GENETIC DIVERSITY OF FRUIT RELATED TRAITS IN TOMATO *(Lycopersicon esculentum)*

BY

MD. FAKHRUL ISLAM

REGISTRATION NO. 06-01905

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

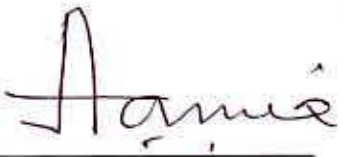
MASTER OF SCIENCE

IN

GENETICS AND PLANT BREEDING

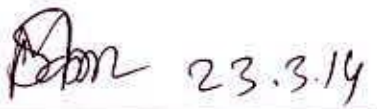
SEMESTER: JANUARY-JUNE, 2013

Approved by:



(Prof. Abu Akbar Mia)
Supervisor

(Dr. Jamilur Rahman)
Associate Professor
Co-supervisor



(Dr. Mohammad Saiful Islam)
Chairman
Examination Committee

Abu Akbar Mia
Professor
Department Genetics and Plant Breeding
Sher-e Bangla Agricultural University
Dhaka-1207, Bangladesh

Phone: +8802 9144270-9, Extn. 315 (off.)
Mob: +8801199104753, Fax: 88029112649

CERTIFICATE

*This is to certify that thesis entitled, "**GENETIC DIVERSITY OF FRUIT RELATED TRAITS IN TOMATO (Lycopersicon esculentum)**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **MD. FAKHRUL ISLAM** , Registration No. **06-01905** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

(Prof. Abu Akbar Mia)
Supervisor

Dated:

Place: Dhaka, Bangladesh

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

First of all I express my best gratitude to Almightly Allah for his never-ending blessing to complete this work successfully. It is a great pleasure to express profound thankfulness to my respected parents, who entiled much hardship inspiring for prosecuting my studies, thereby receiving proper education.

I would like to to express my earnest respect, sincere appreciation and enormous indebtedness to my reverend supervisor, ***Prof. Abu Akbar Mia****, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

I wish to express my gratitude and best regards to my respected Co-Supervisor, ***Dr. Jamilur Rahman****, Associate Professor, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

I am highly grateful to my honorable teacher ***Dr. Mohammad Saiful Islam*** *(chairman), Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, for their valuable teaching, direct and indirect advice, and encouragement and cooperation during the whole study period.*

I am also highly grateful to my honorable teachers Prof. Dr. Naheed Zeba and Prof. Dr. firoz Mahmud, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, for their valuable teaching, direct and indirect advice, and encouragement and cooperation during the whole study period.

I feel to expresses my heartfelt thanks to all the teachers of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for their valuable suggestions and encouragement during the period of the study.

I found no words to thanks my parents, elder brother Md. Ashraf Ali Akand and my uncle Younus Ali Akand for their unquantifiable love and continuous support, their sacrifice never ending affection, immense strength and untiring efforts for bringing my dream to proper shape. They were constant source of inspiration, zeal and enthusiasm in the critical moment of my studies.

I would like to thank zahirullah who has helped me with technical support to prepare this thesis paper. I also thank to my friends Md. Monirul alam, Md. Sajedur Rahman and Md. Anwar Hossain for their help and inspiration in preparing my thesis.

June, 2013 ***The Author***

SAU, Dhaka

GENETIC DIVERSITY OF FRUIT RELATED TRAITS IN TOMATO *(Lycopersicon esculentum)*

BY

MD. FAKHRUL ISLAM

ABSTRACT

A field experiment was conducted with 29 genotypes of tomato (*Lycopersicon esculentum*) considering 13 fruit related characters at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during October 2011 to February 2012. The objectives of the study were to assess the genetic diversity among the genotypes, to know the association of traits, direct and indirect relation between yield contributing characters and to screen out the suitable parents group for hybridization. The phenotypic variances were higher than the genotypic variances. The significant positive correlation with fruit yield per plant was found in fruit diameter, number of locules per fruit, number of clusters per plant, number of fruits per plant and fruit weight. Path coefficient analysis showed that fruit weight had maximum positive direct effect on fruit yield followed days to first fruit setting, fruit diameter, number of clusters per plant and number of fruits per plant. Multivariate analysis techniques were used to classify 29 tomato genotypes. The genotypes were grouped into five clusters. Both cluster I and cluster V contained the highest number of genotypes and cluster II contained the lowest number of genotypes. The highest inter-cluster distance was found between cluster I and III and the lowest inter-cluster distance was observed between cluster I and II. On the other hand, the highest intra cluster distance was found in cluster II and the lowest intra cluster distance was observed in cluster I. Cluster I consists of nearest cluster with D^2 values cluster II & farthest cluster with D^2 values cluster III. The value of Vector I and Vector II revealed that both Vectors had positive values for days to first flowering, fruit diameter, number of locules per plant and number of fruits per plant indicating the highest contribution of these traits towards the divergence among the genotypes. Considering all the characters G_6 (BARI Tomato-4) and G_{10} (BD-7260); G_6 (BARI Tomato-4) and G_{23} (BARI Tomato-11); G_6 (BARI Tomato-4) and G_5 (BARI Tomato-3); G_5 (BARI Tomato-3) and G_{22} (BD-7301) may be suggested for future hybridization program.

TABLE OF CONTENTS

LIST OF TABLES

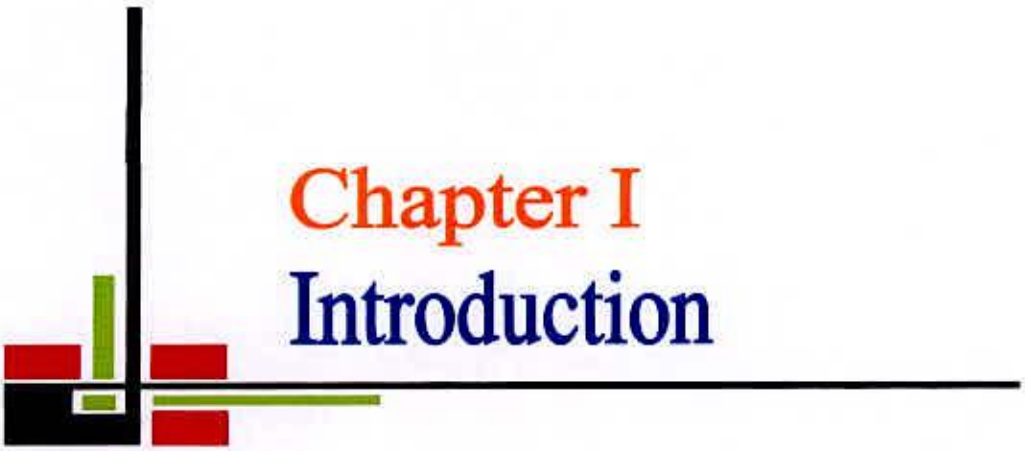
LIST OF PLATES

LIST OF FIGURE

LIST OF APPENDIX

LIST OF ABBREVIATED TERMS

FULL NAME	ABBREVIATION
Agro-Ecological Zone	AEZ
And others	*et. al.*
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Centimeter	cm
Co-efficient of Variation	CV
Days After Sowing	DAS
Degree Celsius	°C
Degrees of freedom	d.f
Etcetera	etc.
Food and Agriculture Organization	FAO
Genetic Advance	GA
Genotypic Co-efficient of Variation	GCV
Genotypic Variance	δ^2_g
Gram	g
Hectare	ha
Heritability in broad sense	h^2b
Journal	j.
Kilogram	Kg
Meter	m
Mean Sum of Square	MSS
Millimeter	mm
Muriate of Potash	MP
Number	No.
Percent	%
Phenotypic Co-efficient of Variation	PCV
Phenotypic variance	δ^2_p
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Standard Error	SE
Square meter	m^2
Triple Super Phosphate	TSP
Unites Nations Development Program	UNDP



Chapter I
Introduction

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicum esculentum* L.) is one of the most important vegetable crops grown widely all over the world. It is a self-pollinated crop and is a member of *Solanaceous* family with 2n = 24. Peru Equator region is considered to be the center of origin (Rick, 1969). The present leading tomato producing countries of the world are China, United States of America, Turkey, India, Egypt, Italy, Iran, Spain, Brazil Mexico, and Russia (Anon., 2010). Now Bangladesh is producing a good amount of tomatoes. In Bangladesh tomato has great demand throughout the year but it is available and cheaper during the winter season. In Bangladesh it is cultivated as winter vegetable, which occupies an area of 58854 acres in 2009-10 (BBS, 2010). The total production of tomato was 339 lac tons in China, 137 lac tons in USA, 109 lac tons in Turkey, 103 lac tons in India and 92 lac tons in Egypt in 2008 (Anon., 2010). The total production of tomato was 190 thousand metric tons in Bangladesh in the year of 2009-2010 (BBS, 2010). The average tomato production in Bangladesh is 50-90 tons/ha (BARI, 2010). Nowadays, tomatoes are grown round the year. Due to increasing consumption of tomato products, the crop is becoming promising. The best tomato growing areas in Bangladesh are Dinajpur, Rajshahi, Dhaka, Comilla and Chittagong.

Tomato is used as a fresh vegetable and can be processed and as paste, juice, ketch-up, sauce, powder or as a whole. It is a good source of vitamins A, B, C and D, minerals, Ca, P and Fe. More than 7% of total vitamin-C (Kalloo, 1989). Tomato is also rich in medicinal value. The pulp and juice are digestible and excellent blood purifiers. It is reported to have antiseptic properties against intestinal infections. The epidemiological studies revealed that, vegetables containing high levels of

phytochemicals lower the risk of several chronical diseases. Fraser *et al.* (1991) reported decreased risk of cancer with the intake of tomatoes. This neutraceutical effect of tomato is attributed to 'lycopene' a major carotenoid present in tomatoes. Lycopene has a straight chain of hydrocarbons containing 12 conjugated and 2 non-conjugated double bonds. It has naturally present antioxidants that is devoid of provitamin-A activity and quenches free radicals which are involved in destruction of healthy body cells and have been linked to every degenerative diseases known to mankind including cancer, arthritis, heart diseases, cataracts and ageing process.

In the last two decades, efforts by vegetable breeders in the commercial breeding programme have resulted in release of many cultivars, resulting in spectacular improvement in yield and other characters. Genotype x Environment interactions pose major problem in developing new cultivars and in choosing suitable cultivars to grow in specific region /location. Relative ranking of genotypes often differ when compared over several locations or environments, making it difficult to identify the most desirable genotype. This interaction is present whether the varieties are pure lines, single crosses or double cross hybrids, top crosses, S_1 lines or any material with which breeder may be working (Eberhart and Russell, 1966). Phenotypically stable genotypes are of great importance, because the environmental condition varies from year to year/region to region. Wide adoption to the particular environment and consistent performance of recommended genotypes is one of the main objectives in breeding programme (Kalloo, 1998).

Commercial F_1 hybrids are very common in Tomato and selection of newer parents for higher heterosis is a continuous process. Generally diverse plants are expected to give high hybrid vigour (Harrington, 1940). And hence, it necessitates study of genetic divergence among the existing varieties and germplasm collection for identification of more heterotic parents for hybridization programme. The information on genetic divergence of various traits particularly of those that contribute to yield would be most useful in planning the breeding programme. D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude of divergence between two

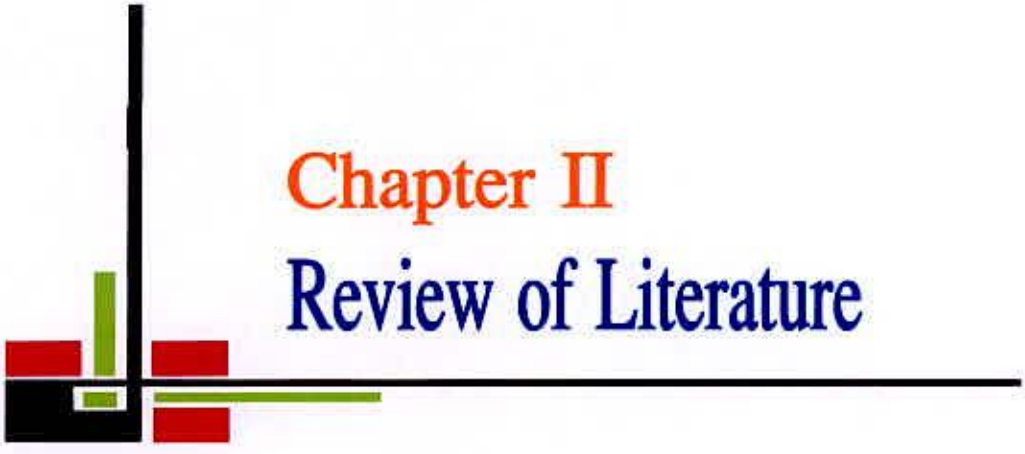
groups under comparison. It considers the variation produced by any character and their consequent effect that it bears on other characters. The technique was first used by Mahalanobis in an anthropometric survey of the United Province in India. This technique has been applied in several crops to select 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 results into release of improved open pollinated varieties for commercial cultivation.

The germplasms were received from the Plant Genetic Resource Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur and Lal Teer Seed Company, Dhaka. Information about species as well as their identifying characters for most of the germplasms collected were unknown. So, it is an opportunity to categorize the germplasm morphologically under different species for future utilization.

A study was, therefore, conducted on the genetic diversity, correlation and path co-efficient analysis between yield and yield contributing characters of tomato.

With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

1. To assess the genetic diversity among the genotypes,
2. To know the association of traits, direct and indirect relation between yield contributing characters through correlation coefficient and path coefficient analysis and
3. To screen out the suitable parents group for hybridization.



Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Vegetable breeder is primarily concerned with the improvement of both qualitative and quantitative plant characters. Hence, adequate knowledge of genetics of various traits is very essential in vegetable breeding programme for obtaining desired results in the generation. An attempt has been made in this chapter to review the available literature on different characters, which play an important role in determining the fruit yield in tomato, pertaining to the present investigation. They are presented below under the following headings:

1. Genetic diversity
2. Correlation studies
3. Path analysis.
4. Variability, heritability and genetic advance.

2.1 Genetic diversity

The assessment of genetic diversity using quantitative traits has been of prime importance in many contexts particularly in differentiating well defined populations. The germplasm in a self-pollinated crop can be considered as a heterogeneous sets of groups, since each group being homozygous within itself. Selecting the parents for breeding program in such crops is critical because, the success of such program depends upon the segregants of hybrid derivatives between the parents, particularly when the aim is to improve the quantitative characters like yield.

To help the breeder in the process of identifying the parents, that need better, several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives. Among them, Mahalanobis's generalized distance occupies a unique place and an efficient method to gauge the extent of diversity among genotypes, which quantify the differences among several quantitative traits. The review of literature pertaining to genetic advance are as followings.

Shashikanth *et al.* (2010) carried out a field experiment to study genetic divergence of 30 tomato genotypes and observed that analysis of variance of the genotypes showed significant differences for all the characters studied indicating the existence of genotypic variation; there was no parallelism between genetic diversity and geographical divergence in tomato and suggested that high diversity among the genotypes belonging to cluster VII and X can be selected in hybridization programmes to obtain good seggregants.

Shashikanth *et al.* (2010) carried out a field experiment to study the genetic variation among 30 tomato germplasm lines and observed that the range of variation and mean values were high for plant height, days to 50% flowering and average fruit weight. He also observed that high genotypic variance was for most of the characters indicating a high contribution of the genetic component for the total variation.

Kumari *et al.* (2007) recorded data for total soluble solids, dry matter content, reducing sugars, titratable acidity, ascorbic acid, lycopene, 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 and found that there were highly significant differences for all the characters among parents except acidity, early yield, total yield, and days to flowering.

Mahesha *et al.* (2006) grouped 30 tomato genotypes into nine clusters studied based on D^2 analysis. The cluster mean indicated that Days to 50% flowering, plant height, number of branches per plant, number of cluster per plant, number of fruit per cluster and fruit yield per plant were reported as chief contributors towards divergence.

Sharma *et al.* (2006) reported 60 genotypes of tomato were studied for genetic divergence. The genotypes grouped into 10 clusters, maximum divergence within a cluster was exhibited by the cluster VIII (1.531), closely followed by cluster III (1.528)and cluster V (1.460), whereas, cluster VIII and II were the most divergent from each other followed by cluster VII and cluster VIII.

Singh *et al.* (2005) conducted a field experiment on 15 advance generation breeding lines of tomato, to study the variation for total soluble solids (TSS), pericarp thickness, fruit firmness, acidity, lycopene content and dry matter content and observed 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. Kumar *et al.* (2004) conducted an experiment with 30 tomato genotypes in Utter Pradesh of India during 2001/02 winter to study their genetic variability and reported significant difference for number of primary branches per plant among the genotypes.

Veershetty (2004) grouped 32 tomato genotypes into 10 cluster based on D^2 analysis number of fruits per cluster, plant height, number of branches, pericarp thickness, average fruit weight and TSS content of fruit were reported as chief contribution towards divergence.

Arun *et al.* (2003) studied the nature and magnitude of genetic divergence in 73 tomato genotypes of different origin for quantitative characters and they grouped genotypes into 15 cluster indicated the presence of wide range of genetic diversity among the genotypes, cluster 5 having 6 genotypes. The mean fruit yield/plant (1034 g/plant) and average fruit weight (102.76 g/plant) were the highest in cluster 5 and 3 respectively. The plant height (135.91 cm), harvest duration (37.77 days) were maximum in cluster 15 and lowest number of leaves (2,0280) was recorded in cluster 9 and cluster 6 consist of highest number of fruits/cluster (4.90).

Parthasarathy and Aswath (2002) conducted a study with 23 genotypes of tomato in Meghalaya and observed a considerable diversity among genotypes for 8 morphological characters. Plant height, fruit number, fruit size were contribute to the divergence among them. Crosses involving L-964 and L-154 with Arka Abha and LE-79 were recommended for improved yield and better fruit size.

Markovic *et al.* (2002) studied genetic divergence of 25 cultivars of tomato originating from the area of the former Yugoslavia and recorded the presence of a high degree of genetic divergence in different genotypes consisting of 5 clusters.

Singh *et al.* (2002) carried out a field experiment with 92 tomato genotypes to study genetic variability and reported that the analysis of variance revealed highly significant genetic variation for plant height, number of days to first fruit set, number of fruit clusters per plant, number of fruits per plant, fruit weight per plant and fruit yield. The traits characterized by adequate variability may be considered in a hybridization program for yield improvement in tomato.

Sharma and Verma (2001) studied genetic divergence of 18 genotypes of tomato and grouped them into 5 clusters irrespective of geographic divergence indicating no parallelism between genetic diversity and geographical divergence. Fruit yield was

one of the three characters which played an important role in divergence between the populations.

Mohanty and Prusti (2001) carried out a study on genetic diversity among 18 indigenous and exotic tomato cultivars for five economic characters (plant height, number of branches per plant, number of fruits per plant, average fruit weight and yield) in Orissa, India during rabi 1998-99 and found considerable variations among the accessions. They could group the genotypes into 5 clusters including two solitary groups and reported that genetic diversity was not associated with geographic distribution. Maximum intercluster distance (D^2=l289.31) was observed between the clusters I and V. The distance between clusters I and Ill, Ill and IV, IV and V was moderate. They also reported that number of fruits per plant and average fruit weight contributed predominantly towards the total divergence.

Kumar *et al.* (1999) studied genetic divergence of 32 tomato genotypes and could group them into 9 clusters based on D^2 values. The magnitude of inter cluster distances was comparatively lower than that of inter cluster distances.

Patil (1984) grouped 55 tomato genotypes into nine cluster studied based on D^2 analysis. A maximum of 16 genotypes entered cluster I, followed by 15 in cluster IV, 9 in cluster III, 7 in cluster II, 4 in cluster V and the remaining four cluster consisted of solitary genotype.

2.1.1 Days to first flowering

Matin *et al.* (2001) reported significant differences among the 26 tomato genotypes for days to first flowering ranging between 49.67 and 68.33 days. He also reported that the phenotypic variance was comparatively higher than the genotypic variance indicating high degrees of environmental effect for days to first flowering .

Aditya *et al.* (1995) reported that there was no it significant difference in days to first flowering among the 44 genotypes which ranged between 52.67 and 58.87.

Biswas and Mallik (1989) observed that a minimum of 66 days was necessary for first flowering for cv. Selectim-7 and a maximum of 83 days for cv.

Geogieva *et al.* (1969) reported that pre-flowering periods of the varieties ranged from 56 to 76 days.

2.1.2 Days to first fruit setting

Singh *et al.* (2000) evaluated days to first fruit setting of 25 tomato cultivars at Summer season and observe that phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 7, 6.90, 97.30 and 12.60 respectively. He also reported the mean was 90.20 days and range was 76.5 to 100.6 days for this character.

Singh *et al.* (2000) evaluated days to first fruit setting of 25 tomato cultivars at Summer season and observe that phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 7, 6.90, 97.30 and 12.60 respectively. He also reported the mean was 90.20 days and range was 76.5 to 100.6 days for this character

The days to first fruit set was ranged from 45.00 to 49.67 with a mean of 47.44. The PCV and GCV were 3.82 and 2.68 days respectively. The moderate heritability estimates of 49.8 per cent with an expected genetic advance over mean of 3.88 per cent were recorded for this trait. Maximum number of days to first fruit set was recorded in the genotype 'KS-229' and minimum days in the genotype 'PANT T-8'.

Singh *et al.* (1988) days to first fruit setting of 25 tomato cultivars at kharif season and observe that phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 13.78, 13.11, 90.50 and 25.69 respectively.

2.1.3 Fruit diameter

Anupam *et al.* (2002) evaluated 30 genotypes of tomato and found similar results for this character.

Singh *et al.* (2002) reported that phenotypic co-efficient of variation was greatest for this character.

2.1.4 Plant Height

Kumari *et al.* (2007) observed the highest genotypic coefficient of variation for plant height followed by early yield, lycopene content, number of fruit bearing branches and titratable acidity.

Golani *et al.* (2007) observed that the phenotypic and genotypic associations of fruit yield was significant and negative with plant height.

Kumar *et al.* (2006) observed low heritability (4.40%) and high genetic advance (35.55) for plant height.

Matin *et al.* (2001) also reported that phenotypic variance was relatively higher than genotypic variance for this trait. They again observed that genotypic co-efficient of variation was lower than phenotypic co-efficient of variation indicating influence of environment for expression of this character.

Prasad *et al.* (1999) found high degrees of phenotypic and genotypic co-efficient of variation for plant height in 75 exotic genotypes of tomato.

According to Aditya (1995) plant height ranged between 48.8 and 104.2 cm while Matin *et al.* (2001) reported that it ranged between 70.70 and 103.80 cm.

Ghosh *et al.* (1995) and Nandpuri *et al.* (1974) reported a high degree of variation for plant height while a narrow range of variations was observed by Ahmed (1987).

Aditya (1995), Matin (2001) and Kumar *et al.* (2004) reported significant variation for plant height.

Sonone *et al.* (1986) and Prasad and Prasad (1977) also reported high phenotypic and genotypic co-efficient of variation for plant height in tomato. But Mallik *et al.* (1985) reported that phenotypic co- efficient of variations were higher than genotypic co-efficient of variations for plant height in tomato.

2.1.5 Peicarp thickness:

Kumar *et al.* (2006) evaluated 6 tomato genotypes include pure line at kharif season and observe that pericarp thickness of fruits mean was 0.38 cm, range was 0.30 to 0.50 cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 19.78, 11.62, 34.50 and 13.50 respectively.

Akhilesh and Gulshanlal (2005) evaluated 13 tomato genotypes at Summer season and observe that pericarp thickness of fruits mean was 0.40 cm, range was 0.28 to 0.49 mm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 22.34, 21.67, 94.80 and 42.50 respectively.

Upadhyay *et al.* (2005) evaluated 34 tomato genotypes at Summer season and observe that pericarp thickness of fruits mean was 3.29 mm, range was 2.00 to 5.33 mm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 30.90, 23.07, 55.41 and 11.65 respectively.

Joshi et *al.* (2004) observed low heritability and low genetic gain was observed for pericarp thickness.

Veerashetty (2004) evaluated 32 tomato genotypes at kharif season and observe that pericarp thickness of fruits mean was 4.95 mm, range was 3.67 to 6.10 mm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2%) and genetic advance as per cent mean (GAM) were 12.41, 10.85, 76.40 and 19.59 respectively.

Veershetty (2004) grouped 32 tomato genotypes into 10 cluster based on D2 analysis number of fruits per cluster, plant height, number of branches, pericarp thickness, average fruit weight and TSS content of fruit were reported as chief contribution towards divergence.

Kumar *et al.* (2003) observed that correlation coefficients at the genotypic level were generally higher than the corresponding phenotypic ones. He found that yield per plant was positively and significantly associated with plant height, fruit number per plant, fruit shape index and pericarp thickness. The mean pericarp thickness noticed was 0.42 cm with a range of 0.30cm to 0.60 cm. The line 'SB-10' showed the minimum pericarp thickness and the maximum pericarp thickness was recorded in the accession 'SEL-7'. The values of 19.96 and 15.84 are noticed for PCV and GCV, respectively. The heritability estimate was 63.0 per cent with high genetic advance over mean of 26.19 per cent could be noted.

Prashant (2003) evaluated 67 tomato genotypes at Rabi season and observe that pericarp thickness of fruits mean was 0.53 cm, range was 0.22 to 0.73cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean (GAM) were 20.03, 18.68, 87.00 and 35.25 respectively.

Arun *et al.* (2003) evaluated 37 tomato genotypes at Summer season and observe that pericarp thickness of fruits mean was 5.41 mm, range was 3.31 to 7.19 mm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean (GAM) were 20.08, 13.27, 43.60 and 18.13 respectively.

Sharma and Verma (2001) reported 18 genotypes of tomato were studied for genetic divergence. The genotypes were developed in cluster irrespective of geographic divergence indicating no parallalization fruit genetic diversity and geographical

divergence. The characters of fruit yield per plant, pericarp thickness and fruit diameter plays an important role in divergence between the population.

Pradeepkumar and Tewari(1999) evaluated 52 tomato genotypes at Summer season and observe that Pericarp thickness of fruits mean was 4.90 mm, range was 3.00 to 6.79 mm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 20.79, 20.69, 99.90 and 42.56 respectively.

Patil (1998) showed pericarp thickness and had positive direct effect on yield mainly due to positive indirect effects through number of fruits per plant and number of branches per plant.

Pujari *et al.* (1995) evaluated 108 tomato genotypes at *kharif* season and observe that Pericarp thickness of fruits mean was 0.47 cm, range was 0.20 to 0.75 cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 4.04, 2.55, 63.16 and 38.16 respectively.

Bhutani *et al.* (1983) evaluated 84 tomato genotypes at Summer season and observe that pericarp thickness of fruits mean was 0.407 cm, range was .256 to 0.708 cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean (GAM) were 24.56, 21.97, 82.01 and 100.74 respectively.

Padda *et al.* (1971) evaluated 56 tomato varieties at Summer season and observe that Pericarp thickness of fruits mean was 4.64mm, range was 2.90 to 6.66mm.He also reported that genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 18.1, 79.70 and 33.40 respectively.

2.1.6 Number of locules per fruit

Golani *et al.* (2007) evaluated 20 tomato genotypes and observed high heritability with high genotypic coefficient of variation and genetic gain for 10-fruit weight, number of locules per fruit and fruit yield, which could be improved by simple selection.

Mahesha *et al.* (2006) carried out an experiment to study genetic variability in 30 genotypes of tomato revealed significant difference for all the characters under study and observed a wide range of variation 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.

Kumar *et al.* (2006) evaluated 6 include pure lines at kharif season and observe that number of locules per fruit mean was 5.21, range was 3.33 to 8.33. He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean (GAM) were 8.33, 30.17, 20.45 and 46.00 respectively.

Joshi *et al.* (2004) observed moderate heritability and moderate genetic gain 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.

Kumar *et al.* (2003) carried out correlation coefficient analysis of thirty diverse tomato and observed that the number of fruits per plant had significant and positive correlation with fruit yield per plant, whereas fruit acidity had significant and positive correlation with number of locules per fruit and average fruit weight was significantly correlated with physiological weight loss.

Prashanth (2003) evaluated 67 tomato genotypes at Rabi season and observe that number of locules per fruit mean was 3.46, range was 2.20 to 5.87.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 24.22, 25.75, 88.40 and 46.98 respectively.

Arun *et al.* (2003) evaluated 37 tomato genotypes at Summer season and observe that number of locules per fruit mean was 3.71, range was 2.00 to 5.74.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 24.89, 19.29, 60.10 and 60.69 respectively.

Das *et al.* (1998) evaluated 23 tomato genotypes at Summer season and observe that number of locules per fruit mean was 3.62, range was 2.00 to 5.72.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 31.15, 21,30.79, 97.69 and 62.57 respectively.

Patil (1998) reported negative direct effect of number of locules per fruit with fruit yield.

Reddy and Gulshanlal (1987) evaluated 32 tomato genotypes at Summer season and observe that number of locules per fruit mean was 3.66, range was 2.00 to 5.40.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 24.15, 21.26, 77.50 and 42.10 respectively.

Bhutani *et al.* (1983) evaluated 84 tomato genotypes at Summer season and observe that number of locules per fruit mean was 3.66, range was 2.07 to 5.42.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 20.63, 19.95, 93.46 and 10.18 respectively.

Arora *et al.* (1982) evaluated 60 tomato genotypes at Summer season and observe that number of locules per fruit mean was 3.90, range was 2.40 to 6.30.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 24.95, 22.45, 80.99 and 41.63 respectively.

Padda *et al.* (1971) evaluated 56 tomato varieties at summer season and observe that number of locules per fruit mean was 4.05, range was 2.00 to 5.50.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 15.20, 13.10,65.10 and 21.70 respectively.

Paranjothi and Muthukrishnan (1979) evaluated 28 tomato genotypes at kharif season and observe that number of locules per fruit mean was 3.80, range was 2.00 to 10.00.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 38.00, 36.00, 85.00 and 68.48 respectively.

Prasad and Prasad (1976) evaluated 25 tomato genotypes at summer season and observe that number of locules per fruit mean was 6.04, range was 2.00 to 12.20.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 52.31, 48.17, 84.84 and 91.72 respectively.

Singh *et al.* (1974) evaluated 20 tomato varieties at winter season and observe that number of locules per fruit mean was 6.04, range was 2.20 to 14.20.He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of

variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 49.60, 42.56, 95.25 and 85.15 respectively.

2.1.7 Number of branches per plant

Singh (2005) evaluated 10 genotypes of tomato and observed a range between 3.40-7.47 branches per plant. He reported the PCV (23.49%) was slightly higher than GCV (22.58%) for this character.

Mohanty (2003) evaluated 18 cultivars of tomato and observed a range between 4.97-13.73 branches per plant. He reported the PCV (32.35%) was higher than GCV (30.62%).

Upadhyay *et al.* (2001) evaluated 34 genotypes of tomato and observed a range between 2.33-7.0 branches per plant. He reported the PCV (35.93%) was higher than GCV (24.72%) for this character.

2.1.8 Number of clusters per plant

Singh *et al.* (2006) observed considerable range of genetic variability for yield, yield components and biochemical characters in the materials under study and maximum genotypic coefficient of variation was recorded for number of leaves per plant, followed by number of clusters per plant.

2.1.9 Number of fruits per cluster

Samadia *et al.* (2006) evaluated 14 cultivars of tomato and found a range between 1.48-4.51 fruits per cluster. He reported almost similar estimates of PCV (41.86%) and GCV (41.83%) for this character.

Arun *et al.* (203) evaluated 37 genotypes of tomato and observed a range between 2.33-6.63 fruits per cluster. He reported the PCV (22.65%) was higher than GCV (15.93%) for this character

Aradhana *et al.* (2003) evaluated 40 genotypes of tomato and found a range between 2.67-4.47 fruits per cluster. He reported the PCV (19.98%) was higher than GCV (10.54%).

2.1.10 Number of fruits per plant

Saeed *et al.* (2007) observed that the variation between the accessions based on the coefficient of variation was greater in traits such as number of fruits per plant (13.92%), followed by number of flowers per plant (10.75%) and yield per plant (9.99%).

Joshi *et al.* (2003) conducted a field experiment with forty tomato genotypes to evaluate their genetic variability and observed the number of fruits per plant gave the highest phenotypic and genotypic coefficient of variation (61.21 and 44.05, respectively) and genetic advance as percentage of mean (65.24).

Brar *et al.* (2000) estimated phenotypic and genotypic co-eflicients of variation and observed high variability in the characters of number of fruits per plant of 186 genotypes of tomatoes.

Das *et al.* (1998) reported wide range of genotypic variation for number of fruits per plant. They also reported high genotypic variation for number of fruits per plant.

Singh *et al.* (1997) studied variability for yield related characters in 23 genotypes of tomato and reported that phenotypic variation was quite large but genotypic variation was low. The phenotypic and genotypic co-efficients of variation indicated that selection may be made for number of fruits per plant.

Islam *et al.* (1996) recorded highest genetic variability for number of fruits per plant in 26 diverse genotypes of tomato.

Sahu and Mishra (1995) also reported wide range of genotypic variation for number of fruits per plant and they found high genotypic variation for number of fruits per plant.

Reddy and Reddy (1992) evaluated 139 tomato genotypes and estimated phenotypic and genotypic variances, phenotypic and genotypic co-efticients of variation. Considerable variation was observed for number of fruits per plant (4.0—296.5).

Islam and Khan (1991) also reported significant variations for number of fruits per plant.

Sidhu and Singh (1989) suggested that maximum genetic improvement would be possible by genetic variability for number of fruits.

Bhutani *et al.* (1989) performed a varietal trial of 84 genotypes and reported that Set-23, Growthens Globe, Punjab Chhuhara, VSII-2, Pusa Red Plum and HS 102 were the best for number of fruits per plant.

Sonone *et al.* (1987) reported that high genotypic and phenotypic co-efficient of variation were estimated for fruits per plant.

2.1.11 Fruit weight (gm)

Kumar *et al.* (2004) studied genetic variability with 30 tomato genotypes in Utter Pradesh of India and reported significant difference for average fruit weight among the genotypes.

Mohanty *et al.* (2003) carried out in a field experiment to study genetic variability of 18 tomato cultivars and observed that the average fruit weight had positive direct effects on the yield and negative indirect effects on number of fruits per plant.

Singh *et al.* (2002) carried out a field experiment to study genetic variability of fifteen heat tolerant tomato and showed that phenotypic (PCV) and genetic (GCV) coefficients of variation were high for average fruit weight.

Matin (2001) reported similar results for average fruit weight in an experiment with 26 tomato genotypes.

Brar *et al.* (1998) reported that varietal differences were significant among 20 cultivars of tomato for average fruit weight ranged between 24.1g and 76.6g. .

Singh *et al.* (1997) studied genetic variability of 23 genotypes of tomato and reported that phenotypic variation was quite large but genotypic variation was low for this character.

Aditya (1995) reported that analysis of variances showed highly significant mean squares due to variety for average fruit weight among the 44 varieties of tomato. Genotypic variance associated with genotypic co-efficient of variation were smaller than phenotypic variance and phenotypic co-efficient of variation respectively.

Sahu and Mishra (1995) reported that fruit weight had high genotypic co-efficient of variation in 16 lines of tomato grown during the winter season of 1986 at Bhubaneswar, India.

Reddy and Reddy (1992) estimated phenotypic and genotypic variances, phenotypic and genotypic co-efiicient of variation for individual fruit weight. Considerable variation was observed for average individual fruit weight (1.25-158.87).

Godekar *et al.* (1992) obtained high values for heritability along with high genetic advance by fruit weight.

Sonone *et al.* (1986) reported that genotypic and phenotypic variances were high for individual fruit weight in the study of genetic variability with 13 genetically diverse tomato lines.

2.1.11 Fruit weight (gm)

Kumar *et al.* (2004) studied genetic variability with 30 tomato genotypes in Utter Pradesh of India and reported significant difference for average fruit weight among the genotypes.

Mohanty *et al.* (2003) carried out in a field experiment to study genetic variability of 18 tomato cultivars and observed that the average fruit weight had positive direct effects on the yield and negative indirect effects on number of fruits per plant.

Singh *et al.* (2002) carried out a field experiment to study genetic variability of fifteen heat tolerant tomato and showed that phenotypic (PCV) and genetic (GCV) coefficients of variation were high for average fruit weight.

Matin (2001) reported similar results for average fruit weight in an experiment with 26 tomato genotypes.

Brar *et al.* (1998) reported that varietal differences were significant among 20 cultivars of tomato for average fruit weight ranged between 24.1g and 76.6g.

Singh *et al.* (1997) studied genetic variability of 23 genotypes of tomato and reported that phenotypic variation was quite large but genotypic variation was low for this character.

Aditya (1995) reported that analysis of variances showed highly significant mean squares due to variety for average fruit weight among the 44 varieties of tomato. Genotypic variance associated with genotypic co-efficient of variation were smaller than phenotypic variance and phenotypic co-efficient of variation respectively.

Sahu and Mishra (1995) reported that fruit weight had high genotypic co-efficient of variation in 16 lines of tomato grown during the winter season of 1986 at Bhubaneswar, India.

Reddy and Reddy (1992) estimated phenotypic and genotypic variances, phenotypic and genotypic co-efiicient of variation for individual fruit weight. Considerable variation was observed for average individual fruit weight (1.25-158.87).

Godekar *et al.* (1992) obtained high values for heritability along with high genetic advance by fruit weight.

Sonone *et al.* (1986) reported that genotypic and phenotypic variances were high for individual fruit weight in the study of genetic variability with 13 genetically diverse tomato lines.

2.2 Heritability and genetic advance

Heritability and genetic advance are the most important parameters to judge the breeding potentiality of a population for future development through selection. Many researchers have studied heritability and genetic advance of yield and many yield contributing characters of tomato. The literatures very relevant to the present study are reviewed below:

Kumari *et al.* (2007) reported that the estimates of heritability were high for all the characteristics and genetic advance was high for plant height, moderate for total number of fruit bearing branches, weight per fruit and days to maturity, while the remaining characteristics had low values of genetic advance.

Saeed *et al.* (2007) observed that 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.

Mahesha *et al.* (2006) estimated heritability and expected genetic advance in 30 genotypes of tomato and observed that fruit weight, fruits per plant and plant height exhibited very high heritability values along with high genetic gain. It indicated the importance of considerable additive gene effects and therefore greater emphasis should be given on these characters while selecting the better genotypes in tomato forward.

Singh *et al.* (2006) estimated heritability for nineteen genotypes of tomato and observed high heritability 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.

Singh *et al.* (2005) estimated heritability and showed that heritability estimates were high for all the characters for November planting except for lycopene content.

Arun *et al.* (2004) reported that moderate heritability associated with moderate genetic advance for plant height of 37 tomato genotypes of tomato.

Kumar *et al.* (2004) estimated heritability and genetic advance in 30 tomato genotypes for the characters like number of primary branches per plant, plant height, number of fruits per plant, fruit yield per plant and average fruit weight. The average fruit weight showed high heritabilities that ranged from 89.10% to 96.50%. The rest of the characters showed moderate heritability and low genetic advance.

Joshi *et al.* (2003) conducted a field experiment with forty tomato genotypes to evaluate their genetic variability and noticed that plant height gave the highest heritability (78.82%).

Mohanty (2003) observed that high heritability with high genotypic coefficient of variation was for fruit weight, plant height, number of fruits and number of branches per plant.

Mohanty (2002) evaluated 18 genotypes of tomato and revealed high heritability with moderate to high genetic gain for average fruit weight, number of fruits per plant and plant height.

Matin (2001) reported high degrees of heritability and genetic advance for fruits per plant, individual fruit weight and number of seeds per fruit.

Brar *et al.* (2000) reported that the number of fruits per plant, total yield per plant and marketable yield per plant had low to moderate estimates of heritability and genetic advance and number of marketable fruits per plant had high values of heritability and genetic advance.

Nessa *et al.* (2000) reported high heritability for number fruits per plant, plant height and moderate heritability for yield per plant.

Prasad *et al.* (1999) estimated heritability in 75 exotic genotypes of tomato and reported very high heritability along with high genetic advance by fruit weight.

Vikram and Kohli (1998) reported high heritability and genetic advance for mean fruit weight which suggested that improvement for this character should be fairly straight

Singh *et al.* (1997) estimated heritability and genetic advance in 23 genotypes of tomato. High values of heritability and genetic advance indicated that effective selection may be made for fruit weight and number of fruits per plant.

Islam *et al.* (1996) studied heritabiltiy and genetic advance in 26 diverse genotypes of tomato. High heritability and genetic advance was observed in number of fruits per plant, plant height, fruit yield and individual fruit weight.

Mittal *et al.* (1996) estimated heritability and genetic advance in 27 genotypes of tomato. High heritability associated with high genetic advance was observed by them indicating the character, predominantly under the control of additive gene, could be improved through selection.

Pujari *et al.* (1995) observed high heritability coupled with high genetic advance for number of fruits per plant, plant height and average fruit weight which indicated additive gene action.

Aditya *et al.* (1995) reported high heritability (in broad sense) with high genetic advance in percentage of mean for number of fruits per plant, individual. fruit weight and plant height. However, yield per plant showed moderate heritability and low genetic advance but highest genetic advance as percentage of mean under selection.

Reddy and Reddy (1992) studied heritability and genetic advance in 139 tomato varieties. Heritability values for yield per plant, number of fruits per fruits per plant and average individual fruit weight were 97.99%, 95.96% and 98.46% respectively.

Bai and Devi (1991) evaluated five varieties and nine hybrids of tomato. Heritability estimates of 90% were obtained for plant height, number of fruits per plant and individual fruit weight.

Islam and Khan (1991) studied 12 tomato genotypes and reported that heritability values were high for most of the characters but moderate for days to first flowering, maturity and plant height.

Kasrawi and Amr (1990) reported that pH gave comparatively higher heritability estimates in a study of seven quality characters using F_2 populations.

Singh *et al.* (1988) evaluated 32 genotypes for agronomic characters and obtained high heritability values for yield per plant only.

Abedin and Khan (1986) also reported high values of heritability in broad sense and high genetic advance for plant height, number of fruits per plant and individual fruit weight.

Sonone *et al.* (1986) reported that heritability estimates for fruit number, plant height and individual fruit weight were high in tomato. He also reported that high genetic advance (>30%) was observed for fruit yield, plant height, individual fruit weight and number of fruits per plant. Estimates of high heritability and high genetic advance for

number of fruits per plant, individual fruit weight and plant height indicated control by additive genetic effects.

Mallik (1985) reported high genetic advance for plant height, number of fruits per plant, individual fruit weight and yield per plant but low heritability for yield per plant.

Dudi *et al.* (1983) reported that heritability and a genetic advance-were high for number of fruits per plant, individual fruit weight and yield by per plant.

Singh and Singh (1980) reported high heritability for average fruit weight (91.08%), total fruits (85.04%) and days to first picking (80.97%).

2.3 Correlation co-efficient:

Correlation between the characters is an estimation to evaluate the inter-relationships between the characters which will help the breeders to choose selection techniques. Fruit yield of tomato is the final character which is contributed by a complex chain of interrelating effects of different yield contributing characters. The yield contributing characters are also interrelated among themselves. So, association of characteristics with yield and among its components is important for planning effective selective breeding programme for maximization of yield. Such correlation studies may vary due to agro-climatological variations from year to year. If any component of yield has higher heritability than yield itself and there is positive correlation between these, then there may be some possibility of increase in the total yield by selecting that component. But, negative correlation co- efficient among yield components was generally observed indicating selection for an increase in any component might not bring improvement for yield. Many authors have studied correlation between yield and yield contributing characters of tomato. Some pertinent recent literatures are reviewed in this section.

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

YaDong *et al.* (2010) showed that the lycopene content is very significantly positively correlated with single inflorescence flower numbers, single inflorescence fruit numbers and soluble solids content, but very significantly negatively correlated with pedicel length and single fruit weight. He also reported that the lycopene content is

significantly positively correlated with fruit shape index, but significantly negatively correlated with fruit firmness, flesh thickness, longitudinal diameter fruit.

Anitha *et al.* (2007) reported that genotypic correlations were higher than their corresponding phenotypic values and oxalate content showed significant positive correlation with seediness and a non-significant positive correlation with lycopene, TSS and locule number.

Golani *et al.* (2007) observed that fruit weight had significant and positive correlation with fruit length, fruit girth and number of locules per fruit at both levels.

Wagh *et al.* (2007) performed correlation analysis and observed that yield improvement can be achieved by selection for 50% flowering, plant height, number of fruits per plant along with fruit quality characters such as lycopene, beta -carotene, ascorbic acid and titratable acidity.

Megha *et al.* (2006) studied correlation in exotic tomato cultivars to determine the correlation of 26 tomato cultivars for number of flowers per cluster, flower clusters at first picking, number of fruits per cluster, weight per fruit, yield per plant, total yield, total soluble solids and juice percentage observed that improvement in yield could be managed by selection for number of flowers per cluster, flower clusters at first picking, number of fruits per cluster and weight per fruit.

Manivannan *et al.* (2005) carried out correlation coefficient analysis in cherry and observed that the phenotypic and genotypic coefficient of variation was highest for the number of fruits per plant, fruit weight and fruit yield. Fruit yield was significantly and positively correlated with the number of leaves, fruit weight and juice content.

Singh *et al.* (2005) carried out correlation coefficient analysis on 15 advance generation breeding lines of tomato and observed that the phenotypic coefficients of variation were higher than genotypic coefficients of variation indicating that the genotypic effect is lessened under the influence of the given environment.

Arun *et al.* (2004) observed that in case of tomato yield per plant was positively and significantly correlated with average fruit weight and plant height.

Joshi *et al.* (2004) performed correlation analysis of 37 tomato genotypes and showed 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 the fruits. However, fruit weight was

negatively correlated with the number of fruits per plant, number of fruits per cluster and ascorbic acid content.

Kumar *et al.* (2004) performed correlation coefficient analysis of 30 tomato genotypes and observed that number of fruits per plant had significant and positive correlation with fruit yield per plant, whereas fruit acidity had significant and positive correlation with number of locules per fruit.

Singh *et al.* (2004) studied genetic parameters, inter-relationships and path co-efficient in 92 tomato genotypes. Highly significant positive correlation was observed between the number of fruits per plant and yield and between plant height and number of fruits per plant while negative correlation was noticed between the number of primary branches per plant and number of fruits per plant.

Mohanty (2003) studied correlation coefficient analysis of 18 tomato cultivars and reported that yield was significantly and positively correlated with number of fruits per plant and number of daya to harvest, and significantly but negatively correlated with plant height, number of branches per plant and average fruit weight and the number of fruits per plant was inversely related to average fruit weight. He also reported that most early cultivars were small fruited and low yielders.

Bodunde *et al.* (2002) studied path co-efficient analysis in tomato and reported that the number of leaves at flowering, plant height and fruit diameter directly affected yield and results showed that the 5 traits were directly responsible for the determination of yield in tomato.

Harer *et al.* (2002) studied correlation of thirty-seven tomato genotypes and showed that genotypic correlation was higher than phenotypic correlation for all characters examined. The number of fruits per cluster and number of fruits per plant were significantly and positively correlated with fruit yield per plant, whereas the number of primary branches per plant, fruit weight and ascorbic acid content had negative association with fruit yield.

Mohanty (2002) reported that the phenotypic and genotypic correlations of fruit yield were significant and positive with days to first harvest, number of branches and fruits per plant while significant and negative with plant height and average fruit weight and he found that number of fruits per plant was inversely related with average fruit weight. He also reported that yield exhibited significantly positive phenotypic and genotypic association with number of branches per plant and number of fruits per plant.

Nesgea *et al.* (2002) studied correlation coefficient analysis in 13 tomato genotypes and revealed that plant height, number of branches per plant, plant spread, fresh plant weight, number of fruiting clusters, number of days to 50% flowering, number of fruits per cluster and number of fruits per plant should be considered for the enhancement of the yield of tomato.

Padma *et al.* (2002) reported that negative correlation was observed between fruit weight and fruit number, plant height and fruit weight, fruit weight and TSS content and fruit yield and plant height. Fruit weight had the greatest direct effect on fruit yield.

Singh *et al.* (2002) showed that total yield was significantly and positively correlated with marketable yield, average fruit weight, and days from fruit setting to red ripe stage. He also reported that the phenotypic coefficient of variation was greatest for fruit length, number of fruits per plant, plant height, fruit weight per plant, fruit yield and number of fruit clusters per plant and moderate for number of fruits per cluster, number of primary branches per plant, fruit diameter and total soluble solid content.

Susic (2002) showed that a significant negative correlation was between mean fruit mass and number of fruits per plant and a significant positive correlation was found between fruit length and fruit width. The number of locules per fruit was significantly and positively correlated with fruit weight, fruit length, fruit width and number of fruits per plant.

Tiwari *et al.* (2002) observed that the highest positive and significant association was between the yield and length of fruit. At the genotypic level, the highest positive association was observed between the yield and length of fruit.

Bhushana *et al.* (2001) studied correlation co- efficient in sixty genotypes of tomato and observed a positive and significant correlation between fruit yield per plant and total soluble solids, ascorbic acid, pH and titratable acidity and a positive and significant correlation was recorded among rind thickness, ascorbic acid and pH. They also observed similar association between total soluble solids and ascorbic acid, and between titratable acidity and pH.

Kumar *et al.* (2001) observed that the genotypic coefficient of variation was higher for all characters except specific gravity and total soluble solids (TSS). He also reported that a significant positive genotypic correlation was found bet wean pericarp thickness and juice viscosity and between lycopene and ascorbic acid contents; and locule number was negatively correlated with pericarp thickness.

Matin *et al.* (2001) studied phenotypic and genotypic correlations of 13 qualitative and quantitative characters of 26 genotypes of tomato and found that individual fruit weight had significant positive correlations with plant height and yield per plant. He also reported that number of fruits per plant also had significant positive correlations with fruit dry matter content and found significant negative correlations between number fruits per plant and individual fruit weight; and dry matter was negatively correlated with individual fruit weight.

Prasad *et al.* (1999) observed very high and significant positive correlation co-efficients were between yield and fruit weight.

Das *et al.* (1998) studied correlation co- efficient in fruit characters of tomato. They observed significant positive correlation of fruit yield per plant with number of fruits per plant.

Aditya *et al.* (1995) studied phenotypic and genotypic correlation co-efficient to find out the associations between eight characters of 44 genotypes of tomato. She reported that yield of fruits per plant showed significant positive correlations with plant height and number of fruits per plant; and insignificant positive correlation with weight of individual fruit (phenotypically) and number of seeds per fruit.

Islam and Khan (1991) observed high positive phenotypic and genotypic correlation with individual fruit weight, fruits per plant, plant height and days to flowering on yield.

Abedin and Khan (1986) studied correlation of 20 cultivars of tomato and found that yield per plant was negatively correlated with number of fruits per plant but positively and significantly correlated with individual fruit weight and plant height.

Mallik (1985) studied phenotypic and genotypic correlations in an experiment with 19 varieties/lines of tomato and observed that individual fruit weight had positive significant correlations with plant height and yield.

Alvarez and Torres (1983) studied correlation between ten characters including yield in 34 varieties/lines of tomato and observed positive correlation between yield and plant height, yield and fruit number per plant also. All three were positively correlated with each other and negatively correlated with weight.

2.4 Path co-efficient:

The study of simple correlation does not provide an exact picture of relative importance of direct and indirect influence of each of the component character towards the desired character. So, this can be overcome by following path coefficient analysis technique by further partitioning the correlation coefficient into direct and indirect effects. Path co-efficient is a standard tool which measures the direct influence of one character upon another and permits the separation of correlation co-efficient into components of direct and indirect effects. Path co-efficient between yield and yield contributing characters provides an exact picture of the relative importance of direct and indirect influences of each other component characters on fruit yield. It also provides valuable additional information for improving fruit yield via selection for its yield components. Recent publications involving path co-efficient analysis between yield and components of yield relevant to the present study are reviewed in this section.

Rani *et al.* (2010) conducted a field experiment to study path coefficient for yield components and quality traits in 23 hybrids of tomato and exhibited that fruit weight had the highest positive direct effect on yield per plant, while, fruit weight was also having high positive indirect effect on yield per plant.

Anitha *et al.* (2007) performed path analysis and revealed that oxalates, acidity, ascorbic acid and TSS had positive and high direct effects on lycopene.

Golani *et al.* (2007) performed path analysis and confirmed that the 10-fruit weight had the highest positive direct effect, followed by the number of locules per fruit.

Manivannan *et al.* (2005) carried out path coefficient analysis in cherry tomato and showed that fruit weight had the highest direct effect on fruit yield.

Mayavel *et al.* (2005) reported that number of branches per plant had the highest positive direct effect on fruit yield. Whereas, plant height, number of fruits per cluster, number of fruits per plants and number of locules per fruit had negative direct effects on fruit yield.

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

Kumar *et al.* (2004) performed path analysis of 30 tomato genotypes and reported that average fruit weight was significantly correlated with physiological weight loss.

Singh *et al.* (2004) performed path analysis between yield and yield contributing characters of 92 tomato genotypes and reported that number of fruits per plant exerted the high positive direct effect on yield followed by average weight per fruit, number of primary branches per plant, plant height, days to 50% flowering, number of fruits per cluster and days to first fruit harvest. However, days to first fruit set, number of primary branches per plant, plant height, number of fruit clusters per plant and total soluble solids had direct negative effects on yield.

Arun *et al.* (2003) revealed that the number of fruits per plant is the most important yield contributing character followed by plant height through path co-efficient analysis.

Mohanty (2003) conducted a field experiment to study path coefficient analysis of 18 tomato cultivars and observed that the number of fruits per plant and average fruit weight had positive direct effects on the yield and negative indirect effects on each other.

Kumar *et al.* (2003) performed path analysis of thirty diverse tomato genotypes and indicated that fruit number per plant had the highest positive direct effect on yield per plant followed by average fruit weight.

Bodunde *et al.* (2002) carried out a field experiment on path coefficient analysis and observed that the number of leaves at flowering, plant height and fruit diameter directly affected yield. Results showed that the 5 traits (number of leaves at first flowering, plant height at first harvest, fruit length, fruit diameter and days to maturity) were directly responsible for the determination of yield in tomato. Harer *et al.* (2002) carried out a field experiment to study path analysis of thirty-seven tomato genotypes and reported that number of fruits per cluster, average fruit weight and number of fruits per plant had direct maximum effects on fruit yield.

Mohanty (2002) performed path analysis and showed that the number of branches per plant and average fruit weight exerted high positive direct effect on yield and high positive indirect effect with each other.

Padma *et al.* (2002) performed path analysis and revealed that number of branches, dry matter production, fruit weight, fruit length, fruit volume, TSS content, juice percentage, and number of fruits per plant exhibited positive effect on yield per plant at the genotypic and phenotypic levels.

Bhushana *et al.* (2001) performed path analysis for fruit quality traits on fruit yield in sixty genotypes of tomato and showed that all the four variables (total soluble solids, ascorbic acid, pH and titratable acidity) exhibited low positive direct effects on fruit yield.

Matin *et al.* (2001) observed that the maximum direct contribution towards yield was through individual fruit weight followed by number of fruits per plant. He also reported that days to first flowering, plant height and number of seeds per fruit had negative direct effect on yield per plant.

Verma *et al.* (2000) conducted a field experiment to perform path analysis of yield components in thirty tomato genotypes and observed that total number of fruits per plant, average weight of fruit, thousand seed weight and number of branches per plant exhibited positive as well as high direct effects.

Vikram and Kohli (1998) carried out an experiment with 25 genotypes of tomato and accomplished path co-efficient analysis and revealed that mean fruit weight is the most important yield contributing trait following fruits per plant.

Domini and Moya (1997) evaluated 18 tomato varieties for the relationship of six yield components to yield in two different seasons. They reported that fruit number per plant was the most important character having a direct effect on yield either in early sowing.

Aditya *et al.* (1995) carried out genotypic and phenotypic path co-efficient analysis and revealed that plant height and number of fruits per plant had high positive direct effect on yield and on the other hand, weight of individual fruit had positive indirect effect on yield per plant.

Supe and Kale (1992) studied correlation and path analysis of seven different characters of twelve indigenous varieties of tomato and observed that plant height had negative direct effect on yield per plant though its correlation co-efficient with yield was positive.

Islam and Khan (1991) observed that fruits per plant, average fruit weight, plant height and days to first flowering had positive direct effects on yield of tomato.

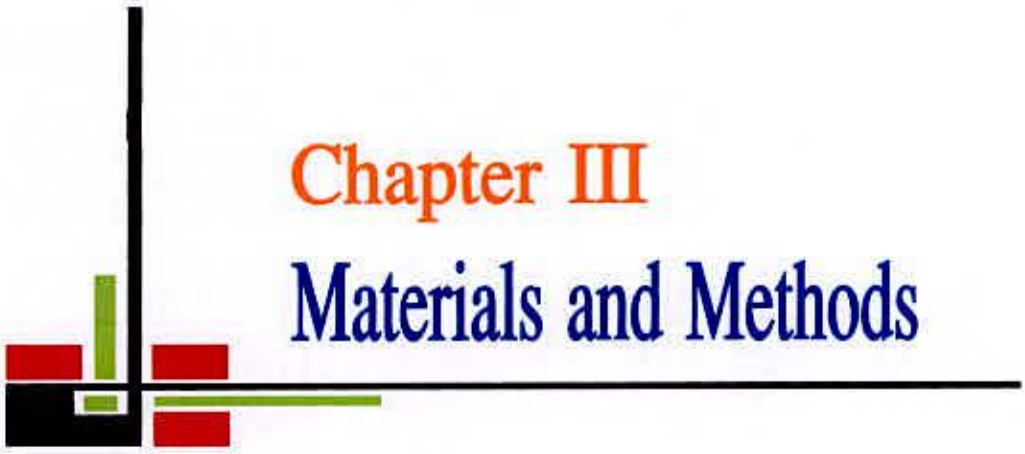
Sonone *et al.* (1987) reported highest direct effect of plant height and fruit weight on fruit yield of tomato.

Alam *et al.* (1988) studied path co-efficient in 19 cultivars of tomato and found that maximum direct contribution towards yield was through individual fruit weight followed by number of fruits per plant.

Gomez (1987) reported that days to first flowering has negative direct effect on yield of tomato.

Gorbatenko and Gorbatenko (1985) carried out path co-efficient analysis of economically useful characters of tomato 2 and found that individual fruit weight had an appreciable direct effect on yield per plant.

Dudi and Kalloo (1982) studied path analysis in tomato and reported highest direct effects of eariy yield per plant, fruit weight and fruits per plant.



Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

A experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from October 2011to February 2012 to study on the genetic diversity, correlation and path coefficient analysis in tomato *(Lycopersicon esculentum)*. A brief description about the locations of the experimental site, characteristics of soil, climate, materials, layout and design of the experiment, land preparation, manuring and fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, economic and statistical analysis etc., which are presented as follows:

3.1. Experimental site

The research work relating to determine the genetic diversity of bitter gourds was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207 during October 2011 to February 2012.

3.2 Geographical Location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004). The experimental field belongs to the Agro-ecological zone of "The Madhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in (Appendix I).

3.3 Climate

Area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in Appendix II.

3.4 Characteristics of soil

Soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.0- 6.6 and had organic matter 0.84%. Experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. Physicochemical properties of the soil are presented in (Appendix III).

3.5 Planting materials

Twenty nine (29) genotypes of tomato were used for the present research work. The purity and germination percentage were leveled as around 100 and 80 respectively. The genetically pure and physically healthy seeds of these genotypes were collected from Plant Genetic Resources Centre (PGRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur and Lal Teer Seed Company, Dhaka. The name and origin of these genotypes are presented in Table 1.

3.6 Design and layout of the experiment

The study was laid out in Randomized Complete Block Design (RCBD) with three (3) replications. The plot size was 320 m^2. A distance of 200 cm from block to block, 50 cm from row to row and 50 cm from plant to plant was maintained. The genotypes were randomly distributed to each row within each line.

3.7 Seed bed preparation and raising seedling

The sowing was carried out on 21 October 2011 in the seedbed; before sowing seeds were treated with Bavistin for 5 minutes. Seedlings of all genotypes were raised in seedbeds in the Sher-e-Bangla Agricultural University, Dhaka-1207 farm Unit. Recommended cultural practices were taken up before and after sowing the seeds. When the seedlings become 27 days old; those were transplanted in the main field.

Table 1. Name and origin of twenty nine tomato genotypes used in the present study

Sl. No.	Genotypes No.	Name/Acc No. (BD)	Origin
1	G1	BD-7306	BARI
2	G2	BD-7759	BARI
3	G3	BD-7761	BARI
4	G4	BD-7762	BARI
5	G5	BARI Tomato-3	BARI
6	G6	BARI Tomato-4	BARI
7	G7	PUSA RUBI	Lal Teer Seed Company
8	G8	BD-7258	BARI
9	G9	BD-7259	BARI
10	G10	BD-7260	BARI
11	G11	BD-7270	BARI
12	G12	BD-7276	BARI
13	G13	BD-7285	BARI
14	G14	BD-7279	BARI
15	G15	BD-7286	BARI
16	G16	BD-7281	BARI
17	G17	BD-7289	BARI
18	G18	BD-7291	BARI
19	G19	BD-7290	BARI
20	G20	BD-7262	BARI
21	G21	BD-7295	BARI
22	G22	BD-7301	BARI
23	G23	BARI Tomato-11	BARI
24	G24	Mintu	BARI
25	G25	Unnayan	BARI
26	G26	Raton	BARI
27	G27	Ruma VF	Lal Teer Seed Company
28	G28	Delta	BARI
29	G29	BARI Hybrid Tomato -4	BARI

3.8 Land preparation

The experimental plot was prepared by several ploughing and cross ploughing followed by laddering and harrowing with tractor and power tiller to bring about to good tilth in the third week of November 2011. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

3.9 Manure and fertilizers application

Total cowdung and triple super phosphate (TSP) were applied in the field during final land preparation. Half Urea and half muriate of potash (MOP) were applied in the plot after three weeks of transplanting. Remaining urea and muriate of potash (MOP) were applied after five weeks of transplanting. Doses of manure and fertilizers used in the study are showing in Table 2.

3.10 Transplanting of seedlings

The seedlings were raised in the seedbed in usual way and 27 days old seedlings were transplanted in the main field on 17 November, 2011. The transplanted seedlings were watered regularly to make a firm relation with roots and soil to stand along.

Table 2. Doses of manures and fertilizers used in the study

Sl. No.	Fertilizers/ Manures	Dose	
		Applied in the plot	Quantity/ha
1.	Urea	13.5 kg	550 kg
2.	TSP	15 kg	450 kg
3.	MOP	7 kg	250 kg
4.	Cow dung	300 kg	10 ton

3.11 Intercultural operations

When the seedlings were well established, 1st mulching and weeding were done uniformly in all the plots. Second weeding was done after 20 days of the first one. Mechanical support was provided to the growing plants by bamboo sticks to keep them erect. During early stages of growth, pruning was done by removing some of the lateral branches to allow and plants to get more sunlight and to reduce the self-shading and incidence of increased insect infestation.

3.11.1 Thinning and gap filling

When the seedlings were well established, the soil around the base of each seedling was pulverized. A few gap filling was done by healthy seedlings of the same stock where initial planted seedlings failed to survive. Thinning was done for the proper development and avoid crowd environment.

3.11.2 Staking

When the plants were well established, staking was done using bamboo sticks to keep the plants erect.

3.11.3 Weeding and mulching

Several weeding and mulching were done as per requirement. At the very first stage weeding was done for ease of aeration and less competition seedling growth and mulch was provided after an irrigation to prevent crust formation and facilitate good aeration.

3.11.4 Irrigation and after-care

After transplanting the seedlings were properly irrigated for 4 consecutive days. Then flood irrigation was given to the plants after each top dressing of urea. Final irrigation was given during active fruiting stage.

3.11.5 Pesticide application

During the cropping period, since there was no significant pest infestation in the field, hence no control measure was undertaken. In order to prevent disease infestation, 'Ripcord' was used for 6 times at an interval of 7 days from 06 December 2011 to 11 January 2012. There were different types of weeds which were controlled effectively by hand weeding.

3.12 Harvesting:

Harvesting continued for about one month because fruits of different lines matured progressively at different dates and over long time. Fruits were picked on the basis of horticultural maturity, size, color and age being determined for the purpose of consumption as the fruit grew rapidly and soon get beyond the marketable stage, frequent picking was done throughout the harvesting period. Harvesting was started from 1 February and completed by 29 February. The fruits per entry were allowed to ripe and then seeds were collected for future use. Photograph showing one replication view of the experimental field in Plate 1 , a single tomato plant in plate 2, a tomato plant with flower in plate 3 and a tomato plant with a cluster of tomatoes Plate 4.

Plate 1: One replication view of the experimental field

Plate 2: A single tomato plant in the experimental field

Plate 3: A tomato plant with flower

Plate 4: A tomato plant with a cluster of tomatoes

3.13 Data recording

Five plants in each entry were selected randomly and were tagged. These tagged plants were used for recording observations for the following characters.

3.13.1 Days to first flowering

The number of days was counted from the date of sowing to days to first flowering.

3.13.2 Days to first fruit setting

The number of days was counted from the date of sowing to first setting of fruit.

3.13.3 Plant height (cm)

The plant height was measured from ground level to tip of the plant expressed in centimeters and mean was computed.

3.13.4 Fruit Diameter (cm)

It was measured from fruit breadth at highest bulged portion of the fruit by using vernier calipers.

3.13.5 Pericarp thickness (cm)

The fruits selected for recording locule number per fruit were sliced at the equatorial plane to measure pericarp thickness in cm. The thickness of fruit pericarp was measured by using vernier calipers.

3.13.6 Number of locules per fruit

Number of locules was counted from five fruits taken at random by cutting transversely in the middle.

3.13.7 Number of branches per plant

The number of branches arising from the main stem above the ground was recorded at 60 days after transplanting.

3.13.8 Number of clusters per plant

The number of clusters per plant was recorded at the time of harvesting.

3.13.9 Number of fruits per cluster

Three clusters in each plant were taken at random and the number of fruits in each cluster was counted. Then the average number of fruits per cluster was calculated.

3.13.10 Number of fruits per plant

The total number of marketable fruits harvested from the five plants was counted and the average number of fruits per plant was calculated.

3.13.11 Fruit weight (g)

The total number of marketable fruits was weighed and the fruit weight was worked out and expressed in grams (g).

3.13.12 Self life of fruit

The number of days was counted from storage date to starting rote of fruits.

3.13.13 Fruit yield per plant

The weight of fruits from each picking was recorded from the five labeled plants of each experimental plot. Total yield per plant was worked out by adding yield of all harvests and was expressed in kilogram (kg) per plant.

3.14.1 Statistical analysis:

Mean data of the characters were subjected to multivariate analysis. Univariate analysis of the individual character was done for all characters under study using the mean values (Singh and Chaudhury, 1985) and was estimated using MSTAT-C computer programme. Duncan's Multiple Range Test (DMRT) was performed for all the characters to test the differences between the means of the genotypes. Mean, range and co-efficient of variation (CV %) were also estimated using MSTAT-C. Multivariate analysis was done by computer using GENSTAT 5.13 and Microsoft Excel 2000 software through four techniques viz., Principal Component Analysis (PCA), Principal Coordinate Analysis (PCO), Cluster Analysis (CA) and Canonical Vector Analysis (CVA).

3.14.1.1 Estimation of genotypic and phenotypic variances

Genotypic and phenotypic variances were estimated according to the formula given by Johnson *et al.* (1955).

$$\text{Genotypic variance } (\sigma^2_g) = \frac{GMS - EMS}{r}$$

Where,

GMS = Genotypic mean sum of squares

EMS = Error mean sum of square

r = number of replications

$$\text{Phenotypic variance } (\sigma^2_{ph}) = \sigma^2_g + EMS$$

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

3.14.1.2 Estimation of genotypic and phenotypic co-efficient of variation

Genotypic and phenotypic co-efficient of variation were calculated by the formula suggested by Burton (1952)

$$\text{Genotypic co-efficient of variation (GCV \%)} = \frac{\sqrt{\sigma^2 g}}{\bar{x}} \times 10$$

Where,

σ^2_g = Genotypic variance

$\bar{x}$ = Population mean

Similarly,

The phenotypic co-efficient of variation was calculated from the following formula.

$$\text{Phenotypic co-efficient variation (PCV)} = \frac{\sqrt{\sigma^2 ph}}{\bar{x}} \times 100$$

Where,

σ^2_{ph}= Phenotypic variance

$\bar{x}$ = Population mean

3.14.1.3 Estimation of heritability

Broad sense heritability was estimated (Lush, 1943) by the following formula, suggested by Johnson *et al.* (1955).

$$h^2_b\% = \frac{\sigma^2_g}{\sigma^2_{ph}} \times 100$$

Where,

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.14.1.4 Estimation of genetic advance

The expected genetic advance for different characters under selection was estimated using the formula suggested by Lush (1943) and Johnson *et al.* (1955).

Genetic advance (GA) = $K. h^2. \sigma_{ph}$

$$GA = K.\frac{\sigma^2_g}{\sigma^2_{ph}}.\sigma_{ph}$$

Where,

K = Selection intensity, the value which is 2.06 at 5% selection intensity

σ_{ph} = Phenotypic standard deviation

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.14.1.5 Estimation of genetic advance mean's percentage

Genetic advance as percentage of mean was calculated from the following formula as proposed by Comstock and Robinson (1952):

$$\text{Genetic advance (\% of mean)} = \frac{\text{Genetic Advance (GA)}}{\text{Population mean } (\bar{x})} \text{ X } 100$$

3.14.1.6 Estimation of simple correlation co-efficient:

Simple correlation co-efficients (r) was estimated with the following formula (Clarke, 1973; Singh and Chaudhary, 1985).

$$r = \frac{\sum xy - \frac{\sum x . \sum y}{N}}{\sqrt{\left[\{\sum x2 - \frac{(\sum x)2}{N}\}\{\sum y2 - \frac{(\sum y)2}{N}\}\right]}}$$

Where, $\sum$ = Summation

x and y are the two variables correlated

N = Number of observations

3.14.1.7 Estimation of genotypic and phenotypic correlation co-efficient

For calculating the genotypic and phenotypic correlation co-efficient for all possible combinations the formula suggested by Miller *et al.* (1958), Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted.

The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

$$\text{Genotypic correlation } (r_{gxy}) = \frac{GCOVxy}{\sqrt{GVx.GVy}} = \frac{\sigma_{gxy}}{\sqrt{(\sigma^2_{gx} . \sigma^2_{gy})}}$$

Where,

σ_{gxy} = Genotypic co-variance between the traits x and y

σ^2_{gx} = Genotypic variance of the trait x

σ^2_{gy} = Genotypic variance of the trait y

$$\text{Phenotypic correlation } (r_{pxy}) = \frac{PCOVxy}{\sqrt{PVx.PVy}} = \frac{\sigma_{pxy}}{\sqrt{(\sigma^2_{px} . \sigma^2_{py})}}$$

Where,

σ_{pxy} = Phenotypic covariance between the traits x and y

σ^2_{px} = Phenotypic variance of the trait x

σ^2_{py} = Phenotypic variance of the trait y

3.14.1.8 Estimation of path co-efficient

Path coefficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using phenotypic correlation coefficient values. In path analysis, correlation coefficients between yield and yield contributing characters were partitioned into direct and indirect effects of

yield contributing characters on grain yield per hectare. In order to estimate direct and indirect effects of the correlated characters, i. e. 1, 2, 3.....and 13 on yield y, a set of simultaneous equations (eight equations in this example) is required to be formulated as shown below:

$$r_{1.y} = P_{1.y} + r_{1.2}P_{2.y} + r_{1.3}P_{3.y} + r_{1.4}P_{4.y} + r_{1.5}P_{5.y} + r_{1.6}P_{6.y} + r_{1.7}P_{7.y} + r_{1.8}P_{8.y} + r_{1.9}P_{9.y} + r_{1.1}P_{10.y} + r_{1.11}P_{11.y} + r_{1.12}P_{12.y} + r_{1.13}P_{13.y}$$

$$r_{2.y} = r_{1.2}P_{1.y} + P_{2.y} + r_{2.3}P_{3.y} + r_{2.4}P_{4.y} + r_{2.5}P_{5.y} + r_{2.6}P_{6.y} + r_{2.7}P_{7.y} + r_{2.8}P_{8.y} + r_{2.9}P_{9.y} + r_{2.10}P_{10.y} + r_{2.11}P_{11.y} + r_{2.12}P_{12.y} + r_{2.13}P_{13.y}$$

$$r_{3.y} = r_{1.3}P_{1.y} + r_{2.3}P_{2.y} + P_{3.y} + r_{3.4}P_{4.y} + r_{3.5}P_{5.y} + r_{3.6}P_{6.y} + r_{3.7}P_{7.y} + r_{3.8}P_{8.y} + r_{3.9}P_{9.y} + r_{3.10}P_{10.y} + r_{3.11}P_{11.y} + r_{3.12}P_{12.y} + r_{3.13}P_{13.y}$$

$$r_{4.y} = r_{1.4}P_{1.y} + r_{2.4}P_{2.y} + r_{3.4}P_{3.y} + P_{4.y} + r4_{1.5}P_{5.y} + r_{4.6}P_{6.y} + r_{4.7}P_{7.y} + r_{4.8}P_{8.y} + r_{4.9}P_{9.y} + r_{4.10}P_{10.y} + r_{4.11}P_{11.y} + r_{4.12}P_{12.y} + r_{4.13}P_{13.y}$$

$$r_{5.y} = r_{1.5}P_{1.y} + r_{2.5}P_{2.y} + r_{3.5}P_{3.y} + r_{4.5}P_{4.y} + P_{5.y} + r_{5.6}P_{6.y} + r_{5.7}P_{7.y} + r_{5.8}P_{8.y} + r_{5.9}P_{9.y} + r_{5.10}P_{10.y} + r_{5.11}P_{11.y} + r_{5.12}P_{12.y} + r_{5.13}P_{13.y}$$

$$r_{6.y} = r_{1.6}P_{1.y} + r_{2.6}P_{2.y} + r_{3.6}P_{3.y} + r_{4.6}P_{4.y} + r_{5.6}P_{5.y} + P_{6.y} + r_{6.7}P_{7.y} + r_{6.8}P_{8.y} + r_{6.9}P_{9.y} + r_{6.10}P_{10.y} + r_{6.11}P_{11.y} + r_{6.12}P_{12.y} + r_{6.13}P_{13.y}$$

$$r_{7.y} = r_{1.7}P1.y + r_{2.7}P_{2.y} + r_{3.7}P_{3.y} + r_{4.7}P_{4.y} + r_{5.7}P_{5.y} + r_{6.7}P_{6.y} + P_{7.y} + r_{7.8}P_{8.y} + r_{7.9}P_{9.y} + r_{7.10}P_{10.y} + r_{7.11}P_{11.y} + r_{7.12}P_{12.y} + r_{7.13}P_{13.y}$$

$$r_{8.y} = r_{1.8}P_{1.y} + r_{2.8}P_{2.y} + r_{3.8}P_{3.y} + r_{4.8}P_{4.y} + r_{5.8}P_{5.y} + r_{6.8}P_{6.y} + r_{7.8}P_{7.y} + P_{8.y} + r_{8.9}P_{9.y} + r_{8.10}P_{10.y} + r_{8.11}P_{11.y} + r_{8.12}P_{12.y} + r_{8.13}P_{13.y}$$

$$r_{9.y} = r_{1.9}P_{1.y} + r_{2.9}P_{2.y} + r_{3.9}P_{3.y} + r_{4.9}P_{4.y} + r_{5.9}P_{5.y} + r_{6.9}P_{6.y} + r_{7.9}P_{7.y} + r_{8.9}P_{8.y} + P_{9.y} + r_{9.10}P_{10.y} + r_{9.11}P_{11.y} + r_{9.12}P_{12.y} + r_{9.13}P_{13.y}$$

$$r_{10.y} = r_{1.10}P_{1.y} + r_{2.10}P_{2.y} + r_{3.10}P_{3.y} + r_{4.10}P_{4.y} + r_{5.10}P_{5.y} + r_{6.10}P_{6.y} + r_{7.10}P_{7.y} + r_{8.10}P_{8.y} + r_{9.10}P_{9.y} + P_{10.y} + r_{10.11}P_{11.y} + r_{10.12}P_{12.y} + r_{10.13}P_{13.y}$$

$$r_{11.y} = r_{1.11}P_{1.y} + r_{2.11}P_{2.y} + r_{3.11}P_{3.y} + r_{4.11}P_{4.y} + r_{5.11}P_{5.y} + r_{6.11}P_{6.y} + r_{7.11}P_{7.y} + r_{8.11}P_{8.y} + r_{9.11}P_{9.y} + r_{10.11}P_{10.y} + P_{11.y} + r_{11.12}P_{12.y} + r_{11.13}P_{13.y}$$

$$r_{12.y} = r_{1.12}P_{1.y} + r_{2.12}P_{2.y} + r_{3.12}P_{3.y} + r_{4.12}P_{4.y} + r_{5.12}P_{5.y} + r_{6.12}P_{6.y} + r_{7.12}P_{7.y} + r_{8.12}P_{8.y} + r_{9.12}P_{9.y} + r_{10.12}P_{10.y} + r_{11.12}P_{11.y} + P_{12.y} + r_{12.13}P_{13.y}$$

$$r_{13.y} = r_{1.13}P_{1.y} + r_{2.13}P_{2.y} + r_{3.13}P_{3.y} + r_{4.13}P_{4.y} + r_{5.13}P_{5.y} + r_{6.13}P_{6.y} + r_{7.13}P_{7.y} + r_{8.13}P_{8.y} + r_{9.13}P_{9.y} + r_{10.13}P_{10.y} + r_{11.13}P_{11.y} + r_{11.12}P_{12.y} + P_{13.y}$$

Where,

r_{iy} = Genotypic correlation coefficients between y and I th character (y = Grain yield)

P_{iy} = Path coefficient due to i th character (i= 1, 2, 3,……..,13)

1 = Days to first flowering

2 = Days to first fruit setting

3 = Plant Height

4 = Fruit diameter (cm)

5 = Pericarp thickness (cm)

6 = Number of locules per fruit

7 = Number of branches per plant

8 = Number of clusters per plant

9 = Number of fruit per cluster

10 = Number of fruit per plant

11 = Fruit weight (gm)

12 = Self life of fruits

13 = Fruit yield per plant (kg)

Total correlation, say between 1 and y i. e., r_{1y} is thus partitioned as follows:

$P_{1.y}$ = the direct effect of 1 on y

$r_{1.2} P_{2.y}$ = indirect effect of 1 via 2 on y

$r_{1.3} P_{3.y}$ = indirect effect of 1 via 3 on y

$r_{1.4} P_{4.y}$ = indirect effect of 1 via 4 on y

$r_{1.5} P_{5.y}$ = indirect effect of 1 via 5 on y

$r_{1.6} P_{6.y}$ = indirect effect of 1 via 6 on y

$r_{1.7} P_{7.y}$ = indirect effect of 1 via 7 on y

$r_{1.8} P_{8.y}$ = indirect effect of 1 via 8 on y

$r_{1.9} P_{9.y}$ = indirect effect of 1 via 9 on y

$r_{1.10} P_{10.y}$ = indirect effect of 1 via 10 on y

$r_{1.11} P_{11.y}$ = indirect effect of 1 via 11 on y

$r_{1.12} P_{12.y}$ = indirect effect of 1 via 12 on y

Where,

$P_{1.y}$, $P_{2.y}$, $P_{3.y}$..... $P_{8.y}$ = Path coefficient of the independent variables 1, 2, 3,.....,12 on the dependent variable y, respectively.

$r_{1.y}, r_{2.y}, r_{3.y}, \ldots\ldots\ldots\ldots, r_{12.y}$ = Correlation coefficient of 1, 2, 3, ..., 12 with y, respectively.

After calculating the direct and indirect effect of the characters, residual effect (R) was calculated by using the formula given below (Singh and Chaudhary, 1985)

$P^2_{RY} = 1 - (r_{1.y}P_{1.y} + r_{2.y}P_{2.y} + \ldots\ldots\ldots\ldots\ldots + r_{12.y}P_{12.y})$

Where,

$P^2_{RY} = R^2$

And hence residual effect, $R = (P^2_{RY})^{1/2}$

$P_{1.y}$ = Direct effect of the i th character on yield y.

$r_{1.y}$ = Correlation of the i th character with yield y.

3.14.2 Multivariate analysis

The genetic diversity among the genotypes was assessed by Mahalanobis's (1936) general distance (D^2) statistic and its auxiliary analyses. The parents selection in hybridization programme based on Mahalanobis's D^2 statistic is more reliable as requisite knowledge of parents in respect of a mass of characteristics is available prior to crossing. Rao (1952) suggested that the quantification of genetic diversity through biometrical procedures had made it possible to choose genetically diverse parents for a hybridization programme. Multivariate analysis viz. Principal Component analysis, Principal Coordinate analysis, Cluster analysis and Canonical Vector analysis (CVA), which quantify the differences among several quantitative traits, are efficient method of evaluating genetic diversity. These are as follows:

3.14.2.1 Principal Component analysis (PCA)

Principal Component analysis, one of the multivariate techniques, is used to examine the inter-relationships among several characters and can be done from the sum of squares and products matrix for the characters. Thus, PCA finds linear combinations of a set variate that maximize the variation contained within them, thereby displaying most of the original variability in a smaller number of dimensions. Therefore, Principles components were computed from the correlation matrix and genotypes scores obtained for first components (which has the property of accounting for

maximum variance) and succeeding components with latent roots greater than unity. Contribution of the different morphological characters towards divergence is discussed from the latent vectors of the first two principal components.

3.14.2.2 Principal Coordinate analysis (PCA)

Principal Coordinate analysis is equivalent to PCA but it is used to calculate inter unit distances. Through the use of all dimension of p it gives the minimum distance between each pair of the n points using similarity matrix (Digby *et al.,* 1989).

3.14.2.3 Cluster analysis (CA)

Cluster analysis divides the genotypes of a data set into some number of mutually exclusive groups. Clustering was done using non-hierarchical classification. In Genstat, the algorithm is used to search for optimal values of chosen criterion proceeds as follows. Starting from some initial classification of the genotypes into required number of groups, the algorithm repeatedly transferred genotypes from one group to another so long as such transfer improved the value of the criterion. When no further transfer can be found to improve the criterion, the algorithm switches to a second stage which examines the effect of swooping two genotypes of different classes and so on.

3.14.2.4 Canonical Vector analysis (CVA)

Canonical vector analysis (CVA) finds linear combination of original variabilities that maximize the ratio of between group to within group variation, thereby giving functions of the original variables that can be used to discriminate between the groups. Thus, in this analysis a series of orthogonal transformations sequentially maximizing of the ratio of among groups to the within group variations. The canonical vector are based upon the roots and vectors of WB, where W is the pooled within groups covariance matrix and B is the among groups covariance matrix.

3.14.2.5 Calculation of D^2 values

The Mahalanobis's distance (D^2) values were calculated from transformed uncorrelated means of characters according to Rao (1952), and Singh and Chaudhury (1985). The D^2 values were estimated for all possible combinations between genotypes. In simpler form D^2 statistic is defined by the formula

$$D^2 = \sum_{i}^{x} d_i^2 = \sum_{i}^{x} (Y_i^j - Y_j^k) \qquad (j \neq k)$$

Where,

Y = Uncorrelated variable (character) which varies from i = 1 ------to x

x = Number of characters.

Superscript j and k to Y = A pair of any two genotypes.

3.14.2.6 Computation of average intra-cluster distances

Average intra-cluster distances were calculated by the following formula as suggested by Singh and Chuadhury (1985).

$$\text{Average intra-cluster distance} = \frac{\sum D_i^2}{n}$$

Where,

D_i^2 = the sum of distances between all possible combinations (n) of genotypes included in a cluster.

n = Number of all possible combinations between the populations in cluster.

3.14.2.7 Computation of average inter-cluster distances

Average inter-cluster distances were calculated by the following formula as suggested by Singh and Chuadhury (1985).

$$\text{Average inter-cluster distance} = \frac{\sum D_{ij}^2}{n_i \times n_j}$$

Where,

$\sum D_{ij}^2$ = The sum of distances between all possible combinations of the populations in cluster i and j.

n_i = Number of populations in cluster i.

n_j = Number of populations in cluster j.

3.14.2.8 Cluster diagram

Using the values of intra and inter-cluster distances ($D = \sqrt{D^2}$), a cluster diagram was drawn as suggested by Singh and Chuadhury (1985). It gives a brief idea of the pattern of diversity among the genotypes included in a cluster.

3.14.2.9 Selection of varieties for future hybridization programme

Divergence analysis is usually performed to identify the diverse genotypes for hybridization purposes. The genotypes grouped together are less divergent among themselves than those, which fall into different clusters. Clusters separated by largest statistical distance (D^2) express the maximum divergence among the genotypes included into these different clusters. Variety (s) or line(s) were selected for efficient hybridization programme according to Singh and Chuadhury (1985). According to them the following points should be considered while selecting genotypes for hybridization programme:

1. Choice of cluster from which genotypes are selected for use as parent (s)
2. Selection of particular genotype(s) from the selected cluster(s)
3. Relative contribution of the characters to the total divergence
4. Other important characters of the genotypes performance

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The results obtained from the study are presented and discussed in this chapter. The data pertaining to twenty nine tomato genotypes as well as yield and its contributing characters were computed and statistically analyzed and the result of the present investigation of genetic variability, correlation co-efficient and path analysis in tomato (*Lycopersicon esculentum* Mill.) carried out during *Rabi* 2011-12 are presented in the following sections.

4.1 Genetic parameters

4.2 Correlation co-efficient

4.3 Path co-efficient analysis

4.4 Multivariate analysis

4.1 Genetic parameters

The mean sum of square, mean, range, variance components, coefficients of genotypic and phenotypic variations, heritability estimates, genetic advance and genetic advance in percent of mean (GAPM) are presented in Table 3.

The results are discussed character wise as follows:

4.1.1 Days to first flowering

Mean sum of square for days to first flowering was significant (36.47) in tomato indicating existence of considerable variation for this trait (Table 3). The mean performance of mean value indicated that the maximum duration to first flowering was found 69.67 DAS in BD-7291 while the minimum was recorded 57.00 DAS in Unnayan with mean value 63.10 DAS (Appendix VI). The genotypic variance and phenotypic variance for this trait were 10.70 and 15.07 respectively.

Table 3. Estimation of genetic parameters in thirteen characters of twenty nine genotypes in tomato

Parameters	Range	Mean	MS	$\sigma^2 p$	$\sigma^2 g$	$\sigma^2 e$	PCV	GCV	ECV	h^2_b	GA (5%)	GAPM
DFF	57.00-69.67	63.10	36.47**	15.07	10.70	4.36	6.15	5.18	3.31	71.04	5.68	9.00
DFFS	73.00-83.67	78.61	17.35**	10.35	3.51	6.84	4.09	2.38	3.33	33.89	2.25	2.86
PH	55.00-102.00	76.10	442.36**	233.27	104.55	128.2	20.07	13.44	14.91	44.82	14.10	18.53
FD	3.10-5.57	4.17	1.09**	0.53	0.28	0.25	17.46	12.74	11.94	53.21	0.80	19.16
PT	0.27-0.63	0.45	0.03**	0.02	0.01	0.01	31.17	19.40	24.40	38.73	0.11	25.03
LPF	2.00-5.00	2.90	1.43**	0.92	0.25	0.67	33.18	17.39	28.26	27.47	0.54	18.75
BPP	6.00-10.00	8.06	2.93**	1.90	0.51	1.39	17.13	8.89	14.64	26.92	0.77	9.50
CPP	8.67-19.33	14.23	27.62**	13.04	7.29	5.75	25.38	18.97	16.85	55.90	4.16	29.22
FPC	2.33-5.33	3.66	1.34*	0.99	0.18	0.81	27.17	11.59	24.57	18.19	0.37	10.17
FPP	29.67-78.33	50.92	435.06**	165.29	134.88	30.41	25.25	22.81	10.83	81.60	21.61	42.44
FW	8.33-46.67	23.28	292.00**	105.66	93.17	12.49	44.16	41.47	15.18	88.18	18.67	80.21
SLF	6.33-9.33	8.01	2.27**	1.01	0.63	0.38	12.56	9.91	7.72	62.20	1.29	16.10
FYP	0.35-2.05	1.13	0.60**	0.23	0.19	0.05	42.91	38.40	19.15	80.08	0.80	70.51

Here, **, * Correlation is significant at the 0.01 and 0.05 level, respectively, DFF = Days of first flowering, DFFS = Days of first fruit setting, PH = Plant height (cm), FD = Fruit Diameter (cm), PT = Pericarp thickness (cm), LPF = Number of locules per fruit, BPP = Number of branches per plant, CPP = Number of clusters per plant, FPC = Number of fruits per cluster, FPP = Number of fruits per plant, FW = Fruit weight (g), SLF = Shelf life of fruits, FYP = Fruit yield per plant (kg), MS = mean sum of square, $\sigma^2 p$ = Phenotypic variance, $\sigma^2 g$ = Genotypic variance and $\sigma^2 e$ = Environmental variance ,GA= Genetic advance and GAPM= Genetic advance in percent of mean.

The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this trait. The difference between the genotypic co-efficient of variation (5.18) and phenotypic co-efficient of variation (6.15) indicated presence of considerable variability among the genotypes for this trait. The heritability (71.04 %) estimates for this trait was high, genetic advance (5.68) and genetic advance over percentage of mean (9.00) were found low (Table 3), indicated that this trait was controlled by non-additive gene. Such values of GCV were also observed by Singh *et al.* (1973) and Korla *et al.* (1998). Patil (1996) also found similar result in tomato. Genetic advances as per cent of mean was low which is in accordance with the findings Singh *et al.* (1973). Genotypic and phenotypic variability in tomato are showing in figure 1; Heritability and genetic advance over mean in tomato are showing in figure 2.

4.1.2 Days to first fruit setting

Significant mean sum of square for days to first fruit setting (36.47) in tomato indicated considerable difference among the genotypes studied (Table 3). The maximum duration to first fruit setting was found 83.67 DAS in 'BARI Tomato-3' and the minimum was recorded 73.00 DAS in 'BD-7306' with mean value 73.00 DA(Table 3). The genotypic variance and phenotypic variance for this trait were 3.51 and 10.35 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this trait. The genotypic co-efficient of variation (2.38) and phenotypic co-efficient of variation (4.09) were close to each other (Table 3). There was a very little difference between phenotypic and genotypic co-efficient of variation, indicating minor environmental influence on this character. The heritability (33.89%) estimates for this trait was moderate , genetic advance (2.25) and genetic advance in per cent of mean (2.86) were found low (Table 3), indicated that this trait was controlled by non-additive gene. Low genotypic and phenotypic coefficient of variability for days to first fruit setting were also observed by Singh *et al.* (1973) and Prasad and Prasad (1976). High heritability coupled with low genetic advance for days to 50 per cent was also observed by Singh *et al.* (1973) and Kumar *et al.* (1980).

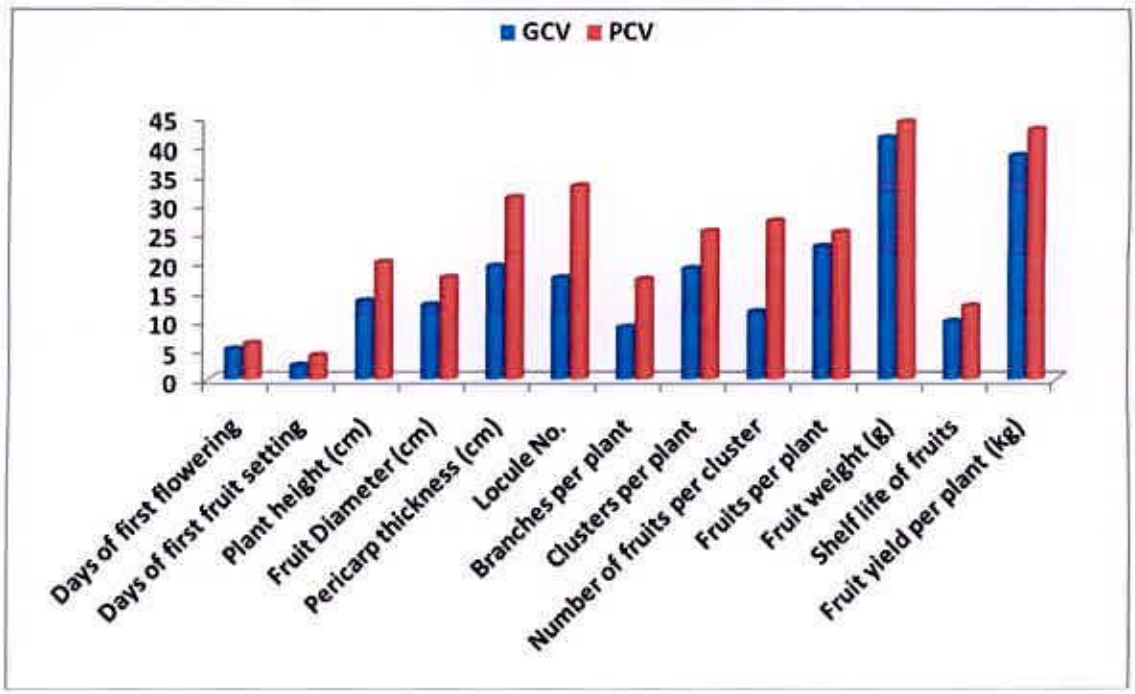


Fig 1. Genotypic and phenotypic variability in tomato

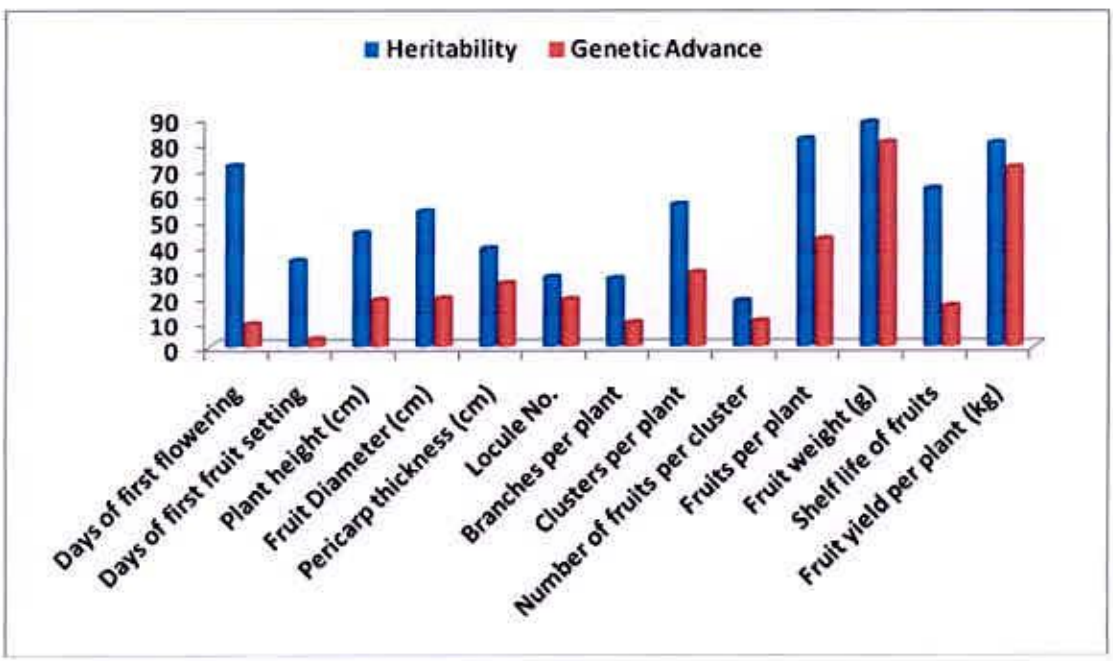


Fig 2. Heritability and genetic advance over mean in tomato

4.1.3 Plant height (cm)

Mean sum of square for plant height was significant (442.36) in tomato indicating existence of considerable variation for this trait (Table 3). The maximum plant height was found 102.00 cm by the genotype 'BARI Hybrid Tomato-11' and the lowest plant height was recorded 55.00 cm by 'BD-776' with mean value 76.10 (Table 3). Highest genotypic and phenotypic variance was observed 104.55 and 233.27 respectively for plant height with large environmental influence. The phenotypic co-efficient of variation (20.07) was higher than the genotypic co-efficient of variation (13.44), which indicated presence of considerable variability among the genotypes for this trait. The heritability (44.82 %) estimates for this trait was high, genetic advance (14.10) and genetic advance in per cent of mean (18.53) were found high (Table 3), revealed that this trait was governed by additive gene. In the present study, the genotypic and phenotypic co-efficient of variation were moderate for plant height. Similar observations were made by Mariane *et al.* (2003). Singh *et al.* (2002) showed that the phenotypic coefficient of variation was greatest for this character. Plant height exhibited high heritability and genetic advance as per cent mean which is similar to the earlier findings by Kumari *et al.* (2007), Singh *et al.* (2006) and Joshi *et al.* (2003).

4.1.4 Fruit diameter (cm)

Mean sum of square for fruit diameter was significant (1.09) in tomato indicating existence of considerable variation for this trait (Table 3). The maximum fruit diameter was found 5.57 cm in 'BARI Tomato-3' and the minimum was recorded 3.10 cm in 'BD-3.10'with mean value 4.17 cm (Table 3). The genotypic variance and phenotypic variance for this trait were 0.28 and 0.53 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation (12.74) and phenotypic co-efficient of variation (17.46) were close to each other (Table 3), indicating minor environmental influence on this character. Therefore selection based upon phenotypic expression of this character would be effective for the improvement of this crop. The heritability (53.21%) estimates for this trait was very high, genetic advance (0.80) was low and genetic advance in per cent of mean (19.16) was moderately high (Table 3), revealed that this character was governed by non-additive gene. Singh *et al.* (2002) also observed that the PCV was

greatest for this character. High heritability coupled with low genetic advance for this character was also observed by Pandit *et al.* (2010).

4.1.5 Pericarp thickness (cm)

Mean sum of square for pericarp thickness was significant (0.03) in tomato indicating existence of considerable variation for this trait (Table 3). The mean Pericarp thickness of fruit noticed was 0.45 cm with a range of 0.27 cm to 0.63 cm. The line 'BD-7286'and 'BD-7281' showed the minimum Pericarp thickness and the maximum Pericarp thickness was recorded in the line 'BD-7301'(Table 3). The values of 31.17 and 19.40 are noticed for PCV and GCV, respectively (Table 3). There was high difference between phenotypic and genotypic co-efficient of variation, indicating high environmental influence on this character. Therefore selection based upon phenotypic expression of this character would be effective for the improvement of this crop. The moderate heritability estimate was 38.73 per cent with high genetic advance over mean of 25.03 per cent could be noted (Table 3).

Padda *et al.* (1971) evaluated 56 tomato varieties at Summer season and observe that Pericarp thickness of fruits mean was 4.64mm, range was 2.90 to 6.66mm.He also reported that genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 18.1, 79.70 and 33.40 respectively.

Bhutani *et al.* (1983) evaluated 84 tomato genotypes at Summer season and observe that Pericarp thickness of fruits mean was 0.407 cm, range was .256 to 0.708 cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 24.56, 21.97, 82.01 and 100.74 respectively.

Pujari *et al.* (1995) evaluated 108 tomato genotypes at *kharif* season and observe that Pericarp thickness of fruits mean was 0.47 cm, range was 0.20 to 0.75 cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean (GAM) were 4.04, 2.55, 63.16 and 38.16 respectively.

Plate 5a. Variation observed for number of locules per fruit, fruit diameter and pericarp thickness in 29 tomato genotypes(G_1-G_{15})

Plate 5b. Variation observed for number of locules per fruit, fruit diameter and pericarp thickness in 29 tomato genotypes(G_{16}-G_{24})

Plate 5c.Variation observed for number of locules per fruit, fruit diameter and pericarp thickness in 29 tomato genotypes(G_{25}-G_{30})

4.1.6 Number of locules per fruit

Mean sum of square for number of locules per fruit was significant (1.43) in tomato indicating existence of considerable variation for this trait (Table 3). The maximum number of locules per fruit was found 5.00 in 'PUSA Rubi' and minimum was recorded 2.00 in 'BD-7279' with mean value 2.90 (Table 3). The genotypic variance and phenotypic variance for this trait were 0.25 and 0.92 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation (17.39) and phenotypic co-efficient of variation (33.18) were close to each other (Table 3). The heritability (27.47 %) estimates for this trait was moderate, genetic advance (0.54) and genetic advance in per cent of mean (18.75) were found moderately high (Table 3), indicated that this trait was controlled by additive gene and selection for this character would be effective. Similar PCV and GCV was also observed by Singh *et al.* (2002). High heritability coupled with high genetic advance was also obtained by Singh *et al.* (2002) and Kumar *et al.* (1980).

4.1.7 Number of branches per plant

Significant mean sum of square for number of branches per plant (2.93) in tomato indicated considerable difference among the genotypes studied (Table 3). The maximum number of branches was found 10.00 in 'BARI Hybrid Tomato-4' and the minimum was recorded 6.00 in 'BARI Tomato-3' with mean value 8.06 (Table 3).

The phenotypic variance (1.90) appeared to be higher than the genotypic variance (0.51) suggested considerable influence of environment on the expression of the genes controlling this trait. The genotypic co-efficient of variation and phenotypic co-efficient of variation were 17.13 and 8.89 respectively (Table 3) which indicated presence of considerable variability among the genotypes. The heritability (26.92 %) estimates for this trait was moderately high, genetic advance (0.77) was low and genetic advance in per cent of mean (9.50) were found moderately high (Table 3), revealed that this trait was governed by non-additive gene. Singh *et al.* (2002) also showed that the PCV was higher than GCV for number of primary branches per plant. Moderate heritability and low genetic advance for this character was also observed by Kumar *et al.* (2004).

4.1.8 Number of clusters per plant

Mean sum of square for number of clusters per plant was significant (27.62) in tomato indicating existence of considerable variation for this trait (Table 3). The maximum number of clusters per plant was found 19.33 in 'BD-7260' and minimum was recorded 8.67 in 'BARI Tomato-11' with mean value 14.23 (Table 3). The genotypic variance and phenotypic variance for this trait were 7.29 and 13.04 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic co-efficient of variation (18.97) and phenotypic co-efficient of variation (25.38) were close to each other (Table 3). The heritability (55.90%) estimates for this trait was high, genetic advance (4.16) and genetic advance in per cent of mean (29.22) were found moderately high (Table 3), indicated that this trait was controlled by additive gene and selection for this character would be effective. Similar PCV and GCV was also observed by Singh *et al.* (2002). High heritability coupled with high genetic advance was also obtained by Singh *et al.* (2002) and Kumar *et al.* (1980).

4.1.9 Number of fruits per cluster

Significant mean sum of square for number of fruits per plant (1.34) in tomato indicated considerable difference among the genotypes studied (Table 3). The maximum fruits per cluster were observed 5.33 in 'BARI Tomato-11' and the minimum was recorded 2.33 in 'BD-7306' with mean value 2.33 (Table 3). The genotypic variance and phenotypic variance for this trait were 0.18 and 0.99 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The genotypic coefficient of variation and phenotypic coefficient of variation for were 11.59 and 27.17 respectively (Table 3), which indicated presence of considerable variability among the genotypes for this trait. The heritability (18.19%) estimates for this trait was very high, genetic advance (0.37) was low and genetic advance in per cent of mean (10.17) was found very high (Table 3), revealed that this character was governed by additive gene and selection for this character would be effective. In the present study, GCV and PCV were high for number of fruits per cluster. These observations are in accordance with the findings of Singh *et al.* (2002). Moderate PCV and GCV were found by Aradhana and Singh (2003). Moderate heritability and moderate genetic gain for this character were also observed by Joshi *et al.* (2004).

4.1.10 Number of fruits per plant

Mean sum of square for number of fruits per plant was significant (435.06) in tomato indicating existence of considerable variation for this trait (Table 3). The maximum number of fruits per plant was found 78.33 in 'Bd-7260' and the minimum was recorded 29.67 in 'BD-7291' with mean value 50.92 (Table 3). The difference in magnitudes in between genotypic (134.88) and phenotypic (165.29) variances was relatively high for this trait indicating large environmental influence on this characters. The phenotypic coefficient of variation and genotypic coefficient of variation were 25.25 and 22.81 respectively (Table 3), which indicated presence of considerable variability among the genotypes. The heritability (81.60%) estimates for this trait was high, genetic advance (21.61) and genetic advance in per cent of mean (42.44) were found very high (Table 3), revealed that this character was governed by additive gene and selection for this character would be effective. Highest phenotypic coefficient of variation was observed by Singh *et al.* (2002) and highest phenotypic and genotypic coefficient of

variation was observed by Saeed *et al.* (2007) and Joshi *et al.* (2003). This character showed high heritability coupled with high genetic gain and the findings are in agreement with the observations of Ara *et al.* (2009) and Saeed *et al.* (2007).

4.1.11 Fruit weight (g)

Mean sum of square for fruit weight was significant (292.00) in tomato indicating existence of considerable variation for this trait (Table 3). The maximum fruit weight was recorded 46.67 g in 'BARI Tomato-3' and and minimum was recorded 8.33g in 'BD-7759' with mean value 23.28g (Table 3). The genotypic variance and phenotypic variance for this trait were 93.17 and 105.66 respectively indicating large environmental influence on this character. The genotypic co-efficient of variation (41.47) and phenotypic co-efficient of variation (44.16) were high and close to each other (Table 3) demonstrated that environment has little influence of the expression of this character (Table 3). Therefore selection based upon phenotypic expression of this character would be effective for the improvement of this crop. The heritability (88.18%) estimates for this trait was very high, genetic advance (18.67) and genetic advance in per cent of mean (80.21) were found very high (Table 3), revealed that this character was governed by additive gene and provide opportunity for selecting high valued genotypes for breeding programme. High GCV and PCV for average fruit weight were also noticed by Manivannan *et al.* (2005) and Singh *et al.* (2002).High heritability coupled with high genetic advance as percentage of mean for average fruit weight was observed by Pandit *et al.* (2010), Ara *et al.* (2009) and Singh *et al.* (2006).

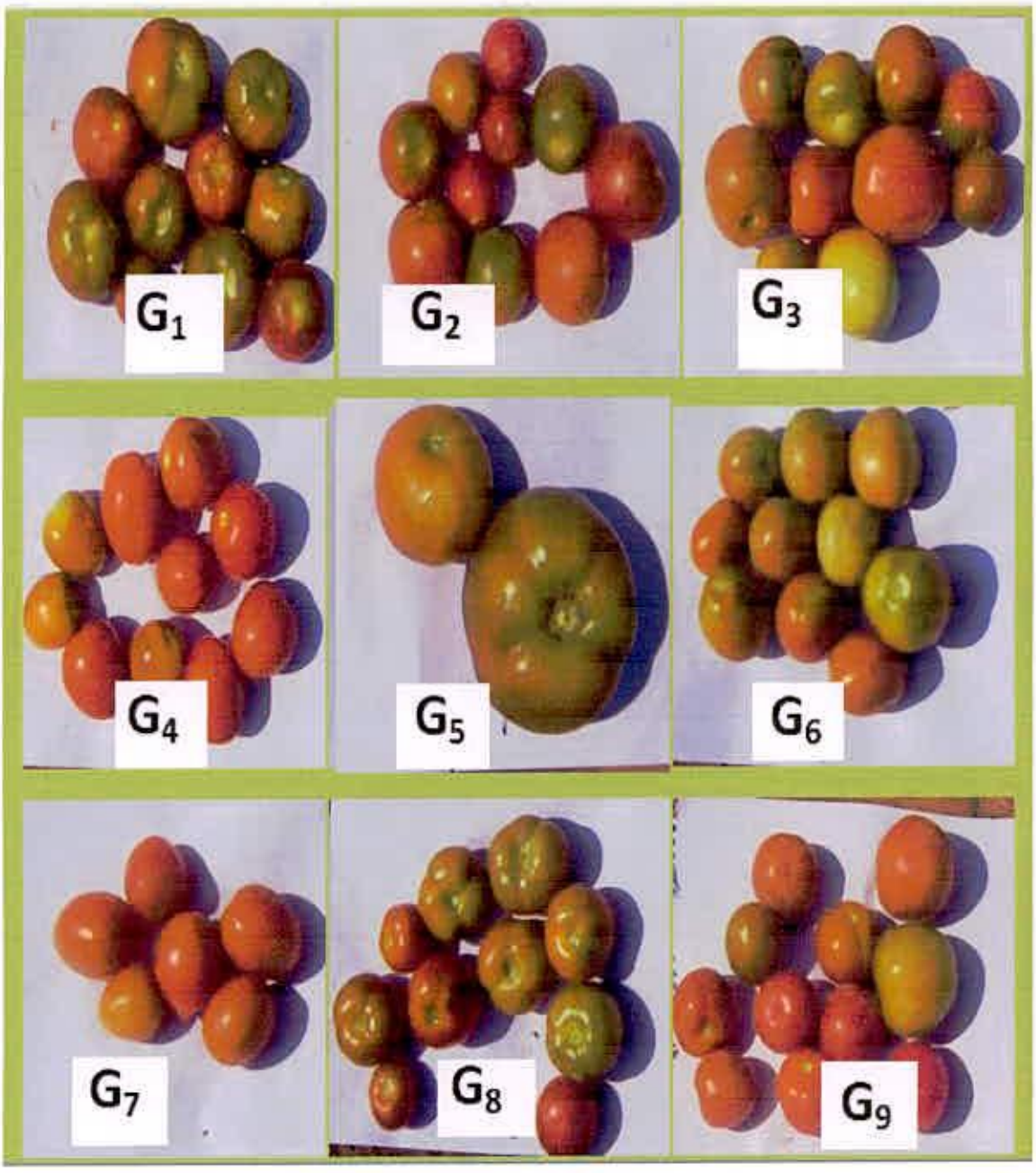


Plate 6a. Showing phenotypic variation in fruits among different genotypes of tomato(G_1-G_9)

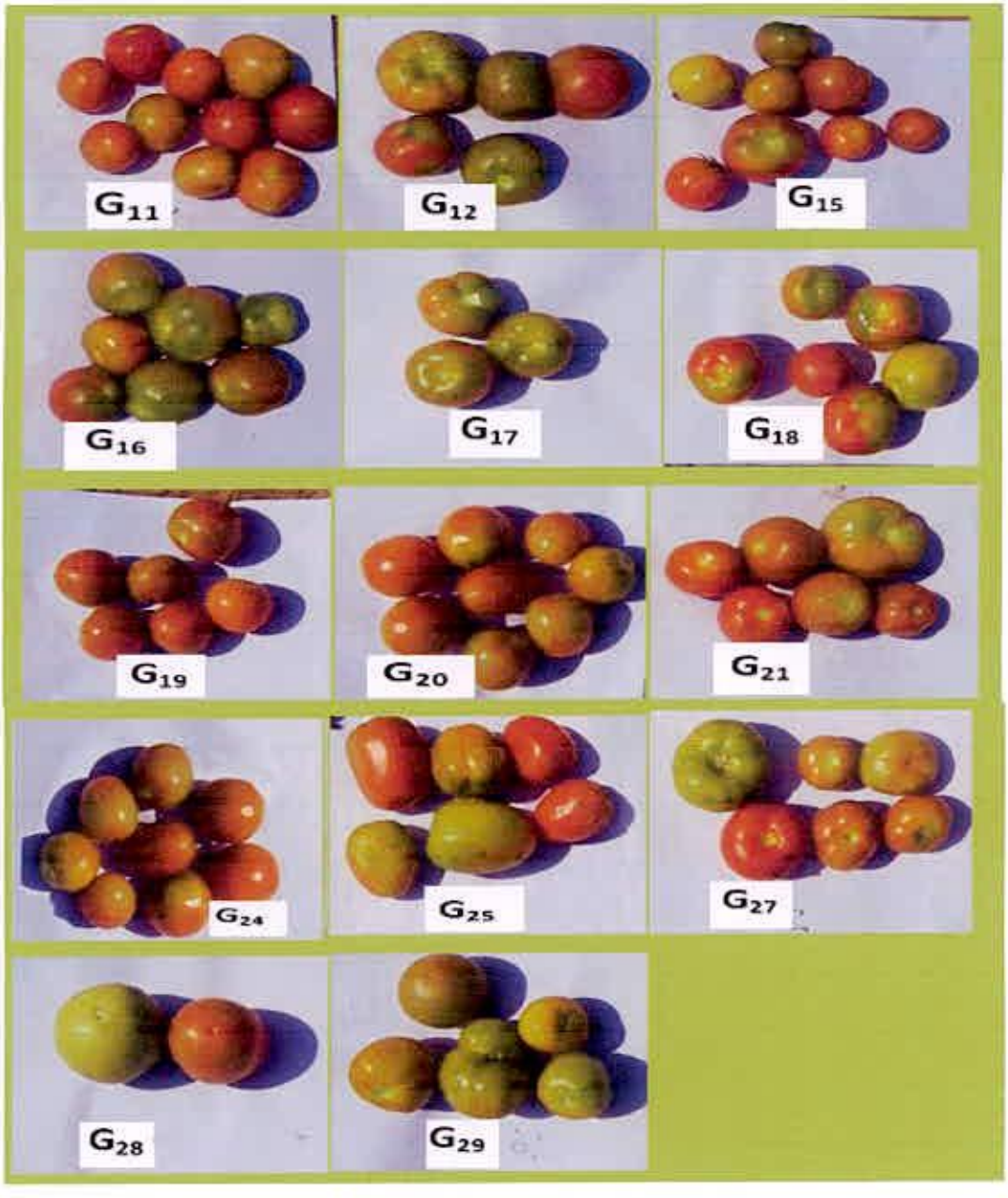


Plate 6b. Showing phenotypic variation in fruits among different genotypes of tomato (G_{11}-G_{29})

4.1.12 Self life of fruit (DAS)

Mean sum of square for self life of fruit was significant (2.27) in tomato indicating existence of considerable variation for this trait (Table 3).The mean self life of fruit noticed was 8.01 DAS with a range of 6.33 DAS to 9.33 DAS. The line 'BD-7291'and variety 'BARI Tomato-11' showed the minimum self life and the maximum self life was recorded in the line 'BD-7286'. The values of 12.56 and 9.91 are noticed for PCV and GCV, respectively (Table 3). There was minor difference between phenotypic and genotypic co-efficient of variation, indicating high environmental influence on this character. Therefore selection based upon phenotypic expression of this character would be effective for the improvement of this crop. The high heritability estimate was 62.20 per cent with low genetic advance over mean of 16.10 per cent could be noted.

4.1.13 Fruit yield per plant (kg)

Significant mean sum of square for fruit yield per plant (0.60) in tomato indicated considerable difference among the genotypes studied (Table 3). The maximum fruit yield per plant was found 2.05 kg in 'BARI Tomato-14' and the minimum was recorded 0.55 kg in 'BD-7292' with mean value 1.13 kg ((Table 3). The genotypic variance and phenotypic variance for this trait were 0.19 and 0.23 respectively. The phenotypic variance appeared to be higher than the genotypic variance suggested considerable influence of environment on the expression of the genes controlling this character. The phenotypic coefficient of variation and genotype coefficient of variation were 42.91 and 38.40 respectively for fruit yield per plant (Table 3), which indicating that significant variation exists among different genotypes. The heritability (80.08%) estimates for this trait was very high, genetic advance (0.80) was low and genetic advance in per cent of mean (70.51) was found very high (Table 3), revealed that this character was governed by additive gene and and provide opportunity for selecting high valued genotypes for breeding programme. This result was also similar with earlier reports of Singh *et al.* (2006) and Manivannan *et al.* (2005). High heritability and high genetic advance was also observed by Ara *et al.* (2009) and Anupam *et al.* (2002).

4.2 Correlation Co-efficient

Yield is a complex product being influenced by several interdependent quantitative characters. Selection for yield may not be effective unless the other yield components influencing it directly or indirectly are taken into consideration. When selection pressure is exercised for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated traits. Hence, knowledge regarding association of character with yield and among themselves provides guideline to the plant breeder for making improvement through selection provide a clear understanding about the contribution in respect of establishing the association by genetic and non genetic factors. Higher genotypic correlations than phenotypic one might be due to modifying or masking effect of environment in the expression of the character under study (Nandpuri *et al.* 1973). Results of genotypic and phenotypic correlation co-efficient of different genotypes yield and its contributing traits of tomato are shown in Table 4 and which discussed character wise as follows:

4.2.1 Days to first flowering:

Days to first flowering showed highly significant and positive correlation with days to first fruit setting (0.385 and 0.383), plant height (0.388 and 0.191) and number of branches per plant (0.675 and 0.226) at genotypic and phenotypic levels.Pericarp thickness (-0.319 and -0.122), number of locules per plant (-0.235 and -0.063), number of fruits per cluster (-0.535 and -0.164) and number of fruits per plant (-0.206 and -0.156) showed significant and negative association genotypic correlation coefficient with days first flowering and non significant and negative association at phenotypic correlation coefficient . It had a non significant and negative correlated with self life of fruits (-0.103 and – 0.035) both at the genotypic and phenotypic level. However, it showed non significant and positive association with other trait namely number of clusters per fruit (0.066 and 0.014) at both the genotypic and phenotypic level. A positive correlation between days to first flowering and plant height; days to first flowering and no. of branches per plant was observed by Patil and Brajappa (1993) and Mayavel *et al.* (2005). A positive correlation between days to first flowering and fruit yield per plant was observed by Patil and Bojappa (1993), Mayavel *et al.*(2005) and Samadia *et al.* (2006). Genotypic and phenotypic correlation co-efficient for eleven characters are showing in figure 3.

4.2.2 Days to first fruit setting:

The correlation of days to first fruit setting with number of clusters per plant (-0.516 and -0.189) was negative and highly significant at the genotypic and phenotypic levels. It had positive and non significant correlation with plant height (0.162 and 0.107), fruit diameter (0.098 and 0.126), number of locules per fruit (0.023 and 0.099), fruit weight (0.163 and 0.037) and fruit yield per plant (0.117 and 0.031) respectively at both the genotypic and phenotypic levels. It had negative and non significant correlation with number of branches per plant (-0.181 and -0.117) at both the the genotypic and phenotypic levels .However, pericarp thickness (-0.215 and -0.078), number of fruits per plant (-0.201 and -0.067) and self life of fruits (-0.212 and -0.099) showed negative correlation and significant at genotypic level, but non significant correlated at phenotypic level. A positive correlation between days to 50% flowering and fruit yield per plant was observed by Patil (1984), Shushila *et al.* (1990), Dhankhar and Dhankhar (2006) and Samadia *et al.*(2006). Days to 50% flowering should be considered for the enhancement of the yield of tomato was revealed by Nesgea *et al.* (2002). Yield improvement can be achieved by selection for days to 50% flowering was reported by Wagh *et al.* (2007).

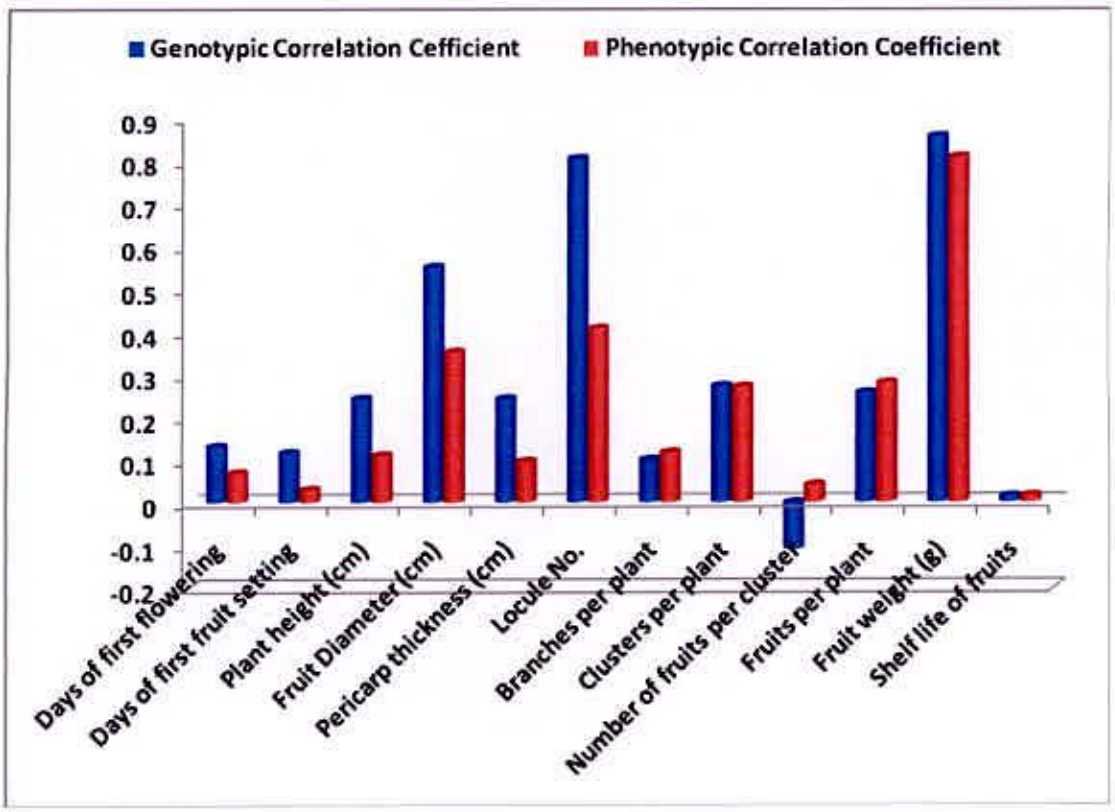


Fig 3. Genotypic and phenotypic correlation co-efficient for thirteen characters

4.2.3 Plant height:

Plant height had no significant and positive correlation with number of branches per plant (0.137 and 0.090) and number of clusters per plant (0.032 and 0.066) at both the levels. It also had no significant and negative correlation with number of fruits per plant (-0.037 and -0.031) at both the levels. Plant height had positive correlation number of locules per fruit (0.312 and 0.159), average fruit weight of fruit (0.215 and 0.123) and average fruit yield per plant (0.244 and 0.111) at both levels and this traits was significant at geneotypic correlation coefficient and non significant at phenotypic correlation coefficient level. It had highly significant association and negative correlation with pericarp thickness at both levels. It had no significant and positive correlation with number of fruits per cluster (0.106) and self life of fruit (0.055) at genotypic level and it had no significant and negative correlation with these traits at phenotypic level. However it had negative correlation with fruit diameter (-0.233 and -0.030) at both level, highly significant at genotypic level and non significant at phenotypic level. (Table 4). A negative correlation between plant height and fruit yield per plant was also observed by Dhankhar *et. al* (2006) and Mohanty (2003). Plant height was positively correlated with number of fruits per plant was observed by Singh (2005) and Mohanty (2002). Dhankhar *et. al* (2006) also observed that plant height was negatively correlated with fruit weight. Mohanty (2003) and Prashant (2003) also observed that plant height was positively correlated with number of branches per plant.

4.2.4 Fruit diameter:

Fruit diameter showed highly significant and positive correlation with pericarp thickness of fruit (0.757 and 0.671), number of locules per fruit (0.513 and 0.403), fruit weight (0.536 and 0.339) and fruit yield per plant (0.552 and 0.345 at both genotypic and phenotypic levels. It had no significant and negative correlation with number of fruits per plant (-0.088 and -0.050) and self life of fruit (-0.013 and - 0.068) at both levels. A significant positive correlation between fruit length and fruit diameter was found by Susic (2002). Kumar (2003), Joshi *et al.* (2004), Ara *et al.* (2009) observed that yield per plant was positively and significantly associated with fruit diameter. Joshi *et al.* (2004), Golani *et al.* (2007) observed that average fruit weight had significant and positive correlation with fruit diameter at both levels. Ara *et al.* (2009) revealed that fruit yield/plant exhibited high positive significant correlation with fruit diameter at both phenotypic as well as genotypic levels.

Table 4. Genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype of tomato

		DFFS	PH	FD	PT	LPF	BPP	CPP	FPC	FPP	FW	SLF	FYP
DFF	Rg	0.385**	0.388**	-0.006	-0.319**	-0.235**	0.675**	0.066	-0.535**	-0.206*	0.254**	-0.103	0.132
	Rp	0.383**	0.191*	0.037	-0.122	-0.063	0.226*	0.014	-0.164	-0.156	0.175	-0.035	0.070
DFFS	Rg		0.162	0.098	-0.215*	0.023	-0.181	-0.516**	0.336**	-0.201*	0.163	-0.212*	0.117
	Rp		0.107	0.126	-0.078	0.099	-0.117	-0.189*	0.011	-0.067	0.037	-0.099	0.031
PH	Rg			-.233**	-0.638**	0.312**	0.137	0.032	0.106	-0.037	0.215*	0.055	0.244**
	Rp			-0.030	-0.260**	0.159	0.090	0.066	-0.051	-0.031	0.123	-0.097	0.111
FD	Rg				0.757**	0.513**	-0.393**	-0.206*	0.386**	-0.088	0.536**	-0.013	0.552**
	Rp				0.671**	0.403**	-0.024	-0.068	0.148	-0.050	0.339**	-0.068	0.354**
PT	Rg					-0.096	-0.553**	-0.133	0.435**	0.032	0.118	-0.006	0.244**
	Rp					0.030	-0.094	-0.072	0.190*	0.050	0.047	-0.024	0.097
LPF	Rg						-0.179	-0.305**	0.313**	-0.118	0.843**	-0.199*	0.806**
	Rp						-0.104	0.024	0.056	-0.046	0.438**	-0.041	0.409**
BPP	Rg							0.081	-0.354**	-0.004	0.249**	0.051	0.101
	Rp							0.361**	-0.311**	0.100	0.125	-0.095	0.118
CPP	Rg								-0.567**	0.746**	-0.077	0.235**	0.274**
	Rp								-0.476**	0.620**	-0.048	0.081	0.272**
FPC	Rg									0.200*	-0.249**	-0.252**	-0.110
	Rp									0.231**	-0.146	-0.033	0.042
FPP	Rg										-0.240**	0.002	0.258**
	Rp										-0.241**	-0.031	0.281**
FW	Rg											-0.006	0.858**
	Rp											0.033	0.810**
SLF	Rg												0.015
	Rp												0.016

** = Significant at 1%. * = Significant at 5%. DFF = Days of first flowering, DFFS = Days of first fruit setting, PH = Plant height (cm), FD = Fruit Diameter (cm), PT = Pericarp thickness (cm), LPF = number of locules per fruit, BPP = Number of branches per plant, CPP = number of clusters per plant, FPC = Number of fruits per cluster, FPP = Fruits per plant, FW = Fruit weight (g), SLF = Shelf life of fruits, FYP = Fruit yield per plant (kg).

4.2.5 Pericarp thickness of fruit:

Pericarp thickness of fruit showed non significant and positive correlation with number of fruits per plant (0.032 and 0.032) and average fruit weight of fruit (0.118 and 0.047) at both the genotypic and phenotypic levels. It had highly significant and positive correlation with number of fruits per plant (0.435 and 0.190) at both levels .It showed non significant and negative correlation with number of fruits per cluster (-0.133 and -0.072) and self life of fruit (-0.006 and -0.024) at both levels. Pericarp thickness of fruit showed positive correlation and significant with average fruit yield per plant (0.244) at genotypic level. Padda *et al.* (1971) evaluated 56 tomato varieties at Summer season and observe that Pericarp thickness of fruits mean was 4.64mm, range was 2.90 to 6.66mm.He also reported that genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean(GAM) were 18.1, 79.70 and 33.40 respectively. Bhutani *et al.* (1983) evaluated 84 tomato genotypes at Summer season and observe that pericarp thickness of fruits mean was 0.407 cm, range was .256 to 0.708 cm..He also reported that the phenotypic coefficient of variance (PCV %), genotypic coefficient of variance (GCV %), heritability (h2 %) and genetic advance as per cent mean (GAM) were 24.56, 21.97, 82.01 and 100.74 respectively

4.2.6 Number of locules per fruit

Number of locules per fruit showed highly significant and positive correlation with average fruit weight of fruit (0.843 and 0.438) and average fruit yield per plant (0.806 and 0.409) at both levels. It showed non significant and negative correlation with number branches per plant (-0.179 and -0.104) and number of fruits per plant (-0.118 and -0.046) at both the genotypic and phenotypic levels. This traits had significant and negative correlation with number of clusters per plant (-0.305) and self life of fruit (-0.199) at the genotypic level.

4.2.7 Number of branches per plant:

The number of branches had positive and significant correlation with number of clusters per plant (0.081 and 0.361) at both genotypic and phenotypic levels. It also exhibited positive and moderately significant correlation with number of fruits per plant (0.354 and 0.311) at both genotypic and phenotypic levels. It had a positive and highly significant association with average fruit weight (0.249 and 0.125.) at both genotypic and phenotypic levels. It showed non significant association and positive correlation with average fruit yield per

plant (0.101 and 0.118) at both levels. Apart from number of branches per plant these related traits showed significant positive association among themselves. Hence, selection for any of these trait would improve the other traits. These results are in conformity with the findings of Anandagouda (1997) and Patil (1998). These results suggested that the number of branches can advantageously be used as criteria for selection. A strong association with number of branches with days to first flowering, days to 50 per cent flowering and plant height was noticed. It also had a significant negative association with fruit yield per plant indicated that the association between these traits is largely influenced by environmental factors. Mohanty (2002) also observed positive phenotypic and genotypic association with number of branches per plant and number of fruits per plant. But a negative correlation between the number of branches per plant and number of fruits per plant was noticed by Singh *et al.* (2004). A positive correlation between yield of fruits per plant and number of branches per plant was observed by Singh *et al.* (2006) and Ara *et al.* (2009).

4.2.8 Number of clusters per plant:

The number of clusters per plant had highly significant and positive association with number of fruit per plant (0.746 and 0.620) and average fruit yield per plant (0.274 and 0.272) at the genotypic and phenotypic levels. It also had a significant and positive association with self life of fruit (0.235 and 0.081) at genotypic level and non significant and positive association at phenotypic level. It had moderate significant and negative association with number of fruits per cluster (-0.567 and -0.476) at both at genotypic and phenotypic levels. It also exhibited moderately significant and negative association with average fruit weight of fruit (-0.077 and - 0.048) at both levels. A positive correlation between number of clusters per plant and fruit yield per plant was also observed by Prasanna *et al.* (2005). Nesgea *et al.* (2002) also found similar results for this trait in tomato.

4.2.9 Number of fruits per cluster:

The number of fruits per cluster showed significant and positive association with number of fruits per plant (0.200 and 0.231) both at genotypic and phenotypic levels. It had significant and negative association with fruit weight (-0.249) and self life of fruit (-0.252) at genotypic level. It also exhibited non significant and negative association with fruit yield per plant (-0.110) at the genotypic level and non significant association and positive correlation at the phenotypic level. The findings also supported Nesgea *et al.* (2002) and Megha *et al.* (2006) finding for this trait in tomato. Joshi *et al.* (2004) also observed that fruit weight was negatively correlated with number of fruits per cluster.

4.2.10 Number of fruits per plant:

The number of fruit per plant had highly significant and positive association with number of clusters per plant (0.746 and 0.620), number of fruits per cluster (0.200 and 0.231) and fruit yield per plant (0.258 and 0.281) respectively both at genotypic and phenotypic levels. It had non significant and negative association with plant height (-0.037 and -0.031), fruit diameter (-0.088 and -0.050) and number of locules per fruit (-0.118 and - 0.046) at both the levels. It also had non significant and positive association with pericarp thickness (0.032 and 0.050) genotypic and phenotypic levels. The number of fruit per plant had negative correlation and significant association with days to first flowering (-0.206) and days to first fruit setting (-0.201) at genotypic level. Joshi *et al.* (2004) showed that fruit weight was negatively correlated with the number of fruits per. Rani *et al.* (2010) also reported that the number of fruits per plant was negatively associated with yield per plant.

4.2.11 Fruit weight:

Fruit weight showed highly significant and positive correlation with fruit diameter (0.536 and 0.339), number of locules per fruit (0.843 and 0.438) and fruit yield per plant (0.858 and 0.810) respectively both at genotypic and phenotypic levels. It showed non significant association and positive correlation with days to first fruit setting (0.163 and 0.037) and pericarp thickness (0.118 and 0.047) both levels. It had moderate significant association and positive correlation with days to first flowering (0.254) and plant height (0.215) at at genotypic level. It had also significant association and negative correlation with number of fruits per plant (-0.240 and -0.241) at both levels.Matin *et al.* (2001) found that individual fruit weight had significant positive correlations with plant height and yield per plant and significant negative correlations between number fruits per plant and individual fruit weight; and dry matter was negatively correlated with individual fruit weight. Arun *et al.* (2004) and Joshi *et al.* (2004) observed that in case of tomato yield per plant was positively and significantly correlated with average fruit weight. Megha *et al.* (2006) also found similar results for this trait in tomato.

4.2.12 Self life of fruits:

Self life of fruits showed non significant and negative correlation with days to first flowering (-0.103 and -0.035), fruit diameter (-0.013 and -0.068) and pericarp thickness (-0.006 and -0.024) at both genotypic and phenotypic levels. It had non significant and positive correlation with fruit yield per plant (0.015 and 0.016) at both levels. Self life of fruits showed significant association and negative correlation with days to first flowering (-0.212), number of locules per fruit (-0.199) and number of fruits per plant (-0.252) at genotypic level.

4.2.13 Fruit yield per plant:

Fruit yield per plant showed non significant association and positive correlation with days to first flowering (0.132 and 0.070), days to first fruit setting (0.117 and 0.031) , number of branches per plant (0.101 and 0.118) and self life of fruits (0.015 and 0.016) at both the genotypic and phenotypic levels. Where as average fruit fruit diameter (0.552 and 0.354), number of locules per fruit (0.806 and 0.409) , number of clusters per fruit (0.274 and 0.272), number of fruits per plant (0.258 and 0.281) and fruit weight (0.858 and 0.810) had significant association and positive correlation with fruit yield per plant at both the levels. It had significant association and positive correlation with plant height (0.244) and pericarp thickness of fruits (0.244) at genotypic level. It had non significant association and negative correlation with number of fruits per cluster (-0.110) at genotypic level, but this trait had non significant association and positive correlation at phenotypic level. Rani *et al.* (2010) also found similar results for this trait in tomato. Ara *et al.* (2009) and Manivannan *et al.* (2005) also observed that yield per plant was positively and significantly correlated with average fruit weight, fruit length and fruit diameter.

4.3 Path Coefficient Analysis

By partitioning the genotypic and phenotypic correlations, the direct effect of a chosen trait on fruit yield per plant and its indirect effect through other characters were computed. Path coefficient analysis was done with days to first flowering, days to first fruit setting, plant height, fruit diameter (cm), pericarp thickness of fruit (cm), number of locules per fruit, number of branches per plant, number of clusters per plant, number of fruits per cluster, number of fruits per plant, fruit weight (g), self life of fruit (DAS) and fruit yield per plant (kg). Path coefficient analysis was showed direct and indirect effects of different characters on yield of tomato in table 5 and figure 4.

4.3.1 Days to first flowering:

Days to first flowering had negative direct effect (-0.018) on yield per plant and days to first flowering had positive indirect effect on days to first fruit setting (0.011), fruit diameter (0.003), pericarp thickness (0.006), number of clusters per plant (0.003), fruit weight of fruit (0.161) and self life of fruit (0.002). Negative indirect effect was found via number branches per plant (-0.015). Matin *et al.* (2001) reported that days to first flowering had negative direct effect on yield per plant. The direct and indirect effects of different characters on yield are present in table 5.

4.3.2 Days to first fruit setting:

Days to first fruit setting had positive direct effect (0.029) on yield per plant. Days to first fruit setting had positive indirect effect on fruit diameter (0.012), pericarp thickness (0.004), number branches per plant (0.006), number of fruits per cluster (0.027), fruit weight (0.037) and self life of fruit (0.003). Negative indirect effect were found via number of locules per fruit (-0.004) and number of fruits per plant (-0.022) (Table 5). Singh *et al.* (2004) showed that days to 50% flowering had high positive direct effect on yield.

4.3.3 Plant height:

Path analysis revealed that plant height had negative direct effect (-0.001) on yield per plant and positive indirect effect through days to first fruit setting (0.002), pericarp thickness (0.012), number of clusters per plant (0.016), fruit weight (0.128) and self life of fruit (0.001). On the other hand, plant height showed negative indirect effect on yield per plant via days to first flowering (-0.003), fruit diameter (-0.004), number of locules per fruit (-0.007), number branches per plant (-0.005), number of fruits per cluster (-0.006) and number of fruits per plant (-0.008) (Table 5). Matin *et al.* (2001) also reported that plant height had negative direct effect on yield per plant.

4.3.4 Fruit diameter:

Path analysis revealed that fruit diameter had direct positive effect (0.085) on yield per plant. This trait had also indirect positive effect on days to first fruit setting (0.004), number of branches per plant (0.003), and number of fruits per cluster (0.030), fruit weight (0.331) and self life fruit (0.002). On the other hand fruit diameter showed indirect negative effect on days to first flowering (-0.001), pericarp thickness (-0.030), number of locules per fruit (-0.016), number of clusters per plant (-0.018), number of fruits per plant (-0.016) (Table 5).

Padma *et al.* (2002) found that fruit diameter had high positive direct effect of number of fruits per plant on yield. This discrepancy with present findings might be due to environmental variation.

4.3.5 Pericarp thickness:

Path analysis revealed that pericarp thickness had negative direct effect (-0.044) on yield per plant and positive indirect effect through days to first flowering (0.003), fruit diameter (0.058), number branches per plant (0.007), number of fruits per cluster (-0.037), number of fruits per plant (0.017) and fruit weight (0.051). On the other hand, pericarp thickness showed negative indirect effect on yield per plant via days to first fruit setting (-0.002), number of locules per fruit (-0.001) and number clusters per plant (-0.017) (Table 5).

4.3.6 Number of locules per fruit:

Number of locules per plant had negative direct effect (-0.040) on yield per plant and positive indirect effect on days to first fruit setting (0.003), fruit diameter (0.035), number of branches per plant (0.006), number clusters per plant (0.001), number fruits per cluster (0.013), fruit weight (0.430) and self life of fruit (0.001). On the other hand this trait showed negative indirect effect on pericarp thickness (-0.001) and number of fruits per plant (-0.015) (Table 5).

4.3.7 Number of branches per plant:

Number of branches per plant had negative direct effect on yield per plant (-0.057). This trait had positive indirect effect on pericarp thickness (0.005), number of locules per fruit (0.004), number of clusters per plant (0.078) , number of fruits per plant (0.028), average fruit weight (0.120) and self life fruit (0.002). On the other hand negative indirect effect was found on days to first flowering (-0.005), days to first fruit setting (-0.003), fruit diameter (-0.004) and number of fruits per clusters (-0.058) (Table 5).Singh *et al.* (2004) also reported that number of primary branches per plant had direct negative effects on yield.

Table 5. Path coefficient analysis showing direct and indirect effects of different characters on yield of tomato

	Direct effect	Indirect effect												Pearson correlation with yield
		DFF	DFFS	PH	FD	PT	LPF	BPP	CPP	FPC	FPP	FW	SLF	
DFF	-0.018		0.011	0.000	0.003	0.006	0.000	-0.015	0.003	-0.035	-0.055	0.161	0.002	0.066
DFFS	0.029	-.007		0.000	0.012	0.004	-0.004	0.006	-.047	0.027	-0.022	0.037	0.003	0.039
PH	-0.001	-.003	0.002		-0.004	0.012	-0.007	-0.005	0.016	-0.006	-0.008	0.128	0.001	0.132
FD	0.085	-.001	0.004	0.000		-0.030	-0.016	0.003	-.018	0.030	-0.016	0.331	0.002	0.376**
PT	-0.044	0.003	-0.002	0.000	0.058		-0.001	0.007	-.017	0.037	0.017	0.051	0.000	0.114
LPF	-0.040	0.000	0.003	0.000	0.035	-0.001		0.006	0.001	0.013	-0.015	0.430	0.001	0.439**
BPP	-0.057	-.005	-0.003	0.000	-0.004	0.005	0.004		0.078	-0.058	0.028	0.120	0.002	0.110
CPP	0.232	0.000	-0.006	0.000	-0.007	0.003	0.000	-0.019		-0.086	0.207	-0.044	-0.002	0.276**
FPC	0.184	0.003	0.004	0.000	0.014	-0.009	-0.003	0.018	-.108		0.075	-0.134	0.001	0.039
FPP	0.326	0.003	-0.002	0.000	-0.004	-0.002	0.002	-0.005	0.147	0.042		-0.218	0.000	0.284**
FW	0.923	-.003	0.001	0.000	0.031	-0.002	-0.019	-0.007	-.011	-0.027	-0.077		-0.001	0.816**
SLF	-0.023	0.001	-0.004	0.000	-0.006	0.001	0.002	0.005	0.024	-0.006	-0.007	0.037		0.028

Residual effect: 0.284,

** = Significant at 1%. DFF = Days of first flowering, DFFS = Days of first fruit setting, PH = Plant height (cm), FD = Fruit Diameter (cm), PT = Pericarp thickness (cm), LPF = Locule No. , BPP = Branches per plant, CPP = Clusters per plant, FPC = Number of fruits per cluster, FPP = Fruits per plant, FW=Fruit weight (g), SLF=Shelf life of fruits, FYP = Fruit yield per plant (kg)

4.3.8 Number of clusters per plant:

Number of clusters per plant had positive direct effect (0.232) on yield per plant and positive indirect effect on days to pericarp thickness (0.003), number of fruits per plant (0.207). On the other hand this trait showed negative indirect effect on days of first fruit setting (-0.006), Number of fruits per cluster (-0.086), Fruit weight (-.044) and Shelf life of fruits (-0.002) (Table 5). Singh *et al.* (2004) reported that number of clusters per plant had direct negative effects on yield. This discrepancy with present findings might be due to environmental variation.

4.3.9 Number of fruits per cluster:

Number of fruits per cluster showed positive direct effect (0.184) on yield per plant and positive indirect effects through days to first flowering(0.003), days to first first fruit setting (0.004), fruit diameter (0.014), Number of branches per plant (0.018), number of fruits per plant (0.075) and self life of fruit (0.001). It also had negative indirect effect on pericarp thickness (-0.009), number of locules per fruit (-0.003), number of clusters per plant (-0.108), and fruit weight (-0.134) (Table 5). Mayavel *et al.* (2005) also reported that number of fruits per cluster had negative direct effects on fruit yield.

4.3.10 Number of fruits per plant:

Number of fruits per plant showed positive direct effect (0.326) on yield per plant and positive indirect effects through days to first flowering (0.003), number of locules per fruit (0.002), number of clusters per plant (0.147), Number of fruits per plant (0.042). It also had negative indirect effect on days to first first fruit setting (-0.002), fruit diameter (-0.004), pericarp thickness (-0.002), number of branches per plant (-0.005), fruit weight (-0.218) (Table 5).Singh *et al.* (2006) and Kumar *et al.* (2003) also observed that total number of fruits per plant had high as well as direct positive effects on fruit yield at the genotypic and phenotypic levels. Ara *et al.* (2009) also found similar results for this trait in tomato.

4.3.11 Fruit weight:

Path analysis revealed that fruit weight had direct positive effect (0.923) on yield per plant. This trait had also indirect positive effect on days to first fruit setting (0.001) and fruit diameter (0.031). On the other hand fruit weight showed indirect negative effect on days to first flowering (-0.003), pericarp thickness (-0.002), number of locules per fruit (-0.019), number of branches per plant (-0.007), number of clusters per plant(-0.011), number of fruits per cluster (-0.027), number of fruits per plant(-0.077) and self life of fruit (-0.001) (Table 5). Significant genotypic correlation between fruit weight and yield further strengthened their reliability in the process of selection for higher yield. Rani *et al.* (2010), Singh *et al.* (2006) and Manivannan *et al.* (2005) also reported that average fruit weight had positive direct effects on fruit yield.

4.3.12 Self life of fruit

Path analysis revealed that shelf life of fruit had direct negative effect (-0.023) on yield per plant. This trait had also indirect positive effect on days to first flowering(0.001), pericarp thickness (0.001), number of locules per fruit (0.002), number of branches per plant (0.005), number of clusters per plant(0.024) and fruit weight (0.037). On the other hand it showed indirect negative effect on days to first fruit setting (-0.004), fruit diameter (-0.006) and number of fruits per plant (-0.007) (Table 5).

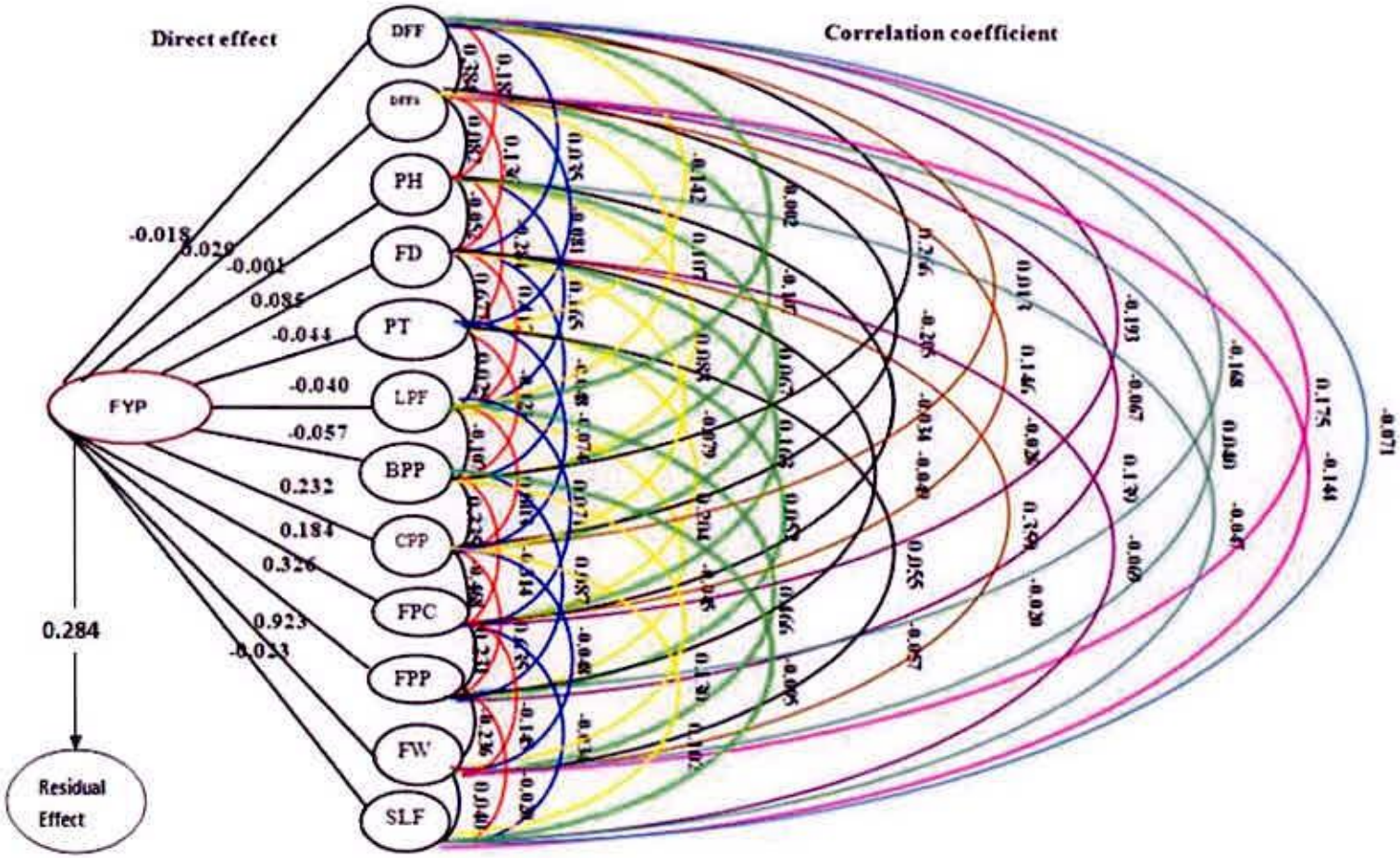


Fig 4. Path diagrammatic representation of direct effect and correlation coefficient

4.4 MULTIVARIATE ANALYSIS

4.4.1 Principal component analysis (PCA)

Principal component analysis was carried out with 29 genotypes of tomato. First three Eigen values for three principal coordination axes of genotypes accounted for 56.41% variation (Table 6). A two dimensional scattered diagram (Fig. 5) was developed.

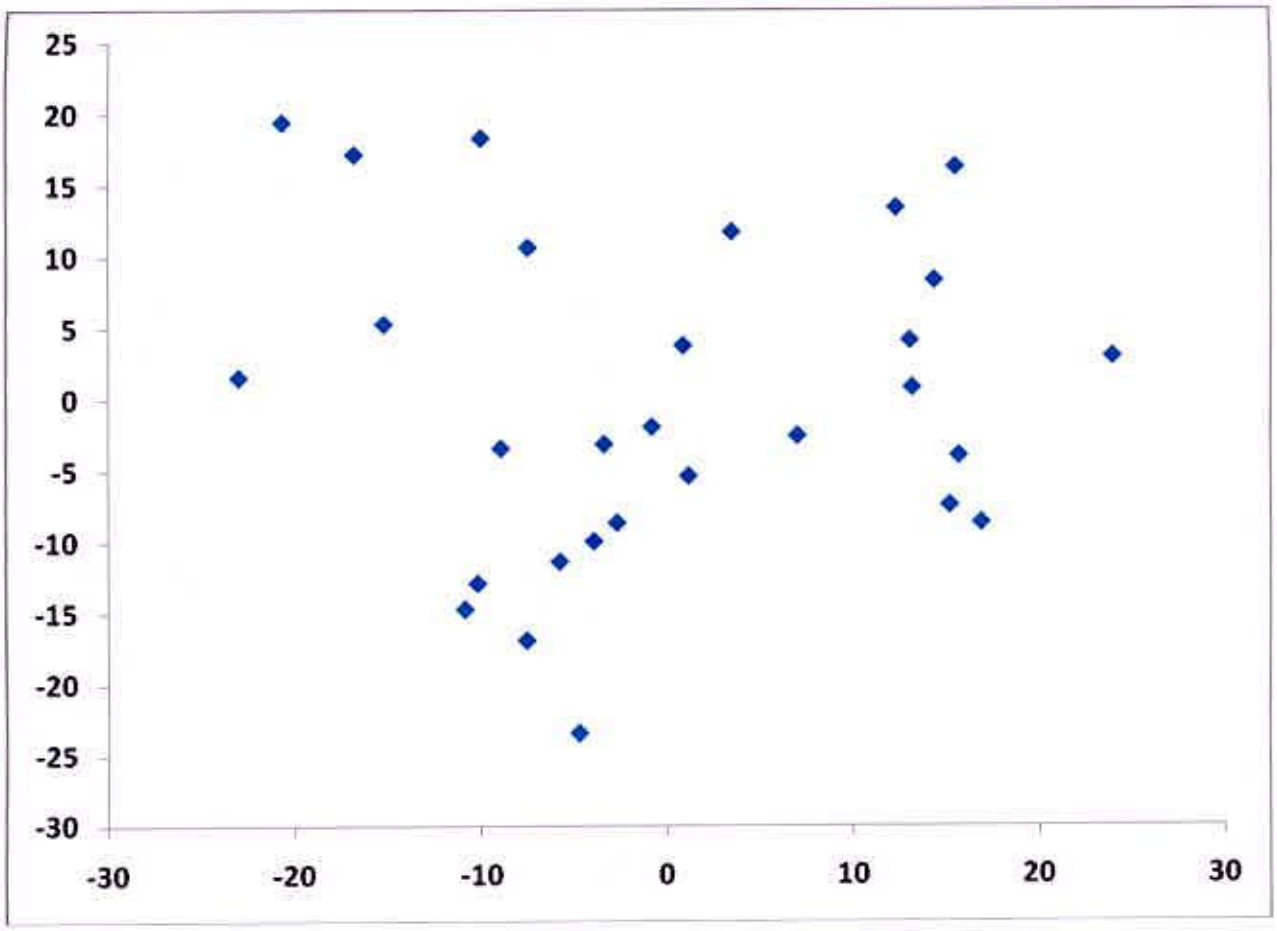


Fig 5. Scatter diagram of 29 tomato genotypes of based on their principal component scores

Table 6. Eigen values and yield percent contribution of thirteen characters of twenty nine tomato germplasm

Characters	Eigen values	Percent variation	Cumulative % of Percent variation
Days of first flowering	3.0782	23.68	23.68
Days of first fruit setting	2.2552	17.35	41.03
Plant height (cm)	1.9992	15.38	56.41
Fruit Diameter (cm)	1.5661	12.05	68.46
Pericarp thickness (cm)	1.3050	10.04	78.50
Locule No.	1.0036	7.72	86.22
Branches per plant	0.6364	4.90	91.12
Clusters per plant	0.5313	4.09	95.21
Number of fruits per cluster	0.3059	2.35	97.56
Fruits per plant	0.2454	1.89	99.45
Fruit weight (g)	0.0528	0.41	99.86
Shelf life of fruits	0.0130	0.10	99.96
Fruit yield per plant (kg)	0.0080	0.04	100.00

4.4.2 Non-hierarchical clustering

The computations from covariance matrix gave non-hierarchical clustering among 29 genotypes of tomato and grouped them into five clusters. The clustering pattern obtained coincided with the apparent grouping patterns performed by PCA. So the results obtained through PCA were confirmed by non-hierarchical clustering. Table 7 represents the clusters occupied by 29 genotypes of tomato. It explains that both cluster I and cluster V contained the highest number of genotypes seven separately, cluster II constitute by four genotypes, cluster III constitute by six genotypes and cluster IV constitute by five genotypes. Cluster I was composed of BD-7761, BD-7762, BD-7258, BD-7262, BD-7301, Unnayan and Raton. All the genotypes of cluster I are collected from Plant Genetic Resource Centre, BARI, Gazipur. The highest cluster mean value was achieved for two characters viz. pericarp thickness of fruits (0.51) and number of fruits per cluster (3.86). Cluster II was formed by four genotypes viz. BD-7759, BD-7260, BD-7279, and BD-7295 were collected from Plant Genetic Resource Centre, BARI, Gazipur. The highest cluster mean value was achieved for three character viz. number of branches per plant (8.67), number of clusters per plant (17.33) and number of fruits per plant (64.50). Cluster III was formed by six genotypes viz. BD-7259, BD-7276, BD-7285, BD-7286, BD-7281, BD-7306, BARI Tomato-11 were collected from Plant Genetic Resource Centre, BARI, Gazipur (Table 5). The highest cluster mean value was achieved for two character viz. plant height (95.00) and shelf life of fruits (8.28). Cluster IV was formed by five genotypes viz. BD-7306, BD-7289, BD-7291, BD-7290 and Mintu were collected from Plant Genetic Resource Centre, BARI, Gazipur. The highest cluster mean value was achieved for two characters viz. days to first flowering (63.67) and days to first fruit setting (77.47). Cluster V was formed by seven genotype viz. BARI Tomato-3, BARI Tomato-4, PUSA Rubi ,BD-7270, Ruma VF , Delta, BARI Hybrid Tomato-4 was collected from Plant Genetic Resource Centre, BARI, Gazipur and PUSA Rubi & Ruma VF was collected from Lal Teer Seed Company, Dhaka. The highest cluster mean value was achieved for five characters viz. fruit diameter (4.55), number of locules per plant (3.28), number of brances per plant (8.67), fruit weight (37.24), and fruit yield per plant (1.64) kg are presented in Table 7 and table 8.

Table 7. Distribution of genotypes in different clusters

Cluster No.	No. of Genotypes	No. of population	Name of genotypes
I	G3, G4, G8, G20, G22, G25, G26	7	BD-7761, BD-7762, BD-7258, BD-7262, BD-7301, Unnayan, Raton
II	2, 10, 14, 21	4	BD-7759, BD-7260, BD-7279, BD-7295
III	9, 12, 13, 15, 16, 23	6	BD-7259, BD-7276, BD-7285, BD-7286, BD-7281, BARI Tomato-11
IV	1, 17, 18, 19, 24	5	BD-7306, BD-7289, BD-729, BD-7290, Mintu
V	5, 6, 7, 11, 27, 28, 29	7	BARI Tomato-3, BARI Tomato-4, PUSA Rubi, BD-7270, Ruma VF, Delta, BARI Hybrid Tomato-4

Table 8. Cluster mean values of 13 different characters of 29 genotypes

Characters	I	II	III	IV	V
Days of first flowering	60.81	62.75	63.06	63.67	63.62
Days of first fruit setting	75.24	76.00	76.28	77.47	75.53
Plant height (cm)	62.76	69.58	95.00	80.73	73.66
Fruit Diameter (cm)	4.16	4.08	3.84	4.05	4.55
Pericarp thickness (cm)	0.51	0.48	0.36	0.43	0.48
Locule No.	2.62	2.67	3.00	2.80	3.28
Branches per plant	7.47	8.67	7.83	7.87	8.67
Clusters per plant	13.48	17.33	15.89	11.14	13.43
Number of fruits per cluster	3.86	3.75	3.61	3.67	3.43
Fruits per plant	49.86	64.50	55.33	38.27	44.48
Fruit weight (g)	15.86	17.33	23.39	18.73	37.24
Shelf life of fruits	8.24	7.67	8.28	7.33	8.24
Fruit yield per plant (kg)	0.80	1.12	1.27	0.71	1.64

4.4.3 Canonical variate analysis

4.4.3.1Inter and intra cluster distances

The highest inter-cluster distance was observed (Table 10 or Figure 5) between cluster I and III (11.712). The lowest inter-cluster distance was observed between cluster I and II (4.069) followed by cluster IV and V (5.240). Moderate or intermediate distance was found between cluster II and IV (6.24), cluster I and IV(6.258), and cluster II and V (6.770). On the other hand, the highest intra cluster distance was found in cluster II (0.327) followed by cluster IV(0.144).The lowest intra cluster distance was observed in cluster I (0.023). The inter cluster distances were found much higher than the intra cluster distances suggesting wider genetic diversity among the genotype of different groups. Inter and intra cluster distances were showed in table 9 and Fig. 6. Results of different multivariate analysis were superimposed in figure 5 from which it may be concluded from the above results that different multivariate techniques supplemented and confirmed one another.

Table 9. Intra (Bold) and inter cluster distances (D^2) for 29 genotypes

Cluster	I	II	III	IV	V
I	**0.063**	4.069	11.712	6.258	7.143
II		**0.327**	10.150	6.424	6.770
III			**0.092**	6.782	7.494
IV				**0.144**	5.240
V					**0.065**

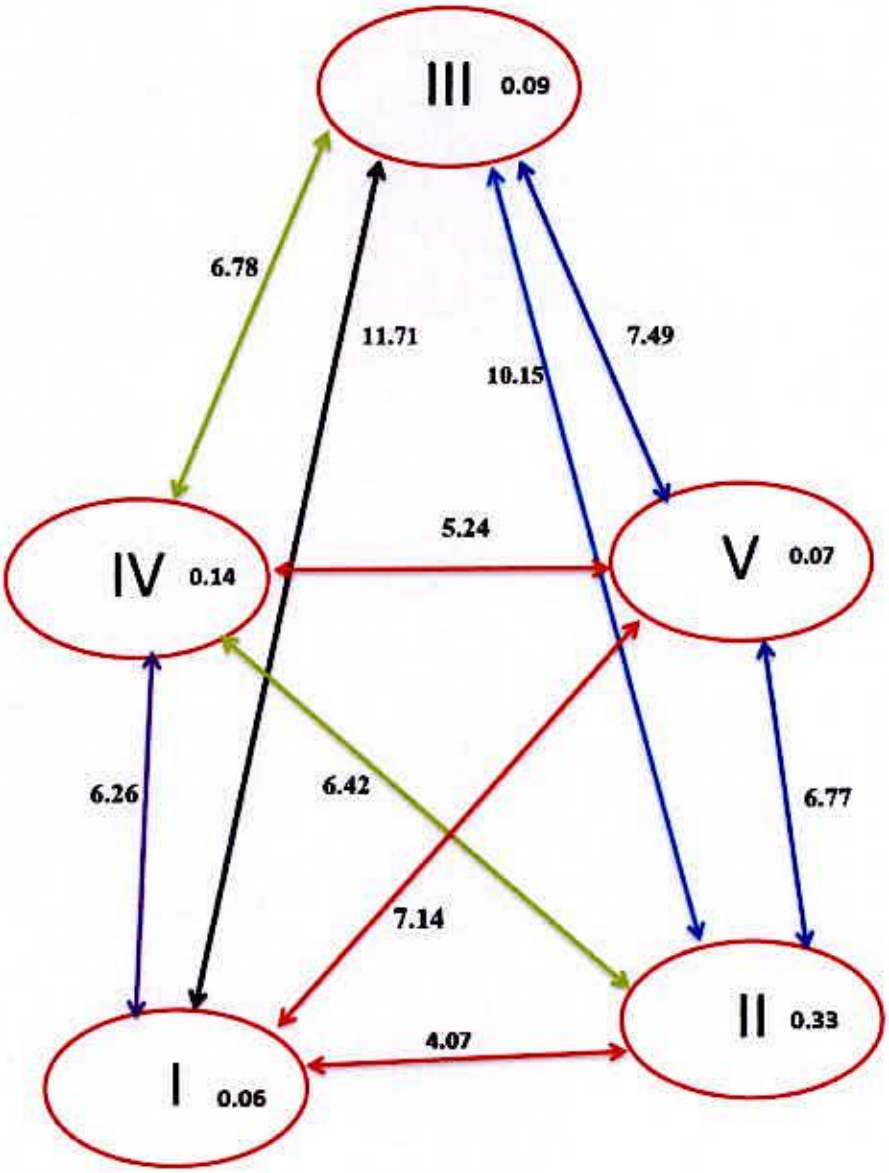


Fig 6. Diagram showing intra and inter -cluster distances (D^2) of twenty nine genotypes in tomato

As per scatter diagram the genotypes were apparently distributed into five clusters. It was also revealed that the genotypes of cluster I were more diverse from the genotypes of cluster III. Shashikanth *et al.* (2010) also observed that there was no parallelism between genetic diversity and geographical divergence in tomato and suggested that high diversity among the genotypes can be selected in hybridization programmes to obtain good seggregants.

Rai *et al.* (1998) also observed the similar result. It is assumed that maximum amount of heterosis will be manifested in cross combination involving the genotypes belonging to most divergent clusters. However, for a practical plant breeding, the objective is not only high heterosis but also to achieved high-level production. In the present study the maximum distance existence between cluster I and III. But considering the yield and duration crossing involving cluster I and III may be exhibit high heterosis for yield. Mohanty and Prusti (2001) reported that genetic diversity was not associated with geographic distribution.

4.4.3.2 Nearest and farthest clusters

Cluster I consists of nearest cluster with D^2 values cluster II (4.069) & farthest cluster with D^2 values cluster III (11.712). Cluster II consists of nearest cluster with D^2 values cluster I (4.069)& farthest cluster with D^2 values III (10.150). Cluster III consists of nearest cluster with D^2 values cluster IV (6.782) & farthest cluster with D^2 values I (11.712). Cluster IV consists of nearest cluster with D^2 values cluster V (5.240) & farthest cluster with D^2 values III (6.782). Cluster V consists of nearest cluster with D^2 values cluster IV (5.240) & farthest cluster with D^2 values III (7.494).

Table 10. The nearest and farthest clusters from each cluster between D^2 values in tomato

Sl No.	Cluster	Nearest Cluster with D^2 values	Farthest Cluster with D^2 values
1	I	II (4.069)	III (11.712)
2	II	I (4.069)	III (10.150)
3	III	IV (6.782)	I (11.712)
4	IV	V (5.240)	III (6.782)
5	V	IV (5.240)	III (7.494)

4.4.4 Contribution of characters towards divergence of the genotypes

The values of Vector I and Vector II are presented in Table 11. Vector I obtained from PCA expressed that days to first flowering (0.0124), days to first fruit setting (0.0832), fruit diameter (2.1426), number of locules per plant (0.4743), number of branches per plant (0.1123) and number of fruits per plant (0.3859) were major characters that contribute to the genetic divergence. It was the reflection of first axis of differentiation. In vector II days to first flowering (0.0154), plant height (0.0770), fruit diameter (0.8213), number of locules per plant (0.5212), number of fruits per plant (0.1775) and fruit yield per plant (1.4945) showed their important role toward genetic divergence. The value of Vector I and Vector II revealed that both Vectors had positive values for days to first flowering, fruit diameter, number of locules per plant and number of fruits per plant indicating the highest contribution of these traits towards the divergence among 29 genotypes of tomato. Negative values in both vectors for pericarp thickness, number of clusters per plant, number of fruits per clusters, fruit weight and shelf life of fruits had lower contribution towards the divergence.

Table 11. Relative contributions of the thirteen characters of 29 varieties to the total divergence

Characters	Vector-1	Vector-2
Days of first flowering	0.0124	0.0154
Days of first fruit setting	0.0832	-0.0643
Plant height (cm)	-0.3036	0.0770
Fruit Diameter (cm)	2.1426	0.8213
Pericarp thickness (cm)	-1.6271	-0.8167
Locule No.	0.4743	0.5212
Branches per plant	0.1123	-0.1832
Clusters per plant	-1.4574	-0.6656
Number of fruits per cluster	-4.7339	-2.6466
Fruits per plant	0.3859	0.1775
Fruit weight (g)	-0.1628	-0.3152
Shelf life of fruits	-0.0803	-0.3490
Fruit yield per plant (kg)	-0.5741	1.4945

4.4.5 Selection of genotypes as parent for hybridization programme

Selectoion of genetically diverse parents is an important step for hybridization program. So the genotypes were to be selected on the basis of specific objectives. Among 29 genotypes Mintu, Unnayan, Raton, Delta and BARI Hybrid Tomato-4 are hybrid varieties. A high heterosis could be produced from the crosses between genetically distance parents (Falconer, 1960; Moll *et al.*, 1962; Ramanujan et al., 1974; Ghaderi et al., 1984). Cosidering the magnitude of cluster mean and agronomic performance the genotype G_6 (BARI Tomato-4) for 2nd minimum days to first flowering from cluster V; G_{23} (BARI Tomato-11) for maximum number of fruits per cluster from cluster III; G_{10} (BD-7260) for number of fruits per plant from cluster II; G_5 (BARI Tomato-3) for maximum fruit weight, fruit yield per plant and fruit diameter from cluster V; G_{22} (BD-7301) for pericarp thickness of fruits and self life of fruits from cluster I were found promising. Therefore considering group distance and other agronomic performance the inter genotypic crosses between G_6 (BARI Tomato-4) and G_{10} (BD-7260); G_6 (BARI Tomato-4) and G_{23} (BARI Tomato-11); G_6 (BARI Tomato-4) and G_5 (BARI Tomato-3); G_5 (BARI Tomato-3) and G_{22} (BD-7301) may be suggested for future hybridization program.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted with a view to identify divergent parents for hybridization programme, identify the characters contributing to genetic diversity, asses the magnitude of genetic divergence in genotypes and determine the variability in respect of yield and some yield contributing characters, the degrees of association among the characters and their direct and indirect effects of thirty seven genotypes of *Lycopersicon esculentum* at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2011 to March 2012. Seeds are grown in seed bed and transplanted in the main field after 27 DAS in Randomized Complete Block Design (RCBD) with three (3) replications. Data on different characters were recorded and analyzed statistically. The analysis of variance of all the traits was computed and significant variations were found for different characters among the genotypes. The highest mean value was observed for days to first fruit setting. This character exhibited the highest range of variation (73.00-83.67) indicated that all the genotypes showed wide range of variation in respect of this character. High heritability showed average fruit weight (88.18%) accompanied with high genetic advance in percentage of mean and the phenotypic variance (44.16) was higher than the genotypic variance (41.47).Among these characters, days tofirst fruit setting, number of fruits per plant, fruit weight, fruit diameter and self life of fruits showed least difference between phenotypic and genotypic variance, which indicated additive gene action for the expression of this characters. All the characters showed moderate to high phenotypic and genotypic co-efficient of variation except days to first flowering, days to flowering and self life of fruits. Among the characters the highest genotypic co-efficient of variation was recorded fruit yield per plant (38.40), fruit weight (41.47) followed by no. of fruits per plant (22.81), no. of clusters per plant (18.97), no. of locules per plant (17.39) and pericarp thickness (19.40). Heritability in broad sense was low to high for all the characters studied and it ranged from 18.19 % to 88.18 % which indicated that selection based on phenotypic expression of any character for breeding could be effective. The genetic advance was very low to moderate. These findings revealed that it was indicative of non-additive gene action.

The high heritability was being exhibited due to favorable influence of environment rather than genotypes. Thus, the genotypes which performed well in various characters were due to genetic reasons and have a possibility for improvement through selection in the subsequent generations.

The significant positive correlation at the 5% level was observed for fruit yield per plant with fruit diameter (0.552, 0.354), number of locules per fruit (0.806, 0.409, number clusters per plant (0.274, 0.272) number of fruits per plant (0.258, 0.281)and fruit fruit weight (0.858, 0.810) at both genotypic level and phenotypic level. A high degree of significant positive association were observed for days to first flowering vs. days to first fruit setting and number of branches per plant; and fruit weight vs. fruit diameter; no. of locules per fruit. Strong negative significant correlations were found between fruit weight vs. no. of fruits per cluster; no. of fruits per cluster and no. of fruits per plant; fruit length vs. no. of clusters per plant. The character fruit weight had maximum positive direct effect on fruit yield per plant. No. of branches per plant had maximum negative direct effect on yield per plant. The residual effect was quite moderate (0.284).

Multivariate analysis was carried out through principal component analysis (PCA), principal coordinate analysis (PCA), cluster analysis, and canonical vector analysis (CVA) using Gemstar 5.13 software programme. As per as PCA, D^2 and cluster analysis using the genotypes were grouped into five different clusters. Cluster I, II, III, IV and V comprised seven, four, six, five and seven genotypes, respectively. The highest inter-cluster distance was observed (Table 10 or Figure 6) between cluster I and III (11.712). The lowest inter-cluster distance was observed between cluster I and II (4.069) followed by cluster IV and V (5.240). Moderate or intermediate distance was found between cluster II and IV (6.24), cluster I and IV(6.258), and cluster II and V (6.770). On the other hand, the highest intra cluster distance was found in cluster II (0.327) followed by cluster IV(0.144).The lowest intra cluster distance was observed in cluster I (0.023). The inter cluster distances were found much higher than the intra cluster distances suggesting wider genetic diversity among the genotype of different groups. Cluster I consists of nearest cluster with D^2 values cluster II (4.069) & farthest cluster with D^2 values cluster III (11.712). Cluster II consists of nearest cluster with D^2 values cluster I (4.069)& farthest cluster with D^2 values III (10.150).

Vector I obtained from PCA expressed that days to first flowering (0.0124), days to first fruit setting (0.0832), fruit diameter (2.1426), number of locules per plant (0.4743), number of branches per plant (0.1123) and number of fruits per plant (0.3859) were major characters that contribute to the genetic divergence. It was the reflection of first axis of differentiation.

In vector II days to first flowering (0.0154), plant height (0.0770), fruit diameter (0.8213), number of locules per plant (0.5212), number of fruits per plant (0.1775) and fruit yield per plant (1.4945) showed their important role toward genetic divergence. The value of Vector I and Vector II revealed that both Vectors had positive values for days to first flowering, fruit diameter, number of locules per plant and number of fruits per plant indicating the highest contribution of these traits towards the divergence among 29 genotypes of tomato. G_6 (BARI Tomato-4) for 2nd minimum days to first flowering from cluster V; G_{23} (BARI Tomato-11) for maximum number of fruits per cluster from cluster III; G_{10} (BD-7260) for number of fruits per plant from cluster II; G_5 (BARI Tomato-3) for maximum fruit weight, fruit yield per plant and fruit diameter from cluster V; G_{22} (BD-7301) for pericarp thickness of fruits and self life of fruits from cluster I were found promising. Therefore considering group distance and other agronomic performance the inter genotypic crosses between between G_6 (BARI Tomato-4) and G_{10} (BD-7260); G_6 (BARI Tomato-4) and G_{23} (BARI Tomato-11); G_6 (BARI Tomato-4) and G_5 (BARI Tomato-3); G_5 (BARI Tomato-3) and G_{22} (BD-7301) may be suggested for future hybridization program.

From the findings of the present study, the following conclusions could be drawn:

i. Selection procedure would be applied for desired characters such as lowest days to first flowering and increase number of clusters per plant, number of fruits per cluster, number of fruits per plant, fruit weight, fruit diameter to develop high yielding varieties.
ii. Wide range of genetic diversity existed among the tomato genotypes. That variability could be used for future breeding programme of tomato in Bangladesh.
iii. Relatively higher value and lower differences between genotypic co-efficient of variation and phenotypic coefficient of variation of different yield contributing characters like fruit weight, number of fruits per plant, yield per plant were observed which indicates high potentiality to select these traits in future which were less affected by environmental influence.

References

REFERENCES

Abedin, J. and S.H. Khan. (1986). Study of the morphogenetic divergence in tomato. *Bangladesh J. Agric. Res.* **11**(1): 39-47.

Aditya, T. L. (1995). Genetic divergence among tomato genotypes for yield and yield contributing characters. MS thesis submitted to the Dept. Genet. Pl. Breed., BAU, Mymensingh, Bangladesh.

Akhilesh Tiwari and Gulshan Lal, (2005), Variability and genetic parameters of yield components and processing characters in tomato *((Lycopersicon esculentum* Mill.).*Progr. Hort.*, **37**(2) : 372-376.

Alam, M.S., Ahmed, Q.N. and Ali, M.N. (1988). Correlation and path co-efficient analysis for some characters in tomato. *Bangladesh J. Genet. Pl. Breed.*, **1**(1&2): 42-46.

Alvarez, M. and Torres, V. (1983). Correlation analysis in a collection of varieties and lines of tomato (*Lycopersicon esculentum* Mill) Cultivos Tropicals. **5**(1): 49-59.

Anitha, P., Sharma, R. R., Tiwari, R. N. and Surja, A. K. (2007). Correlation and path analysis for some horticultural traits in tomato. *Indian J. Hort.*, **64**(1): 90-93.

Anonymous, (2010). Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701.

Anonymous, (2010). www.faostat.fao.org, FAO Statistic Division, Rome, Italy.

Anonymous, (1988b). Crop Status Report. Christian Reformed Worlds Relief Committee, Bogra. Pp. 124-127.

Anandgowda, N. (1997). Variability and gene action- studies for characteristics related to processing in tomato *(Lycopersicon esculentum* Mill.). M.Sc. (Agri.) Thesis, *Univ. Agric. Sci., Dharwad (India).*

Anupam B., Jain, B. P. and Verma, A. K. (2002). Genetic variability heritability and genetic advance in tomato (*Lycopersicon esculentum* (L.) Karst.). *J. Res. Birsa Agril.Univ.*, **14**(2): 249-252.

Ara A., Narayan R., Ahmed N., and Khan S.H. (2009). Genetic variability and selection parameters for yield and quality attributes in tomato. *Indian J. Hort.*, **66**(1): 73- 78

Aradhana, J. C. and Singh, J. P. (2003). Studied on genetic variability in tomato. *Progr. Hort.*, **35**(2): 179-182.

Arora, S. K., Pandita, M. L. And Pratap, P. S., 1982, Genetic variability and heritability studies in tomato in relation to quality characters under high temperature conditions. *Haryana Agril. Univ. J. Res.,* **12** (4) : 583-590.

Arun K. R. and Veeraragavathatham, (2004). Variability studies in tomato (*Lycopersicon esculentum* Mill.) genotypes under green house and open conditions in different seasons. *South Indian. Hort.,* **53**(1-6): 18-24.

Arun, J., Kohil, U. K. and Joshi, A. (2003). Genetic divergence for quantitative and qualitative traits in tomato *(Lycopersicon esculentum* Mill.). *Indian J. Agric. Sci.,* **73**(2): 110-113.

Bai, N. R. and Devi, D. S. (1991). Study on genetic parameters in tomato hybrids. *Orissa J. Agric. Res.,* **4**: 27-29.

BBS. (2010). Year Book of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning, Govt. of the Peoples Republic of Bangladesh, Dhaka. p. 163.

Bhusana, H. O., Kulkarni, R. S., Basavarajaiah, D., Helaswamy, B. H. and Halesh, G. K. (2001). Correlation and path analysis for fruit quality traits on fruit yield in tomato *(Lycopersicon esculentum* Mill.). *Crop Res. Hissar.,* **22**(1) : 107-109.

Bhutani, R. D. and Kalloo, G. (1989). Correlation and path coefficient analysis of some quality traits in tomato *(Lycopersicon esculentum* Mill). *Haryana J. Hort. Sci.,* **18**: 130-135.

Bhutani, R. D., Kalloo, G. and Pardita, M. L. (1983). Genetic variability and scope of improvement of quality traits in tomato *(Lycopersicon esculentum* MilL). *Haryana Agric. Univ. J. Res.,* 13: 408-412.

Biswas, J. and S. C. Mallik. (1989). Days required for flowering and harvesting of some promising cultivars of tomato (*Lycopersicon esculentum). Environ. Ecol.,* **7**(4): 1003-1095.

Bodunde, J.G. (2002). Path co-efficient and correlation studies in tomato (*Lycopersicon esculentum* Mill.). *Moor J. Agric. Res.,* **3**(2): 195-198.

Brar, G. S., Singh, S., Cheema, D.S., Dhaliwal, M.S. and Singh, S. (2000). Studies on variability, heritability and genetic advance for yield and component characters in tomato (*Lycopersicon esculentum* Mill.). *J. Res. Punjab Agric. Univ.*, **37**(3-4): 190-193.

Brar, G. S., Surjan Singh, Chima, D. S. and Dhariwal, M. S. (1998). Studies on variability, heritability, genetic advance for yield and components characters in tomato *(Lycopersicon esculentum* MilL). *J. Res. Punjab Agric. Univ.*, **37**(3-4): 190-193.

Das, B., Hazarika, M. H. And Das, P. K. (1998). Genetic variability and correlation in fruit characters of tomato (*Lycopersicon esculantum* Mill.). *Ann. Agril. Res.*, **19**(1):77-80.

Dhankhar, S. K. and Dhankar, S. S. (2006). Variability, heritability, correlation and path coefficient studies in tomato. *Haryana J. Hort. Sci.*, **35**(1&2): 179-181.

Domani, M. R. and Maya, C. (1997), Correlation and path coefficient stimates of different tomato seedlings stage. *Cult. Trop.*, **18**(3): 63-65.

Dudi, B. S. and Kalloo, G. (1982). Correlation and path analysis studies in tomato. *Haryana J.Hort. Sci.*, **11**: 122-126.

Dudi, B. S., Dixit, J. and Partap, P. S. (1983). Components of variability, heritability and genetic advance studies in tomato *(Lycopersicum esculentum* Mil1.). *Haryana Agric.Univ. J.Res.*, **13**: 135-139.

Eberhart, S. A. and Russell, W. A. (1966). Stability parameters for comparing varieties. *Crop sci.*, **6** : 36-40.

Falconer, D. S., 1981, *Introduction to Quantitative Genetics,* 2nd edition Oliver and Boyd, Edinburg, London, p. 316.

Fraser, G.E., Beeson, L. and Phillips, R.L. (1991). Diet and lung cancer in California : Seventhday Adventists. *American J. Epidemiol.*, **133**: 683-693.

Geogieva, M. (1969). The biological characters of certain tomato varieties in Bulgaria. Grad. Le 3ar, Nauka, **6**(7): 21-31.

Ghosh, P. K., Syamai, M.M., Rai, N. and Joshi. A. K. (1995). Improvement of hybrid tomatoes. *Adv. Pl. Sci.*, **2**(1) : 207-213.

Godekar, D. A., Dhanukshe, B. L. and Patil, F. B. (1992). Studies on variability, heritability and genetic advance in tomato. *J. Maharasthra Agric. Univ.*, **17**: 305-306.

Golani, I.J., Mehta, D. R., Purohit,V.L., Pandya, H. M. and Kanzariya, M.V. (2007). Genetic variability, correlation and path coefficient studies in tomato. *Indian J. Agril. Res.*, **41**(2): 146-149.

Gomez, O. (1987). Correlations and path co-efficient analysis in tomato breeding lines. *Agrotecnia decuba.*, **20**(2): 252-256.

Gorbatenko, E.M. and I.Y.U. Gorbatenko. (1985). Path analysis of economically usefull characters in tomato, *Tsitologiya i Genetica.*, **19**(3): 206-210.

Harrington, J.B. (1940). Yielding capacity of wheat crosses as indicated by bulk hybrid test.*Canadian J. Res.*, **18**: 578-584.

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

Islam, P., Prakash, S. And Singh, A.K. (1996). Variability studies in tomato (*Lycopersicon esculentum* Mill). *Bangladesh J. Pl. Breed. Genet.* **4**(1&2): 49-53.

Islam, M.S. and S. Khan. (1991). Variability and character association in tomato (*Lycopersicon esculentum* Mill). *Bangladesh J. Pl. Breed. Genet.* **4**(1&2): 49-53.

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* Mil1.). *Progr. Hort.*, **36**(1): 51-58.

Joshi, A. and Singh, J.P. (2003). Studies on genetic variability in tomato. *Progr. Hort.*, **35**(2): 179-182

Kalloo, G. (1989). Correlation and path coefficient analysis of some quality traits in tomato (*Lycopersicon esculentum* Mill.). *Haryana J. Hort. Sci.*, 18:130-135.

Kalloo, G., Chaurasia, S.N.S. and Singh, M., 1998, Stability analysis in tomato. *Veg. Sci.*,**25**(1): 81-84.

Kasrawi, M. A. and Amr, A. S. (1990). Genotypic variation and correlation for quality characteristics in processing tomatoes. *J. Genet. Pl. Breed.*, **44**: 85-99.

Korla, B. N., Thakur, B. S. and Joshi, A. K. (1998). Variability studies in beans. *Haryana J. Hort. Sci.*, **27**: 43-48.

Kumar, R., Niraj Kumar, Jagadeesh Singh and Rai, G. K. (2006). Studies on yield and quality traits in tomato. *Veg. Sci.*, **33**(2): 126-132.

Kumar, S., Singh, T., Singh, B. and Singh, J.P. (2004). Studies on correlation coefficient and path analysis among the different characters including fruit yield of tomato (*Lycopersicon esculentum* Mill.). *Pl. Arc.*, **4**(1): 191-193.

Kumar, V.R.A., Thakur, M.C. and Hedau, N.K. (2003). Correlation and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Ann. Agric. Res.* **24**(1): 170-177

Kumar, P., Dijee Bastian, Joy, M., Radhakrishnan, N. V. and Aipe, K. C. (2001). Genetic variation in tomato for yield and resistance to bacterial wilt. *J. Trop.Agric.*, **39**:157-158.

Kumar, P. and Tewari, R. N. (1999). Studies on genetic variability for processing characters in tomato. *Indian J. Hort.*, **56**(4): 332-336.

Kumar, N., Muthukrishnan, C. R. and Irulappan, I. (1980). Genetic variability, heritability and coheritability in the segregating generation of tomato. *South Indian Hort.*, **28**; 105-108.

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.). *Progr. Agric.*, 7(1/2): 80-83.

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

Mallik, A.K. (1985). Study on genetic parameters and character association of tomato. A master degree thesis, Dept. Genet. Pl. Breed., BAU, Mymensingh.

Manivannan, M.I., Prasad D. and Mir,M. (2005). Correlation and path coefficient analysis in cherry tomato (*Lycopersicon esculentum* var. *cerasiforme*). *New Agric.*, **16**(1/2): 151-154.

Mariane, F., Ravishankar, H. and Dessalegne, L. (2003). Study on variability in tomato germplasm under conditions of Central Ethiopia, *Veg. Crops Res. Bull.*, **58**: 41- 50.

Markovic, Z., Zdravkovic, J., Mijatovic, M., Danjanovic, M., Paroussi, G., Voyiatzis, D. and Paroussis, E. (2002). Breeding potential of local tomato populations for beta-carotene and vitamin C. Proceedings of the Second Balkan Symposium on Vegetables and Potatoes, Thessaloniki, Greece. *Acta-Hort.*, **579**: 157-161.

Matin, M. A. (2001). Study on the variability, interrelationship of agro-morphological and some qualitative characters of tomato. A master degree thesis, *Dept. Genet. Pl. Breed.*, BAU, Mymensingh.

Mayavel, A., Balakrishnamurthy, G., Natarajan, S. (2005b). Correlation and path analysis in tomato (*Lycopersicon esculentum* Mill.). *South Indian Hort.*, **53**(1-6): 253-257.

Megha. U., Gautam, J. P.S., Singh. Anita., Joshi A. (2006). Correlation studies in exotic tomato (*Lycopersicon esculentum* Mill.) cultivars. *Res. Crops.*, 7(2): 493-495.

Mittal. P. Prakash, S. and Singh, A. K. (1996). Variability studies in tomato (*Lycopersicon esculentum* Mill.) under sub-humid condition of Himachal pradesh. *South Indian Hort.*, **44**: 132-148.

Mohanty, B. K. (2003). Genetic variability, correlation and path coefficient studies in tomato. *Indian J. Agril. Res.*, **37**(1): 68-71.

Mohanty, B. K. (2002). Variability, heritability, correlation and path coefficient studies in tomato. *Haryana J. Hort. Sci.*, **31**(3/4): 230-233.

Mohanty, B. K. (2002). Studies on variability, heritability, interrelationship and path analysis in tomato. *Ann. Agric. Res.*, **2**(1): 65-69.

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

Nandpuri, K. S., Singh, S. and Tarsemlal. (1973). Studies on the genetic variability and correlation of some economic characters in tomato. *J. Res. Punjab Agric. Univ.*, **10**(3):36-321.

Nesgea, S., Krishnappa, K.S. and Raju, T.B. (2002). Correlation coefficient analysis in tomato. *Current Res. Univ. Agric. Sci.*, Bangalore. **31**(7/8): 127-130.

Nessa, J., Rahman, L. and Alam, M. S. (2000). Comperative performance of ten genotypes of tomato in late planting. *Bangladesh J. Agric. Sci.*, **27**(1): 121-124.

Padda, D. S., Saibhi, M. S. and Singh, S. (1971). Genotypic and phenotypic variabilities and correlations in quality characters of tomato *(Lycopersicon esculentum* Mill.).*Indian J. Agric. Sci.*, **41** : 199-202.

Padma, E., Ravisankar, C. and Srinivasulu, R. (2002). Correlation and path coefficient studies in tomato (*Lycopersicon esculentum* Mill). *J. Res. ANGRAU.* **30**(4): 68-71.

Pandit, M.K., Dutta, A., Akhter, S. and Hazra, P. (2010). Variability and heritability estimates of quality parameters in tomato (*Lycopersicon esculentum* Mill.). *Environ. Ecol.*, **28**(4A): 2594-2596.

Parthasarathy, V. A. and Aswath, E. (2002). Genetic diversity among tomato genotype. *South Indian J. Hort.*, **59**(2): 162-166.

Patil, A. A. and Brajappa, K. M. (1993). Studies on phenotypic and genotypic correlations on growth, yield and quality attributes in tomato (*Lycopersicon esculentum* Mill.). *Karnataka J. Agric. Sci.*, **46**: 395-398.

Patil, M. C. (1996). Investigation on genetic improvement and production practices in processing tomato *(Lycopersicon esculentum* Mill.). Ph.D. Thesis, *Univ. Agric. Sci., Dharwad* (India).

Patil, S. S. (1998). Studies on association of characters, heterosis and combining ability in processing tomato *(Lycopersicon esculentum* Mill.). M. Sc. (Agri.) Thesis, *Univ. Agric. Sci., Dharwad* (India).

Patil, A.A. (1984). Studies on correlation, path analysis, genetic divergence, Heterosis and combining ability in ten parent diallel cross of tomato (*Lycopersicum esculentum* Mill.). Ph.D. Thesis, Univ. Agric. Sci., Dharwad (India).

Pradeep Kumar, T. and Tewari, R. N. (1999). Studies on genetic variability for processing characters in tomato. *Indian J. Hort.*, **56**(4) : 332-336.

Prasad, A. and Prasad, R. A. (1976). Studies on variability in tomato *(Lycopersicon esculentum* Mill.). *Pl. Sci.*, **8**: 45-48.

Prasad, A. and Prasad, R. A. (1977). Variability and correlation studies in tomato. *Indian J. Agric. Sci.*, **47**: 77-80.

Prasad, V. S. R. and Rai, M. (1999). Genetic variability, components association and direct and indirect selection in some exotic tomato germplasm. *Indian J. Hort.*, **56** (3): 262-266.

Prasanna, H. C., Verma, A., Rai, M. And Singh, A. K. (2005). Genetic variability and association analysis in exotic cherry tomato. *Indian J. Pl. Genet. Reso.*, **18**(1): 90-91.

Paranjothi, G. and Muthukrishnhan, C. R. (1979). Studies on variability and association of characters in tomato. *Madras Agric. J.*, **69**: 314-320.

Prashanth, S. J. (2003). Genetic variability and divergence study in tomato (*Lycopersicon esculentum* Mill). M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad (India).

Pujari, C. V., Wagh, R. S. and Kale, P. N. (1995). Genetic variability and heritability in tomato. *J. Maharashtra Agric. Univ.,* **20**(1): 15-17.

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

Reddy, V. V. P. and Reddy, K. V. (1992). Studies in variability in tomato. *South Indian Hort.*, **40**: 257- 260.

Reddy, M. L. N.a dn Gulshanlal, (1987). Genetic variability and path coefficient analysis intomato (*Lycopersicon esculentum* Mill.) under summer season. *Progr. Hort.,* **19**(3-4): 284-288.

Rick, C.M., 1969, Origin of cultivated tomato, current status and the problem. *Abstract, XI International Botanical Congress,* p. 180.

Sachan, K.S. and Sharma, J.R. (1971). Multivariate analysis of genetic divergence in tomato. *Indian J. Gen. Pl. Breed.*, **31(1)**: 86-93.

Saeed A., Hayat K., Khan, A.A., Iqbal S. and Abbas G. (2007). Assessment of genetic variability and heritability in *Lycopersicon esculentum* Mill. *Int. J. Agric. Bio.*, **9**(2): 375-377.

Sahu, G. S. and Mishra, R. S. (1995). Genetic divergence in tomato *Mysore J. Agric. Sci.* **29**: 5-8.

Samadia, D. K., Aswani, R. C. and Dhandar, G. (2006). Genetic analysis for yield components in tomato land races. *Haryana J. Hort. Sci.,* **35**(1&2): 116-119.

Sharma, H. R., Sharma, D. and Thakur, A. K. (2006). Studies on analysis of genetic divergence in tomato (*Lycopersicon esculentum* Mill.). *J. Hort. Sci.,* **1**(1): 52-54.

Sharma, K. C. And Verma, S. (2001). Analysis of genetic divergence in tomato. *Annals Agric. Res.,* **22**(1): 71-73.

Shashikanth., Basavaraj, N., Hosamani, R.M. and Patil, B.C. (2010). Genetic variability in tomato (*Solanum lycopersicon* [Mill].Wettsd.). *Karnataka J. Agric. Sci.* **23**(3): 536-537.

Sidhu, A. S. and Singh, S. (1989). Genetic variability and correlation for yield and quality characters in tomato (*Lycopersicon esculentum* Mill.). *Indian J. Agric. Sci.*, **59**(12): 810-812.

Singh, H. and Cheema, D. S. (2006). Correlation and path coefficient studies in tomato (*Lycopersicon esculentum* Mill.). *Haryana J. Hort. Sci.*, **35**(1&2): 126-129.

Singh P. K., Singh, B. and Pandey S. (2006). Genetic Variability and Character Association Analysis in Tomato. *Indian J. Pl. Genet. Res.* **19**(2) :196- 199.

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*). *J. Interacade*. **10**(3): 314-318.

Singh, A. K. (2000). Genetic variability, correlation and path coefficient studies in tomato *(Lycopersicon esculentum* Mill.) under cold arid region. *Progr. Hort.*, **37**(2):437- 443.

Singh, J.K., Singh, J.P., Jain, S.K. and Joshi, A. (2004). Correlation and path coefficient analysis in tomato. *Progr. Hort.* **36**(1): 82-86.

Singh, J. K., Singh, J. P., Jain, S. K., Aradhana-Joshi. and Joshi, A. (2002). Studies on genetic variability and its importance in tomato *(Lycopersicon esculentum* Mil!-). *Progr. Hort.*, **34**(1): 77-79.

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

Singh, D. N., Sahu, A. and Parida, A. K. (1997). Genetic variability and correlation studies in tomato (*Lycopersicon esculentum* Mill). *Env. Ecol.*, **15**(1): 117-121.

Singh, R. R. and Singh, H. N. (1980). Correlation Studies in tomato. *Indian. J. Agric. Sci.*, **50**(8): 595-598.

Singh, R. R. and Singh, H. N. (1988. Genetic Divergence in tomato. *Indian. J. Agric. Sci.*, **50**(8): 591-594.

Singh, R. R., Mital, R. K. and Singh, H. N. (1973). Note on variability studies in some inter varietal crosses of tomato *(Lycopersicon esculentum* Mill.). *Indian J. Genet. Pl. Breed.*, **38**: 330-335.

Singh, J. P., Anita Singh and Aradhana Joshi. (2005). Studies on genetic variability in tomato (*Lycopersicon esculentum* Mill.). *Prog. Hort.*, **37**(2): 463-465.

Singh, H. N., Singh, R. R. and Mital, R. K. (1974). Genotypic and phenotypic variability in tomato. *Indian J. Agril. Sci.*, **44** (2) : 807-811.

Sonone, A. H., Patil. S.B. and More, D. C. (1986). Variability and heritability in intervarietal crosses of tomato (*Lycopersicon esculentum* Mill). Current Research Reporter, Mahatma Phule Agric. Univ. **2**(1): 125-127.

Sonone, A. H., More, D. C. and Thombre, M. V. (1987). Path analysis in tomato. *J. Maharashtra Agric. Univ.*, **12**: 115-116.

Supe, V. S. and Kale, P. B. (1992). Correlation and path analysis in tomato. *J. Maharashtra Agric. Univ.*, **17**: 331-333.

Susic, Z., Pavlovic, N., Cvikic, D., Rajicic, S. T. (2002). Studies of correlation between yield and fruit characteristics of (*Lycopersicon esculentum* Mill.) hybrids and their parental genotypes. *Acta Hort.*, **579**: 163-166.

Susic, Z., Palvovic, N., Evikic, D., Sretenovic Rojicic, T. and Paroussi, G. (2002). Sttidies of correlation between yield and fruit characteristics of *(Lycopersicon esculentum* Mill.) hybrid and their parental genotypes. *Acta Hort.*, **579**: 263-266.

Sushila, T., Pampapathy, K. and Ravishanker, C. (1990). Correlation studies on yield attributing characters in tomato. *South Indian Hort.*, **38**(4) : 189-190.

Tiwari, J. K. (2002). Correlation studies in tomato. *Haryana J. Hort. Sci.*, **31**(1&2): 146-147.

Upadhyay, M., Singh, J. P., Anita Singh and Aradhana Joshi. (2005). Studies on genetic variability in tomato (*Lycopersicon esculentum* Mill.). *Prog. Hort.*, **37**(2): 463-465.

Upadhay R., Lal, G. and Ram, H.H. (2001). Genotype environment interaction and stability analysis in tomato. *Prog. Hort.*, **33**(2) : 190-193.

Veershety, ().2004, Studies on variability, character association and genetic diversity in tomato (*Lycopersicon esculentum* Mill.). M. Sc. (Agri.) Thesis, *Univ. Agric. Sci., Dharwad* (India).

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

Vikram, A. and Kohli, U. K. (1998). Genetic variability, correlation and path analysis in tomato. *J. Hill. Sci.*, **11**(1): 107-111.

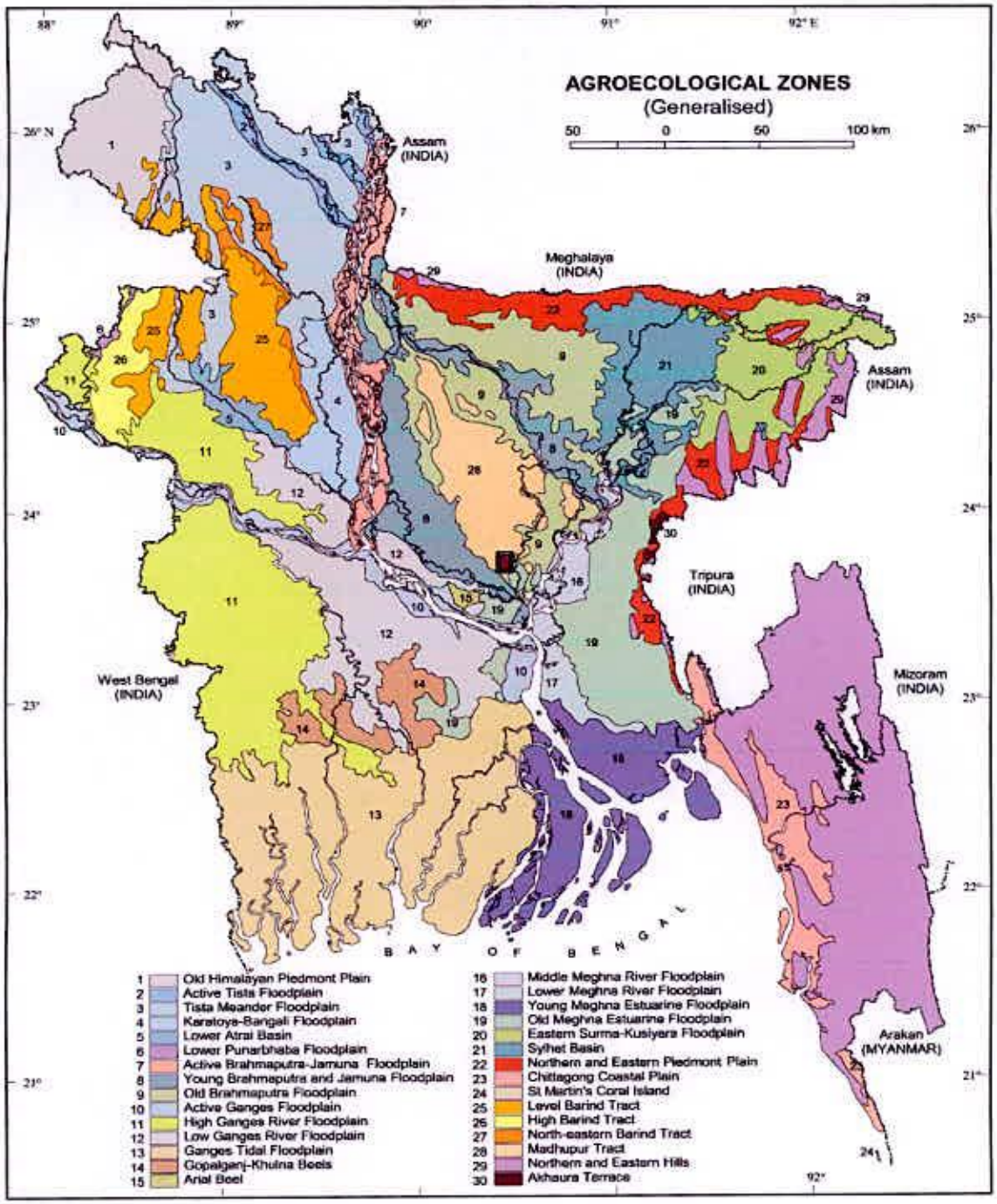
Wagh, R.S., Bharud, R.W., Patil, R.S. and Bhalekar, M.N. (2007). Correlation analysis of growth, yield and fruit quality components in tomato. *J. Mahar. Agric. Uni.* 2007; **32**(1): 29-31

YaDong, S., Yan, L., JiangMin, W., Lei, L. and XiaoJing W. (2010). Correlation analysis on quantitative traits of tomato germplasm resources. *China Veg.*, **6**: 74-76.

Appendices

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly average Temperature, Relative Humidity and Total Rainfall and sunshine of the experimental site during the period from October, 2011 to March, 2012

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)	Sunshine (hr)
	Maximum	Minimum			
October, 2011	34.8	18.0	77	227	5.8
November, 2011	32.3	16.3	69	0	7.9
December, 2011	29.0	13.0	79	0	3.9
January, 2012	28.1	11.1	72	1	5.7
February, 2012	33.9	12.2	55	1	8.7
March, 2012	34.6	16.5	67	45	7.3

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka - 1212

Appendix III. Physical characteristics and chemical composition of soil of the experimental plot

Soil characteristics	Analytical results
Agrological Zone	Madhupur Tract
P^H	6.00 – 6.63
Organic matter	0.84
Total N (%)	0.46
Available phosphorous	21 ppm
Exchangeable K	0.41 meq / 100 g soil

Source: Soil Resource and Development Institute (SRDI), Dhaka

Appendix IV. Mean performance of various growth parameter and yield components.

Genotypes	DFF	DFFS	PH	FD	PT	LPF	BPP	CPP	FPC	FPP	FW	SLF	FYP
BD-7306	61.67	73.00	78.33	4.00	0.43	3.00	8.00	16.67	2.33	35.33	18.33	9.00	0.65
BD-7759	64.67	78.33	69.33	3.10	0.33	2.00	8.00	15.00	4.33	62.00	8.33	9.00	0.57
BD-7761	59.33	78.67	55.00	3.83	0.50	2.33	7.33	18.00	3.33	59.67	16.33	8.67	0.97
BD-7762	58.33	79.33	66.33	4.07	0.53	2.33	7.33	15.00	3.67	61.00	16.33	9.00	0.99
BARI Tomato-3	67.67	83.67	76.00	5.57	0.50	4.33	6.00	12.33	3.67	42.67	46.67	8.67	2.05
BARI Tomato-4	57.33	78.00	70.33	3.83	0.47	3.00	7.67	11.33	4.67	52.33	35.33	8.67	1.84
PUSA Rubi	62.33	79.33	74.33	3.90	0.30	5.00	9.33	11.67	3.33	41.00	40.33	8.00	1.47
BD-7258	60.67	79.67	61.67	3.50	0.43	2.33	8.33	14.00	3.33	49.00	16.33	7.33	0.77
BD-7259	66.00	78.00	90.00	4.13	0.43	3.33	9.00	16.00	3.33	46.33	33.33	8.00	1.53
BD-7260	67.33	78.67	67.00	4.17	0.50	3.00	9.00	19.33	3.67	78.33	23.33	6.67	1.65
BD-7270	67.33	78.67	75.33	3.97	0.50	2.33	7.67	16.33	3.00	51.00	26.67	7.67	1.33
BD-7276	62.67	75.33	86.67	3.93	0.37	3.33	7.00	19.00	3.00	59.67	23.67	7.67	1.36
BD-7285	62.00	75.67	93.67	3.13	0.27	2.67	9.00	16.67	3.67	67.00	15.67	7.33	0.89
BD-7279	67.00	81.00	65.67	4.50	0.47	2.00	9.33	17.33	3.33	66.33	15.67	8.33	0.91
BD-7286	65.00	81.33	99.00	3.33	0.27	2.67	7.67	14.67	3.00	46.00	25.67	9.33	1.14
BD-7281	64.67	81.00	98.67	3.70	0.27	2.33	9.33	17.33	3.33	57.33	18.67	8.33	1.07
BD-7289	63.67	78.33	79.00	3.73	0.37	2.67	7.33	12.67	4.00	49.33	13.33	7.67	0.65
BD-7291	69.67	82.00	83.67	3.60	0.30	2.67	8.67	9.00	3.33	29.67	19.67	6.33	0.62
BD-7290	60.67	80.67	78.67	3.97	0.47	2.67	7.00	9.67	3.67	32.33	19.67	7.33	0.67
BD-7262	63.33	79.00	61.00	4.17	0.47	2.67	7.67	10.33	4.33	40.00	9.00	8.33	0.35

Appendix IV. Mean performance of various growth parameter and yield components (Cont'd)

Genotypes	DFF	DFFS	PH	FD	PT	LPF	BPP	CPP	FPC	FPP	FW	SLF	FYP
BD-7295	57.33	78.67	76.33	4.97	0.60	3.67	6.67	17.33	3.67	62.67	22.00	6.67	1.37
BD-7301	62.00	76.67	62.67	4.60	0.63	2.33	7.67	12.33	3.67	41.00	10.33	9.33	0.42
BARI Tomato-11	62.67	78.33	102.00	4.90	0.57	3.67	7.67	13.00	5.33	61.67	23.33	9.00	1.44
Mintu	65.00	82.67	84.00	4.97	0.60	3.00	7.67	8.67	5.00	42.33	22.67	6.33	1.02
Unnayan	57.00	74.67	64.00	4.53	0.60	3.00	7.33	13.00	4.33	62.67	20.67	7.33	1.22
Raton	58.33	78.67	68.67	4.77	0.40	3.33	7.33	12.00	4.33	50.00	22.00	7.67	1.09
Ruma VF	64.33	75.67	70.33	4.53	0.53	2.33	9.00	11.33	3.33	30.33	38.33	7.67	1.05
Delta	67.67	77.33	75.00	4.60	0.57	2.33	9.67	15.67	2.67	46.33	35.67	8.67	1.70
BARIHybridTomato-4	64.33	77.33	74.33	5.07	0.47	3.67	10.00	17.00	3.33	53.33	37.67	8.33	1.85
Mean	63.10	78.61	76.10	4.17	0.45	2.90	8.06	14.23	3.66	50.92	23.28	8.01	1.13
Min.	57	73	55	3.1	0.27	2	6	8.67	2.33	29.67	8.33	6.33	0.35
Max.	69.67	83.67	102	5.57	0.63	5	10	19.33	5.33	78.33	46.67	9.33	2.05

DFF = Days of first flowering, DFFS = Days of first fruit setting, PH = Plant height (cm), FD = Fruit Diameter (cm), PT = Pericarp thickness (cm), LPF = Locule No. , BPP = Branches per plant, CPP = Clusters per plant, FPC = Number of fruits per cluster, FPP = Fruits per plant, FW = Fruit weight (g), SLF = Shelf life of fruits, FYP = Fruit yield per plant (kg).