) and fruit borer incidence (-0.569 and -0.659), respectively.

Beside this, average fruit weight resulted in positive and significant association with fruit length (0.882 and 0.893) and fruit breadth (0.772 and 0.766) and it revealed significantly negative correlation with buckeye rot incidence (-0.402 and -0.441), respectively. Significantly positive correlation of number of fruits per plant was found with number of fruit clusters per plant (0.326 and 0.334), number of fruits per cluster (0.698 and 0.713) and harvest duration (0.909 and 0.966), while significant negative association of this trait was found with days to first fruit harvesting (-0.608 and -0.667), buckeye rot incidence (-0.596 and -0.704) and fruit borer incidence (-0.655 and -0.772), respectively. Shelf life showed significantly positive correlation with pericarp thickness (0.815 and 0.799) and total soluble solids (0.278 and 0.387), while pericarp thickness revealed significantly positive phenotypic and genotypic correlation with lycopene content (0.241 and 0.268), respectively.

4.3. Path coefficient analysis

Path coefficient analysis depicts the effects of different independent characters individually and in combination with other characters on the expression of different characters on marketable fruit yield per plant. The data on path coefficient analysis at genotypic level showing the direct and indirect effects of significant characters over marketable fruit yield per plant have been represented in (Table 4.8). The data revealed

Table 4.7 Phenotypic and genotypic coefficients of correlation among different traits in tomato

Traits		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	P	1.00	-0.206	0.291**	-0.036	-0.317**	-0.339**	-0.608**	-0.659**	-0.282**	-0.078	0.097	-0.441**	0.298**	0.372**	-0.497**
	G	1.00	-0.190	0.357**	0.008	-0.349**	-0.384**	-0.667**	-0.688**	-0.307**	-0.078	0.102	-0.590**	0.322**	0.440**	-0.505**
2	P		1.00	0.420**	0.882**	0.170	-0.131	0.000	-0.044	0.400**	0.657**	0.394**	0.119	-0.341**	-0.110	0.735**
	G		1.00	0.429**	0.893**	0.179	-0.153	-0.017	-0.058	0.424**	0.692**	0.423**	0.142	-0.387**	-0.129	0.743**
3	P			1.00	0.772**	-0.186	0.033	-0.128	-0.193	-0.055	0.417**	0.424**	-0.233*	-0.382**	-0.195	0.492**
	G			1.00	0.766**	-0.202	0.032	-0.139	-0.213*	-0.075	0.443**	0.467**	-0.320**	-0.415**	-0.212*	0.482**
4	P				1.00	0.001	-0.071	-0.073	-0.145	0.259*	0.631**	0.487**	-0.039	-0.402**	-0.168	0.752**
	G				1.00	-0.002	-0.091	-0.094	-0.167	0.268*	0.671**	0.534**	-0.069	-0.441**	-0.188	0.748**
5	P					1.00	-0.436**	0.326**	0.375**	0.446**	0.306**	-0.429**	0.395**	-0.133	-0.055	0.249*
	G					1.00	-0.413**	0.334**	0.407**	0.518**	0.350**	-0.508**	0.525**	-0.185	-0.054	0.263*
6	P						1.00	0.698**	0.566**	0.037	0.056	0.239*	0.008	-0.460**	-0.554**	0.354**
	G						1.00	0.713**	0.618**	0.048	0.072	0.284**	-0.043	-0.549**	-0.675**	0.346**
7	P							1.00	0.909**	0.421**	0.309**	-0.087	0.329**	-0.596**	-0.655**	0.570**
	G							1.00	0.966**	0.480**	0.351**	-0.096	0.373**	-0.704**	-0.772**	0.561**
8	P								1.00	0.372**	0.235*	-0.161	0.415**	-0.556**	-0.628**	0.487**
	G								1.00	0.406**	0.255*	-0.170	0.512**	-0.652**	-0.717**	0.497**
9	P									1.00	0.815**	-0.027	0.278**	-0.224*	-0.197	0.412**
	G									1.00	0.799**	-0.021	0.387**	-0.247*	-0.250*	0.453**
10	P										1.00	0.241*	0.098	-0.451**	-0.260*	0.638**
	G										1.00	0.268*	0.150	-0.507**	-0.318**	0.698**
11	P											1.00	-0.149	-0.289**	-0.275**	0.314**
	G											1.00	-0.148	-0.369**	-0.324**	0.347**
12	P												1.00	-0.071	-0.289**	0.231*
	G												1.00	-0.114	-0.382**	0.262*
13	P													1.00	0.627**	-0.704**
	G													1.00	0.880**	-0.814**
14	P														1.00	-0.569**
	G														1.00	-0.659**
15	P															1.00
	G															1.00

***Significant at 5% level of significance**

****Significant at 1% level of significance**

Where,

1=Days to first fruit harvesting (Days), 2=Fruit length (cm), 3=Fruit breadth (cm), 4=Average fruit weight (g) 5=Number of fruit clusters per plant, 6=Number of fruits per cluster 7=Number of fruits per plant 8=Harvest duration (days), 9=Shelf life (days), 10=Pericarp thickness (mm), 11=Lycopene content (mg/100g), 12=Total soluble solids (^{o}Brix), 13=Buckeye rot incidence (%), 14=Fruit borer incidence (%) and 15=Marketable fruit yield per plant (kg)

Table 4.8 Estimates of direct and indirect effects of different traits on marketable fruit yield per plant in tomato

Traits	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	**-0.269**	-0.024	0.069	0.002	-0.045	-0.053	0.101	-0.098	-0.076	-0.005	-0.021	0.029	-0.076	-0.039	-0.505**
2	0.089	**0.126**	0.083	0.209	0.023	-0.061	0.015	-0.017	0.105	0.041	-0.087	-0.007	0.212	0.012	0.743**
3	-0.167	0.054	**0.194**	0.179	-0.026	0.013	0.125	-0.062	-0.020	0.026	-0.096	0.016	0.227	0.019	0.482**
4	-0.004	0.112	0.148	**0.334**	0.000	-0.036	0.085	-0.048	0.066	0.040	-0.110	0.003	0.141	0.017	0.748**
5	0.164	0.023	-0.039	0.000	**0.130**	-0.164	0.101	0.117	0.128	0.020	0.105	-0.026	-0.201	-0.095	0.263*
6	0.180	-0.019	0.006	-0.021	-0.054	**0.398**	0.300	0.178	0.012	0.004	-0.058	0.002	-0.342	-0.240	0.346**
7	0.313	-0.002	-0.027	-0.122	0.043	0.284	**0.385**	**0.278**	0.119	0.021	0.020	-0.220	-0.200	-0.331	0.561**
8	-0.278	-0.007	-0.041	-0.039	0.053	0.246	0.356	**0.288**	0.101	0.015	0.035	-0.025	-0.271	0.064	0.497**
9	0.144	0.053	-0.015	0.063	0.067	0.019	-0.432	0.117	**0.247**	0.047	0.005	-0.019	0.135	0.022	0.453**
10	0.037	0.087	0.086	0.157	0.046	0.029	-0.316	0.073	0.198	**0.058**	-0.055	-0.007	0.277	0.028	0.698**
11	-0.048	0.053	0.090	0.125	-0.066	0.113	0.086	-0.049	-0.005	0.016	**-0.206**	0.007	0.202	0.029	0.347**
12	0.276	0.018	-0.062	-0.016	0.068	-0.017	-0.336	0.148	0.096	0.009	0.030	**-0.049**	0.063	0.034	0.262*
13	-0.151	-0.049	-0.080	-0.103	-0.024	-0.218	0.133	-0.188	-0.061	-0.030	**0.275**	0.207	**-0.447**	-0.078	-0.814**
14	-0.206	-0.016	-0.041	-0.044	-0.007	-0.268	0.195	-0.207	-0.062	-0.019	0.267	0.219	-0.381	**-0.089**	-0.659**

Where,

1=Days to first fruit harvesting (Days), 2=Fruit length (cm), 3=Fruit breadth (cm), 4=Average fruit weight (g) 5=Number of fruit clusters per plant, 6=Number of fruits per cluster 7=Number of fruits per plant, 8=Harvest duration (days), 9=Shelf life (days), 10=Pericarp thickness (mm), 11=Lycopene content (mg/100g), 12=Total soluble solids (^{o}Brix), 13= Buckeye rot incidence (%), 14=Fruit borer incidence (%) and 15=Genotypic correlation coefficient for marketable fruit yield per plant (kg)

Residual effect: 0.01863

Diagonal figures represent the direct effect

that number of fruits per cluster has maximum positive direct effect on marketable fruit yield per plant (0.398) followed by number of fruits per plant (0.385), average fruit weight (0.334), harvest duration (0.288), shelf life (0.247), fruit breadth (0.194), number of fruit clusters per plant (0.130), fruit length (0.126) and pericarp thickness (0.058). While, negative direct effect of buckeye rot incidence (-0.447), days to first fruit harvesting (-0.269), lycopene content (-0.206), fruit borer incidence (-0.089) and total soluble solids (-0.049) was observed on marketable fruit yield per plant.

Maximum positive indirect effects of harvest duration (0.356) via number of fruits per plant, number of fruits per plant (0.313) via days to first fruit harvesting, number of fruits per cluster (0.300) via number of fruits per plant, number of fruits per plant (0.278) via harvest duration, pericarp thickness (0.277) via buckeye rot incidence and total soluble solids (0.276) via days to first fruit harvesting was observed on marketable fruit yield per plant. In the mean while, maximum negative indirect effects of shelf life (-0.432) via number of fruits per plant, fruit borer incidence (-0.381) via buckeye rot incidence, number of fruits per cluster (-0.342) via buckeye rot incidence, total soluble solids (-0.336) via number of fruits per plant, number of fruits per plant (-0.331) via fruit borer incidence and pericarp thickness (-0.316) via number of fruits per plant was recorded on marketable fruit yield per plant. At genotypic level residual effect was found to be 0.01863.

4.4 Genetic divergence studies

On the basis of performance of various traits, the clustering pattern of thirty diverse genotypes of tomato has been presented in the table 4.9. All the genotypes were grouped into 4 clusters. Maximum number of genotypes were accommodated in the cluster-IV (13) followed by cluster-III (8), cluster-II (7) and I (2).

Average inters and intra cluster divergence (D^2) values have been presented in the table 4.10. The diagonal figures in the table represent the intra cluster distances. The intra cluster distance was found maximum in cluster III (2.928) and minimum in cluster I (0.986). Whereas, highest inter cluster distance (8.789) was recorded between cluster I and III and lowest (3.617) was observed between cluster II and IV.

The cluster means for various horticultural and quality traits have been presented in the table 4.11. Minimum days to first fruit harvesting were observed in cluster III (67.21) followed by cluster I (69.50), cluster II (72.90) and cluster IV (75.05). Maximum fruit length was recorded in cluster III (5.32) followed by cluster IV (4.80), cluster II (3.98)

and cluster I (3.12), while fruit breadth was highest in cluster IV (5.07) followed by cluster II (4.99), cluster III (4.67) and cluster I (2.76). The average fruit weight was maximum in cluster III (61.44) followed by cluster IV (58.33), cluster II (47.70) and cluster I (24.18).

Table 4.9 Clustering pattern of 30 genotypes of tomato on the basis of genetic divergence

Cluster	Number of genotypes	Genotypes along with their sources
I	**2**	LC-2 (Kotdwara) and LC-3 (Uttarakashi)
II	**7**	LC-1 (Nainital), LC-4 (Tehri Garhwal), LC-7 (Sirmour), Arka Meghali (IIHR), Arka Vikas (IIHR), Arka Saurabh (IIHR) and Pant T-3 (GBPUAT)
III	**8**	LC-8 (Shimla), LC-9 (Bilaspur), Punjab Chhuhara (PAU), Roma (IARI), AVTO0201 (AVRDC), AVTO9803 (AVRDC), AVTO9001 (AVRDC) and Solan Lalima (UHF)
IV	**13**	LC-5 (Almora), LC-6 (Solan), LC-10 (Kangra), Arka Alok (IIHR), Arka Abha (IIHR), Sioux (IARI), AVTO0101 (AVRDC), AVTO1173 (AVRDC), AVTO1002 (AVRDC), AVTO1130 (AVRDC), AVTO1219 (AVRDC), AVTO1314 (AVRDC) and AVTO1315 (AVRDC)

Table 4.10 Average intra and inter cluster distance (D^2)

Cluster	I	II	III	IV
I	**0.986**			
II	6.508	**2.018**		
III	8.789	3.961	**2.928**	
IV	6.491	3.617	4.730	**2.660**

Table 4.11 Cluster means for different characters in 30 genotypes of tomato

Sr. No.	Characters	Clusters			
		I	II	III	IV
1.	**Days to first fruit harvesting (Days)**	69.50	72.90	67.21	75.05
2.	**Fruit length (cm)**	3.12	3.98	5.32	4.80
3.	**Fruit breadth (cm)**	2.76	4.99	4.67	5.07
4.	**Average fruit weight (g)**	24.18	47.70	61.44	58.33
5.	**Number of fruit clusters per plant**	5.50	5.29	6.06	5.54
6.	**Number of fruits per cluster**	3.56	4.97	4.66	3.58
7.	**Number of fruits per plant**	19.30	26.02	28.03	19.37
8.	**Harvest duration (days)**	32.83	39.33	42.08	32.03
9.	**Shelf life (days)**	13.67	15.48	22.58	18.41
10.	**Pericarp thickness (mm)**	1.63	4.70	6.45	5.59
11.	**Lycopene content (mg/100g)**	4.15	5.73	6.57	6.61
12.	**Total soluble solids (^{o}Brix)**	4.55	4.30	4.81	4.34
13.	**Buckeye rot incidence (%)**	31.45	15.49	14.28	21.99
14.	**Fruit borer incidence (%)**	29.23	17.87	15.65	25.97
15.	**Marketable fruit yield per plant (kg)**	0.47	1.24	1.69	1.13

Highest number of fruit clusters per plant were recorded in the cluster III (6.06) followed by cluster IV (5.54), cluster I (5.50) and cluster II (5.29), while number of fruits per cluster were found maximum in the cluster II (4.97) followed by cluster III (4.66), cluster IV (3.58) and cluster I (3.56). Maximum number of fruits per plant were observed in cluster III (28.03) followed by cluster II (26.02), cluster IV (19.37) and cluster I (19.30), while harvest duration was maximum in cluster III (42.08) followed by cluster II (39.33), cluster I (32.83) and cluster II (32.03). Maximum shelf life of fruits was observed

in the cluster III (22.58) followed by cluster IV (18.41), cluster II (15.48) and cluster I (13.67). Pericarp thickness was recorded maximum in the cluster III (6.45) followed by cluster IV (5.59), cluster II (4.70) and cluster I (1.63). The highest lycopene content was recorded in cluster IV (6.61) followed by cluster III (6.57), cluster II (5.73) and cluster I (4.15), while total soluble solids were observed maximum in the cluster III (4.81) followed by cluster I (4.55), cluster IV (4.34) and cluster II (4.30). For Buckeye rot incidence, Cluster III (14.28) exhibited minimum value followed by cluster II (15.49), cluster IV (21.99) and cluster I (31.45). Similarly, fruit borer incidence was also minimum in Cluster III (15.65) followed by cluster II (17.87), cluster IV (25.97) and cluster I (29.23). Marketable fruit yield per plant was recorded maximum in the cluster III (1.69) followed by cluster II (1.24), cluster IV (1.13) and cluster I (0.47).

Chapter-5
Discussion

Chapter-5
Discussion

Tomato (*Solanum lycopersicum* L.) is one of the most popular warm season fruit vegetable crops grown throughout the world because of its wider adaptability, high yielding potential and suitability for variety of cuisines in fresh as well as in preserved form. It is most remunerative cash crop of mid hills of Uttarakhand being grown as an off season vegetable for fresh market and supply the produce to the plains of northern India. Realizing this, there is a need for continuous crop improvement in tomato which can be achieved by isolating superior breeding lines/varieties having desirable horticultural traits.

Large amount of variation in the germplasm provide better chance of selecting desired genotypes. Hence, knowledge of the magnitude and kind of variability existing in the germplasm for yield and its attributing traits is essentially important. Heritability examines the extent of heritable portion of variability, while study of genetic advance predicts the possible yield through selection. The fruit yield in tomato is a complex character and is dependent on number of yield components. To incorporate desirable yield and quality traits in a variety/hybrid, there is a need to know the inter-relationship of different characters. Moreover, knowledge of inter character relationship helps in the identification of important attributes which, in other words, is used to design suitable plant type with improved characters and for multiple trait selection. Path coefficient analysis on the other hand; partitioned the correlation coefficients into direct and indirect effects and the information so generated could be utilized in restructuring desirable plant type. Further, grouping of genotypes based on D^2 analysis is useful in choosing suitable parental lines for heterosis breeding. Such studies are also useful in selection of parents for hybridization to recover superior transgressive segregants, which can be released as improved open pollinated varieties for commercial cultivation.

Therefore, the present investigation was carried out on 30 diverse genotypes of tomato to study genetic variability, correlation, path analysis and genetic divergence for different horticultural and quality traits. These traits have been discussed here under in the light of available literature:

5.1 VARIABILITY STUDIES

5.1.1 Mean performance of genotypes

The analysis of variance indicated highly significant differences among the genotypes for all the traits studied *viz.*, days to first fruit harvesting (Days), fruit length (cm), fruit breadth (cm), average fruit weight (g), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration (days), marketable fruit yield per plant (kg), per plot (kg) and per hectare (q), shelf life (days), pericarp thickness (mm), lycopene content (mg/100 g), total soluble solids (^{o}Brix), buckeye rot incidence (%), fruit borer incidence (%) and, which revealed the existence of good deal of variability in the germplasm. The experimental results have been discussed under the following headings:

5.1.1.1 Days to first fruit harvesting (Days)

Earliness is one of the most important factors which decide how early the fruits reach the market and how best they appeal to the eyes of the customers. Significant variations were observed among all the genotypes for days to first fruit harvesting (64.00-80.00 days). Fourteen genotypes including check cultivar took lesser days to first fruit harvesting than the population mean. Minimum days to first fruit harvesting (64.00 days) were recorded in the genotype Punjab Chhuhara followed by LC-9 (65.00 days) and LC-8 (65.33 days). Amongst all the genotypes under study, nine genotypes were found earlier than check cultivar Solan Lalima (69.00 days) for days to first fruit harvesting. Similar results had also been reported earlier by Kumari *et al.* (2007), Kumar *et al.* (2013), Patel *et al.* (2013) and Reddy *et al.* (2013) for days to first fruit harvesting in tomato.

5.1.1.2 Fruit length (cm)

Fruit length is an important parameter, which directly contributes to the fruit weight, thereby affecting the total yield. All the genotypes studied indicated significant variations for fruit length (3.10-6.22 cm). Maximum fruit length was recorded in the genotype Roma (6.22 cm) followed by LC-8 (6.08 cm). Two genotypes *viz.*, AVTO0201 (5.32 cm) and LC-9 (5.35 cm) had greater fruit lengths than check cultivar Solan Lalima (5.25 cm). The results of present studies are in line with Kumari *et al.* (2007), Bernousi *et al.* (2011), Kaushik *et al.* (2011), Islam *et al.* (2012), Rahaman *et al.* (2012), Kumar *et al.* (2013), Patel *et al.* (2013), Reddy *et al.* (2013), Kumar *et al.* (2014) and Nwosu *et al.* (2014) for the trait under study.

5.1.1.3 Fruit breadth (cm)

Fruit breadth had also direct effect on fruit weight, and ultimately on total yield. Significant variations for fruit breadth were obtained among all the genotypes studied (2.74 -6.35 cm). Eighteen genotypes including check cultivar had higher fruit breadth than population mean. Significantly, maximum fruit breadth was observed in the genotype Sioux (6.35 cm). Sixteen genotypes were found superior than check cultivar Solan Lalima (5.02 cm) for this trait. Kumari *et al.* (2007), Asati *et al*. (2008), Bernousi *et al.* (2011), Kaushik *et al.* (2011), Islam *et al.* (2012), Rahaman *et al.* (2012), Kumar *et al.* (2013), Patel *et al.* (2013), Reddy *et al.* (2013), Kumar *et al.* (2014) and Nwosu *et al.* (2014) had also reported significant variations for fruit breadth in tomato.

5.1.1.4 Average fruit weight (g)

Fruit weight has direct effect on yield and this is a character which appeals to the consumers. Wide variations were recorded among all the genotypes for average fruit weight (22.98- 75.90 g). Seventeen genotypes including the check cultivar had higher average fruit weight than population mean. Maximum average fruit weight was recorded in Sioux (75.90 g) followed by LC-8 (71.41 g) and AVTO0201 (69.11 g). Eight genotypes gave higher average fruit weight than check cultivar Solan Lalima (63.17 g). Tremendous variations for average fruit weight were also reported earlier by Kumari *et al.* (2007), Asati *et al*. (2008), Dar and Sharma (2011), Islam *et al.* (2012), Mohamed *et al*, (2012), Rahaman *et al.* (2012), Kumar *et al.* (2013), Kumari and Sharma (2013), Patel *et al.* (2013), Reddy *et al.* (2013), Agrawal *et al.* (2014), Kumar *et al.* (2014), Nwosu *et al.* (2014) and Meena and Bahadur (2014).

5.1.1.5 Number of fruit cluster per plant

Number of fruits per cluster is an important trait contributing towards the total number of fruits per plant. The observations recorded for this trait showed significant differences among all the genotypes (3.53-7.50). Maximum number of fruit cluster per plant were observed in AVTO9803 (7.50) followed by AVTO1315 (7.33) and AVTO1314 (7.07). In overall, twenty three genotypes were found superior over check cultivar (5.20) for number of fruit cluster per plant. Similar results have also been reported earlier by Tasisa *et al*. (2011), Islam *et al.* (2012), Kumar *et al.* (2013) and Reddy *et al.* (2013) for number of fruits per cluster.

5.1.1.6 Number of fruits per cluster

This trait also directly contributes to the total number of fruits per plant. Significant variations among all the genotypes were observed for number of fruits per cluster (2.74-5.61). Maximum numbers of fruits per cluster were observed in Arka Meghali and LC-4 (5.61) followed by AVTO9803 (5.58) and LC-9 (5.14). Four genotypes *viz.*, LC-9 (5.14), AVTO9803 (5.58), LC-4 (5.61) and Arka Meghali (5.61) were found to have more number of fruits per cluster than Solan Lalima (5.07). Haydar *et al.* (2007), Islam *et al.* (2012), Mohamed *et al*, (2012), Kumar *et al.* (2013), Kumari and Sharma (2013) and Reddy *et al.* (2013) have also reported similar variations for this trait.

5.1.1.7 Number of fruits per plant

Number of fruits per plant is a major yield contributing character. The observations recorded for this trait showed significant differences among all the genotypes (15.10-34.61). Significantly higher number of fruits per plant were observed in the genotype AVTO9803 (34.61), Amongst all the genotypes under study, seven genotypes were found superior than check cultivar Solan Lalima (26.35) for number of fruits per plant. Wide variations for number of fruits per plant were also reported earlier by Mariame *et al.* (2003), Kumari *et al.* (2007), Haydar *et al*. (2007), Saeed *et al*. (2007), Bernousi *et al.* (2011), Dar and Sharma (2011), Tasisa *et al*. (2011), Rahaman *et al.* (2012), Kumar *et al.* (2013), Kumari and Sharma (2013), Patel *et al.* (2013), Reddy *et al.* (2013), Agrawal *et al.* (2014), Kumar *et al.* (2014) and Meena and Bahadur (2014) in tomato.

5.1.1.8 Harvest duration (days)

Longest harvest duration is preferred in the present marketing system under Indian conditions because, it will not only avoid the glut in the market but off-season nature of the crop is also maintained. Significant variations were observed among all the genotypes for harvest duration (21.33-49.33 days). Significantly higher harvest duration was recorded in AVTO9803 (49.33 days). In overall, six genotypes were found to have more harvest duration than check cultivar Solan Lalima (40.00 days). The results of present studies for harvest duration are in line with Kumar *et al.* (2013), Kumari and Sharma (2013) and Patel *et al.* (2013).

5.1.1.9 Marketable fruit yield per plant (kg), per plot (kg) and per hectare (q)

The main focus of cultivating a crop is to have the maximum yield per unit area for better returns. Moreover, high fruit yield is the ultimate goal of any breeding program; hence, it requires the highest consideration. All the genotypes studied revealed significant variations for marketable fruit yield per plant, per plot and per hectare (0.43-1.98 kg, 5.02-23.74 kg and 128.48-586.11 q, respectively). Maximum marketable fruit yield was recorded in the genotype LC-8 (1.98 kg, 23.74 kg and 586.11 q, respectively) followed by AVTO9001 (1.94 kg, 23.23 kg and 573.47 q, respectively), LC-9 (1.91 kg, 22.96 kg and 566.86 q, respectively) and Punjab Chhuhara (1.77 kg, 21.29 kg and 525.63 q, respectively). In the present studied, five genotypes *viz.* AVTO0201, Punjab Chhuhara, LC-9, AVTO9001 and LC-8 recorded higher marketable fruit yield than check cultivar Solan Lalima. Tremendous variations regarding yield parameter in tomato have also been reported earlier by Saeed *et al*. (2007), Asati *et al*. (2008), Dar and Sharma (2011), Kaushik *et al.* (2011), Islam *et al.* (2012), Rahaman *et al.* (2012), Mohamed *et al.* (2012), Kumar *et al.* (2013), Patel *et al.* (2013), Reddy *et al.* (2013), Kumar *et al.* (2014), Meena and Bahadur (2014), and Nwosu *et al.* (2014).

5.1.1.10 Shelf life (days)

Shelf life plays an important role in keeping quality of the fruits. Fruits having longer shelf life can be transported to distant markets, whereas fruits with poor shelf life are vulnerable to long distance transport and disease injury. In the present studies, observations recorded for this trait showed significant differences among all the genotypes (13.33-31.00 days). Maximum shelf life was observed in the genotype AVTO9803 (31.00 days) and it was found statistically superior over all other genotypes. Amongst all the genotypes under study, seven genotypes had more shelf life than check cultivar (20.67 days). Earlier workers like Singh *et al.* (2002a), Singh *et al.* (2002b), Kaushik *et al.* (2011) and Reddy *et al.* (2013) have also observed similar results for shelf life in tomato.

5.1.1.11 Pericarp thickness (mm)

Pericarp thickness has been globally identified as an important component of keeping quality and whole fruit firmness in tomato. All the genotypes studied revealed significant variations for the trait under study (1.59-7.05 mm). In the present studies, maximum pericarp thickness was observed in AVTO9803 (7.05 mm) followed by AVTO0201 (6.76 mm), AVTO9001 (6.57 mm) and Punjab Chhuhara (6.47 mm). Six

genotypes were found superior over check cultivar Solan Lalima (6.26 mm) for this trait. These findings are in line with Singh and Cheema (2005), Asati *et al*. (2008), Hidayatullah *et al.* (2008), Bernousi *et al.* (2011), Kumar *et al.* (2013b), Patel *et al.* (2013), Kumari and Sharma *et al.* (2013), Agrawal *et al.* (2014), and Kumar *et al.* (2014).

5.1.1.12 Lycopene content (mg/100 g)

Lycopene content is important quality parameters in the processing industry. In the present studies, lycopene content ranged from 3.41-9.02 mg/100 g. Maximum lycopene content was observed in Sioux (9.02 mg/100 g) followed by Arka Alok (8.87 mg/100 g), LC-8 (8.63 mg/100 g), Solan Lalima (8.55 mg/100 g) LC-9 (8.54 mg/100 g) and Arka Abha (8.27 mg/100 g). Three genotypes *viz.*, LC-8 (8.63 mg/100 g), Arka Alok (8.87 mg/100 g) and Sioux (9.02 mg/100 g) had higher lycopene content than the check cultivar Solan Lalima (8.55 mg/100 g). Singh and Cheema (2005), Kumari *et al.* (2007) and Dar and Sharma (2011) have also reported wide variability for lycopene content in different genotypes of tomato under study.

3.1.1.13 Total soluble solids (^{o}Brix)

Total soluble solids content is also one of the most important quality parameters in the processing industry. Significant variations were observed among all the genotypes for total soluble solids content (3.17-5.60 ^{o}B). Significantly higher total soluble solids were observed in LC-8 (5.60 ^{o}B). Four genotypes *viz.*, Arka Abha (4.87 ^{o}B), AVTO0201 (4.90 ^{o}B), AVTO9803 (5.00 ^{o}B) and LC-8 (5.60 ^{o}B) were found superior over check cultivar Solan Lalima (4.83 ^{o}B) for total soluble solids. Singh and Cheema (2005), Kumari *et al.* (2007), Hidayatullah *et al.* (2008), Bernousi *et al.* (2011), Islam *et al.* (2012), Kumar *et al.* (2013b), Kumari and Sharma (2013), Patel *et al.* (2013), Reddy *et al.* (2013), Agrawal *et al.* (2014), Kumar *et al.* (2014) and Meena and Bahadur (2014) had also similar results for total soluble solids content in tomato.

5.1.1.14 Buckeye rot incidence (%)

Buckeye rot is one of the serious diseases infecting tomato and no variety having resistance to disease has been bred and is under commercial cultivation. In the present studies, buckeye rot incidence among different tomato genotypes under study ranged from 9.73-32.15%. Minimum buckeye rot incidence was recorded in the genotype LC-9 (9.73%) followed by LC-1 (10.36%), LC-4 (11.06%), Arka Vikas (13.11%), Solan Lalima

(13.15%), LC-8 (13.17%) and Punjab Chhuhara (13.49%). Amongst all the genotypes under study, four genotypes *viz.*, LC-9 (9.73%), LC-1 (10.36%), LC-4 (11.06%) and Arka Vikas (13.11%) recorded less incidence of buckeye rot than check cultivar (13.15%). These findings are in agreement with Buckseth *et al.* (2012) and Kumar (2014) for buckeye rot incidence in different tomato genotypes.

5.1.1.15 Fruit borer incidence (%)

Tomato fruit borer has been found to cause a yield loss of up to 35% in tomato. Insecticides cause ill effects like development of insecticide resistance in the pests, pest resurgence, environmental pollution and health hazards. Therefore, there is a need for borer resistant tomato varieties to minimize the use of insecticides. In the present investigations, significant variations among all the genotypes were observed for fruit borer incidence (9.38–30.75 %) Minimum fruit borer incidence was recorded in the genotype LC-1 (9.38%) followed by LC-8 (11.07%) and Solan Lalima (11.20%). Amongst all the genotypes under study, two genotypes LC-1 (9.38%) and LC-8 (11.07%) were less affected from fruit borer as compared to check cultivar Solan Lalima (11.20%). These results of present investigation are in line with Iqbal *et al.* (2013) for incidence of fruit borer in tomato.

5.1.2. Parameters of variation

5.1.2.1 Coefficients of variation

The estimates of phenotypic and genotypic coefficients of variation gave a clear picture of amount of variations present in the available germplasm. For all the characters studied, phenotypic coefficients of variation were higher in magnitude than genotypic coefficients of variation, though difference was very less in majority the cases. Thus, showing that these traits are less influenced by environmental factors. Coefficients of variation varied in magnitude from character to character (either low or moderate or high). Therefore, it indicated that there was a great diversity in the experimental material used.

The phenotypic coefficients of variation (PCV) were found high for buckeye rot incidence, fruit borer incidence and marketable fruit yield per plot, per hectare and per plant. Earlier workers like Singh *et al.*, (2002a), Singh *et al*., (2002b), Ahmed *et al*. (2006), Suarma *et al*. (2009), Sharma *et al.* (2010), Vyas *et al.* (2011), Iqbal *et al.* (2013), Reddy *et al*. (2013) had also reported high phenotypic coefficients of variation for these traits.

Moderate phenotypic coefficients of variation were recorded for lycopene content, pericarp thickness, average fruit weight, shelf life, number of fruits per cluster, number of fruits per plant, fruit length, number of fruit clusters per plant, fruit breadth, harvest duration. Similar results were also reported by Singh *et al*., (2002b) and Rahaman *et al.* (2012). In the mean while, phenotypic coefficients of variation were recorded low in magnitude for days to first fruit harvesting and total soluble solids. Patel *et al*. (2013) had also reported similar results for phenotypic coefficients of variation in tomato.

The genotypic coefficients of variation (GCV) were recorded high for buckeye rot incidence, whereas moderate genotypic coefficients of variation were observed for marketable fruit yield per plot, marketable fruit yield per hectare, marketable fruit yield per plant, fruit borer incidence, lycopene content, pericarp thickness, average fruit weight, shelf life, number of fruits per cluster, number of fruits per plant, fruit length, number of fruit clusters per plant, fruit breadth and harvest duration, while phenotypic coefficients of variation were recorded low in magnitude for days to first fruit harvesting and total soluble solids. Earlier workers like Rahaman *et al.* (2012) and Patel *et al*. (2013) had also reported similar genotypic coefficients of variation trends for different traits under study.

5.1.2.2 Heritability

The genotypic coefficient of variation does not offer full scope to estimate the variations that are heritable and therefore, estimation of heritability becomes necessary. Burton and De-Vane (1953) has suggested that genetic coefficient of variation along with heritability estimates would give a reliable indication of expected amount of improvement through selection.

The estimates of heritability (broad sense) varied from 63.90-96.20% for different characters under study. It was found high for the characters *viz.*, harvest duration, fruit length, lycopene content, pericarp thickness, average fruit weight, days to first fruit harvesting, fruit breadth, marketable fruit yield per plant, marketable fruit yield per plot, marketable fruit yield per hectare, number of fruits per plant, shelf life, number of fruits per cluster, number of fruit clusters per plant and buckeye rot incidence. High heritability for above studied traits was also reported earlier by Mariame *et al.* (2003), Singh and Cheema (2005), Ahmed *et al*. (2006), Saeed *et al.* (2007), Asati *et al*. (2008), Ghosh *et al.* (2010), Rani and Anitha (2011), Vyas *et al.* (2011), Buckseth *et al.* (2012), Mohamed *et al*. (2012), Iqbal *et al.* (2013) and Reddy *et al*. (2013). Moderate heritability was observed for

fruit borer incidence and total soluble solids. Similar results had also been reported earlier by Singh *et al.* (2002a) and Singh *et al.* (2002b).

5.1.2.3 Genetic advance and genetic gain

Genetic gain (expressed as per cent of population mean) was low to high in nature and ranged from 11.54-56.35% for different characters under study. It was found high for the characters *viz.*, marketable fruit yield per plant, buckeye rot incidence, marketable fruit yield per plot, marketable fruit yield per hectare, fruit borer incidence and lycopene content. Ahmed *et al*. (2006), Asati *et al*. (2008), Ara *et al.* (2009), Suarma *et al*. (2009), Ghosh *et al.* (2010), Vyas *et al.* (2011), Aysh *et al.* (2012), Buckseth *et al.* (2012), Kumar *et al*. (2013a), Patel *et al*. (2013), Reddy *et al*. (2013) had also reported high genetic gain for above traits under study. Moderate genetic gain was observed for pericarp thickness, average fruit weight, shelf life, number of fruits per plant, number of fruits per cluster, fruit length, harvest duration, fruit breadth and number of fruit clusters per plant. These results of present findings are in agreement with Mariame *et al.* (2003). Genetic gain was recorded low for days to first fruit harvesting and total soluble solids.

High heritability estimates coupled with high genetic gain were observed marketable fruit yield, lycopene content, buckeye rot incidence and fruit borer incidence, which indicated that these characters are under additive gene effects and these characters are more reliable for effective selection (Panse, 1957). Similar results were also reported by Ahmed *et al*. (2006), Asati *et al*. (2008), Ara *et al.* (2009), Suarma *et al*. (2009), Ghosh *et al.* (2010), Vyas *et al.* (2011), Aysh *et al.* (2012), Buckseth *et al.* (2012), Kumar *et al*. (2013a), Patel *et al*. (2013) and Reddy *et al*. (2013) for these traits under study. High heritability coupled with moderate genetic gain observed for shelf life, pericarp thickness, fruit length, fruit breadth, average fruit weight, number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant and harvest duration, indicated that these characters are under non-additive gene effects and selection for these characters will be less effective. Such traits are more under the influence of environment and do not respond to selection. Similar results for different traits under study were also reported by Joshi *et al.* (2004) and Mahesha *et al.* (2006).

5.2 Correlation studies

Knowledge of degree of association of yield with its components is of great importance, because yield is not an independent character, but it is the resultant of the

interactions of a number of component characters among themselves as well as with the environment in which the plant grow. Further each character is likely to be modified by action of genes present in the genotypes of plant and also by the environment and it becomes difficult to evaluate this complex character directly. Therefore, correlation study of yield with its component traits has been executed, to find out the yield contributing traits.

The correlation coefficients among the different characters were worked out at phenotypic and genotypic levels. In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. The phenotypic and genotypic correlation coefficients among different characters showed that marketable yield per plant had positive and significant association with fruit length, fruit breadth, average fruit weight, number of fruit clusters per plant, number of fruits per cluster, number of fruits per, harvest duration, shelf life, pericarp thickness, lycopene content and total soluble solids, while significant and negative correlations were observed with days to first fruit harvesting, buckeye rot incidence and fruit borer incidence. Beside this, average fruit weight resulted in positive and significant association with fruit length and fruit breadth and it revealed significantly negative correlation with buckeye rot incidence, respectively. Significantly positive correlation of number of fruits per plant was found with number of fruit clusters per plant, number of fruits per cluster and harvest duration, while significant negative association of this trait was found with days to first fruit harvesting, buckeye rot incidence and fruit borer incidence, respectively. Shelf life showed significantly positive correlation with pericarp thickness and total soluble solids, while pericarp thickness revealed significantly positive phenotypic and genotypic correlation with lycopene content. Similar correlation of yield with various horticultural and quality traits have also been reported earlier by several workers viz., Kumar *et al.* (2003), Joshi *et al*. (2004), Kant and Mani (2004), Makesh *et al.* (2006), Ramana *et al.* (2007), Rani *et al*. (2008), Islam *et al.* (2010), Kumar (2010), Dar *et al.* (2011), Buckseth *et al.* (2012), Khan and Samadia (2012), Manna and Paul (2012), Sharma and Singh (2012), Ahirwar *et al.* (2013), Kumar *et al*. (2013a), Kumari and Sharma (2013), Mahapatra *et al.* (2013), Reddy *et al.* (2013), Shushay *et al.* (2013), Khapte and Jansirani (2014), Shushay *et al.* (2014), Meena and Bahadur (2015) and Prajapati *et al.* (2015).

5.3. Path coefficient analysis

Although correlation studies are helpful in determining the components of yield but it does not provide a clear picture of nature and extent of contributions made by number of independent traits. Path coefficient analysis devised by Dewey and Lu (1959), however, provides a realistic basis for allocation of appropriate weightage to various attributes while designing a pragatic programme for the improvement of yield. Path coefficient analysis depicts the effects of different independent characters individually and in combination with other characters on the expression of different characters on marketable fruit yield per plant.

The path coefficient analysis at genotypic level revealed that number of fruits per cluster has maximum positive direct effect on marketable fruit yield per plant followed by number of fruits per plant, average fruit weight, harvest duration, shelf life, fruit breadth, number of fruit clusters per plant, fruit length and pericarp thickness. While, negative direct effect of buckeye rot incidence, days to first fruit harvesting, lycopene content, fruit borer incidence and total soluble solids was observed on marketable fruit yield per plant.

Maximum positive indirect effects of harvest duration via number of fruits per plant, number of fruits per plant via days to first fruit harvesting, number of fruits per cluster via number of fruits per plant, number of fruits per plant via harvest duration, pericarp thickness via buckeye rot incidence and total soluble solids via days to first fruit harvesting was observed on marketable fruit yield per plant. In the mean while, maximum negative indirect effects of shelf life via number of fruits per plant, fruit borer incidence via buckeye rot incidence, number of fruits per cluster via buckeye rot incidence, total soluble solids via number of fruits per plant, number of fruits per plant via fruit borer incidence and pericarp thickness via number of fruits per plant was recorded on marketable fruit yield per plant. At genotypic level residual effect was found to be 0.01863. Verma and Sarnaik (2000), Harer *et al*. (2002), Kumar *et al.* (2003), Joshi *et al*. (2004), Joshi and Kohli (2005), Makesh *et al*. (2006), Ramana *et al*. (2007), Prashant *et al*. (2008), Ara *et al.* (2009), Islam *et al.* (2010), Kumar (2010), Rani *et al.* (2010), Buckseth *et al.* (2012), Manna and Paul (2012), Kumar *et al*. (2013a), Mahapatra *et al.* (2013), Reddy *et al.* (2013), sharma *et al*. (2013), Khapte and Jansirani (2014), Shushay *et al.* (2014), Meena and Bahadur (2015) and Prajapati *et al.* (2015) had reported similar direct and indirect effects of various horticultural and quality traits on yield in tomato.

5.4 Genetic divergence studies

The analysis of variance revealed highly significant differences among the genotypes for all the characters studied, indicating the existence of wide genetic divergence among them. On the basis of performance of various traits, all the genotypes were grouped into different clusters. Information on genetic diversity was also used to identify the promising diverse genotypes, which may be used in further breeding programmes. Genotypes from same centre of origin were placed in separate clusters, indicating wide genetic diversity among them. This may be due to frequent exchange of germplasm between different geographical regions. In the present studies, the genetic divergence observed among thirty diverse genotypes of tomato showed low quantum of divergence. On the basis of performance of various traits, All the genotypes were grouped into 4 clusters. Maximum numbers of genotypes were accommodated in the cluster-IV followed by cluster-III, cluster-II and I. The resultant four clusters showed genetic diversity. The intra cluster distance was found maximum in cluster III and minimum in cluster I. Theoretically, crossing of genotypes belonging to same cluster will not expect to yield superior hybrids or segregants. Whereas, highest inter cluster distance was recorded between cluster I and III. Such diverse genotypes characterized by maximum inter cluster distance will differ in phenotypic performance and therefore, chances to obtain favourable transgressive seggregants are more on the basis of results obtained.

The existence of diversity among the genotypes was also assessed by the considerable amount of variation in cluster means for different characters. Cluster-III exhibited most desirable means for days to first fruit harvesting,` fruit length, average fruit weight, number of fruit clusters per plant, number of fruits per plant, harvest duration, shelf life, pericarp thickness, total soluble solids, buckeye rot incidence, fruit borer incidence, marketable fruit yield per plant, whereas cluster-IV exhibited higher means for lycopene content and fruit breadth, while cluster-II was found superior for number of fruits per cluster. Crossing between the genotypes of two clusters appeared to be most promising to combine the desirable characters. In the present investigations, cluster I and III were found more divergent and there will be more chances of getting better segregants in F_2 and subsequent generations from the crossing genotypes from cluster I and III. Earlier workers like Mohanty and Prusti (2001), Mehta *et al*. (2007), Prasanth *et al.* (2008), Ara *et al.* (2009), Shashikant *et al*. (2010), Pathak and Kumar (2011), Sharma *et al*. (2011), Mulge *et al.* (2012), Narolia and Reddy (2012), Kumar *et al*. (2013), Reddy *et al*. (2013), Iqbal *et al.* (2014), Nalla *et al.* (2014), Srivastava *et al.* (2014) and Thapa *et al.* (2014) have also indicated the significance of genetic divergence in tomato.

Chapter-6
Summary and conclusion

Chapter-6
Summary and Conclusion

The present investigations entitled "Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)" were carried out in diverse group of thirty genotypes of tomato, including indigenous and exotic collections along with one check cultivar (Solan Lalima), to ascertain nature and magnitude of variability, correlation, path coefficient analysis and genetic divergence. The experiment was laid out in Randomized Complete Block Design with three replications of each genotype at vegetable research block of VCSG Uttarakhand University of Horticulture and Forestry, Bharsar. Pauri Garhwal (U.K.) during *Kharif* 2014. The observations were recorded days to first fruit harvesting (Days), fruit length (cm), fruit breadth (cm), average fruit weight (g), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration (days), marketable fruit yield per plant (kg), per plot (kg) and per hectare (q), shelf life (days), pericarp thickness (mm), lycopene content (mg/100 g), total soluble solids (^{o}Brix), buckeye rot incidence (%) and fruit borer incidence (%). The results obtained from present investigations have been summarized as below:

6.1 Variability Studies

6.1.1 Mean performance

The analysis of variance showed highly significant variations among the genotypes for all the horticultural traits under study, which revealed the existence of good deal of variability in the germplasm.

- Among all the genotypes, Punjab Chhuhara was found earliest in maturity (64.00 days) followed by LC-9 (65.00 days) and LC-8 (65.33 days). Besides this, nine genotypes matured earlier than check cultivar Solan Lalima (69.00 days).
- Highest fruit length (cm) was recorded in Roma (6.22 cm) followed by LC-8 (6.08 cm). Two genotypes *viz.* AVTO0201 (5.32 cm), LC-9 (5.35 cm) had greater fruit lengths than check cultivar Solan Lalima (5.25 cm).
- Significantly maximum fruit breadth (cm) was observed in Sioux (6.35 cm) and sixteen other genotypes were found superior than check cultivar (5.02 cm).

- Maximum average fruit weight (g) was recorded in Sioux (75.90 g) followed by LC-8 (71.41 g) and AVTO0201 (69.11 g). Eight genotypes recorded higher average fruit weight than checks cultivar Solan Lalima (63.17 g).
- Number of fruit cluster per plant were recorded maximum in AVTO9001 (7.50) followed by AVTO1315 (7.33) and AVTO1314 (7.07). Besides this, twenty three genotypes were found superior over check cultivar (5.20).
- Highest numbers of fruits per cluster were observed in Arka Meghali and LC-4 (5.61) followed by AVTO9803 (5.58) and LC-9 (5.14). In overall, four genotypes *viz.*, LC-9 (5.14), AVTO9803 (5.58), LC-4 (5.61) and Arka Meghali (5.61) were found to have more number of fruits per cluster than Solan Lalima (5.07).
- Significantly higher numbers of fruits per plant were recorded in the genotype AVTO9803 (34.61). Amongst all the genotypes under study, seven genotypes were found superior than check cultivar Solan Lalima (26.35).
- Harvest duration (days) was recorded significantly maximum in AVTO9803 (49.33 days). Moreover, six genotypes were found to have longer harvest duration than check cultivar Solan Lalima (40.00 days).
- Maximum marketable fruit yield per plant (kg), per plot (kg) and per hectare (q) was recorded in the genotype LC-8 (1.98 kg, 23.74 kg and 586.11 q, respectively) followed by AVTO9001 (1.94 kg, 23.23 kg and 573.47 q respectively), LC-9 (1.91 kg, 22.96 kg and 566.86 q, respectively) and Punjab Chhuhara (1.77 kg, 21.62 kg and 525.63 q respectively). In overall, five genotypes *viz.* AVTO0201 (1.72 kg, 20.62 kg and 509.13 q, respectively), Punjab Chhuhara (1.77 kg, 21.29 kg and 525.63 q, respectively), LC-9 (1.91 kg, 22.96 kg and 566.86 q, respectively), AVTO9001 (1.94 kg, 23.23 kg and 573.47 q, respectively) and LC-8 (1.98 kg, 23.74 kg and 586.11 q, respectively) recorded higher marketable fruit yield than check cultivar Solan Lalima (1.67 kg, 19.99 kg and 493.53 q, respectively).
- Shelf life (days) was recorded significantly maximum in the genotype AVTO9803 (31.00 days). Besides this, seven genotypes had more shelf life than check cultivar (20.67 days).
- Maximum pericarp thickness (mm) was observed in AVTO9803 (7.05 mm) followed by AVTO0201 (6.76 mm), AVTO9001 (6.57 mm) and Punjab Chhuhara (6.47 mm). Six genotypes were found superior over check cultivar Solan Lalima (6.26 mm).

- Lycopene content (mg/100 g) was observed maximum in Sioux (9.02 mg/100 g) followed by Arka Alok (8.87 mg/100 g), LC-8 (8.63 mg/100 g), Solan Lalima (8.55 mg/100 g), LC-9 (8.54 mg/100 g) and Arka Abha (8.27 mg/100 g). Three genotypes *viz.*, LC-8 (8.63 mg/100 g), Arka Alok (8.87 mg/100 g) and Sioux (9.02 mg/100 g) had higher lycopene content than the check cultivar (8.55 mg/100 g).
- Significantly higher total soluble solids (^{o}B) were observed in LC-8 (5.60 ^{o}B). Four genotypes *viz.*, Arka Abha (4.87 ^{o}B), AVTO0201 (4.90 ^{o}B), AVTO9803 (5.00 ^{o}B) and LC-8 (5.60 ^{o}B) were found superior over check cultivar Solan Lalima (4.83 ^{o}B).
- Minimum buckeye rot incidence (%) was recorded in the genotype LC-9 (9.73%) followed by LC-1 (10.36%), LC-4 (11.06%), Arka Vikas (13.11%), Solan Lalima (13.15%), Punjab Chhuhara (13.49%) and LC-8 (13.67%). In overall, four genotypes *viz.*, LC-9 (9.73%), LC-1 (10.36%), LC-4 (11.06%) and Arka Vikas (13.11%) recorded less incidence of buckeye rot than check cultivar (13.15%).
- Fruit borer incidence (%) was recorded minimum in the genotype LC-1 (9.38%) followed by LC-8 (11.07%) and Solan Lalima (11.20%). Amongst all the genotypes under study, two genotypes LC-1 (9.38%) and LC-8 (11.07%) were less affected from fruit borer as compared to check cultivar Solan Lalima (11.20%).

6.1.2 Coefficients of variation

For all the characters studied, phenotypic coefficients of variation were higher in magnitude than genotypic coefficients of variation, though difference was very less in majority of cases. The phenotypic coefficients of variation (PCV) were found high for buckeye rot incidence, fruit borer incidence, marketable fruit yield per plot, marketable fruit yield per hectare and marketable fruit yield per plant, while genotypic coefficients of variation (GCV) were recorded high for buckeye rot incidence. The estimates of heritability (broad sense) were found high for all the characters under study except fruit borer incidence and total soluble solids, thereby suggesting that straight selection for these traits may bring worthwhile improvement in identifying superior genotypes in tomato. Besides this, high heritability estimates coupled with high genetic gain were observed marketable fruit yield, lycopene content, buckeye rot incidence and fruit borer incidence, which indicated that these characters are under additive gene effects and these characters are more reliable for effective selection.

4.2 Correlation studies

The phenotypic and genotypic correlation coefficients among different characters showed that marketable yield per plant had positive and significant association with fruit length, fruit breadth, average fruit weight, number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration, shelf life, pericarp thickness, lycopene content and total soluble solids. Beside this, average fruit weight resulted in positive and significant association with fruit length and fruit breadth. Moreover, significantly positive correlation of number of fruits per plant was found with number of fruit clusters per plant, number of fruits per cluster and harvest duration. Hence, there is ample scope for yield improvement in tomato through selection for these traits.

4.3. Path coefficient analysis

The path coefficient analysis revealed that maximum positive direct effect towards fruit yield per plant was contributed by number of fruits per cluster followed by number of fruits per plant, average fruit weight, harvest duration, shelf life, fruit breadth, number of fruit clusters per plant, fruit length and pericarp thickness, indicating direct selection for these trait as a criteria for improvement in tomato. In the mean while, maximum positive indirect effects of harvest duration via number of fruits per plant, number of fruits per plant via days to first fruit harvesting, number of fruits per cluster via number of fruits per plant, number of fruits per plant via harvest duration was observed on marketable fruit yield per plant, thereby indicating the importance of yield contributing traits for yield improvement in tomato through indirect selection.

4.4 Genetic divergence studies

For those traits, where selection is not responsive and non-additive gene effects are playing major role in the expressions, hybridization between diverse parents on the basis of their mean performance to get superior hybrids or transgressive segregants or partitioning of additive genetic variation and non-additive genetic variation in segregating generations will be useful. Studies on genetic divergence will be helpful in identification of better parents. Here in this case, genetic divergence studies grouped thirty genotypes into four clusters. The hybridization between genotypes of cluster I and cluster III can be utilized for getting superior recombinants or transgressive segregants in segregating population because these clusters were found most divergent.

LC-8

LC-9

Punjab Chhuhara

AVTO9001

AVTO0201

Plate 2 : Best genotypes identified on the basis of overall performance

Conclusion

- From the present investigation, it can be concluded that five genotypes *viz.*, LC-8, AVTO9001, LC-9, Punjab Chhuhara and AVTO0201 recorded higher fruit yield and also performed better for other horticultural traits than check cultivar Solan Lalima. These genotypes need further testing to be released as a substitute of already existing tomato varieties or they can be involved in further breeding programme for development of superior varieties or hybrids for yield and quality improvement in tomato.
- High heritability estimates coupled with high genetic gain were observed for marketable fruit yield, lycopene content, buckeye rot incidence and fruit borer incidence. Hence selection can prove effective for improvement in yield. Besides this, high heritability coupled with moderate genetic gain was observed for pericarp thickness, average fruit weight, shelf life, number of fruits per plant, number of fruits per cluster, fruit length and breadth, harvest duration and number of fruit clusters per plant. Therefore, these characters also show some scope for improvement through selection.
- The correlation studies revealed that marketable yield per plant had positive and significant association with fruit length, fruit breadth, average fruit weight, number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration, shelf life, pericarp thickness, lycopene content and total soluble solids. Hence, there traits should be taken into consideration, while making the selection for yield improvement in tomato.
- The path coefficient analysis revealed that maximum positive direct effect towards fruit yield per plant was contributed by number of fruits per cluster followed by number of fruits per plant, average fruit weight and harvest duration, while maximum positive indirect effects of harvest duration via number of fruits per plant was observed on marketable fruit yield per plant, thereby indicating the importance of these traits for yield improvement in tomato through direct or indirect selection.
- For the traits, where selection is not effective, genetic divergence can play an important role on further partitioning of variability. In the present investigation, the cluster I and cluster III were found more divergent and there will be more chances of getting better segregants in F_2 generations from the crossing of genotypes from cluster I and cluster III. Therefore, hybridization between the genotypes of these groups can be very effective for further improvement in tomato.

Chapter-7

Literature cited

Chapter-7

Literature Cited

Agarwal A, Arya D N and Ahmed Z. 2014. Genetic variability studies in tomato (*Solanum lycopersicum* L.). *Progressive Horticulture* **46**(2):358-361.

Ahirwar S, Bahadur V and Prakash V. 2013. Genetic variability, heritability and correlation studies in tomato genotypes (*Lycopersicon esculentum* Mill.). *International Journal of Agricultural Sciences* **9**(1):172-176.

Ahmed N, Khan M I and Gupta A J. 2006. Variability and heritability in tomato (*Lycopersicon esculentum* Mill.). *Environment and Ecology* **24**(2): 386-388.

Al-Jibouri H A, Miller P A and Robinson H F. 1958. Genotypic and environmental variances and co-variances in an upland cotton cross of interspecific origin. *Agronomy Journal* **50**: 633-636.

Allard R W. 1960. *Principles of Plant Breeding*. John Wiley and Sons, Inc. New York, 485p.

Anonymous. 2013 .www.nhb.gov.in.

Ara A, Raj N, Ahmed N and Khan S H. 2009. Genetic variability and selection parameters for yield and quality attributes in tomato. *Indian Journal of Horticulture* **66**(1): 73-78.

Asati B S, Rai N and Singh A K. 2008. Genetic parameters study for yield and quality traits in tomato. *Asian Journal of Horticulture* **3**(2): 222-225.

Aysh Al F, Serhan Al M, Shareef Al A, Nasser Al and Kutma M H. 2012. Study of genetic parameters and character interrelationship of yield and some yield components in tomato (*Solanum lycopersicum* L.). *International Journal of Genetics* **2**(2): 29-33.

Bernousi I, Emami A, Tajbakhsh M, Darvishzadeh R and Henareh M. 2011. Studies on genetic variability and correlation among the different traits in *Solanum lycopersicum* L. *Notulae Botanicae Horti AgrobotaniciCluj-Napoca* ***39****(1):152-158.*

Buckseth T, Sharma M K and Thakur K S. 2012. Genetic diversity and path analysis in tomato (*Solanum lycopersicum* L.). *Vegetable Science* **39** (2): 221-223.

Burton G W and De Vane E H. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal* **45**: 478-481.

Clinton S K. 2005. Tomatoes or lycopene: a role in prostate carcinogenesis. *Journal of Nutrition* **135**(8): 2057-2059.

Dar R N A, Sharma J P, Gupta R K and Chopra S. 2011. Studies on correlation and path analysis for yield and physico chemical traits in tomato (*Lycopersicon esculentum* Mill.). *Vegetos* **24**(2): 136-141.

Dewey J R and Lu K H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal* **51**:515-518.

Dhankar S K, Dhankar B S and Sharma N K. 2001. Correlation and path analysis in tomato under normal and high temperature conditions. *Haryana Journal of Horticultural Sciences* **30**(1/2): 89-92.

Dodan D S. 1995. Variability in some *Phytophthora nicotianae* var. *parasitica* (Dastur) Water house and management of buckeye rot of tomato in Himachal Pradesh. Ph D. Thesis. Department of Mycology and PlantPathology, Dr. Y. S. Parmar, UHF, Nauni, Solan.

Dorgan J F, Sowell A, Swanson C A, Potischman N, Miller R, Schussler N, and Stephenson Jr. H E. 1998. Relationships of serum carotenoids, retinol, alpha tocopherol, and selenium with breast cancer risk: results from a prospective study in Columbia, Missouri (United States). *Cancer Causes Control* **9**(1): 89-97.

Fisher R A and Yates F. 1963. *Statistical Tables for Biological, Agricultural and Medical Research.* 6th ed. Oliver and Boyd Ltd, London. 146p.

Fisher R A. 1918. Correlations between relatives on the supposition of Mendelian inheritance. *Transactions* of the *Royal Society* of *Edinburgh* **52**: 399-433.

Galton F. 1889. Natural Inheritance. Mac Millan and Co. London.

Ghosh K P, Islam A K M A, Milan M A K and Hossian M M. 2010. Variability and character association in F2 segregating population of different commercial hybrids of tomato (*Solanum lycopersicum* L.). *Journal of Applied Science Management* **41**(2): 91-95.

Gomez K A and Gomez A A. 1983. *Statistical Procedures for Agricultural Research*. John Wiley and Sons Inc., New York. pp. 357-427.

Goulden C H. 1959. *Method of Statistical Analysis*. John Wiley and Sons, New York. 134p.

Harer P N, Lad D B and Bhor T J. 2002. Correlation and path analysis studies in tomato. *Journal of Maharashtra Agricultural Universities* **27**(3): 302-303.

Harrington J B. 1940. Yielding capacity of wheat crosses as indicated by balk hybrid tests. *Candian Journal of Research* **18**: 5-584.

Haydar A, Mandal M, Ahmed M B, Hannan M M, Karim R, Razvy M A, Roy U K and Salahin M. 2007. Studies on genetic variability and interrelationship amongthe different traits in tomato (*lycopersicon esculentum* mill.). *Middle-East Journal of Scientific Research* **2** (3-4): 139-142.

Hazra P, Pandit M K, Dutta A and Akhter S. 2010. Variability and heritability estimate of quality parameters in tomato (*Lycopersicon esculentu* Mill.). *Environment and Ecology* **28**(4A): 2594-2596.

Hidayatullah, Jatoi S A and Mahmood A. 2008. Path coefficient analysis of yield component in tomato (*Lycopersicon esculentum*). *Pakistan Journal of Botany* **40**(2): 627-635.

Indian Horticulture database. 2013-14. National Horticulture Board Gurgaon. pp. 177-185.

Iqbal M, Ahmad W, Shafi J, Ayub C M, Atiq M, Shahid M and Saleem M. 2013. Comparative genetic variability and heritability in some tomato varieties against fruit borer, shape disorders and their correlation. *Bioengineering and Bioscience* **1**(2): 17-23.

Iqbal Q, Saleem M Y, Hameed A and Asghar M. 2014. Assessment of genetic divergence in tomato through agglomerative hierarchical clustering and principal component analysis. *Pakistan Journal of Botany* **46**(5): 1865-1870.

Islam B M R, Ivy N A, Rasul M G and Zakaria M. 2010. Character association and path analysis of exotic tomato (*Solanum lycopersicum* L.) genotypes. *Bangladesh Journal of Plant Breeding and Genetics* **23**(1):13-18.

Islam M S, Mohanta H C, Ismail M R, Rafii M Y and Malek M A. 2012. Genetic variability and trait relationship in cherry tomato (*Solanum lycopersicum* L. *var. Cerasiforme*). *Bangladesh Journal of Botany* **41**(2): 163-167.

Johanson H W, Robinson H F and Comstock R E. 1955. Estimates of genetic and environmental variability in soyabean. *Agronomy Journal* **47**: 314-318.

Joshi A and Kohli U K. 2005. Evaluation, path coefficient and correlation studies for fruit shelf life in tomato (*Lycopersicon esculentum* Mill.) .*Horticultural Journal* **18**(2): 110-113.

Joshi A, Vikram A and Thakur M C. 2004. Studies on genetic variability, correlation and path analysis for yield and physico-chemical traits in tomato (*Lycopersicon esculentum* Mill.). *Progressive Horticulture* **36**(1): 51-58.

Kant L and Mani V P. 2004. Association and contribution of different characters towards fruit yield in tomato (*Lycopersicon esculentum* Mill.) in north western Hill Zone. *Indian Journal of Horticulture* **61**(4): 327-330.

Kaushik S K, Tomar D S and Dixit A K. 2011. Genetics of fruit yield and it's contributing characters in tomato (*Solanum lycopersicum*). *Journal of Agricultural Biotechnology and Sustainable Development* **3**(10): 209-213.

Khan H and Samadia D K. 2012. Variability and association studies in tomato germplasm under high-temperature arid region. *Journal of Horticultural Sciences* **7**(2): 194-198.

Khapte P S and Jansirani P. 2014. Correlation and path coefficient analysis in tomato (*Solanum lycopersicum* L.). *Electronic Journal of Plant Breeding* **5**(2): 300-304.

Kumar D, Kumar R, Kumar S, Bhardwaj M L, Thakur M C, Kumar R, Thakur K S, Dogra B S, Vikram A, Thakur A and Kumar P. 2013. Genetic variability, correlation and path coefficient analysis in tomato. *International Journal of Vegetable Science* **19**(4): 313-323.

Kumar R, Ram C N, Yadav G C, Deo C, Vimal S C and Bhartiya H D. 2014. Appraisal studies on variability, heritability and genetic advance in tomato (*Solanum lycopersicon* l.). *Plant Archives* **14**(1):367-371.

Kumar S, Rattan P and Sharma J. 2013. Genetic variation and character interrelationship studies for identification of selection parameters in tomato (*Solanum lycopersicum*). *Indian Journal of Agricultural Sciences* **83** (11): 1149–52.

Kumar S. 2010. Genetic variability and interrelationship of traits in F3 progenies of tomato (*Lycopersicon esculentum* Mill.) under cold desert of Leh-Ladakh. *Crop Improvement* **37**(1): 66-72.

Kumar V R A, Thakur M C and Hedau N K. 2003. Correlation and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Annals of Agricultural Research* **24**(1): 175-177.

Kumari N, Srivastava J P, Shekhavat A K S, Yadav J R and Singh B. 2007.Genetic variability and heritability of various traits in tomato (*Lycopersicon esculentum* Mill.). *Progressive Agriculture* **7**(1/2): 80-83.

Kumari S and Sharma M K. 2013. Genetic variability studies in tomato (*Solanum lycopersicum* L.). *Vegetable Science* **40**(1): 83-86.

Madhurina M and Paul A. 2012. Studies on genetic variability and characters association of fruit quality parameters in tomato. *HortFlora Research Spectrum* **1**(2): 110-116.

Mahalanobis P C. 1936. On the generalized distance in statistics. *Proceedings of National Academic Science (India)* **2**: 79-85.

Mahapatra A S, Singh A K, Vani V M, Mishra R, Kumar H and Rajkumar B V. 2013. Inter-relationship for various components and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Current Microbiology and Applied Sciences* **2**(9): 147-152.

Mahesha D K, Apte U B and Jadhav B B. 2006. Genetic variability in tomato (*Lycopersicon esculentum* Mill.). *Research on Crops* **7**(3): 771-773.

Makesh S, Ramaswamy N and Puddan M. 2006. Character association and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Research on Crops* **7**(2): 496-499.

Manna M and Paul A. 2012. Studies on genetic variability and characters association of fruit quality parameters in tomato. *HortFlora Research Spectrum* **1**(2): 110-116.

Mariame F, Ravishankar H and Dessalegene L. 2003. Study on variability in tomato germplasm under conditions of Central Ethiopia. *Vegetable Crops Research Bulletin* **58**: 41-50.

Meena O P and Bahadur V. 2014. Assessment of genetic variability, heritability and genetic advance among tomato (*Solanum lycopersicum* L.) germplasm. *The Bioscan* **9**(4):1619-1623.

Meena O P and Bahadur V. 2015. Genetic associations analysis for fruit yield and its contributing traits of indeterminate tomato (*Solanum lycopersicum*) germplasm under open field condition. *Journal of Agricultural Science* **7**(3): 1916-9752.

Mehta D R, Golani I J, Purohit V L, Naliyadhara M V and Pandya H M. 2007. Genetic diversity in tomato. *Orissa Journal of Horticulture* **35**(2): 70-72.

Mohamed, S M, Ali E E, Mohamed T Y. 2012. Study of heritability and genetic variability among different plant and fruit characters of tomato (*Solanum lycopersicon* L.). *International Journal of Scientific and Technology Research* **1**(2): 2277-8616.

Mohanty B K and Prusti A M. 2001. Analysis of genetic distance in tomato. *Research on Crops* **2**(3): 382-385.

Mulge R, Mahendrakar P and Prashanth S J. 2012. Prediction of heterosis based on genetic divergence in tomato. *Indian Journal of Horticulture* **69**(4): 530- 535.

Murty B R and Arunachalam V. 1966. Computer programmes for some problems in biometerical genetics of Mahalanobis D2 in classificatory problems. *Indian Journal of Genetics* **27**: 60-69.

Nalla M K,Rana M K, Singh S J, Sinha A K, Reddy P K, and Mohapatra P P. 2014. Assessment of genetic diversity through D2 analysis in tomato*(Solanum lycopersicon* L.*). International Journal of Innovation and Applied Studies* **6**(3): 431-438.

Narolia R K, Reddy R S V K and Sujatha M. 2012. Genetic architecture of yield and quality in tomato. *Agricultural Science Digest* **32**(4):281-285.

Nwosu D J, Onakoya O A, Okere A U, Babatunde A O and Popoola A F. 2014. Genetic variability and correlations in rainfed tomato (*Solanum* spps.) accessions in Ibadan, Nigeria. *Greener Journal of Agricultural Sciences* **4** (5): 211-219.

Osekita O S and Ademiluyi A T. 2014. Genetic advance, heritability and character association of component of yield in some genotypes of tomato (*Lycopersicon esculentum* Mill.). *Academia Journal of Biotechnology* **2**(1): 6-10.

Panse V G. 1957. Genetics of quantitative characters in relation to plant breeding. *Indian Jouranl of Genetics* **17**:318-328.

Patel S A, Kshirsagar D B, Attar A V and Bhalekar M N. 2013. Study on genetic variability, heritability and genetic advance in tomato. *International Journal of Plant Sciences* **8**(1): 45-47.

Pathak P and Kumar K. 2011. D^2 analysis in some varieties of tomato. *Advances in Plant Sciences* **24**(1): 335-338.

Prabuddha H R, Kulkarni R S and Marappa N. 2008. Genetic evaluation of interspecific mapping population for yield and quality parameters in tomato (*Lycopersicon esculentum* Mill.). *Environment and Ecology* **26**(4A): 1884-1886.

Prajapati S, Tiwari A, Kadwey S, Sharma S K and Raghuwanshi O. 2015. Correlation and path coefficient analysis of fruits yield and it's attributing traits in tomato (*Lycopersicon esculentum* Mill.). *Indian Research Journal Of Genetics and Biotechnology* **7**(1): 138 –147.

Prashant S J, Jaiprakashnarayan R P, Mulge R and Madalageri M B. 2008. Correlation and path analysis in tomato (*Lycopersicon esculentum* Mill.). *Asian Journal of Horticulture* **3**(2): 403-408.

Prashanth S J, Prakashnarayan R P, Mulge R and M B, Madalageri. 2008. Genetic divergence in tomato (*Lycopersicon esculentum* Mill.). *The Asian Journal of Horticulture* **3**(2):290-292.

Rahaman S and Bhatt J S. 2013. Path coefficient analysis of yield component in tomato. *International Journal of Agricultural Sciences* **9**(1): 227-231.

Rahaman S, Lakshman S. S. and Maitra N. J. 2012. Genetic variability and heritability studies in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Plant Sciences* **7**(1): 58-62.

Ramana C V, Shankar V G, Kumar S S and Rao P V. 2007. Trait interrelationship studies in tomato (*Lycopersicon esculentum* Mill.). *Research on Crops* **8**(1): 213-218.

Ranganna S. 1994. *Handbook of Analysis and Quality Control for Fruit and Vegetable products*, 2nd Ed., New Delhi: Tata McGraw Hill, pp.64-65.

Rani C I, Muthuvel I and Veeraragavathatham D. 2010. Correlation and path coefficient for yield components and quality traits in tomato (*Lycopersicon esculentum* Mill.). *Agricultural Science Digest* **30**(1): 11-14.

Rani C I, Veeraragavathatham D and Sanjutha S. 2008. Studies on correlation and path coefficient analysis on yield attributes in root knot nematode resistant F1 hybrids in tomato. *Journal of Applied Sciences* **4**(3): 287-295.

Rani K R and Anitha V. 2011. Studies on variability, heritability and genetic advance in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Bioresource and Stress Management* **2**(4): 382-385.

Rao R. 1952. *Advanced Statistical Methods in Biometrical Research.* John Willey and sons Inc., New York, pp. 357-363.

Reddy B R, Begum H, Sunil N and Reddy T M. 2013. Genetic divergence studies in exotic collections of tomato (*Solanum lycopersicum* L.). *International Journal of Agricultural Sciences* **9**(2): 588-592.

Reddy B R, Reddy D S, Reddaiah K and Sunil N. 2013. Studies on genetic variability, heritability and genetic advance for yield and quality traits in tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences* **2**(9): 238-244.

Rick C M. 1973. Potential genetic resources in tomato species: Clues from observations in native habitats. *In*: AM Srb (Editor). *Genes, Enzymes and Populations*. Plenum, New York. pp. 255-269.

Robinson H F, Comstock, R E and Harvey, P H. 1949. Estimates of heritability and the degree of dominance in corn. *Agronomy Journal* **41**(8): 353–359.

Rocha MC, Rodrigues L S A, Silva R, PRA da Carmo MGF do and Abboud AC de S. 2010. Using gower's algorithm on the genetic divergence determination among cherry tomato accessions. *Acta Scientiarum Agronomy*. **32**(3): 423-431.

Saeed A, Hayat K, Khan A S, Iqbal S and Abbas G.2007. *Short communication* assessment of genetic variability and heritability in tomato (*Lycopersicon esculentum* Mill.). *International Journal Of Agriculture and Biology* **9**(2):375-377.

Sepat N K, Sepat S R, Sepat S and Kumar A. 2013. Energy use efficiency and cost analysis of tomato under greenhouse and open field production system at Nubra valley of Jammu and Kashmir. *International Journal of Environment Science* **3(**4): 1233-1241.

Sharma B and Singh J P. 2012. Correlation and path coefficient analysis for quantitative and qualitative traits for fruit yield and seed yield in tomato genotypes. *Indian Journal of Horticulture* **69**(4): 540-544.

Sharma J P, Singh A K and Tiwari S P. 2010. Selection parameters for productive plant type in tomato (*Lycopersicon esculentum* Mill.). *Journal of Hill Agriculture* **1**(1): 52-55.

Sharma J P, Singh A K, Rattan P, Kumar S and Kumar S. 2011. D^2 clustering of exotic germplasm of tomato (*Solanum lycopersicum* L.) for genetic improvement. *Mysore Journal of Agricultural Sciences*. **45**(1): 48-52.

Sharma J P, Singh A K, Rattan P, Kumar S and Kumar S. 2011. D^2 clustering of exotic germplasm of tomato (*Solanum lycopersicum* L.) for genetic improvement. *Mysore Journal of Agricultural Sciences*. **45**(1): 48-52.

Sharma P, Yashi S, Vidyasagar and Bhardwaj N. 2013. Correlation and path- coefficient studies in tomato (*Solanum lycopersicum* L.) under protected environment. *Environment and Ecology* **31**(2B): 848-855.

Sharma P. 1994. Genetic variability and path coefficient analysis in cabbage (*Brassica oleracea* var. *capitata*) M.sc. Thesis, H P K V, Palampur.

Shashikanth B N, Patil B C, Salimath P M, Hosamani R M and Krishnaraj P U. 2010. Genetic divergence in tomato (*Solanum lycopersicon* L). *Karnataka Journal of Agricultural Sciences* **23**(3): 538-539.

Shashikanth N, Basavaraj and Dhotre M. 2012. Correlation and path co-efficient studies in tomato. *The Asian Journal of Horticulture* **7(**2): 379-384

Shushay C, Belew D and Abay F. 2013. Genetic variability and association of characters in tomato (*Solanum lycopersicon* L.) genotypes in northern Ethiopia. *International Journal of Agricultural Research* **8**(2): 67-76.

Shushay S, Belew D and Fetien A. 2014. Performance evaluation and path analysis studies in tomato (*Solanum lycopersicon L*.) genotypes under Humera, Northern Ethiopia Condition. *World Journal of Agricultural Research* **2**(6):267-271.

Singh A K and Narayan R. 2004. Variability studies in tomato under cold arid condition of Ladakh. *Horticultural Of Journal* **17**(1): 67-72.

Singh H and Cheema D S. 2005. Studies on genetic variability, heritability for quality traits of tomato (*Lycopersicon esculentum* Mill.) under stress conditions. *Journal of Applied Horticulture* **7**(1): 55-57.

Singh J K, Singh J P, Jain S K and Joshi A. 2002. Studies on genetic variability and its importance in tomato (*Lycopersicon esculentum* Mill.) *Progressive Horticulture* **34**(1): 77-79.

Singh K P, Mandal G and Saha B C. 2006. Genetic variability of yield components and bio-chemical characters in spring season tomato (*Lycopersicon esculentum* Mill.). *Journal of Interacademicia* **10**(3): 314-318.

Singh P, Singh S, Chemma D S and Dhaliwal M S. 2002. Genetic variability and correlation study of some heat tolerant tomato genotypes. *Vegetable Science* **29**(1): 68-70.

Srivastava M K, Vishal K. Agrawal and Agrawa R.K. 2014. Estimation of genetic divergence among indigenous and exotic accessions of tomato (*Solanum lycopersicum* L.). *Asian Journal of Bioscience* **9**(1): 30-34.

Suarma J P, Singh A K, Kumar S and Kumar S. 2009. Identification of traits for ideotype selection in tomato (*Lycopersicon esculentum* Mill.). *Journal of Hill Agriculture Sciences* **43(**2**):** 222-226.

Tasisa J, Belew D, Bantte K and Gebreselassie W. 2011. Variability, heritability and genetic advance in tomato (*Lycopersicon esculentum* Mill.) genotypes in West Shoa, Ethiopia. *American Eurasian Journal of Agricultural and Environmental Sciences* **11**(1): 87-94.

Taylor I B. 1986. Biosystematics of the tomato. *In*: JG Atherton and J Rudich, *eds*. *The Tomato Crop: A Scientific Basis for Improvement*. Chapman and Hall. London. pp.1-34.

Thapa R P, Jha A K, Deka B C, Reddy A N, Verma V K and Yadav R K. 2014. Genetic divergence in tomato grown in subtropical mid-hills of Meghalaya. *Indian Journal of Horticulture* **71**(4): 581-583.

Vavilov, N I. (1951). The origin, variation, immunity and breeding of cultivated plants. *Chronica Bot* 13: 1-366.

Verma S K and Sarnaik D A. 2000. Path analysis of yield components in tomato (*Lycopersicon esculentum* Mill). *Journal of Applied Biology* **10**(2): 136-138.

Vyas M, Singh A K, Rai V K. and Mishra R. 2011. Genetic variability, correlation and path coefficient analysis of tomato (*L.esculentum esculentum* Mill.). *Environment and Ecology* **29**(3): 1076-1081.

Wakil, W, Ashfaq M, Ghazanfar M U, Afzal M and Riasat T. 2009. Integrated management of *Helicoverpa armigera* in chickpea in rainfed areas of Punjab, Pakistan. *Phytoparasitica* **37**:415-420.

Wright S. 1921. Correlation and causation. *Journal of Agricultural Resources* **66**(4): 557-585.

Appendices

APPENDIX- I

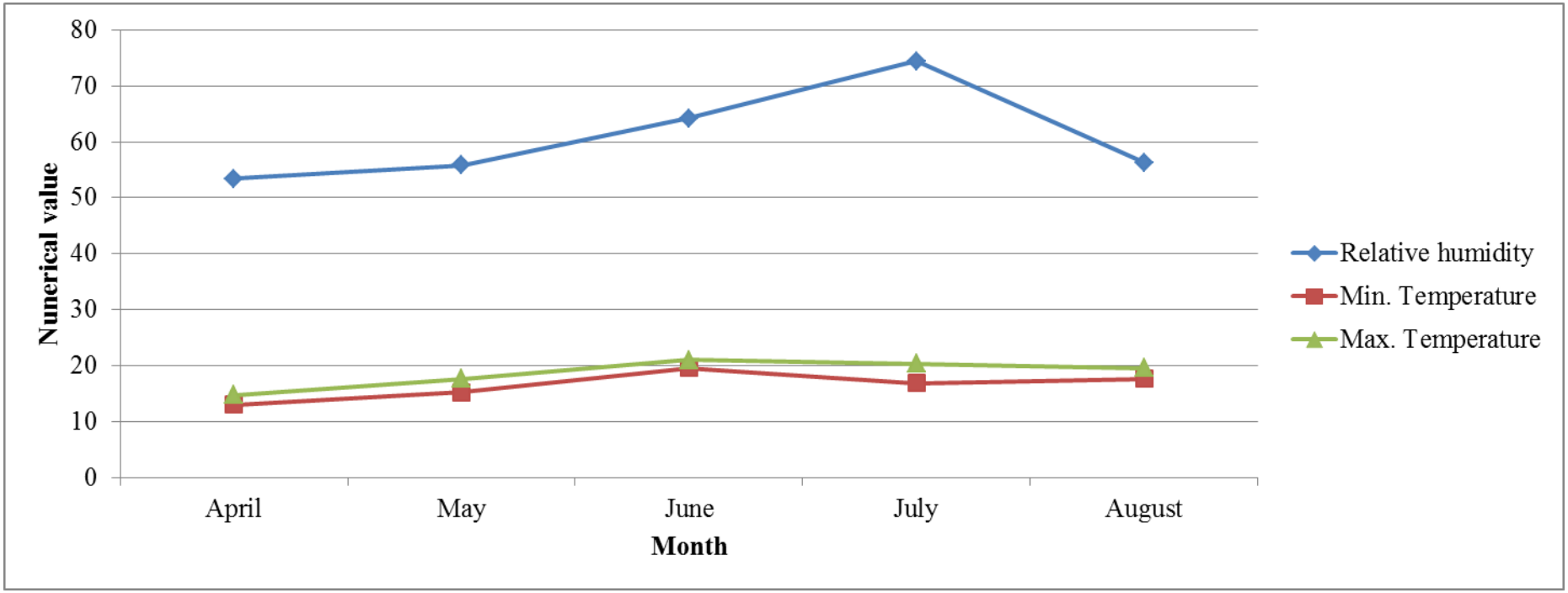

Fig. 1 Graphical representation of relative humidity (%), minimum and maximum average temperature (^{0}C).

APPENDIX- II

Table showing analysis of variance for various horticultural traits in tomato

	d.f	Mean sum of squares																
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Replication	2	2.31	0.037	0.18	43.18	0.09	0.39	7.00	2.43	0.07	10.09	6152.45	1.64	0.21	0.01	0.19	3.29	1.92
Treatment	29	55.86*	1.99*	1.64*	488.05*	2.26*	1.96*	61.19*	92.70*	0.40*	58.75*	35816.15*	41.92*	5.01*	7.74*	0.72*	109.33*	125.24*
Error	58	1.83	0.03	0.04	13.68	0.13	0.10	2.31	1.19	0.01	2.87	1333.50	1.64	0.13	0.20	0.11	8.43	10.85

*Significant at 5% level of significance

Where,

1=Days to first fruit harvesting (Days), 2=Fruit length (cm), 3=Fruit breadth (cm), 4=Average fruit weight (g) 5=Number of fruit clusters per plant, 6=Number of fruits per cluster 7=Number of fruits per plant 8=Harvest duration (days), 9=Marketable fruit yield per plant (kg), 10=Marketable fruit yield per plot (kg), 11=Marketable fruit yield per hectare (q), 12=Shelf life (days), 13=Pericarp thickness (mm), 14=Lycopene content (mg/100g), 15=Total soluble solids (^{o}Brix), 16=Buckeye rot incidence (%) and 17=Fruit borer incidence (%)

Abstract

ABSTRACT

Name: Harish Chandra Badhani Id. No. 13123
Semester of admission and year: I, 2013
Degree: M.Sc. Horticulture (Vegetable Science)
Department: Vegetable Science
Major: Vegetable Science
Thesis Title: **"Studies on genetic divergence in tomato (*Solanum lycopersicum* L.).**
Advisor: Prof. B.P. Nautiyal

The present investigations entitled "Studies on genetic divergence in tomato (*Solanum lycopersicum* L.)" were carried out at the Vegetable Research Block, VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, during *Kharif*, 2014 to evaluate diverse germplasm of tomato. The experiment was laid out in a RCBD with three replications. In this study, thirty genotypes including one check cultivar Solan Lalima were evaluated for different horticultural traits *viz.,* days to first fruit harvesting, fruit length (cm), fruit breadth (cm), average fruit weight (gm), number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration (days), marketable fruit yield per plant (kg), per plot (kg) and per hectare (q), shelf life (days), pericarp thickness (mm), lycopene content (mg/100g), total soluble solids (^{o}Brix), buckeye rot incidence (%) and fruit borer incidence (%). The genotypes, LC-8, AVTO9001, LC-9, Punjab Chhuhara and AVTO0201 recorded higher fruit yield and also performed better for other horticultural traits than check cultivar. These genotypes need further testing to be released as a substitute of already existing tomato varieties or they can be involved in further breeding programme for development of superior varieties or hybrids in tomato. The phenotypic coefficients of variation were found high for buckeye rot incidence, fruit borer incidence, marketable fruit yield per plot, per hectare and per plant, while genotypic coefficients of variation was recorded high for buckeye rot incidence. The estimates of heritability (broad sense) were found high for all the characters under study except fruit borer incidence and total soluble solids. Besides this, high heritability estimates coupled with high genetic gain were observed for marketable fruit yield, lycopene content, buckeye rot incidence and fruit borer incidence, which indicated that these traits are under additive gene effects and are more reliable for effective selection. The phenotypic and genotypic correlation coefficients among different characters showed that marketable yield per plant had positive and significant association with fruit length, fruit breadth, average fruit weight, number of fruit clusters per plant, number of fruits per cluster, number of fruits per plant, harvest duration, shelf life, pericarp thickness, lycopene content and total soluble solids. Hence, there traits should be taken into consideration, while making the selection for yield improvement in tomato. The path coefficient analysis revealed that maximum positive direct effect towards fruit yield per plant was contributed by number of fruits per cluster followed by number of fruits per plant, average fruit weight and harvest duration, while maximum positive indirect effects of harvest duration via number of fruits per plant was observed on marketable fruit yield per plant, thereby indicating the importance of these traits for yield improvement in tomato through direct or indirect selection. Further, on the basis of D^2 analysis these genotypes were grouped into four divergent clusters and hybridization between cluster I and III is expected to give maximum heterotic cross combinations in future breeding programmes.

Prof. B.P. Nautiyal
Name and signature of Advisor

Harish Chandra Badhani
Name and signature of Author

सारांश

नाम	हरीश चन्द्र बधानी	अभिज्ञान संख्या 13123	
प्रवेश का समय और वर्ष	प्रथम षटमास् 2013	उपाधि	औद्यानिकी (सब्जी विज्ञान)
मुख्य	सब्जी विज्ञान	विभाग	सब्जी विज्ञान
शोध का शीर्षक	**"टमाटर (सोलेनम लाइकोप्रसिकम) में आनुवंशिक विविधता का अध्ययन"**		
सलाहकार	प्रो. बी.पी. नौटियाल		

वर्तमान शोध जिसका शीर्षक **"टमाटर (सोलेनम लाइकोप्रसिकम) में आनुवंशिक विविधता का अध्ययन"**, खरीफ 2014 के दौरान वी.च.सि.ग. उत्तराखण्ड़ औद्यानिकी एवं वानिकी विश्वविद्यालय, भरसार के सब्जी अनुसंधान ब्लॉक में किया गया। प्रयोग को एक यादृच्छिक ब्लॉक डिजाइन (आरबीडी) में तीन अनुकरणों में आवंटित किया गया। इस अध्ययन के अन्तर्गत 30 (तीस) जिनोटाइप तथा एक मानक किस्म सोलन लालीमा को विविध प्रकार के बागवानी लक्षणों के लिये मूल्यांकित किया गया। पहले तुडाई दिवस (दिन), फल की लम्बाई (से0मी0), फल की चौड़ाई (से0मी0), औसत फल वजन (ग्राम), फल गुच्छों की संख्या प्रति पौधा, फल की संख्या प्रति गुच्छ, फल की संख्या प्रति पौधा, तुडाई अवधि (दिन), विक्रय योग्य फल उपज प्रति पौधा (कि0ग्रा0), विक्रय योग्य फल उपज प्रति भूखण्ड़ (कि0ग्रा0), विक्रय योग्य फल उपज प्रति हेक्टेयर (क्विन्टल), जीवनावधि (दिन), फल मोटाई (मि.मी.), लाईकोपिन मात्रा (मि.ग्रा./100 ग्रा.), कुल घुलनशील ठोस (°ब्रिक्स), बकआई रौट बिमारी (%), फल छेदक (%)। जीनोटाइप LC- 8, AVTO9001, LC- 9, पंजाब छुआरा और AVTO0201 में अधिक फल प्राप्ति दर्ज की गई तथा इन्होने अन्य बागवानी लक्षणों के लिए प्रतिबन्ध किस्म से अच्छा प्रदर्शन दिया। अतः इन किस्मों को टमाटर में बेहतर किस्मों में या संकर के विकास के लिये आगे प्रजनन कार्यक्रम में शामिल किया जा सकता है। प्रारूपिक गुणांक परिवर्तन सर्वाधिक बकआई रौट बिमारी, फल छेदक, विक्रय योग्य फल उपज प्रति भूखण्ड़, प्रति हैक्टेयर और प्रति पौधों में दर्ज की गई। जबकि जीनोटाइपिक गुणांक परिवर्तन सबसे अधिक बकआई रौट बिमारी में दर्ज की गई। अनुवांशिकता के अनुमान फल छेदक तथा कुल घुलनशील ठोस को छोडकर सभी लक्षणों के लिये अधिकतम पाये गये। इसके अलावा उच्च आनुवांशिक लाभ के साथ युग्मिक उच्च आनुवांशिकता विक्रय योग्य फल उपज, लाइकोपिन मात्रा, बकआई रौट बिमारी व फल छेदक के लिये पाया गया। अलग–अलग लक्षणों के बीच प्रारूपिक और जेनोटाइपिक सह सम्बन्ध गुणांक विक्रय योग्य उपज प्राप्ति सकारात्मक और महत्वपूर्ण सम्बन्ध के साथ फल लम्बाई, फल चौडाई, औसत फल वनज, फल गुच्छों की संख्या प्रति पौधा, फल की संख्या प्रति गुच्छ, फल की संख्या प्रति पौधा, तुडाई अवधि, जीवनावधी, फल की मोटाई, लाइकोपिन मात्रा और कुल घुलनशील ठोस को दर्शाया गया। पाथ गुणांक विश्लेषण द्वारा ज्ञात हुआ कि फल उपज प्रति पौधों के लिये अधिकतम सकारात्मक प्रत्यक्ष प्रभाव फलों की संख्या प्रति गुच्छ, फलों की संख्या प्रति पौधा, औसत फल वजन तथा तुडाई अवधि द्वारा दर्शाया गया। जबकि अधिकतम प्रभाव तुडाई अवधि, फलों की संख्या प्रति पौधा, विक्रय योग्य फल उपज प्रति पौधा धनात्मक अप्रत्यक्ष प्रभाव देते है। इस प्रकार के प्रमुख गुणों को प्रत्यक्ष–अप्रत्यक्ष चुनाव के द्वारा टमाटर की उपज सुधार के लिए भविष्य में उपयोग में लाया जा सकता है। D^2 अध्ययन के आधार पर इन जिनोटाइप को चार समूहों में विभाजित किया गया। समूह प्रथम और तृतीय के बीच में संकर अधिकतम संकर ओज संकरण देगा।

(प्रो. बी.पी. नौटियाल)
सलाहकार का नाम व हस्ताक्षर

(हरीश चन्द्र बधानी)
लेखक का नाम व हस्ताक्षर

CURRICULUM VITAE

Name	:	Harish Chandra Badhani
Father's Name	:	Sh. Ganesh Datt Badhani
Date of Birth	:	15. 06. 1991
Sex	:	Male
Marital Status	:	Unmarried
Nationality	:	Indian

Educational Qualifications:

Certificate/ degree	Class/ grade	Board/ University	Year
10+2	First	Uttarakhand Board.	2009
B.Sc. (Agriculture)	First	H.N.B. Garhwal University,Srinagar	2013

Whether sponsored by some state/ Central Govt./Univ./SAARC : No

Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period : No

Harish

(Harish Chandra Badhani)