GENETIC DIVERSITY ANALYSIS AMONG SOME TOMATO GENOTYPES (*Solanum lycopersicum* L.)

JANNATUL NAIME

DEPARTMENT OF GENETICS AND PLANT BREEDING
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

JUNE, 2016

GENETIC DIVERSITY ANALYSIS AMONG SOME TOMATO GENOTYPES (S*olanum lycopersicum* L.)

BY

JANNATUL NAIME

REGISTRATION NO.:10-04184

A Thesis
submitted to the Department of Genetics and Plant Breeding
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, 2016

APPROVED BY:

Prof. Dr. Md. Sarowar Hossain	**Prof. Dr. Naheed Zeba**
Supervisor	**Co-Supervisor**

.....

Prof. Dr. Jamilur Rahman
Chairman
Examination Committee

Dr. Md. Sarowar Hossain
Professor
Department of Genetics and Plant Breeding,
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh

Phone: +88029144270-9, Ext.: 315 (Office)
Mobile No.: 01766535088
E-mail: sarwar2001@rediffmail.com

CERTIFICATE

This to certify that thesis entitled, **"Genetic diversity analysis among some tomato genotypes (Solanum lycopersicum L.)"** 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 **Jannatul Naime, Registration No. 10-04184** 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 been duly acknowledged.

Dated: June, 2016

Prof. Dr. Md. Sarowar Hossain
Supervisor


Dedicated To
My Beloved Parents

ACKNOWLEDGEMENTS

All of the gratefulness to almighty Allah who enabled the author to accomplish this thesis.

The author would like to express her heartiest respect, deepest sense of gratitude, profound appreciation to her supervisor, **Prof. Dr. Md. Sarowar Hossain**, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without his intense co-operation this work would not have been possible.

The author feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her co-supervisor **Prof. Dr. Naheed Zeba**, Professor, Department of Genetics and Plant Breeding SAU, Dhaka for her scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.

She express her sincere respect to the Chairman, **Prof. Dr. Jamilur Rahman** and all the teachers of the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study. The author would also thankful to all of the staffs of the Department of Genetics and Plant Breeding.

Mere diction is not enough to express her profound gratitude and deepest appreciation to the author's family and her heartfelt thanks to her father Nur Muhammad, mother Mariam Khatun and sister Jannatul Ferdous Moonmoon and for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate her to this level.

Dated: June, 2016 **The Author**

GENETIC DIVERSITY ANALYSIS AMONG SOME TOMATO GENOTYPES (*Solanum lycopersicum* L.)

BY

JANNATUL NAIME

ABSTRACT

The present study was undertaken at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh with fifteen genotypes of tomato to study the genetic diversity among them during November 2015 to April 2016. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The genotypes were BARI tomato-2, BARI tomato-3, BARI hybrid tomato-4, BARI hybrid tomato-5, BARI tomato-11, BARI tomato-14, BARI tomato-15, BARI tomato-16, BARI tomato-17, BD-7287, BD-7290, BD-7278, BD-7757, BD-9960 and BD-7291. Considering agronomic performance the genotype G13 showed the maximum number of branches plant^{-1} and number of fruits plant^{-1}, G5 showed the maximum number of fruits cluster^{-1}, G14 for the maximum number of clusters plant^{-1}, G9 for the maximum fresh fruit weight (single) and G4 for the maximum fruit yield plant^{-1} (kg).The number of fruit yield plant^{-1} showed the highest range of variation (3.75 kg - 1.05 kg) that means wide range of variation exists for this character. In case of plant height, number of leaves plant^{-1}, number of flowers plant^{-1}, number of fruits plant^{-1}, fruit yield plant^{-1}, showed the higher influence of environment for the expression of these characters. All the characters under the present study exhibited the highest value of heritability. Most of the characters showed the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the characters under study. The significant positive correlation with yield per plant was found in number of branches per plant (0.065 and 0.071), number of flowers plant^{-1} (0.059 and 0.048), number of fruits plant^{-1} (0.053 and 0.039), fruit length (0.524 and 0.517), single fresh fruit weight (0.331 and 0.337), percentage of brix (0.139 and 0.142) at genotypic and phenotypic level while the significant negative correlation was found in days to maturity and the number of fruits per cluster at genotypic and phenotypic level. Path coefficient analysis showed that single fruit weight had the positive correlation with fruit yield per plant. Coherently, this trait contributed to the yield through direct effect (0.086) indicating selection would be judicious and more effective for these characters in future breeding program. Positive direct effect was also found in plant height, number of branches plant^{-1}, number of flowers plant^{-1}, days to first flowering, number of clusters plant^{-1}, number of fruits plant^{-1}, fruit length, fruit diameter and dry weight of 5 g fresh fruit. Considering the magnitude of cluster mean and agronomic performance the genotype G13 for the maximum number of branches plant^{-1}, number of fruits plant^{-1}, G5 for maximum number of fruits cluster^{-1}, G14 for the maximum number of clusters plant^{-1}, G9 for the maximum fresh fruit weight (single) and G4 for maximum fruit yield plant^{-1} (kg) were found promising. Therefore, considering group distance and other agronomic performance the inter-genotypic crosses between G5, G9, G13 and G14 might be suggested for future hybridization program.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

FULL WORD		ABBREVIATION
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	MiliLitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tomato, ranking 1st in the world for vegetables, accounts for 14% of world vegetable production over 100 million metric tons/year $ 1.6 billion market (FAO, 2010). Tomato is a rich source of micronutrients for human diet. It is also an acknowledged model species for genetic research. The major goals of tomato breeders are higher productivity, better tolerance to biotic and abiotic stresses and increased sensory and health value of the fruit. It requires a good comprehension and management of tomato genetic resources diversity. The tomato (*Solanum lycopersicum* L.) is the edible, often red berry-type fruit of the nightshade commonly known as a tomato plant. Tomato species are diploid with twelve pairs of chromosomes (2n = 24) and is a self-pollinated annual crop which belongs to the family solanaceae. The species originated in the South American Andes and its use as a food originated in Mexico and spread throughout the world following the Spanish colonization of the Americas. It is the most frequently consumed vegetable in many countries becoming the main supplier of several plant nutrient and providing an important nutritional value of human diet (Willcox *et al*., 2003).

Tomato is a rich source of vitamins (A and C), minerals (Ca, P and Fe) and a strong antioxidant against cancer and heartdiseases (Anonymous, 2011; Dhaliwal *et al*., 2003). More than 7% of total vitamin-C of vegetable origin comes from tomato in Bangladesh. Besides tomato varieties are available with double the normal vitamin C, 40 times normal vitamin A, high levels of anthocyanin and two to four times the normal amount of lycopene.

In Bangladesh, tomato is grown on an area of 26,300 million hectares with an average production of 251 thousand metric tons (FAOSTAT, 2013) which is very low (0.2%) compared to other countries The best tomato growing areas in Bangladesh are Dinajpur, Rajshahi, Dhaka, Comilla and Chittagong. The yield of

tomato is not enough satisfactory in Bangladesh in comparison to the other tomato growing countries of the world. The low yield of tomato in Bangladesh however is not an indication of low yielding potentially of this crop but of the fact that the low yield may be attributed to a number of reasons, *viz*. unavailability of quality seeds of high yielding and summer varieties, land for production based on light availability, fertilizer management, pest infestation and improper irrigation facilities as well as production in abiotic stress conditions especially drought (Aditya, 1997).

Very recently exotic hybrid varieties are being introduced due to their high yield potentiality but seed costs of those hybrid varieties are very high. Moreover, due to unique nature of hybrid variety, the tomato growers need to buy seeds every year. The main constraints of tomato production are pest and disease incidence, adverse climatic conditions, absence of high yielding varieties. Therefore we need to generate high yielding tomato genotypes suitable for our environment as well as our country. Yield contributing components are interrelated with each other and influenced by the environmental conditions.

A large number of tomato varieties are grown in Bangladesh. Most of them lost their potentiality due to genetic deterioration, diseases and insect infestations. So, in order to increase the tomato production in Bangladesh, it is very much essential to find out the varieties capable of growing round the year, higher yield and resistant to disease and insect pests. Recently various research organizations have developed a few high yielding and disease, insect resistant varieties but these do not show better performance throughout the year.

Success of crop improvement program depends on the extent of genetic variability, choice of parents for hybridization and selection procedure. Morphological characters are important diagnostic features for distinguishing genotypes. These distinct morphological characters of genotypes facilitate the selection process in crop improvement by serving as genetic markers. Thus

character association by assessing their agromorphogenic and nutritional description, increases knowledge of the genetic variability available which facilitates breeding for wider geographic adaptability, with respect to biotic and abiotic stresses.

Parameters of genotypic and phenotypic coefficients of variation (GCV and PCV) are useful in detecting the amount of variability present in the available genotypes. Heritability and genetic advance help in determining the influence of environment expression of the characters and the extent to which improvement is possible after selection (Robinson *et al*., 1949). Genetic analysis of tomato is essential to enhance the genetic yield potential and maximum utilization of the desirable characters for synthesizing of any ideal genotypes (Kumar *et al*., 2003).

To recognize and estimate the genetic variation in plant germplasms, different methods can be applied including morphological, biochemical and molecular markers. Morphological markers are used plentifully to study genetic diversity in plants. Compared with other markers, use from morphological traits for genetic diversity is direct, inexpensive and easy (Bernousi *et al*., 2011). Morhphological-based estimation of genetic diversity in tomato has been the subject of many researchers in different regions of the world (Meena and Bahadur, 2015; Meitei *et al*., 2014; Hu, *et al*., 2012).

In tomato, yield is the cumulative effect of many components contributing individually to yield (Bernousi *et al*., 2011). Different characteristics *viz*., number of flowers cluster^{-1}, days to first fruit ripening, fruit weight, fruit length, fruit width assume vital importance and must be assessed for genetic divergence aiming to develop high yielding tomato varieties or hybrids. The most commonly used algorithms for this purpose, are canonical variable analysis, principal component analysis and clustering methods (Sudre *et al*., 2007; Mohammadi and Prasanna, 2003). Principal component analysis is frequently used to determine the relative significance of different variables of classification, prior to cluster analysis

(Jackson, 1991). Additionally PCA also gives a reduced dimension model that would point out the measured differences among different groups and leads to understanding of variables by telling how much of the total variance is explained by each one.

However, Bangladesh Agricultural Research has Institute (BARI) has released 17 open pollinated and eight hybrid tomato varieties so far (some of these already obsolete) and several leading seeds companies are also supplying some tomato varieties and some seeds of these tomato varieties are being imported from different countries. Therefore, a study was conducted on the variability, correlation, path co-efficient, and genetic diversity analysis between agromorphogenic and nutritional traits of tomato, conceiving the above scheme in mind, to fulfill the following objectives:

1. To know the yield potential genotypes
2. To assess the correlation among the yield and yield contributing traits of tomato genotypes
3. To assess the genetic diversity among the genotypes for identifying the genetically divergent parents to use them in the future breeding program

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the most important and popular winter vegetable in Bangladesh. Tomato is an introduced crop in Bangladesh and provides less genetic variability. It is estimated that the genomes of tomato cultivars contain <5% of the genetic variation of their wild relatives. The scheduling of a breeding program for enhancement of any crop considering any definite traits requires information on the genetic variability, character and magnitude of genetic diversity present in the available breeding materials and association among different agromorphogenic and nutritional traits. On that view point, an experiment was conducted for progress of tomato using fifteen genotypes. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter under the followings:

2.1 Nomenclature, Origin and distribution of tomato

Tomatoes originated from the Andes, in what is now called Peru, Bolivia, Chile and Ecuador - where they grew wild. They were first cultivated by the Aztecs and Incas as early as 700 AD. Tomatoes didn't arrive in Europe until the 16th Century, although it is not known how. It has been said that they were brought back from Central America by Spanish Conquistadors. Another legend suggests that two Jesuit priests brought them to Italy from Mexico. Others say Columbus brought the first tomato to Europe (Anonymous, 2014).

Right now the accepted scientific name for most of the scientific community is *Solanum lycopersicum* L. The old scientific name is *Lycopersicon esculentum* Mill. and was widely used from 1768 to 2005. In 2005 Spooner and his associates proposed a change back to the original nomenclature used by Linnaeus in 1753 (Anonymous, 2015). According to "International Plant Name Index" in 1753,

Linnaeus placed the tomato in the genus *Solanum* as *Solanum lycopersicum* and in 1768 Philip Miller moved it to its own genus, naming it *Lycopersicon esculentum* (Anonymous, 2014).

According to "International Plant Name Index" and "Slow Food ® Upstate", in 1753, Linnaeus placed the tomato in the genus *Solanum* as *Solanum lycopersicum* and in 1768 Philip Miller moved it to its own genus, naming it *Lycopersicon esculentum*. This name came into wide use, but was in violating of the plant naming rules. Genetic evidence has now shown that Linnaeus was correct to put the tomato in the genus *Solanum*, making *Solanum lycopersicum* the correct name (Natural History Museum; Peralta and Spoonar, 2001). Both names, however, will probably be found in the literature for some time.

Tomato translates to "wolfpeach" - peach because it was round and luscious and wolf because it was erroneously considered poisonous (Fillipone, 2014). The English word "tomato" comes from the Spanish word, tomate, which in turn comes from the Nahuatl (Aztec language) word tomatotl. It first appeared in print in 1595. A member of the deadly nightshade family, tomatoes were erroneously thought to be poisonous (although the leaves are poisonous) by Europeans who were suspicious of their bright, shiny fruit. Native versions were small, like cherry tomatoes, and most likely yellow rather than red (Filippone, 2014).

The tomato (*Solanum lycopersicum* L.), is an autogamous species with a narrow genetic base. The introduction of the species in Europe, from Mexico, was pivotal in the reduction of genetic variability, since in the European habitat tomatoes were generally cultivated in protected environments. This protected the wild forms, then allogamous, from the action of wind and insect pollinators, culminating in the maintenance of a germplasm adapted to autogamy only (Foolad, 2007).

The tomato is native to western South America and Central America (Filippone, 2014). Tomato is a tropical plant and grown in almost every corner of the world

from tropics to within a few degrees of the Arctic Circle. Mexico has been considered the most likely center of domestication of tomato. Italy and Spain are considered secondary centers of diversification (Gentilcore, 2010; Smith, 1994). The cultivated tomato originated in the Peru-Ecuador-Bolivia area of the South American (Vavilov, 1951). Major tomato producing countries are Spain, Brazil, Iran, Mexico, Greece, Russia, China, USA, India, Turkey, Egypt and Italy (Anon., 2010). It is believed that the tomato was introduced in subcontinent during the British regime. It is adapted to a wide range of climates. In tomato (*Solanum lycopersicum* L.), one cultivated species and 12 wild relatives have been reported (Peralta *et al*., 2006). Genetic variation in modern cultivars or hybrids is limited (Chen *et al*., 2009). It is estimated that cultivated tomato genome contains less than 5% of the genetic variation of the wild relatives (Miller and Tanksley, 1990). It has been suggested by Yi *et al*. (2008) that domestication and inbreeding dramatically reduced the genetic variation.

2.2 Variability, heritability and genetic advance

2.2.1 Variability

The basic input to achieve the genetic perfection of a crop through a proper breeding program is to appraise the amount and nature of variation of plant characters in breeding population. It helps the breeder for improving the selection efficiency. For this reason, many researchers studied variation of various characters in tomato.

Paul *et al*. (2014) conducted the study to reveal the genetic variability among the yield contributing traits and their direct and indirect contribution of these parameters towards the yield and identify better combinations as selection criteria for developing high yielding tomato genotypes. Significant differences among genotypes were observed. The success of any crop improvement programme depends on the presence of genetic variability and the extent to which the

desirable trait is heritable. The presence of genetic variability in the breeding material has been emphasized by previous researchers (Naz *et al*., 2013; Reddy *et al*., 2013; Singh, 2009; Shuaib *et al*., 2007). Morphological trait measurements can provide a simple technique of quantifying genetic variation and simultaneously assessing genotype performance under relevant growing environments (Shuaib *et al*., 2007).

An experiment was conducted out by Naz *et al*. (2013) to study the genetic variation among twenty five tomato accessions that helped in the reliable varietal selection programme for breeding. This study revealed that height of plant, fruit color and fruit size show variability. Using nineteen exotic collections of tomato, Reddy *et al*. (2013) revealed considerable genetic variability for all the eighteen quantitative characters which was pertaining to the growth, earliness, yield and quality. Fruit weight, plant height and number of fruits per plant contributed to the total variation.

Mahesha *et al*. (2006) exposed significant variability for all the characters under study and detected a wide range of variation for plant height, number of branches per plant, fruit weight, fruit length, fruit diameter, fruit set percentage, fruits per plant, fruit yield per plant. A number of germplasms on the basis of phenotypic characters like color, size, taste etc. are available in tomato. 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. Singh (2005) conducted a field experiment with 30 tomato and five genotypes (DT-39, RHR-33-1, ATL-16, DARL-13 and RT-JOB-21) showed higher number of primary branches than the control. The maximum

number of fruits per plant was obtained from BT-117-5-3-1. Fruit yield was maximum (1.84 kg/plant) in DT-39. Most of the cultivars showed higher total soluble solids content in their fruits compared to the control. The acidity percentage in fruits was highest in KS-60. The physiological loss in weight at seven days was highest in NDT-111 and lowest in Plant T-3. ATL-13 showed the highest lycopene content (59.67 mg/100 g).

The evaluation of the Kenyan tomato germplasm by Agong *et al*. (2001) showed a large and significant variation in the quantitative traits between the accessions. The average fresh and dry fruit weight varied notably among the accessions. Most of the landraces gave lower fresh and dry fruit yields than the market cultivars.

Mohanty and Prusti (2001) showed considerable genetic variability 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). The fundamental key to achieve the genetic improvement of a crop through a proper breeding programme is to calculate the amount and nature of variation of plant characters in breeding population. The assessment helps breeder for improving the selection efficiency. Many researchers studied variation of various characters in tomato. Some of those are presented here.

2.2.1.1 Plant height (cm)

Paul *et al*. (2014) revealed that the significant differences among different genotypes of tomato were observed in all parameters studied except height of first leaf appearance at seedling stage.

Naz *et al*. (2013) used 25 tomato germplasam to characterize morphologically by comparing the height of plant, leaf length, shape and arrangement, fruit shape and size. This study revealed that height of plant show highest variability. Hannan *et al*. (2007) carried out an experiment, to estimate heterosis and character association in 45 single cross hybrids, obtained from 10 parental lines of tomato

for yield and yield component traits. The characters studied were plant height, days to first flowering (DFF), number of flowers per cluster (NFPC), number of fruits per plant (NFPP), fruit weight per plant (FWPP) and days to first fruit ripening. They obtained significant differences among genotypes for all the traits and found positive high significant hererosis for FPP (72.9, 75.33 and 20.74), TFWPP (189, 172 and 187), NFPC (48.65, 44.14 and 37.86) over the mid parent, better parent and standard parent heterosis, respectively, and significantly high percentage of positive heterosis for NFPP, TFWPP and NFC. They concluded that five hybrids possessed significant positive useful heterobeltiosis for TFWPP, positively correlated with FPP, NFPC and Plant height. They selected three single cross hybrids for their heterotic performance. Ravindra *et al*. (2003) also observed significant variation for genotype × environment interaction for plant height.

Joshi *et al*. (2004) conducted a field experiment with forty tomato genotypes to evaluate their genetic variability and noticed that plant height gave the highest heritability (78.82%). Kumari *et al*. (2007) observed the highest genotypic coefficient of variation for plant height. Shravan *et al*. (2004) Prasad and Mathura (1999) and Aditya and Phir (1995) reported significant variation for plant height.

Considerable variability was found among 23 genotypes of tomato for 8 morphological characters. Plant height, fruit number, fruit size were contribute higher variability among them (Parthasarathy and Aswath, 2002).

A field experiment with 92 tomato genotypes carried out by Singh *et al*. (2002) 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 sufficient variability may be considered in a hybridization program for yield improvement in tomato. Ghosh *et al*. (1995) and Nandpuri *et al*. (1974) reported a high degree of variation for plant height

while a thin range of variations was pragmatic by Ahmed *et al*. (1986). Phenotypic variance was relatively higher than genotypic variance for plant height and also the genotypic co-efficient of variation was lowering than phenotypic co-efficient of variation that indicating influence of environment for expression of this character reported by Matin and Kuddus (2001).

Dev *et al*. (1994) concluded that the best F1 hybrid was EC156 × Marglove, which gave 83.18 and 29.23% greater yields than the better parent and the control variety, respectively. They also observed heterosis in tomato in a line × tester analysis. Appreciable heterosis was observed for the nine characters studied over their respective better parent. Heterosis over the better parent ranged from 0.05 to 115.7%, the minimum being for plant height and the maximum for number of fruits per plant.

Farkas (1993) found high GCA variances for early and total yield, mean fruit weight and fruit firmness, but not for plant height and width. Estimation of GCA effects indicated that the maternal parent was superior in early and total yield. He observed that GCA and SCA effects were not directly correlated to the observed performance of hybrids for given characters. Moreover, heterosis effects compensated for a yield decrease in hybrids of the processing type.

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

2.2.1.2 Number of leaves plant^{-1}

Shravan *et al*. (2004) conducted an experiment with 30 tomato genotypes to study their genetic variability and reported significant difference for number of leaves per plant among the genotypes. Upadhaya *et al*. (2001) also observed PCV was slightly higher than GCV for number of leaves per plant.

Singh *et al*. (2005) carried out a field experiment with 30 tomato lines and five genotypes (DT-39, RHR-33-1, ATL-16, DARL-13 and RT-JOB-21) and observed higher number of leaves per plant than the control. Upadhyay *et al*. (2005) evaluated 34 genotypes of tomato and observed a range between 140.65-160.50 leaves per plant. He reported the PCV (26.90%) was higher than GCV (22.48%) for this character.

Ravindra *et al*. (2003) found significant genotype × environment interaction for number of leaves per plant. Singh *et al*. (2002) carried out a field experiment with 92 tomato genotypes to study genetic variability and also reported that the analysis of variance revealed highly significant genetic variation for plant height and number of leaves per plant. The traits characterized by adequate variability may be considered in a hybridization program for yield improvement in tomato.

2.2.1.3 Number of branches per plant

Singh *et al*. (2005) carried out a field experiment with 30 tomato lines and five genotypes (DT-39, RHR-33-1, ATL-16, DARL-13 and RT-JOB-21) and observed higher number of primary branches than the control. The maximum number of fruits per plant was obtained from BT-117-5-3-1. Fruit yield was maximum (1.84 kg/plant) in DT-39. Most of the cultivars showed higher total soluble solids content in their fruits compared to the control. The acidity percentage in fruits was highest in KS-60. The physiological loss in weight at 7 days was highest in NDT-111 and lowest in Plant T-3. ATL-13 showed the highest lycopene content (59.67 mg/100 g). Upadhyay *et al*. (2005) 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.

Singh (2005), Mohanty (2003) and Upadhaya *et al*. (2001) observed PCV was slightly higher than GCV for number of branches per plant. Shravan *et al*. (2004) conducted an experiment with 30 tomato genotypes to study their genetic

variability and reported significant difference for number of primary branches per plant among the genotypes.

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. Ravindra *et al*. (2003) also found significant genotype × environment interaction for number of primary branches.

Singh and Singh (1993) conducted an experiment on heterosis breeding in tomato. Eight cultivars with diverse values for quantitative characters were crossed in a diallel set. Hybrid Punjab Chhuhara × 84-8 showed the highest heterosis for fruit yield plant^{-1} (1200 g). Heterosis for this hybrid was also superior for number of fruits plant^{-1} and early yield over the mean parent and number of branches plant^{-1} over the better parent.

2.2.1.4 Days to first flowering

Farzaneh *et al.* (2013) showed earliness in number of days to first flowering while studying combining abilty from a 9×9 diallele cross. Whereas Monamodi *et al.* (2013) had not found any significant differences in days to first flowering among tomato genotypes. 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.

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

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. Mtuatham in an experiment with 18 promising cultivars of tomato considering local cultivar Patharkutchi as control at Mymensingh reported significant variation for days to first flowering in six cultivars of tomato. The phenotypic variance was comparatively higher than the genotypic variance indicating high degrees of environmental effect for days to first flowering (Matin, 2001 and Aditya, 1995).

Singh *et al*. (1993) conducted an experiment on heterosis breeding in tomato. Eight cultivars with diverse values for quantitative characters were crossed in a diallel set. Data on yield and nine component traits were recorded for the 28 F1 hybrids and parents. Hybrids Punjab Chhuhara × 84-8, HS102 × Pusa Ruby, HS102 × 84-8 and Pusa Ruby × 84-10 showed significant negative heterosis for days to first flowering over the better parent, indicating their potential for producing an early crop. Hybrid Punjab Chhuhara × 84-8 showed the highest heterosis for fruit yield plant^{-1} (1200 g).

2.2.1.5 Days to 50% flowering

Nalla *et al.* (2014) done a field experiment using 27 tomato genotypes and reported days to 50% flowering (1.14%) contributed very little for variability. Thirteen quantitative characters were studied in 55 genotypes of tomato by Narolia (2012) and found high variability for all the characters studied except number of branches per plant and days to 50% flowering for which variability was moderate

and low, respectively. The stability of 5 cultivars of tomatoes for growth and earliness was determined in a field experiment by Ravindra *et al.* (2003). Significant genotype × environment interaction was observed for number of days to 50% flowering.

Pujari *et al*. (1994) studied the results from an 8 × 8 half diallel cross in tomato which indicated high heterosis for yield plant^{-1}, fruits plant^{-1}, fruits cluster^{-1} and earliness. Punjab Chhuhara × Roma was the top ranking hybrid which gave 6.37 kg of fruit plant^{-1} produced 120 fruits plant^{-1} and had an average fruit weight of 55.9 grams. It produced 6.4 fruits cluster^{-1} and took 52 days to 50% flowering.

Srivastava *et al.* (1998) studied heterosis in relation to combining ability in tomato, in a field experiment through line × tester method using 15 female lines and three testers. The analysis revealed that none of the parents was a good general combiner for all the characters. However, lines viz. 53106, 6601, 8105 and 8730 were good general combiners for as many as four to five characters. They found the ratio of general to specific combining ability less than unity for all the characters, revealing predominance of non-additive variance. They found high heterotic response in most of the hybrids which supports the role of non-additive gene effects. They suggested the selection, for improvement of traits like days to 50% flowering and maturity while yield related traits such as number fruits plant^{-1}, size of fruit may be exploited through heterosis breeding.

Chadha *et al.* (2001) conducted an experiment pertaining to number of combinations evincing combining ability for days to 50% flowering and found that out of 40 F1s, 3 % showed good specific combining ability. Baishya *et al.* (2001) carried out a 9 × 9 half diallel analysis in tomato, and observed that majority of the crosses out of 36, exhibited desirable negative heterosis over better parent for days to 50% flowering. Dhaliwal *et al*. (2002) reported that concerning combining ability studies for days to flowering in tomato, highly significant variance for

GCA and SCA were observed. Similarly, Cheema *et al.* (2003) also detected highly significant variances for General and Specific combining abilities in tomato (*Lycopersicon esculentum* Mill.).

2.2.1.6 Days to Maturity

Saleem *et al*. (2013) carried out an experiment using twenty five F_1 hybrids generated from 5×5 diallel crosses and found moderate heritability for days to maturity indicated favourable influence of environment rather than genotypes consequently, selection of superior genotypes to develop early maturing genotypes would not be rewarding in early generations. Prashanth (2003) evaluated 67 genotypes of tomato and found phenotypic coefficient of variation was higher than genotypic coefficient of variation for days to maturity.

Pradeepkumar *et al.* (2001) conducted an experiment to quantify genetic variation in tomato for yield and resistance to Bacterial Wilt based on the idea that proper and systematic evaluation of genetic resources was essential to understand and estimate the genetic variability, heritability and genetic advance. Data were recorded on plant height, days to maturity, number of fruits plant^{-1}, pericarp thickness, locule number, total soluble solids, average fruit weight, number of harvest per plant and plant yield. They observed highly significant differences among the genotypes for all the traits as well as high genotypic coefficient of variation for all the characters. Higher heritability estimates and high genetic advance for all the characters indicated lesser influence of environment and higher role of additive gene action, respectively, so they suggested selection for rewarding improvement of these traits.

2.2.1.7 Number of clusters per plant

Dufera (2013) conducted an experiment using twenty one tomato germplasms. Higher genotypic and phenotypic co-efficients variation values were recorded by

the character fruit clusters per plant, indicating the presence of variability among the genotypes and the scope to improve these characters through selection**.**

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

2.2.1.8 Number of fruits cluster^{-1}

Samadia *et al.* (2006) evaluated 14 cultivars of tomato and reported almost similar estimates of PCV and GCV for this character. In contrast Arun *et al*. (2003) evaluated 37 genotypes of tomato and observed the PCV was higher than GCV for Number of fruits per cluster. Similar result was observed by Aradhana *et al.* (2003).

Arun *et al*. (2003) evaluated 37 genotypes of tomato and observed the PCV was higher than GCV for Number of fruits per cluster. Similar result was observed by Aradhana and Singh (2003). In compare Samadia *et al*. (2006) experimented with 14 cultivars of tomato and reported almost similar estimates of PCV and GCV for this character.

Singh *et al*. (1997) derived information on genetic variability, heritability and yield correlations from data on 14 agronomic and yield-related traits in 23 genotypes of tomato. They concluded that based on heritability and genetic advance values, effective selection may be made for fruit weight and number of fruits plant^{-1} as fruit yield showed strong positive correlation with number of fruits plant^{-1} and number of fruits cluster^{-1}. They recommended that number of fruits plant^{-1} and number of fruits cluster^{-1} are the most important character for consideration in a selection programme for improvement of yield.

Pujari *et al*. (1994) studied the results from an 8×8 half diallel cross in tomato which indicated high heterosis for yield plant^{-1}, fruits plant^{-1}, fruits cluster^{-1} and

earliness. Punjab Chhuhara × Roma was the top ranking hybrid which produced 6.4 fruits cluster^{-1}.

2.2.1.9 Number of Fruits per plant

Seventeen diverse genotypes of tomato were evaluated by Thakur (2009) for their performance and interaction with changing environments through the characters like fruit yield, number of fruits per plant. The analysis of variance indicated highly significant differences between the genotypes and environments for all the characters studied. According to Buckseth *et al.* (2012) high GCV obtained for average fruit weight, yield per plant, pericarp thickness, and number of seeds per fruit.

Saeed *et al*. (2007) observed the variation among the accessions. The coefficient of variation was greater in traits such as number of fruits per plant followed by number of flowers per plant and yield per plant. 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 which provide the highest phenotypic and genotypic coefficient of variation.

Brar *et al*. (2000) estimated phenotypic and genotypic co-efficient of variation and observed high variability in the characters of number of fruits per plant of 186 genotypes of tomatoes. Islam *et al.* (1996) reported wide range of 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-efficient of variation indicated that selection may be made for number of fruits per plant.

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

et al. (1986); Dudi *et al*. (1983) and Prasad and Prasad (1977) estimated the high genotypic and phenotypic co-efficient of variation for fruits per plant.

Reddy and Reddy (1992) evaluated 139 tomato genotypes and estimated phenotypic and genotypic variances, phenotypic and genotypic co-efficient of variation. Considerable variation was observed for number of fruits per plant (4.0-296.5). Islam and Khan (1991) and Sharma and Rastogi *et al.* (1993) reported significant variations for number of fruits per plant.

Das *et al*. (1998) and Sahu and Mishra (1995) 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 tomato and reported that phenotypic variation was quite large but genotypic variation was low. The phenotypic and genotypic co-efficient of variation indicated that selection may be made for members of fruits per plant. Islam *et al.* (1996) recorded highest genetic variability for number of fruits per plant in 26 diverse genotypes of tomato.

Mohanty *et al.* (2003) observed that the number of fruits per plant had positive direct effects on the yield and negative indirect effects on average fruit weight. 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%).

2.2.1.10 Average fruit weight

A study was conducted by Farzaneh *et al*. (2013) and found significant variation due to general combining ability (GCA) as well as specific combining ability (SCA) that indicated the importance of additive and non-additive types of gene action in inheritance of all characters except number of fruits per plants.

Shravan *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. Kumar *et al*. (2004) also found similar result in respect of average fruit weight.

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 high phenotypic (PCV) and genetic (GCV) coefficients of variation for average fruit weight. Kumar and Tewari (1999) also obtained similar results in their experiments with tomato.

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.

Padmini and Vadivel (1997) performed an experiment to study genetic variability of six F_2 crosses and their parental cultivars and reported that progeny of cross In Memory 5.30 p. m. X PKM-1 produced the highest mean values for individual. They also reported that fruit weight small difference was observed between genotypic and phenotypic variance for individual fruit weight. In another study of genetic variability in 23 genotypes of tomato, Singh *et al*. (1997) reported that phenotypic variation was quite large but genotypic variation was low.

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

Mishra (1995) also reported that fruit weight had high genotypic co-efficient of variation in 16 lines of tomato.

Ahmed (1987) reported that a wide range of variation was observed for individual & unit weight among 4 genotypes of tomato. He also reported that genotypic co-efiicient of variation was very high for individual fruit weight in four tomato varieties namely EC32099, HS102, HS107 and Columbia respectively. 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.

Arora *et al*. (1982) reported that a wide range of variation was observed in fruit weight of four genotypes of tomato. He also reported that genotypic co-efficient of variation was very high for individual fruit weight in four tomato varieties.

2.2.1.11 Fruit length

A study conducted by Chishti *et al*. (2008) on the analysis of combining ability for yield, yield components and quality characters in tomato(*Lycopersicon esculentum* Mill.), on plant material comprising 12 parental lines and their F_1 hybrids (direct crosses). Analysis of variance revealed highly significant differences among genotypes, parents and hybrids, as well as highly significant mean squares due to GCA and SCA for all the characters.

Kumari *et al*. (2007) verified data on fruit length and found that there were highly significant differences for this character among parents. Singh *et al*. (2002) reported high phenotypic coefficient of variation for this character.

2.2.1.12 Fruit diameter

Twenty-five F_1 hybrids generated from 5×5 diallel crosses and were evaluated to study the quantitative genetics of yield and some yield related traits by Saleem *et al*. (2013). The highest estimates of genotypic and phenotypic coefficients of

variability were recorded for number of fruits per plant while fruit width was the most heritable trait.

Data on fruit width recorded by Kumari *et al*. (2007) and found that there were highly significant differences among parents. 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.

2.2.1.13 Fruit yield 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.

Matin and Kuddus (2001) reported significant differences for yield per plant among the genotypes tested. He also reported that phenotypic variance was little higher than genotypic variance indicating slight environmental influence on this trait.

Sachan (2001) performed an experiment with certain tomato genotypes and he reported significant differences among the genotypes for yield per plant. Kumar and Tiwari (2002) also reported higher genotypic co-efficient of variation for average yield per plant among thirty two tomato genotypes.

Brar *et al*. (2000) reported high degrees of variation for average yield per plant among the 186 genotypes tested. Reddy and Gulshanlal (1990) also observed considerable variations for yield per plant in 139 tomato varieties. Sonone *et al*. (1986) and Dudi *et al*. (1983) also reported that genotypic and phenotypic variances were high for average yield per plant. Singh *et al*. (2009) assessed 48 genotypes for their genetic divergence using Mahalar statistics. They observed that

clustering pattern indicated no difference between geographical distribution of genotypes and genetic divergence. They concluded that characters like number of fruits plant^{-1}, average fruit weight, plant height and fruit yield contributed maximum to genetic divergence.

2.3 Heritability and genetic advance

The most important task for all plant breeding practices is selection of plants on phenotypic characteristics. The effectiveness of selection for yield depends upon heritability. A character with high heritability gives better response to selection. Heritability and genetic advance are the most important parameters to judge the breeding potentiality of a population for future development through selection Kumar *et al*. (2006).

Paul *et al*. (2014) observed that the genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for days to germination, fruits per bunch, harvest index and yield per plant (g) of tomato. All characters were highly heritable in broad sense.

A study of quantitative genetics of yield and some yield related traits conducted by Saleem *et al*. (2013). The highest estimates of genotypic and phenotypic coefficients of variability (GCV and PCV) were recorded for number of fruits per plant while fruit width was the most heritable trait.

Narolia (2012) studied thirteen quantitative characters in 55 genotypes of tomato. High heritability coupled with high genetic advance as percentage of mean was observed for all the characters except days to 50% flowering indicating the presence of additive gene action in the expression of these characters.

Buckseth *et al*. (2012) found high heritability with high genetic advance for number of fruits per plant, average fruit weight, yield per plant and pericarp

thickness indicating that most likely the heritability is due to additive gene effects and selection may be effective.

Pandit *et al*. (2010) recorded that high heritability coupled with low genetic advance as percentage of mean for rest of the characters except pericarp thickness, indicating most of the characters were governed by non-additive genetic components from evaluating of 12 varieties of tomato and also reported that high heritability coupled with high genetic advance as percentage of mean for average fruit weight indicating the control of such character by additive gene.

Ponnusviamy *et al*. (2010) evaluated 12 varieties of tomato to estimate heritability and reported that high heritability coupled with high genetic advance as percentage of mean for average fruit weight, indicating the control of such character by additive gene. He also recorded that high heritability coupled with low genetic advance as percentage of mean for rest of the characters except pericarp thickness indicating most of the characters were governed by non-additive genetic components.

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

Shashikanth *et al*. (2010) observed the range of variation and mean values were high for plant height, days to 50% flowering and average fruit weight. He also observed high genotypic variance for most of the characters indicating a high contribution of the genetic component for the total variation.

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. 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.

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.

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

Singh *et al*. (2006) estimated Heritability for nineteen genotypes of tomato and found high heritability for ascorbic acid content, average weight of fruits and number of fruits per plant. Estimates of high 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. Heritability was also estimated by Singh *et al*. (2005) and showed that heritability estimates (in the broad sense) were high for all the characters. 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. Moderate heritability and low genetic gain for harvest duration suggests the presence of dominance and epistatic effects.

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 heritability that ranged from 89.10% to 96.50%. The rest of the characters showed moderate heritability and low genetic advance.

Heritability and genetic advance estimated by Shravan *et al*. (2004) 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 heritability. The rest of the characters showed moderate heritability and low genetic advance. Moderate heritability associated with moderate genetic advance for plant height of 37 tomato genotypes of tomato were reported by Arun *et al*. (2004).

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. 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.

Hanson *et al*. (2002) proposed heritability as the ratio of genotypic variance to the total variance in a non-segregating population. Since, the estimate of heritability gives indication of the amount of progress expected from selection, as they are most meaningful when accompanied by estimate of genetic advance. Genetic

advance is the measure of improvement that can be achieved by practicing selection in a population.

Singh (2002) reported that heritability was high for all characters except days from fruit setting to red ripe stage and the highest genetic advance was predicted for average fruit weight, followed by shelf life of red ripe fruits. Matin (2001) reported high degrees of heritability and genetic advance for fruits per plant, individual fruit weight and number of seeds per fruit.

Matin and Kuddus (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 and Mathura (1999) and Vikram and Kohli (1998) estimated very high heritability along with high genetic advance by fruit weight.

Phookan *et al*. (l998) observed high heritability and genetic advance in percentage of mean were 4 estimated for fruits per plant and average fruit weight suggesting their importance in selection for tomato improvement.

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 heritability 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.

Aditya (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.

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

Naidu (1993) reported high heritability for number fruits per plant, plant height and moderate heritability for yield per plant. Godekar *et al*. (1992) obtained high values for hetitability along with high genetic advance by fruit weight.

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

Bai and Devi (1991) evaluated five varieties and nine hybrids of tomato. Heritability estimates high for plant height, number of fruits per plant and individual fruit weight. Islam and Khan (1991) also 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 was observed for fruit yield, plant height, individual fruit weight and number of fruits per plant.

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 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, total fruits and days to first picking.

2.4 Correlation and path co-efficient analysis

2.4.1 Correlation co-efficient analysis

Correlation among yield and yield contributing characters was studied because yield is one of the main targets of most of the breeders. Correlation among the characters is an estimate to evaluate the inter-relationships between the characters which will help the breeders to choose selection techniques. The yield contributing characters are also interrelated among themselves. So, association of characteristics with yield and among its components is important for planning effective selected breeding programme for maximization of yield. Correlation analysis in tomato revealed that percent fruit set, number of primary branches, number of fruits per plant, average fruit weight, total soluble solids, fruit length, fruit firmness, number of flower trusses per plant and pericarp thickness were positively and significantly associated with yield per plant.

Paul *et al*. (2014) found that the characters; germination(%), fruits per bunch, harvest index, vitamin C content, sugar content(%) of tomato were positively correlated with yield per plant. Among them germination (%), fruits per bunch, harvest index were significantly correlated with yield per plant.

Forty nine genotypes of tomato (*Solanum lycopersicum* L.) were evaluated for various quantitative and quality traits by Kumar *et al*. (2013). The character association analysis indicated that total numbers of fruits/plant were significantly and positively correlated with gross yield (g/plant), marketable yield (g/plant), number of marketable fruits/plant and plant height (cm).

Mahapatra *et al*. (2013) found fruit yield had positive and significant correlation with plant height, number of primary branches per plant, number of flower clusters per plant, number of fruits per plant, fruit length, fruit width, and average fruit weight. It was observed that with increase in plant height, there was corresponding increase in number of primary branches per plant, days to 50% flowering and number of flower clusters per plant.

According to Monamadi *et al*. (2013) there was a strong positive significant correlation between numbers of branches per plant with fruit number per plant. This was because the more the branch number in a plant, such plant will produce more fruits in a plant.

The experiment carried out by Buckseth *et al*. (2012) consisting of 40 genotypes of tomato to study the correlation among different quantitative and qualitative traits in tomato genotypes. The study revealed highly significant differences among the genotypes for all the characters studied.

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.

Islam *et al*. (2010) found the inter relationship among the characters studied with a study on 33 genotypes of tomato. Yield per plant was found highly significant and positively correlated with flowers per plant, fruits per plant, fruit length, fruit diameter and individual fruit weight which indicated that yield could be increased by improving a traits.

According to Ara *et al*. (2009) there was a strong positive significant correlation between numbers of trusses per plant with fruit number per plant. This was because the more the truss number in a plant, such plant will produce more fruits resulting in more fruit weight. This is supported by the observed strong positive association between fruit number per plant and fruit weight per plant. 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 at both levels. Correlation coefficient analysis was studied for thirty diverse tomato genotypes and noticed that correlation coefficients at the genotypic level were generally higher than the corresponding phenotypic ones and yield per plant was positively and significantly associated with plant height, fruit number per plant, fruit shape index and pericarp thickness (Kumar *et al*., 2007). Correlation analysis performed by Wagh *et al*. (2007) showed 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. Wright (2007) performed correlation analysis and observed that yield improvement can be achieved by selection for 50% flowering, plant height, number of fruits per plant. Kumar *et al*. (2006) 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. 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 and total yield. They 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.

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. Manivannan *et al*. (2005) carried out correlation coefficient analysis in cherry and observed that fruit yield was significantly and positively correlated with the number of leaves and fruit weight. 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. However, fruit weight was negatively correlated with the number of fruits per plant, number of fruits per cluster and ascorbic acid content. Correlation coefficient analysis of 30 tomato genotypes was performed and

observed that number of fruits per plant had significant and positive correlation with fruit yield per plant Kumar *et al*. (2004). Similarly, inter-relationships were studied 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 (Singh *et al*., 2004). Correlation coefficient analysis carried out by Kumar *et al*. (2003) for thirty diverse tomato genotypes and observed that correlation coefficients at the genotypic level were generally higher than the corresponding phenotypic ones. He also observed that yield per plant was positively and significantly associated with plant height, fruit number per plant, fruit shape index and pericarp thickness.

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 day 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. Dhaliwal *et al*. (2002) studied genetic parameters and correlations concerning fruit weight, yield plant^{-1}. The correlation studies indicated that it would be possible to develop firm fruited - high yielding true breeding lines. Harer *et al*. (2002) studied correlation of thirty-seven tomato genotypes and showed that 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 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/plant, significant and negative with plant height and average fruit weight and

number of fruits per plant was inversely related with average fruit weight. 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. The negative correlation was observed between fruit weight and fruit number, plant height and fruit weight, fruit weight and fruit yield and plant height Padma *et al*. (2002).

Susic *et al*. (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. Tiwari (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 p^H. They also observed similar association between total soluble solids and ascorbic acid, and between titratable acidity and p^H. Dhankar *et al*. (2001) reported the average fruit weight under normal condition showed the highest positive effect on yield, therefore selection for average fruit weight, number of fruits per plant and number of fruits per cluster is important for improvement of fruit yield. Kumar *et al*. (2001) 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 and Kuddus (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. Dry matter was negatively correlated with individual fruit weight. Information on yield correlations is derived from data on eight yield components recorded in eighteen genetically diverse genotypes by Sharma and Verma (2000). It is concluded that when selected for high yield in tomato, the main emphasis should be placed on number of fruits/plant. Fruit diameter and average fruit weight are also important components.

2.4.2 Path analysis

Path analysis revealed that average fruit weight had the high positive direct effect on yield per plant followed by number of fruits per plant. Traits viz., fruit diameter and fruit shape, fruit index had negative direct effect on fruit yield per plant. Most of the other traits had indirect effect via fruit weight, fruits per plant, fruit diameter and fruit shape index. When more characters are involved in correlation study it becomes difficult to ascertain the traits which really contribute towards the yield. The path analysis under such situation helps to determine the direct and indirect contribution of these traits towards the yield. Hence, these characters should be given more weight age in selection programme of high yielding genotypes in tomato (Khapte and Jansirani, 2014).

Meena and Bahadur (2015) studied the character association for tomato germplasm under open field condition. They evaluated nineteen indeterminate tomato germplasm to estimate the nature and magnitude of associations of different characters with fruit yield and among themselves. In order to obtain a clear picture of the interrelationship between fruit yield per plant and its components, direct and indirect effects were measured using path coefficient

analysis. The character showed high direct effect on yield per plant indicated that direct selection for these traits might be effective and there is a possibility of improving yield per plant through selection based on no. of flowers per plant, fruits per plant and fruit weight. Low residual effect indicates that the characters used explained almost all variability towards yield.

Paul *et al*. (2014) found that the germination percent (0.26), height of first leaf appearance (0.19) days to first flowering (0.20) and harvest index (0.42) exhibited direct effect on fruit yield of tomato by a field experiment with 30 genotypes. On the basis of correlation and path analysis, percent germination, days to first flowering, fruits per bunch and harvest index are important characters to be considered for the development of high yielding tomato genotype.

Monamodi *et al*. (2013) used six determinate tomatoes. Results obtained suggest that fruit number and single fruit weight are relevant components to use as selection criteria for improving tomato yield. The direct effects of marketable fruit number and fruit weight on fruit yield were positive and large.

A field experiment was carried out by Monamodi *et al*. (2013) using six determinate tomatoes. Path coefficient analysis results showed that marketable fruit number and single fruit weight were directly related to yield.

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.

Islam *et al*. (2010) carried a study with a field experiment of 33 genotypes of tomato in order to obtain a clear picture of the inter relationship between yield per plant and its components. Direct and indirect effects were measured using path

coefficient analysis. Fruits per plant showed the highest positive direct effect (0.980) on yield per plant followed by individual fruit weight (0.958). On the other hand, the highest negative direct effect on yield per plant showed by days to first flowering (-0.277) followed by fruit length (-0.141). The characters showed high direct effect on yield per plant indicated that direct selection for these traits might be effective and there is a possibility of improving yield per plant through selection based on these characters. Residual effect was considerably low (0.183) which indicated that characters included in this study explained almost all variability towards yield.

Golani *et al*. (2007) performed path analysis and confirmed that the 10-fruit weight had the highest positive direct effect. Dhankhar and Dhankhar (2006) reported that number of fruits per plant had the maximum positive direct effect.

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.

Singh (2005) reported that the genotypic and phenotypic path coefficient studies described that number of fruits per plant had the maximum positive effect on yield followed by average fruit weight. Regarding indirect effects, it was observed that number of fruits per plant exhibited positive indirect effect towards fruit yield via number of branches per plant; it was negative via plant height, days to 50 per cent flowering.

Singh and Cheema (2006) have revealed that positive direct effect of number of fruits per plant on yield. It was also reported by Kumar *et al*. (2003). Its positive

indirect effects through average fruit weight mainly contributed towards its strong association with yield. The findings were on consonance with Mohanty (2002).

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.

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.

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.

Mohanty (2003) conducted a field experiment to study path coefficient analysis of eighteen 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.

Bodund (2002) carried out a field experiment on path coefficient analysis and observed that plant height and fruit diameter directly affected 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, fruit weight, fruit length 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 and Kuddus (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 and Sarnaik (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 and number of branches per plant exhibited positive as well as high direct effects.

Domini and Maya (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 and Phir (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.

McGiffen *et al*. (1994) revealed that number of fruits was the most important yield component which had direct effect on yield. Supe and Kale (1992) studied 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. 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. 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. Sonone *et al*. (l987) reported highest direct effect of plant height and fruit weight on fruit yield of tomato. Gorbatenko and Gorbatenko (1985) carried out path co-efficient analysis of economically useful characters of tomato 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 early yield per plant, fruit weight and fruits per plant.

2.5 Principal Component Analysis

Appropriate and most efficient approach should be used for germplasm evaluation and characterization, and while further detailed evaluation is mostly done by the breeders for taking additional information. In that sense Hotelling (1933) indicated that principal component analysis (PCA) is an exploratory tool designed by Pearson (1901) to identify unknown trends in a multi-dimensional data set. However, in a typical micro-array experiment, the expression of thousands of genes is measured across many conditions such as treatments or time points. PCA is among these techniques that reduced the data into two dimensions (Smith, 2002; Raychaudhuri *et al*., 2000). PCA has been used frequently for evaluation of germplasm of different crops such as barley Sorghum, wheat, peanut and vineyard peach and in rice.

2.6 Biochemical analysis

2.6.1 Total Soluble Solids (% of brix)

Brix percentage is the sugar content of an aqueous solution. One percent brix is 1 gram of sucrose in 100 grams of solution and represents the strength of the

solution as percentage by mass. If the solution contains dissolved solids other than pure sucrose, then the % Bx only approximates the dissolved solid content. Various reports are available on variation of brix % for different genotypes of tomato.

The chemical constituents are concerned in the quality of tomato fruit in respect to colour, texture, flavour, nutritive value, and wholesomeness. In general, high sugar contents, redness of color, and firm texture are associated with prominence of rich flavour. Biochemical changes as influenced by growth, maturation, and environment of tomato fruit are discussed.

Nalla *et al*. (2014) done a field experiment using 27 tomato genotypes and reported fruit yield per plant (20.51), total soluble solids (17.38), and equatorial diameter (15.38) contributed high for divergence. For total fruit number, total soluble solids content, fruit firmness, length and pH, in a general way and for the majority of the genotypes, there were no statistical differences between the averages of the F_1 and F_2 generations found by Hernandez (2013).

There was a significant ($p<0.01$) difference among genotypes and environments for all quality traits, Genotype x Environment interaction was significant ($p<0.01$) for all quality traits except for TSS found by Panthee *et al*. (2013). Narolia *et al*. (2012) found high estimates of genotypic coefficient of variation, heritability and genetic advance for acidity, total soluble solids, ascorbic acid content, and shelf life. A study by Silva *et al*. (2012) evaluated the components of production and total soluble solids (brix) of tomato cultivar Carolina. The fruits were harvested when they began the color change from green to red; on the occasion were evaluated content of soluble solids, number, weight, length and diameter.

Seven tomato lines studied by Chen *et al*. (2009) and found general heritability for vitamin C and total soluble solid content was high. Lines belonging to L. *esculentum* var. *cerasiforme* were better breeding materials in terms of vitamin C,

organic acid and total soluble solid content. Krishna and Allolli (2005) found highest fruit yield (27.79 t/ha), total soluble solid content (6.11%), acidity (0.93%) and lycopene content (7.64 mg/100 g of juice).

Cheema *et al*. (2003) studies on combining ability for 10 important characters and significant general (GCA) and specific combining ability (SCA) variances were observed for different characters except for total soluble solids indicating the importance of both additive and non-additive gene effects in the expression of these characters. Four commercial brands of tomato juices and ketchups were studied. Results showed that Brix is higher in ketchup (25-33 degrees brix) than in tomato juices (4.8-5.5 degrees brix). Pearson correlations showed statistically significant ($P<0.05$) correlations between brix and HMF, lycopene, dry matter (negative correlation) and juice (negative); HMF and lycopene and dry matter (negative correlation); lycopene and dry matter (negative), pulp and juice; dry matter and pulp (negative) and juice; and pulp and juice (negative correlation). Harer *et al*. (2002) were grown 37 tomato genotypes in a field experiment and correlation studies showed that genotypic correlation was higher than phenotypic correlation for all characters examined. Among them the total soluble solid content had positive but low direct effects and positive association with fruit yield. Dhaliwal *et al*. (1999) conducted an experiment with twelve parents and their 66 F_1 hybrids to study the genetics of traits that are important for processing and bulk handling of tomatoes viz. TSS%, pericarp thickness and number of locules. The analysis of variance for combining ability exhibited the significance of both general combining ability and specific combining ability effects for all characters studied.

CHAPTER III

MATERIALS AND METHODS

Tomato is the very important vegetable crop next only to potato because of its wider adaptability, high yielding potential and multipurpose uses. This chapter illustrates information pertaining to methodology that was used in implementation of the experiment. It comprises a brief description of locations of experimental site, planting materials, climate and soil, seed bed preparation, layout and design of the experiment, land preparation, fertilization, transplantation of seedlings, intercultural operations, harvesting, data recording procedure, statistical and nutritional analysis etc. which are presented as follows:

3.1 Experimental site

The research work was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from October 2015 to April 2016.

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 (Anonymous 2004). The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anonymous 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hill rocks of red soils as 'islands' surrounded by floodplain. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.3 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.

3.4 Planting materials

Fifteen genotypes of tomato were used for the present research work. The genetically pure and physically healthy seeds of these genotypes were collected from Plant Genetic Resources Centre (PGRC) and Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute (BARI), Gazipur. The name and origin of these genotypes are presented in Table 1. The morphology of single tomato plant and replification plants in the field showed in Plate 1 and Plate 2.

3.5 Design and layout of the experiment

The study was laid out in Randomized Complete Block Design (RCBD) with three (3) replications during Rabi 2015-16. A distance of 1.0m from block to block, 60 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.

Genotype	:	15
Replications	:	3
Spacing	:	50 cm × 60 cm
Plot size	:	6×37 m^2
Date of transplanting	:	10th November 2015

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

Sl. No.	Genotypes No.	Name/Acc No. (BD)	Origin
1	G1	BARI tomato-2	HRC, BARI
2	G2	BARI tomato-3	HRC, BARI
3	G3	BARI hybrid tomato-4	HRC, BARI
4	G4	BARI hybrid tomato-5	HRC, BARI
5	G5	BARI tomato-11	HRC, BARI
6	G6	BARI tomato-14	HRC, BARI
7	G7	BARI tomato-15	HRC, BARI
8	G8	BARI tomato-16	HRC, BARI
9	G9	BARI tomato-17	HRC, BARI
10	G10	BD-7287	PGRC, BARI
11	G11	BD-7290	PGRC, BARI
12	G12	BD-7278	PGRC, BARI
13	G13	BD-7757	PGRC, BARI
14	G14	BD-9960	PGRC, BARI
15	G15	BD-7291	PGRC, BARI

Plate 1: The morphology of single tomato plant

Plate 2: Replication view of the experimental field

3.6 Seed bed preparation and raising of seedling

The sowing was carried out on 15 October 2015 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 25 days old those were transplanted in the main field.

3.7 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 filth in the second week of November 2015. Weeds and other stubbles were removed carefully from the experimental plot and leveled properly.

3.7.1 Transplanting of seedlings

The seedlings were raised in the seedbed in usual way and 25 days old seedlings were transplanted in the main field on November 10, 2015. The transplanted seedlings were watered regularly to make a firm relation with roots and soil to stand along.

3.8 Manure and fertilizers application

Total cow dung 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 presented in Table 2.

3.9 Intercultural operations

When the seedlings were well established, first weeding was done uniformly in all

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

Sl. No.	Fertilizers/ Manures	Dose (Kg ha^{-1})
1.	Urea	550 kg
2.	TSP	450 kg
3.	MOP	250 kg
4.	Cow dung	10 ton

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. Thinning and gap filling, staking, pesticide application, irrigation and after-care were also done as per requirement.

3.10 Harvesting and processing

All of the tomato varieties used in this experiment was indeterminate types. So, harvesting continued for about one and half month because fruits of different lines matured progressively at different dates and over long time. The fruits per entry were allowed to ripe and then seeds were collected and stored at $4^{o}C$ for future use. Harvesting was started from February 12, 2016 and completed by April 15, 2016. Raising of seedlings, experimental field in growing condition of plants, growth stage of a single tomato plant, flowering and fruiting stages of tomato plant are displayed in Plate 3 and Plate 4.

3.11 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.

Plate. 3: Different stages of the tomato seedlings in the experimental field

A. Raising of tomato seedlings in the seed bed

B. Growing condition of tomato plant in the experimental field

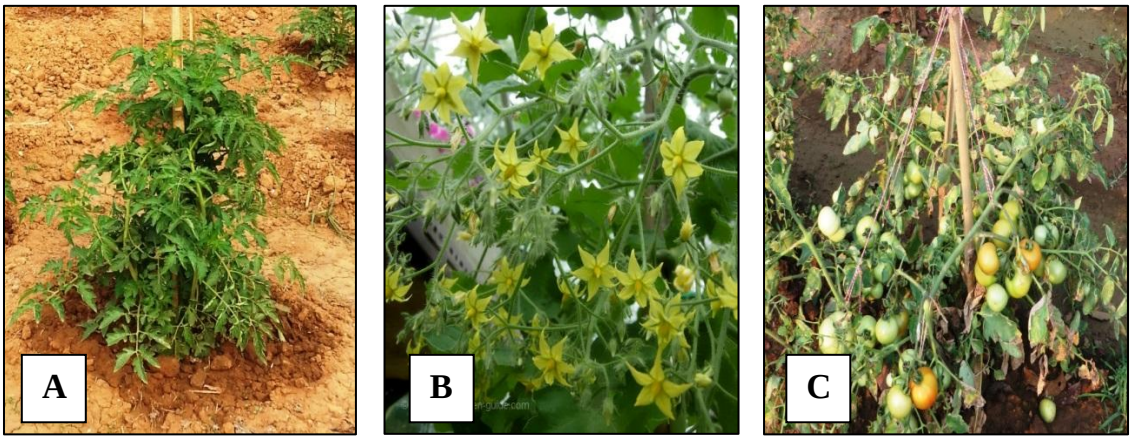


Plate. 4: Different stages of the matured tomato plant in the experimental field

A. Foliar stage of a single tomato plant

B. Flowering stage of a single tomato plant

C. Fruiting stage of a single tomato plant

3.11.1 Plant height (cm)

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

3.11.2 Number of leaves per plant

From randomly selected five plants in each plot, number of leaves in each plant was counted. Then the average number of leaves per plant was calculated.

3.11.3 Number of branches per plant

The number of branches arising from the main stem above the ground was recorded at 70 days after transplanting.

3.11.4 Number of flowers per plant

Five plants in each plot were selected at random and the number of flowers in each plant was counted. Then the average number of flowers per plant was calculated.

3.11.5 Days to first flowering

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

3.11.6 Days to 50% flowering

The number of days was counted from the date of sowing to 50 per cent of plants flowered.

3.11.7 Days to maturity

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

3.11.8 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.

3.11.9 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.

3.11.10 Number of clusters per plant

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

3.11.11 Fruit length (mm)

It was measured from stalk end to blossom end by using vernier caliper.

3.11.12 Fruit diameter (mm)

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

3.11.13 Fresh fruit weight (g)

The total number of marketable fresh fruits plant^{-1} was counted and weighed and the average fresh fruit weight was calculated by the following formula and expressed in grams (g).

$$\text{Average fresh fruit weight} = \frac{\text{Average fresh fruit weight per plant}}{\text{Total number of fresh fruit per plant}}$$

3.11.14 Dry weight of 5 g fresh fruit

From randomly selected five fruits were taken for dry weight. Five grams fresh fruit from each fruit was in use and oven dried at 70°C for 72 hours and averaged.

3.11.15 Fruit yield per plant (kg)

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.

3.11.16 Percent (%) brix

Brix percentage was measured by Portable Refractometer (Appendix V) at room temperature. Single fruit was blend and juice was collected to measure brix percentage.

3.11.17 p^H of tomato juice

p^H of tomato juice was determinate by digital Hanna pH meter (Appendix V) at room temperature. Single fruit was blend and juice was collected to measure p^H of tomato.

3.12 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).

3.12.1 Estimation of genotypic and phenotypic variances

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

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

Phenotypic variance, $\sigma^2_{ph} = \sigma^2_g + EMS$

Where,

σ^2_g = Genotypic variance

EMS = Error mean sum of square

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

Where,

EMS = Mean Square Error

3.12.2 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)

Genotypic co-efficient of variation, GCV % = $\frac{\sqrt{\sigma^2_g}}{\bar{x}} \times 100$

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

3.12.3 Estimation of heritability

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

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

Where,

h^2_b = Heritability in broad sense

σ^2_g = Genotypic variance

σ^2_{ph} = Phenotypic variance

3.12.4 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).

$$\text{Genetic advance, GA} = K.\ h^2.\ \sigma_p$$

$$\text{Or Genetic advance, GA} = K.\ \frac{\sigma^2_g}{\sigma^2_{ph}}.\sigma_{ph}$$

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

3.12.5 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):

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

3.12.6 Estimation of simple correlation co-efficient:

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

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

Where,

$\sum$ = Summation

x and y are the two variables correlated

N = Number of observation

3.12.7 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) and Johnson *et al.* (1955) 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 trait x and y

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

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

3.12.8 Estimation of path co-efficient

Path coefficient is a standardized partial regression coefficient and as such it is a measure of direct and indirect effect of set variables (component characters) as a

dependent variable such as fruit yield. Direct and indirect effect of component characters on fruit yield were computed using appropriate correlation coefficient of different component characters.

Path coefficient analysis was done according to the procedure employed by 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 yield per plant. In order to estimate direct and indirect effects of the correlated characters, i. e. 1, 2, 3…….and 17 on yield y, a set of simultaneous equations (five equations in this example) is required to be formulated as shown below:

$$r_{1.y} = P_{1.y} + r_{1.2}P_{2.y} + r_{1.3}P_{3.y} + r_{1.4}P_{4.y} + r_{1.5}P_{5.y} + r_{1.6}P_{6.y} + r_{1.7}P_{7.y} + r_{1.8}P_{8.y} + r_{1.9}P_{9.y} + r_{1.10}P_{10.y} + r_{1.11}P_{11.y} + r_{1.12}P_{12.y} + r_{1.13}P_{13.y} + + r_{1.14}P_{14.y} + + r_{1.15}P_{15.y} + + r_{1.16}P_{16.y} + r_{1.17}P_{17.y}$$

$$r_{2.y} = r_{1.2}P_{1.y} + P_{2.y} + r_{2.3}P_{3.y} + r_{2.4}P_{4.y} + r_{2.5}P_{5.y} + r_{2.6}P_{6.y} + r_{2.7}P_{7.y} + r_{2.8}P_{8.y} + r_{2.9}P_{9.y} + r_{2.10}P_{10.y} + r_{2.11}P_{11.y} + r_{2.12}P_{12.y} + r_{2.13}P_{13.y} + r_{2.14}P_{14.y} + r_{2.15}P_{15.y} + r_{2.16}P_{16.y} + r_{2.17}P_{17.y}$$

$$r_{3.y} = r_{1.3}P_{1.y} + r_{2.3}P_{2.y} + P_{3.y} + r_{3.4}P_{4.y} + r_{3.5}P_{5.y} + r_{3.6}P_{6.y} + r_{3.7}P_{7.y} + r_{3.8}P_{8.y} + r_{3.9}P_{9.y} + r_{3.10}P_{10.y} + r_{3.11}P_{11.y} + r_{3.12}P_{12.y} + r_{3.13}P_{13.y} + r_{3.14}P_{14.y} + r_{3.15}P_{15.y} + r_{3.16}P_{16.y} + r_{3.17}P_{17.y}$$

$$r_{4.y} = r_{1.4}P_{1.y} + r_{2.4}P_{2.y} + r_{3.4}P_{3.y} + P_{4.y} + r4_{1.5}P_{5.y} + r_{4.6}P_{6.y} + r_{4.7}P_{7.y} + r_{4.8}P_{8.y} + r_{4.9}P_{9.y} + r_{4.10}P_{10.y} + r_{4.11}P_{11.y} + r_{4.12}P_{12.y} + r_{4.13}P_{13.y} + r_{4.14}P_{14.y} + r_{4.15}P_{15.y} + r_{4.16}P_{16.y} + r_{4.17}P_{17.y}$$

$$r_{5.y} = r_{1.5}P_{1.y} + r_{2.5}P_{2.y} + r_{3.5}P_{3.y} + r_{4.5}P_{4.y} + P_{5.y} + r_{5.6}P_{6.y} + r_{5.7}P_{7.y} + r_{5.8}P_{8.y} + r_{5.9}P_{9.y} + r_{5.10}P_{10.y} + r_{5.11}P_{11.y} + r_{5.12}P_{12.y} + r_{5.13}P_{13.y} + r_{5.14}P_{14.y} + r_{5.15}P_{15.y} + r_{5.16}P_{16.y} + r_{5.17}P_{17.y}$$

Where,

r_{1y} = Genotypic correlation coefficients between y and i^{th} character (y = Fruit yield)

P_{iy} = Path coefficient due to i^{th} character (i= 1, 2, 3,….17)

1 = Plant Height

2 = Number of leaves $plant^{-1}$

3 = Number of branches $plant^{-1}$

4 = Number of flowers $plant^{-1}$

5 = Days to first flowering

6 = Days to 50% flowering

7 = Days to maturity

8 = Number of fruits $plant^{-1}$

9 = Number of fruits $cluster^{-1}$

10 = Number of clusters $plant^{-1}$

11 = Fruit length (mm)

12 = Fruit Diameter (mm)

13 = Fresh fruit weight (kg)

14 = Dry weight of 5 g fresh fruit

15 = Fruit yield per plant (kg)

16 = Percent (%) brix

17 = pH of tomato juice

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

$r_{1.13} P_{13.y}$ = indirect effect of 1 via 13 on y

$r_{1.14} P_{14.y}$ = indirect effect of 1 via 14 on y

$r_{1.15} P_{15.y}$ = indirect effect of 1 via 15 on y

$r_{1.16} P_{16.y}$ = indirect effect of 1 via 16 on y

$r_{1.17} P_{17.y}$ = indirect effect of 1 via 17 on y

Where,

$P_{1.y,}$ $P_{2.y,}$ $P_{3.y.}$ …… $P_{17.y}$ = Path coefficient of the independent variables 1, 2, 3,….,17 on the dependent variable y, respectively.

$r_{1.y,}$ $r_{2.y,}$ $r_{3.y,}$ …., $r_{17.y}$ = Correlation coefficient of 1, 2, 3,…., 17 with y, respectively.

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

$$P^2_{RY} = 1- (r_{1.y}P_{1.y} + r_{2.y}P_{2.y} +\text{……..}+ r_{17.y}P_{17.y})$$

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.

3.12.9 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:

3.12.10 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 unit. Contribution of the different morphological characters towards divergence is discussed from the latent vectors of the first two principal components.

3.12.11 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).

3.12.12 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.

3.12.13 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.

3.12.14 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.

3.12.15 Computation of average intra-cluster distances

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

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.

3.12.16 Computation of average inter-cluster distances

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

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 opulations in cluster i and j.

n_i = Number of populations in cluster i.

n_j = Number of populations in cluster j.

3.13 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

3.14 Determination of brix percentage

Brix percentages were measured by portable refractometer (ERMA, Tokyo, Japan). Single fruit was blend and juice was collected to measure brix percentage. Mean was calculated for each genotype. Brix percentage of fruits was measured at room temperature.

CHAPTER IV

RESULTS AND DISCUSSIONS

The experiment was conducted to execute the character association, path and diversity analysis among some tomato (*Solanum lycopersicum* L.) genotypes using agromorphogenic traits. This chapter comprises the presentation and discussion of the findings obtained from the experiment. The data pertaining to seventeen characters have been presented and statistically analyzed with the possible interpretations.

4.1 Analysis of variance

The analysis of variance indicated significantly higher amount of variability among the genotypes for all the characters studied *viz*., plant height (PH), number of leaves plant^{-1} (NLP), number of branches plant^{-1} (NBP), number of flowers plant^{-1} (NFP), days to first flowering (DFF), days to 50% flowering (DF50%), days to maturity (DM), number of fruits plant^{-1} (NFrP), number of fruits cluster^{-1} (NFC), number of clusters plant^{-1} (NCP), fruit length (FL), fruit diameter (FD), fresh fruit weight (FFW), dry weight of 5 g fresh fruit (FDW), fruit yield plant^{-1} (FYP), % of Brix (% Bx), p^{H} of tomato (p^{H}) (Appendix IV). The variation due to replication was non-significant for all the characters studied.

4.2 Genetic variability, heritability and genetic advance

The extent of variation among the genotypes in respect of fifteen characters was studied and mean sum of square, phenotypic variance (σ^2p), genotypic variance (σ^2g), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2b), genetic advance (GA), genetic advance in percent of mean and coefficient of variation (CV) presented in Table 3. The mean value of all

genotypes for each character is shown in Table 3. Performance of the genotypes is described below for each character.

4.2.1 Plant height (cm)

Significant variations were found among the genotypes for plant height (Appendix IV), which ranged from 110.00 cm (G4) to 50.67 cm (G8) with mean value of 75.53 (Table 4). Naz *et al*. (2013), Ravindra *et al*. (2003) and Shravan *et al*. (2004) also found similar significant variation for plant height.

The genotypic and phenotypic variance was observed as 29.003 and 34.206, respectively with large environmental influence (Table 3). The phenotypic co-efficient of variation (7.743%) and genotypic co-efficient of variation (7.13%) were low for plant height (Table 3). Kumari *et al*. (2007) obtained highest genotypic coefficient of variation which disagree with this result. Singh *et al*. (2002) showed that the phenotypic coefficient of variation was greatest for this character. Similar observations with the present study were made by Matin and Kuddus (2001).

The heritability (84.78%) estimates for this trait was high with high genetic advance (59.747%) and genetic advance in per cent of mean (79.099%) revealed that this trait was governed by additive gene. Bai and Devi (1991), Kumari *et al*. (2007), Mahesha *et al*. (2006), Singh *et al*. (2006), Singh *et al*. (2005) and Joshi *et al*. (2004) also reported similar results.

4.2.2 Number leaves per plant

The grand mean number of leaves plant^{-1} was registered 100.93 and ranged from 177.67 to 34.67 (Table 4 and Appendix V). The maximum number of leaves plant^{-1} (177.67) was recorded in the genotype G15 and the minimum number of leaves plant^{-1} (34.67) was recorded by the G6.

Table 3. Estimation of genetic parameters for agro-morphogenic traits related to yield

Characters	Phenotypic variance (σ^2p)	Genotypic variance (σ^2g)	Grand mean	PCV (%)	GCV (%)	Heritability (%)	GA	GA (%)
PH	34.206	29.003	75.756	7.743	7.130	84.789	59.747	79.099
NLP	30.140	24.911	100.933	5.439	4.945	82.651	51.317	50.842
NBP	9.165	7.671	18.111	16.717	15.294	83.699	15.803	87.261
NFP	41.086	35.930	111.044	5.772	5.398	87.451	74.016	66.654
DFF	10.291	9.025	24.667	13.005	12.179	87.698	18.592	75.371
DF50%	15.798	13.382	29.156	13.612	12.528	84.707	27.566	94.405
DM	22.439	18.077	55.822	8.479	7.610	80.560	37.238	66.655
NFrP	35.705	29.700	105.067	5.687	5.187	83.182	61.182	58.232
NFC	3.292	2.984	6.978	25.997	24.751	90.644	6.147	88.075
NCP	9.444	7.725	19.467	15.786	14.277	81.799	15.914	81.748
FL	18.108	15.284	39.202	10.855	9.973	84.404	31.484	80.317
FD	17.038	14.016	41.248	10.012	9.081	82.263	28.872	70.034
FFW	28.064	22.455	50.513	10.488	9.381	80.014	46.257	91.576
FDW	0.279	0.202	4.589	11.473	9.764	72.434	0.417	9.048
FYP	0.422	0.403	2.237	29.032	28.371	95.494	0.829	37.086
% Bx	1.446	1.301	2.933	40.999	38.890	89.975	2.681	91.389
pH	0.254	0.148	4.840	10.406	7.940	58.213	0.304	6.285

Note: δ^2p = Phenotypic variance, δ^2g = Genotypic variance, PCV = Phenotypic Coefficient of Variation, GCV= Genotypic Coefficient of Variation and GA = Genetic Advance**,** GA(%) = Genetic Advance in % of mean, PH = Plant height, NLP = Number of leaves plant^{-1}, NBP = Number of branches plant^{-1}, NFP = Number of flowers plant^{-1}, DFF = Days to first flowering, DF50% = Days to 50% flowering, DM = Days to maturity, NFrP = Number of fruits plant^{-1}, NFC = Number of fruits cluster^{-1}, NCP = Number of clusters plant^{-1}, FL = Fruit length (mm), FD = Fruit diameter (mm), FFW = Fresh fruit weight (g), FDW = Dry weight of 5 g fresh fruit, FYP = Fruit yield plant^{-1}, % Bx = % of Brix, p^H = p^H of tomato

Table 4: Mean performance of 15 tomato genotypes based on different morphological traits related to yield

Genotypes	Plant height	Number of leaves plant^{-1}	Number of branches plant^{-1}	Number of flowers plant^{-1}	Days to first flowering	Days to 50% flowering	Days to maturity	Number of fruits plant^{-1}	Number of fruits cluster^{-1}	Number of clusters plant^{-1}	Fruit length (mm)	Fruit diameter (mm)	Fresh fruit weight (g)	Dry weight of 5g fresh fruit	Fruit yield plant^{-1} (kg)	% of Brix	pH of tomato
G1	70.00	51.00	10.00	65.67	30.00	40.00	70.00	61.67	5.67	10.67	51.46	44.94	55.00	4.80	2.25	3.20	4.40
G2	72.67	81.33	12.67	67.67	28.00	38.00	70.00	64.00	5.67	13.00	42.51	46.16	47.90	4.80	2.50	2.10	4.70
G3	63.67	90.00	12.67	82.00	23.00	29.00	55.00	78.00	6.00	12.00	43.14	49.73	62.40	4.70	2.50	3.00	4.90
G4	110.0	157.67	30.00	188.00	22.00	28.00	55.00	181.67	6.00	37.67	38.16	35.90	23.40	4.80	3.75	4.10	5.00
G5	90.00	82.67	11.33	147.67	29.00	34.00	65.00	143.33	9.33	14.00	31.11	17.92	9.30	4.50	1.05	6.00	5.00
G6	72.33	34.67	10.00	30.67	23.00	28.00	55.00	28.00	8.67	10.00	38.09	39.79	46.60	4.80	2.10	4.00	4.70
G7	71.67	107.67	18.33	147.67	24.00	28.00	55.00	140.67	8.67	17.67	41.97	36.10	43.30	2.90	2.90	2.00	5.00
G8	50.67	52.00	11.33	38.00	29.00	30.00	55.00	34.00	6.67	8.67	43.10	33.25	37.60	4.80	2.00	1.20	5.10
G9	75.33	61.33	9.33	75.33	22.00	25.00	52.00	70.67	6.67	11.67	52.49	81.06	209.50	4.80	2.75	3.10	5.20
G10	74.33	123.00	14.67	88.00	25.00	28.00	52.00	79.33	6.67	13.00	38.23	38.23	46.00	4.70	2.40	3.10	4.50
G11	78.33	167.33	22.33	152.67	24.00	27.00	52.00	146.00	7.00	24.00	26.63	34.57	29.40	4.60	1.75	2.10	5.00
G12	54.67	117.67	22.00	77.67	25.00	27.00	50.00	74.00	6.67	14.33	44.92	48.38	61.90	4.70	2.40	2.10	4.90
G13	108.0	177.67	32.33	192.33	22.00	25.00	50.00	181.00	6.67	35.33	32.66	40.30	35.60	4.70	1.90	3.10	4.70
G14	66.67	92.33	22.33	190.00	23.00	26.00	50.00	180.33	8.33	40.00	33.70	33.46	22.60	4.80	1.55	2.00	4.70
G15	74.67	117.67	32.33	122.33	21.00	25.00	52.00	113.33	6.00	30.00	29.83	38.60	27.19	4.70	1.75	2.90	4.80
$LSD_{0.05}$	5.229	4.226	1.604	6.317	3.264	2.586	4.193	7.221	0.384	4.759	5.142	6.337	5.913	0.142	0.312	1.004	1.032
Mean	75.53	100.93	18.11	111.05	24.67	29.20	55.87	105.07	6.98	19.47	39.20	41.23	50.51	4.61	2.24	2.93	4.84
Max	110.0	177.67	32.33	192.33	30.00	40.00	70.00	181.67	9.33	40.00	52.49	81.06	209.50	4.80	3.75	6.00	5.20
Min	50.67	34.67	9.33	30.67	21.00	25.00	50.00	28.00	5.67	8.67	26.63	17.92	9.30	2.90	1.05	1.20	4.40
STDEV	16.47	43.40	8.32	55.30	2.94	4.60	6.81	53.37	1.19	10.95	7.54	13.45	46.49	0.48	0.64	1.16	0.22
CV(%)	12.32	14.53	8.49	12.36	7.59	10.27	11.56	13.84	6.92	7.39	9.28	10.44	8.45	6.76	7.83	5.22	6.71

PH = Plant height, NLP = Number of leaves plant^{-1}, NBP = Number of branches plant^{-1}, NFP = Number of flowers plant^{-1}, DFF = Days to first flowering, DF50% = Days to 50% flowering, DM = Days to maturity, NFrP = Number of fruits plant^{-1}, NFC = Number of fruits cluster^{-1}, NCP = Number of clusters plant^{-1}, FL = Fruit length (mm), FD = Fruit diameter (mm), FFW = Fresh fruit weight (g), FDW = Dry weight of 5 g fresh fruit, FYP = Fruit yield plant^{-1}, % Bx = % of Brix, p^H = p^H of tomato

The PCV and GCV were 5.439 and 4.945 percent respectively (Table 3). The PCV values were slightly higher than the respective GCV for all the characters denoting little influence of environmental factors on their expression (Table 3). Singh *et al.* (2002) also showed that phenotypic coefficient of variation was the largest for leaves per plant. This indicated that it may be attributed to non-additive gene effects controlling its expression and selection would not be rewarding.

The estimate of heritability was high at 82.651% with high genetic advance 51.317 with medium genetic advance in % of mean (50.842).

4.2.3 Number of branches per plant

The grand mean number of branches plant^{-1} was recorded 18.11. It ranged from 32.33 to 9.33 (Table 4 and Appendix IV). The maximum number of branches (32.33) was recorded in the genotype G13 and the minimum (9.33) was recorded with G9.

The PCV and GCV were 16.717 and 15.294 percent, respectively (Table 3). Singh *et al*. (2002) also showed that phenotypic coefficient of variation was the largest for branches per plant. Coefficient of variation studies indicated that this character was slightly influenced by the environment. Therefore, selection as the basis of phenotype alone cannot be effective for the improvement of the trait.

The estimates of heritability were high at 83.699% with low genetic advance 15.803 with higher genetic advance in % of mean (87.261).

4.2.4 Number of flowers per plant

Significant differences were observed among the genotypes for number of flowers plant^{-1}which ranged from 192.33 (G13) to 30.67 in (G6) with mean value of 111.05 (Table 4 and Appendix IV). The genotypic variance and phenotypic variance for this trait were 35.93 and 41.08, respectively (Table 3). Phenotypic and

genotypic coefficients of variation were low but the phenotypic variance appeared higher than the genotypic variance. The genotypic coefficient of variation and phenotypic coefficient of variation were 5.77% and 5.398%, respectively, which indicated presence of high variability among the genotypes.

The heritability (87.45%) estimates for this trait was very high, genetic advance (74.016%) was high and genetic advance in percent of mean (66.654%) was found moderately high, revealed that this character was governed by additive gene and selection for this character would be effective. High heritability and moderate genetic gain for this character were also observed by Joshi *et al*. (2004).

4.2.5 Days to first flowering

An important character that influences the yield is days to first flowering. Analysis of variance indicated that, there was wide range of variability among the 15 genotypes of tomato (Table 4). The range varied from 30 days to 21 days. Genotype G15 showed early flowering and G1 showed late flowing (Table 4).

Phenotypic variance (10.291) was moderately higher than genotypic variance (9.025). Also narrow difference was observed between GCV (12.179%) and PCV (13.005%).

Heritability was high (87.698%) (Table 3). The genetic advance (18.592) and genetic advance in percent of mean (75.371) was considerable for this trait indicating apparent variation was due to genotypes. Therefore, the plant breeder should select this trait for breeding purposes.

4.2.6 Days to 50% flowering

Analysis of variance indicated that, there was wide range of variability among the 15 genotypes of tomato in terms of days to 50% flowering (Table 4). The range varied from 40 days to 25 days with mean values of (29.20). Genotype G15, G13

and G9 showed early 50% flowering and G1 showed highest days to 50% flowing (Table 4).

Phenotypic variance (15.798) was moderately higher than genotypic variance (13.382). Also narrow difference was observed between GCV (12.528%) and PCV (13.612%).

Heritability was high (84.707%) (Table 3). The genetic advance (27.566) and genetic advance in percent of mean (94.405) was considerable for this trait indicating visible variation was due to genotypes. Therefore, the plant breeder should select this trait for breeding purposes.

4.2.7 Days to maturity

The highest days to maturity of different tomato genotypes was found 70 days in G1 and G2 and the lowest was recorded as 50 days in G12, G13 and G14 with mean value of 55.82 (Table 4 and Appendix IV).

The phenotypic variance (22.439) found higher than genotypic variance (18.077), suggested considerable influence of environment on the expression of the genes controlling this character (Table 3). The phenotypic coefficient of variation and genotypic coefficient of variation were 8.479% and 7.61%, respectively for days to maturity, which indicating that significant variation exists among different genotypes which made the trait effective for selection (Table 3).

The heritability (80.56%) for days to maturity was high with moderate genetic advance (37.238%) and genetic advance in percent of mean (66.655%) was found high, revealed that this character was governed by additive gene and selection for this character would be effective.

4.2.8 Number of fruits per plant

Significant differences were observed among the genotypes for number of fruits plant^{-1} which ranged from 28.00 in (G6) and 181.00 in (G4) with mean value of 105.07 (Table 4 and Appendix IV).

The genotypic variance and phenotypic variance for this trait were 29.70 and 35.705 respectively (Table 3). Phenotypic and genotypic coefficients of variation were low but the phenotypic variance appeared higher than the genotypic variance. The genotypic coefficient of variation and phenotypic coefficient of variation were 5.687% and 5.187%, respectively, which indicated presence of high variability among the genotypes. Similar observation found by Singh *et al*. (2002). Moderate PCV and GCV were found by Aradhana and Singh (2003) also.

The heritability (83.182%) estimates for this trait was very high, genetic advance (61.182%) was moderately high and genetic advance in percent of mean (58.232%) was also found moderately high, revealed that this character was governed by additive gene and selection for this character would be effective. High heritability and moderate genetic gain for this character were also observed by Joshi *et al*. (2004).

4.2.9 Number of fruits per cluster

Significant differences were observed among the genotypes for number of fruits cluster^{-1} which ranged from 9.33 in G5 and 5.67 in G1 and G2 with mean value of 6.98 (Table 4 and Appendix IV).

The genotypic variance and phenotypic variance for this trait were 2.984 and 3.292, respectively (Table 3). Phenotypic and genotypic coefficients of variation were moderate but the phenotypic variance appeared higher than the genotypic variance. The genotypic coefficient of variation and phenotypic coefficient of variation were 24.751% and 25.997%, respectively, which indicated presence of

high variability among the genotypes. Similar observation found by Singh *et al*. (2002). Moderate PCV and GCV were found by Aradhana and Singh (2003) also.

The heritability (90.644%) estimates for this trait was very high, genetic advance (6.147%) was low and genetic advance in percent of mean (88.075%) was found high, revealed that this character was governed by additive gene and selection for this character would be effective. High heritability and moderate genetic gain for this character were also observed by Joshi *et al*. (2004).

4.2.10 Number of cluster per plant

Significant differences were observed among the genotypes for number of cluster plant $^{-1}$ which ranged from 40.00 in G14 and 8.67 in G8 with mean value of 19.47 (Table 4 and Appendix IV).

The genotypic variance and phenotypic variance for this trait were 7.725 and 9.444, respectively (Table 3). Phenotypic and genotypic coefficients of variation 15.786 and 14.277 respectively were moderate but the phenotypic variance appeared higher than the genotypic variance which indicated presence of high variability among the genotypes. Similar observation found by Singh *et al*. (2002).

The heritability (81.799%) estimates for this trait was very high, genetic advance (15.914%) was low and genetic advance in percent of mean (81.748%) was found high, revealed that this character was governed by additive gene and selection for this character would be effective.

4.2.11 Fruit length (mm)

The mean fruit length was noticed as 39.20 mm with a range of 52.49 mm to 26.63 mm (Table 4 and Appendix IV). The genotype G11 showed the minimum fruit length and the maximum fruit length was recorded in G9 (Table 4, Plate 5). The phenotypic variance (18.108) and genotypic variance (15.284) were high and genotypic co-efficient of variation (9.973%) and phenotypic co-efficient variation

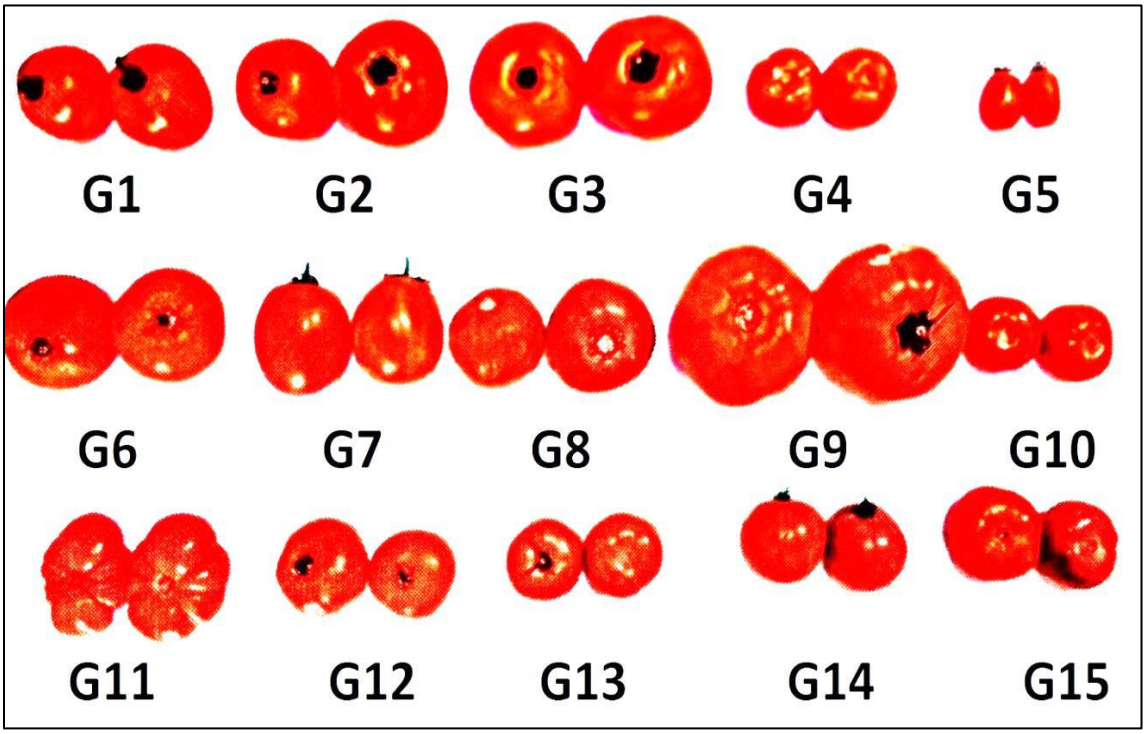


Plate 5: Picture showing phenotypic variation among fifteen genotypes of tomato

(10.855%) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of this crop (Table 3). Singh *et al*. (2002) showed that the phenotypic coefficient of variation was greatest for this character which does not support the present study.

High heritability estimates (84.404%) with low genetic advance (31.484%) over high percent of mean (80.317%) indicate that effective selection may be made for fruit length.

4.2.12 Fruit diameter (mm)

The mean fruit diameter was 41.23 mm with a range of 81.06 mm in G9 to 17.92 mm in G5 (Table 4 and Appendix IV and Plate 5).

The phenotypic variance (17.038) and genotypic variance (14.016) were moderate and genotypic co-efficient of variation (9.081%) and phenotypic co-efficient variation (10.012%) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of tomato (Table 3). Singh *et al*. (2002) showed that the phenotypic coefficient of variation was greatest for this character which does not support the present study.

High heritability (82.263%) estimate with high genetic advance over percent of mean (70.034%) indicate that effective selection may be made for fruit length. High heritability coupled with low genetic gain for this character was observed by Pandit *et al*. (2010).

4.2.13 Average fresh fruit weight (g)

The maximum fruit weight was recorded as 209.50 g in G9 where minimum was recorded as 9.30 g in G5 with mean value of 50.51 g (Table 4 and Appendix IV).

The genotypic variance (22.455) and phenotypic variance (28.064) for fruit weight was moderate (Table 3). The genotypic co-efficient of variation (9.381%) and

phenotypic co-efficient of variation (10.488%) were moderate and close to each other, proved that environment has little influence on 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. High GCV and PCV for average fruit weight were noticed by Manivannan *et al*. (2005) and Singh *et al*. (2002).

High heritability estimates (80.014%) with high genetic advance (46.257%) over very high percent of mean (91.576%) indicate that effective selection may be made for fruit weight. Pandit *et al*. (2010), Ara *et al*. (2009) and Singh *et al*. (2006) also supported the present findings.

4.2.14 Dry matter (g)

The highest dry matter of 5 g fresh tomato was found 4.80 g in G1, G2, G4, G6, G8, G9 and G14 and the lowest was recorded as 2.90 g in G7 with mean value of 4.61 g (Table 4 and Appendix IV).

The phenotypic variance (0.279) found higher than genotypic variance (0.202), suggested considerable influence of environment on the expression of the genes controlling this character (Table 3). The phenotypic coefficient of variation and genotypic coefficient of variation were 11.473% and 9.764%, respectively for dry weight of 5g fresh fruit, which indicating that significant variation exists among different genotypes and proved that environment has little influence on the expression of this character which made the trait effective for selection (Table 3). Estimation of high heritability (72.434%) for dry weight of 5g fresh fruit with low genetic advance (0.417%) and moderate genetic advance in percent of mean (9.048%) revealed that this character governed by additive gene and provide opportunity for selecting genotypes for breeding programme.

4.2.15 Fruit yield per plant (g)

Fruit yield per plant was found 3.75 kg in G4 which is highest and the lowest was recorded as 1.05 kg in G5 with mean value of 2.24 kg (Table 4 and Appendix IV).

The phenotypic variance (0.422) found higher than genotypic variance (0.403), suggested considerable influence of environment on the expression of the genes controlling this character (Table 3). The phenotypic coefficient of variation and genotype coefficient of variation were 29.032% and 28.371%, respectively for fruit yield per plant, which indicating that significant variation exists among different genotypes which made the trait effective for selection (Table 3). Similar findings were recorded by Singh *et al*. (2006) and Manivannan *et al*. (2005).

Estimation of high heritability (95.494%) for fruit yield per plant with low genetic advance (0.829%) and moderate genetic advance in percent of mean (37.086%) revealed that this character was governed by additive gene and provides opportunity for selecting high valued genotypes for breeding programme. High heritability and high genetic advance was also observed by Ara *et al*. (2009) and Anupam *et al*. (2002).

4.2.16 Percent (%) of brix

Percentage of brix is primarily a measure of the carbohydrate level of tomato (Table 4 and Appendix IV). The mean values of tomato brix was 2.93% with a range of 6.00% (G5) to 1.20% (G8) with very low phenotypic and genotypic variance (1.446 and 1.301 respectively) (Table 3).

Genotypic co-efficient of variation (38.890%) and phenotypic co-efficient variation (40.999%) (Table 3) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of tomato.

High heritability estimates (89.975%) with low genetic advance (2.681%) over high percent of mean (91.389%) indicate that effective selection may be made for % brix content (Table 3).

4.2.17 p^H

The mean value of tomato p^H was 4.84 with a range of 5.20 (G9) to 4.40 (G1) with very low phenotypic and genotypic variance (0.254 and 0.148 respectively) (Table 3 and Appendix IV).

Genotypic co-efficient of variation (7.940%) and phenotypic co-efficient variation (10.406%) (Table 3) were close to each other, indicating minor environmental influence on this character that would be effective for the improvement of tomato.

Moderate heritability estimates (58.213%) with very low genetic advance (0.304%) over low percent of mean (6.285%) indicate that effective selection may be made for p^H of tomato (Table 3).

4.3 Correlation Co-efficient

Correlation studies along with path analysis provide a better understanding of the association of different characters with fruit yield. Simple correlation was partitioned into phenotypic (that can be directly observed), genotypic (inherent association between characters) components as suggested by (Singh and Chaudhary, 1985). As we know yield is a complex product being influenced by several inter-dependable quantitative characters. So selection may not be effective unless the other contributing components are not considered. When selection pressure is applied for improvement of any character highly associated with yield, it simultaneously affects a number of other correlated characters. Hence knowledge regarding association of character with yield and among themselves provides guideline to the plant breeders for making improvement through selection with a clear understanding about the contribution in respect of establishing the

association by genetic and non-genetic factors (Dewey and Lu, 1959). Phenotypic and genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotypes of tomato are given in Table 5 and Table 6.

4.3.1 Plant height

Plant height had non-significant negative correlation with fruit yield per plant (-0.172 and -0.183) at genotypic and phenotypic levels respectively (Table 5 and Table 6) which is supported by Mohanty (2003). Plant height had also non significant negative correlation with days to first flowering, days to 50% flowering, fruit diameter, fresh fruit of weight and p^H content. It had significant positive correlation with number of leaves plant^{-1}, number of branches plant^{-1}, number of fruits cluster^{-1} and % of Brix (Table 5 and Table 6). However, it had strong negative correlation with fruit diameter (-0.389 and -0.217) at genotypic and phenotypic levels respectively.

4.3.2 Number of leaves per plant

Number of leaves plant^{-1} showed non-significant positive relationship with yield of plant^{-1} (0.128, 0.119 respectively) and showed non-significant positive association with pH at genotypic and phenotypic level (Table 5 and Table 6). It also showed positive significant association with number of branches plant^{-1}, number of flowers plant^{-1}, number of fruits plant^{-1} and number of clusters plant^{-1}. Number of leaves plant^{-1} showed significant negative correlation with days to first flowering, days to 50% flowering, days to maturity and fruit length and also showed non-significant negative association with number of fruits cluster^{-1}, fruit diameter, fresh fruit weight, dry weight of 5 g fresh fruit and % of brix.

Table 5. Genotypic correlation co-efficients among different pairs of morphological traits related to yield of fifteen tomato genotypes

Characters	pH	NLP	NBP	NFP	DFF	DF50%	DM	NFrP	NFC	NCP	FL	FD	FFW	FDW	FYP	% Bx	pH
PH	1	0.592**	0.511**	0.675**	-0.332	-0.121	0.002	0.678**	0.016	0.579**	-0.398*	-0.182	-0.174	0.024	-0.172	0.584**	-0.008
NLP		1	0.821**	0.748**	-0.463*	-0.444*	-0.446*	0.742**	-0.183	0.680**	-0.573**	-0.222	-0.324	-0.112	0.128	-0.045	0.055
NBP			1	0.726**	-0.600**	-0.536**	-0.506**	0.716**	-0.185	0.864**	-0.577**	-0.234	-0.388*	-0.028	0.065**	-0.095	0.001
NFP				1	-0.409*	-0.357*	-0.300	0.999**	0.221	0.873**	-0.603**	-0.381*	-0.377*	-0.241	0.059**	0.171	0.100
DFF					1	0.849**	0.772**	-0.399*	0.018	-0.574*	0.289	-0.305	-0.204	0.042	0.266	0.024	-0.196
DF50%						1	0.969**	-0.343	-0.181	-0.465**	0.348	-0.170	-0.177	0.080	-0.046	0.167	-0.391*
DM							1	-0.285	-0.129	-0.423**	0.296	-0.139	-0.126	0.037	-0.041**	0.287	-0.302
NFrP								1	0.228	0.866**	-0.598**	-0.384*	-0.378*	-0.243	0.053**	0.183	0.115
NFC									1	-0.003	-0.340	-0.442*	-0.208	-0.454*	-0.426*	0.329	0.201
NCP										1	-0.578**	-0.266	-0.366*	0.046	0.002	-0.008	-0.033
FL											1	-0.687**	0.674**	0.008	0.524**	-0.193	0.002
FD												1	0.938**	0.190	0.441*	-0.230	0.166
FFW													1	0.103	0.331**	-0.094	0.325
FDW														1	-0.182	0.137	-0.229
FYP															1	0.139*	0.157
% Bx																1	-0.039
pH																	1

** = Significant at 1%. * = Significant at 5%.

Note: PH = Plant height, NLP = Number of leaves plant^{-1}, NBP = Number of branches plant^{-1}, NFP = Number of flowers plant^{-1}, DFF = Days to first flowering, DF50% = Days to 50% flowering, DM = Days to maturity, NFrP = Number of fruits plant^{-1}, NFC = Number of fruits cluster^{-1}, NCP = Number of clusters plant^{-1}, FL = Fruit length (mm), FD = Fruit diameter (mm), FFW = Fresh fruit weight (g), FDW = Dry weight of 5 g fresh fruit, FYP = Fruit yield plant^{-1}, % Bx = % of Brix, p^H = p^H of tomato

Table 6. Phenotypic correlation co-efficients among different pairs of morphological traits related to yield of fifteen tomato genotypes

Characters	p^H	NLP	NBP	NFP	DFF	DF50%	DM	NFrP	NFC	NCP	FL	FD	FFW	FDW	FYP	% Bx	p^H
PH	1	0.576**	0.494*	0.677**	-0.340	-0.117	0.011	0.675**	0.011	0.572**	-0.389*	-0.180	-0.155	0.033	-0.183	0.558**	-0.011
NLP		1	0.788**	0.693**	-0.460*	-0.442*	-0.442*	0.740**	-0.177	0.622**	-0.567**	-0.222	-0.318	-0.116	0.119	-0.051	0.048
NBP			1	0.723**	-0.604**	-0.540**	-0.503**	0.715**	-0.181	0.858**	-0.580**	-0.227	-0.364*	-0.021	0.071**	-0.103	0.006
NFP				1	-0.405*	-0.360*	-0.303	0.987**	0.215	0.866**	-0.598**	-0.379*	-0.371*	-0.240	0.048**	0.154	0.092
DFF					1	0.844**	0.760**	-0.393*	0.012	-0.569*	0.290	-0.292	-0.192	0.046	0.252	0.031	-0.178
DF50%						1	0.965**	-0.340	-0.173	-0.448	0.341	-0.159	-0.180	0.069	-0.061	0.170	-0.385*
DM							1	-0.282	-0.134	-0.416**	0.289	-0.142	-0.129	0.033	-0.053**	0.273	-0.289
NFrP								1	0.222	0.861**	-0.593**	-0.377*	-0.352*	-0.231	0.039**	0.176	0.121
NFC									1	-0.005	-0.337	-0.433*	-0.211	-0.436*	-0.414*	0.318	0.192
NCP										1	-0.568**	-0.257	-0.351*	0.040	0.006	-0.013	-0.035
FL											1	-0.681**	0.678**	0.015	0.517**	-0.181	0.004
FD												1	0.884**	0.172	0.419	-0.217	0.176
FFW													1	0.109	0.337**	-0.102	0.329
FDW														1	-0.168	0.141	-0.211
FYP															1	0.142*	0.142
% Bx																1	-0.028
p^H																	1

** = Significant at 1%. * = Significant at 5%.

Note: PH = Plant height, NLP = Number of leaves plant^{-1}, NBP = Number of branches plant^{-1}, NFP = Number of flowers plant^{-1}, DFF = Days to first flowering, DF50% = Days to 50% flowering, DM = Days to maturity, NFrP = Number of fruits plant^{-1}, NFC = Number of fruits cluster^{-1}, NCP = Number of clusters plant^{-1}, FL = Fruit length (mm), FD = Fruit diameter (mm), FFW = Fresh fruit weight (g), FDW = Dry weight of 5 g fresh fruit, FYP = Fruit yield plant^{-1}, % Bx = % of Brix, p^H = p^H of tomato

4.3.3 Number of branches per plant

The number of branches per plant had positive and highly significant correlation with yield per plant (0.065 and 0.071), Number of flowers plant^{-1} (0.726 and 0.723), Number of fruits plant^{-1} (0.716 and 0.715), Number of clusters plant^{-1} (0.864 and 0.858) at genotypic and phenotypic levels (Table 5 and Table 6). Monamodi *et al*. (2013) found more branch number in a plant will produce more fruits. But a negative correlation between the number of branches per plant and number of fruits per plant was noticed by Singh *et al*. (2005). It had non-significant positive correlation with pH (0.001 and 0.006) at both levels. The number of branches plant^{-1} showed non-significant negative relation for Number of fruits cluster^{-1} (0.185 and -0.181), Fruit diameter (-0.234 and -0.227), Dry weight of 5 g fresh fruit (-0.028, -0.021) and % of Brix (-0.095 and -0.103) at both levels indicated that the association between these traits is largely influenced by environmental factors. 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).

4.3.4 Number of flowers per plant

The number of flowers plant^{-1} had positive and highly significant correlation with yield per plant (0.059 and 0.048) at the genotypic and phenotypic levels (Table 5 and Table 6). It had also highly significant positive association with Number of fruits plant^{-1} (0.999 and 0.987) and Number of clusters plant^{-1} (0.873 and 0.866) at the genotypic and phenotypic levels. It had highly significant negative association with length of fruit (-0.603 and -0.598) at genotypic and phenotypic level. It had also significant negative association with Days to first flowering, Days to 50% flowering, fruit diameter and fresh fruit weight. It had non-significant positive association with Number of fruits cluster^{-1}, % of Brix and p^{H} of tomato at both the levesl. A non-significant negative correlation with Days to maturity and Fresh fruit weight was also observed (Table 5 and Table 6).

4.3.5 Days to first flowering

Days to first flowering had non-significant positive correlation with fruit yield per plant at genotypic and phenotypic level (0.266 and 0.252) (Table 5 and Table 6). Patil and Bojappa (1993), Mayavel *et al.* (2005) and Samadia *et al.* (2006) observed positive correlation which support the present findings. This character also showed non-significant positive association with Number of fruits cluster^{-1} (0.018 and 0.012), Fruit length (0.289 and 0.290), Dry weight of 5 g fresh fruit (0.042 and 0.046) and % of Brix (0.024 and 0.031) and highly significant positive association with Days to 50% flowering (0.849 and 0.844) and Days to maturity (0.772 and 0.760) at both genotypic and phenotypic levels (Table 5 and Table 6). It had negatively significant correlation at genotypic and phenotypic level with Number of fruits plant^{-1} (0.399 and 0.393) and Number of clusters plant^{-1} (0.574 and 0.569) (Table 5 and Table 6). Days to first flowering had also negative but non-significant correlation with Fruit diameter (0.305 and 0.292), Fresh fruit weight (0.204 and 0.192) and pH (0.196 and 0.178) at both levels.

4.3.6 Days to 50% flowering

Days to 50% flowering showed non-significant negative association with fruit yield per plant -0.046 and -0.061) at both levels (Table 5 and Table 6). Dhankhar *et al.* (2006) and Samadia *et al.* (2006) observed positive correlation. It showed highly significant positive association with Days to maturity (0.969 and 0.965) at genotypic and phenotypic level (Table 5 and Table 6). Days to 50% flowering exhibited strongly significant negative relationship with Number of clusters plant^{-1} (-0.465) at genotypic but at the relationship was non-significant and negative (-0.448). It had also non-significant negative correlation with Number of fruits plant^{-1} (-0.343 and -0.340), Number of fruits cluster^{-1} (-0.181 and -0.173), Fruit diameter (-0.170 and -0.159) and Fresh fruit weight (-0.177 and -0.180) where significant negative correlation was with pH (-0.391 and -0.385) at genotypic and

phenotypic level. Days to 50% flowering showed non-significant positive association with fruit length (0.348 and 0.341), dry weight of 5 g fresh fruit (0.080 and 0.069) and % of brix (0.167 and 0.170) at genotypic and phenotypic level. Non-significant association of this trait with yield indicated that the association was largely influenced by environment. Yield improvement can be achieved by selection for days to 50% flowering were reported by Wright *et al*. (2007).

4.3.7 Days to maturity

Days to maturity had highly significant negative correlation with fruit yield per plant (-0.041 and -0.053) at genotypic and phenotypic levels (Table 5 and Table 6). It had also highly significant negative association with Number of clusters plant^{-1} (-0.423 and -0.416) at both levels (Table 5 and Table 6). It had also non-significant negative correlation with number of fruits plant^{-1} (-0.285 and -0.282), number of fruits cluster^{-1} (-0.129 and -0.134), fruit diameter (-0.139 and -0.142), Fresh fruit weight (-0.126 and -0.129) and p^{H} (-0.302 and -0.289) and non-significant positive correlation with fruit length (0.296 and 0.289), dry weight of 5 g fresh fruit (0.037 and 0.033) and % of brix (0.287 and 0.273) at genotypic and phenotypic levels (Table 5 and Table 6). A significant and positive correlation observed by Singh *et al.* (2002) and Mohanty (2003) between days to maturity and fruit yield per plant and. This doesn't support the present findings.

4.3.8 Number of fruits per plant

The number of fruits plant^{-1} had highly significant and positive association with yield per plant (0.053 and 0.039) at genotypic and phenotypic levels respectively (Table 5 and Table 6). Rani *et al.* (2010) reported that the number of fruits per plant was negatively associated with yield per plant. It had also highly significant positive correlation with Number of clusters plant^{-1} (0.866 and 0.861) and highly significant negative correlation with Fruit length (-0.598 and -0.593) at both level. The number of fruits plant^{-1} had also non-significant association with number of

fruits cluster^{-1} (0.228 and 0.222), % of brix (0.183 and 0.176) and p^{H} of tomato (0.115 and 0.121) where significant negative association was with fruit diameter (-0.384 and -0.377) and fresh fruit weight (-0.378 and -0.352) at genotypic and phenotypic levels (Table 5 and Table 6).

4.3.9 Number of fruits per cluster

The number of fruits cluster^{-1} had significant but negative association with fruit yield per plant -0.426 and -0.414) both at genotypic and phenotypic level (Table 5 and Table 6). It had also significant negative association with fruit diameter (-0.442 and -0.433) and dry weight of 5 g fresh fruit (-0.454 and -0.436) and non-significant negative association with number of clusters plant^{-1} (-0.003 and -0.005), fruit length (-0.340 and -0.337) and fresh fruit weight (-0.208 and -0.211) at both the levels. Number of fruits cluster^{-1} also exhibited non-significant positive correlation with % of brix (0.329 and 0.318) and p^{H} of tomato (0.201 and 0.192) both at genotypic and phenotypic level. The findings also supported by Nesgea *et al.* (2002) and Megha *et al* (2006). But Joshi *et.al* (2004) found number of fruits per cluster showed negative association.

4.3.10 Number of clusters per plant

The number of clusters plant^{-1} had non-significant and positive association with fruit yield per plant (0.002 and 0.006) and Dry weight of 5 g fresh fruit (0.046 and 0.040) which highly associated with fruit length (-0.578 and -0.568) negatively both at genotypic and phenotypic level (Table 5 and Table 6). Number of clusters plant^{-1} had non-significant negative association with Fruit diameter (-0.266 and -0.257), % of brix (-0.008 and -0.013) and p^{H} of tomato (-0.033 and -0.035) at the genotypic and phenotypic levels (Table 5 and Table 6). A positive correlation between number of clusters per plant and fruit yield per plant was also observed by Prasanth (2003). Nesgea *et al*. (2002) also found similar results for this trait in tomato.

4.3.11 Fruit length (cm)

Fruit length was highly significantly and positively correlated with fruit yield per plant (0.524 and 0.517) at genotypic and phenotypic level (Table 5 and Table 6). Fruit length (FL) also showed highly negative correlation with fruit diameter (-0.687 and -0.681) but highly positive correlation with fresh fruit weight (0.674 and 0.678) at genotypic and phenotypic level. Fruit length also showed non-significant positive correlation with dry weight of 5 g fresh fruit (0.008 and 0.015) and p^H of tomato (0.002 and 0.004) but it had negative non-significant association with % of brix (-0.193 and -0.181) at both the levels.

4.3.12 Fruit diameter (cm)

Fruit diameter showed significant positive relation with fruit yield per plant (0.441) at genotypic level but non-significant positive correlation at phenotypic level (0.419) (Table 5 and Table 6). It had also strong positive association with fresh fruit weight (0.938 and 0.884) at both the levels. Fruit diameter also showed significant positive non-significant relation with dry weight of 5 g fresh fruit (0.190 and 0.172) and p^H of tomato (0.166 and 0.176) and negative non-significant association with % of Brix (-0.230 and -0.217) at both the levels.

4.3.13 Fresh fruit weight (single fruit)

Single fresh fruit weight showed highly significant positive correlation with fruit yield per plant (0.331 and 0.337) which was also non-significant and positively correlated with dry weight of 5 g fresh fruit (0.103 and 0.109) and p^H of tomato (0.325 and 0.329) but negative and non-significant correlation with % of brix (-0.094 and -0.102) for both levels (Table 5 and Table 6). Matin *et al*. (2001) found that individual fruit weight had significant positive correlations with yield per plant. 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. It

had highly significant negative effect at both levels for days to 50% flowering and number of fruits per plant and for fruit per cluster only at genotypic level. Matin *et al*. (2001) found significant negative correlations between number fruits per plant and individual fruit weight.

4.3.14 Dry weight of 5 g fresh fruit

Dry weight of 5 g fresh fruit showed non-significant and negative correlation with fruit yield per plant (-0.182 and -0.168) which was also non-significant and negatively correlated with p^H of tomato (-0.229 and -0.211) but it showed positive and non-significant correlation with % of Brix (0.137 and 0.141) for both genotypic and phenotypic levels (Table 5 and Table 6).

4.3.15 Fruit yield per plant

The main target of improvement breeding is fruit yield. From Table 5 and 6 it is observed that, fruit yield per plant (FYP) was strongly and positively correlated with single fresh fruit weight (SFW) at both genotypic and phenotypic level (0.331 and 0.337). Same observation was found in terms of number of branches $plant^{-1}$, number of flowers $plant^{-1}$, number of fruits $plant^{-1}$ and fruit length both at genotypic and phenotypic content. Similar result was also reported by several authors. Rani *et al*. (2010) conducted an experiment with tomato and found average fruit weight (AFW) was positively and significantly associated with fruit yield per plant (FYP). Findings' of Weber *et al.* (2010) also evidenced the positive and strong association between FYP and AFW. Strong association between FYP and FD and FL were reported earlier by Susic (2002). Again, fruit yield per plant (FYP) showed strong negative association with Days to maturity (-0.041 and -0.053) at both genotypic and phenotypic level. Inconsistently, number of fruits per plant (FPP) manifested strong positive association with fruit yield per plant (FYP) in several earlier investigations (Kumar *et al*., 2004; Kumar *et al*., 2003 and Singh *et al*., 2004). In more recent study, Rani *et al*. (2010) investigated

negative association between numbers of fruit per plant with fruit yield. It is assumed that, less fruit number enabled high single fruit weight and thereby high positive correlation between SFW and FYP had already been established in the present study.

4.3.16 Percent (%) of brix

Percentage of brix had significant and positively association with fruit yield plant^{-1} (0.139 and 0.142) at genotypic and phenotypic level (Table 4 and Table 5). It had non-significant and positive association with number of fruits plant^{-1} 0.183 and 0.176) at both level. It also showed non-significant and negative association with single fresh fruit weight (-0.094 and -0.102) at genotypic and phenotypic level. On the other hand, it also showed non-significant and negative association pH of tomato (-0.039 and -0.028) at both level.

4.3.17 pH of tomato juice

pH of tomato had non-significant and negative association with fruit yield plant^{-1} (-0.229 and -0.211) at genotypic and phenotypic level (Table 4 and Table 5). It had significant and negative association with Days to 50% flowering (-0.391 and -0.385) at genotypic and phenotypic level. It had also non-significant and positive association with Fresh fruit weight 0.325 and 0.329) at genotypic and phenotypic level.

4.4 Path coefficient analysis

The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. Here FYP (fruit yield per plant) was considered as effect (dependent variable) and PH (plant height), NLP (number of leaves plant^{-1}), NBP (number of branches plant^{-1}), NFP (number of flowers plant^{-1}), DFF (days to first flowering), DF50% (Days to 50% flowering), DM (Days to maturity), NFrP (number of fruits plant^{-1}), NFC (number of fruits cluster^{-1}), NCP (number of clusters plant^{-1}), FL (fruit length), FD (Fruit diameter), FFW (fresh fruit weight), FDW (dry weight of 5 g fresh fruit), FYP (fruit yield plant^{-1}), % Bx (% of brix), and p^H (p^H of tomato) were treated as independent variables. Path coefficient analysis was showed direct and indirect effects of different characters on yield of tomato in Table 7.

4.4.1 Plant height

Plant height (PH) had positive direct effect (0.212) on yield per plant (Table 7). It had positive indirect effect through NLP (0.192), NFP (0.038), NCP (0.045), FL (0.062), FD (0.071), FFW (0.059), and FDW (0.043). On the other hand, plant height showed negative indirect effect on yield per plant through NBP (-0.056), DFF (-0.047), DF50% (-0.075), DM (-0.038), NFrP (-0.072), NFC (-0.086), % Bx (-0.052) and p^H (-0.063) (Table 7). Matin *et al*. (2001) reported that plant height had negative direct effect on yield per plant.

4.4.2 Number of branches per plant

Number of leaves per plant had negative direct effect on yield per plant (-0.478). This trait had positive indirect effect on PH (0.448), NBP (0.069), DF50% (0.067), DM (0.254), NCP (0.176), FFW (0.079) and FDW (0.248). On the other hand negative indirect effect was found on NFP -0.157), DFF -0.027), NFrP -0.183), NFC -0.244), FL (-0.058), FD (-0.112), % Bx (-0.064) and p^H (-0.152) (Table 7).

Table 7. Partitioning of phenotypic correlation coefficients into direct and indirect effects of seventeen important traits of fifteen tomato genotypes by path analysis

Characters	PH	NLP	NBP	NFP	DFF	DF50%	DM	NFrP	NFC	NCP	FL	FD	FFW	FDW	% Bx	p^H	FYP
PH	**0.212**	0.448	-0.114	0.056	-0.152	-0.078	-0.124	0.144	0.106	-0.026	0.018	0.044	0.038	0.012	-0.044	-0.034	0.188
NLP	0.192	**-0.478**	0.085	-0.072	0.068	0.052	-0.064	-0.072	-0.008	-0.022	0.074	-0.018	-0.022	-0.036	-0.032	-0.061	0.217
NBP	-0.056	0.069	**0.396**	0.113	-0.042	-0.071	-0.048	-0.120	0.102	-0.024	-0.014	0.087	0.078	0.042	-0.004	-0.024	0.194
NFP	0.038	-0.157	0.048	**0.217**	-0.139	0.093	0.149	0.059	0.083	0.051	0.082	-0.194	-0.091	0.008	0.012	-0.016	-0.314
DFF	-0.047	-0.027	0.138	-0.042	**0.152**	0.086	-0.092	-0.109	0.164	-0.019	0.012	0.054	0.012	0.012	0.004	0.028	-0.352*
DF50%	-0.075	0.067	-0.143	-0.018	0.093	**-0.277**	0.137	-0.037	-0.133	-0.007	0.106	-0.217	-0.118	-0.060	0.014	-0.007	-0.277
DM	-0.038	0.254	0.066	0.036	0.076	0.115	**-0.183**	-0.125	0.283	-0.022	0.111	-0.202	-0.107	-0.018	0.018	-0.009	-0.312
NFrP	-0.072	-0.183	0.162	0.054	0.034	-0.136	0.018	**0.382**	0.208	0.041	-0.061	0.309	0.103	-0.032	-0.022	0.012	0.408*
NFC	-0.086	-0.244	0.086	0.126	-0.137	0.082	0.050	0.241	**-0.306**	0.049	0.031	0.137	0.037	0.014	-0.030	0.018	-0.396*
NCP	0.045	0.176	0.072	0.072	-0.062	0.059	-0.028	0.149	-0.071	**0.066**	0.094	-0.286	-0.088	0.028	-0.025	-0.032	0.286
FL	0.062	-0.058	-0.218	-0.133	0.114	-0.073	-0.144	-0.026	-0.006	-0.020	**0.172**	-0.230	-0.030	-0.022	-0.031	0.008	0.686**
FD	0.071	-0.112	-0.177	-0.028	0.048	-0.032	0.052	0.069	0.108	0.062	-0.038	**0.511**	0.041	-0.036	0.026	0.032	0.594**
FFW	0.059	0.079	0.057	0.016	0.029	0.048	0.075	0.122	-0.046	0.024	-0.017	0.049	**0.160**	0.044	0.019	0.018	0.388*
FDW	0.043	0.248	0.060	-0.114	0.083	0.019	0.104	0.027	-0.212	0.028	0.013	0.199	0.099	**0.086**	0.028	0.029	0.297
% Bx	-0.052	-0.064	-0.175	0.071	-0.071	-0.144	-0.081	0.038	0.174	0.023	-0.154	-0.072	0.044	0.027	**-0.064**	0.021	-0.098
p^H	-0.063	-0.152	-0.127	0.044	-0.113	-0.076	-0.088	0.040	0.221	0.044	-0.145	-0.285	-0.086	0.019	-0.022	**-0.118**	-0.072
Diagonally bold figures indicate the direct effect										Residual effect = 0.1763							

Note: PH = Plant height, NLP = Number of leaves plant^{-1}, NBP = Number of branches plant^{-1}, NFP = Number of flowers plant^{-1}, DFF = Days to first flowering, DF50% = Days to 50% flowering, DM = Days to maturity, NFrP = Number of fruits plant^{-1}, NFC = Number of fruits cluster^{-1}, NCP = Number of clusters plant^{-1}, FL = Fruit length (mm), FD = Fruit diameter (mm), FFW = Fresh fruit weight (g), FDW = Dry weight of 5 g fresh fruit, FYP = Fruit yield plant^{-1}, % Bx = % of Brix, p^H = p^H of tomato

Singh *et al.* (2005) also reported that number of leaves per plant had direct negative effects on yield which is supported by present findings.

4.4.3 Number of branches per plant

Number of branches per plant had positive direct effect on yield per plant (0.396). This trait had positive indirect effect on NLP (0.085), NFP (0.048), DFF (0.138), DM (0.066), NFrP (0.162), NFC (0.086), NCP (0.072), FFW (0.057) and FDW (0.060). On the other hand negative indirect effect was found on PH (-0.114), DF50% (-0.143), FL (-0.218), FD (-0.177), % Bx (-0.175) and p^H (-0.127) (Table 7). Singh *et al.* (2005) also reported that number of branches per plant had direct negative effects on yield which is not supported by present findings. This disagreement with present findings might be due to environmental variation.

4.4.4 Number of flowers per plant

Number of flower $plant^{-1}$ had highly positive direct effect (0.217) on yield per plant (Table 6). It showed positive indirect effect through PH (0.056), NBP (0.113), DM (0.036), NFrP (0.054), NFC (0.126), NCP (0.072), FFW (0.016), % Bx (0.071) and p^H (0.044). On the other hand, Flower per plant showed negative indirect effect on yield per plant through NLP (-0.072), DFF (-0.042), DF50% (-0.018), FL (-0.133), FD (-0.028) and FDW (-0.114).

4.4.5 Days to first flowering

Days to first flowering had positive direct effect on yield per plant (0.152) which is contributed to result significant positive genotypic correlation with yield per plant (0.266). Matin *et al*. (2001) reported dissimilar result with the present study and they stated that days to first flowering had negative direct effect on yield per plant. It had positive indirect effect on NLP (0.068), DF50% (0.093), DM (0.076), NFrP (0.034), FL (0.114), FD (0.048), FFW (0.029) and FDW (0.083). Negative

indirect effect was also found on PH (-0.152), NBP (-0.042), NFP (-0.139), NFC (-0.137), NCP (-0.062), % Bx (-0.071) and p^H (-0.113) (Table 7).

4.4.6 Days to 50% flowering

Days to 50% flowering had negative direct effect (-0.277) on yield per plant. Days to 50% flowering had positive indirect effect on NFP (0.093), DFF (0.086), DM (0.115), NFC (0.082), NCP (0.059), FFW (0.048) and FDW (0.019). But it had negative indirect effect on, PH (-0.078), NBP (-0.071), NFrP (-0.136), FL (-0.073), FD (-0.032), % Bx (-0.144) and p^H (-0.076) (Table 7). Singh *et al.* (2004) showed that days to 50% flowering had high positive direct effect on yield, which is supported by present findings.

4.4.7 Days to maturity

Days to maturity had negative direct effect on yield per plant (-0.183) and it had also significant negative correlation with yield per plant (-0.041) at genotypic level. Singh *et al.* (2005) also reported that days to maturity had high negative direct effects on yield in tomato. Days to maturity had positive indirect effect on NFP (0.149), DF50% (0.137), NFrP (0.018), NFC (0.050), FD (0.052), FFW (0.075) and FDW (0.104). This trait had also negative indirect effect on PH (-0.124), NLP (-0.064), NBP (-0.048), DFF (-0.092), NCP (-0.028), FL (-0.144), % Bx (-0.081) and p^H (-0.088) (Table 7).

4.4.8 Number of fruits per plant

Number of fruits per plant showed positive direct effect (0.382) on yield per plant. It had also significant positive correlation with yield per plant (0.053). Number of fruits per plant had positive indirect effects on PH (0.144), NFP (0.059), NFC (0.241), NCP (0.149), FD (0.069), FFW (0.122), FDW (0.027), %Bx (0.038) and p^H (0.040). It had negative indirect effect on NLP (-0.072), NBP (-0.120), DFF (-0.109), DF50% (-0.037), DM (-0.125) and FL (-0.026) (Table 7). Singh *et al.*

(2006) and Kumar *et al.* (2003) also observed fruits per plant had 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. This is not supported by present findings. This discrepancy with present findings might be due to environmental variation.

4.4.9 Number of fruits per cluster

Number of fruits per cluster showed negative direct effect (-0.306) on yield per plant and negative significant correlation (-0.426) at genotypic level. It also showed positive indirect effects through PH (0.106), NBP (0.102), NFP (0.083), DFF (0.164), DM (0.283), NFrP (0.208), FD (0.108), % Bx (0.174) and p^H (0.221) (Table 7). It also showed negative indirect effects on NLP (-0.008), DF50% (-0.133), NCP (-0.071), FL (-0.006), FFW (-0.046) and FDW (-0.212). Mayavel *et al.* (2005) also reported that number of fruits per cluster had negative direct effects on fruit yield.

4.4.10 Number of clusters per plant

Number of clusters per plant had positive direct effect (0.066) on yield per plant and non-significant positive correlation with yield per plant (002). It had positive indirect effect on NFP (0.051), NFrP (0.041), NFC (0.049), FD (0.062), FFW (0.024), FDW (0.028), % Bx (0.023) and p^H (0.044). This trait showed negative indirect effect PH (-0.026), NLP (-0.022), NBP (-0.024), DFF (-0.019), DF50% (-0.007), DM (-0.022) and FL (-0.020) (Table 7). Similar findings reported by Singh *et al.* (2005).

4.4.11 Fruit length

Fruit length had positive direct effect (0.172) on yield per plant. It had also significant positive correlation with yield per plant (0.524). This trait had also indirect positive effect on PH (0.018), NLP (0.074), NFP (0.082), DFF (0.012),

DF50% (0.106), DM (0.111), NFC (0.031), NCP (0.094) and FDW (0.013). Fruit length showed indirect negative effect on NBP (-0.014), NFrP (-0.061), FD (-0.038), FFW (-0.017), % Bx (-0.154) and p^H (-0.145) (Table 7). Padda *et al.* (2007), Singh *et al.* (2004) revealed that fruit length exhibited positive effect on yield per plant at the genotypic and phenotypic levels.

4.4.12 Fruit diameter

Fruit diameter showed highly positive direct effect (0.511) on yield per plant. It had also significant positive correlation with yield per plant (0.441). It had positive indirect effect on PH (0.044), NBP (0.087), DFF (0.054), NFrP (0.309), NFC (0.137), FFW (0.049) and FDW (0.199). Fruit diameter had negative indirect effects on NLP (-0.018), NFP (-0.194), DF50% (-0.217), DM (-0.202), NCP (-0.286), FL (-0.230), % Bx (-0.072) and p^H (-0.285) (Table 7). Padma *et al.* (2002) found that fruit diameter had high positive direct effect on fruit yield at the genotypic and phenotypic levels. This is supported by present findings.

4.4.13 Fresh fruit weight (Single)

Path analysis revealed that single fruit weight had direct positive effect (0.160) on yield per plant and significant positive correlation with yield per plant (0.331). This trait had also indirect positive effect on PH (0.038), NBP (0.078), DFF (0.012), NFrP (0.103), NFC (0.037), FD (0.041), FDW (0.099) and % Bx (0.044). Further, fruit weight showed indirect negative effect on NLP (-0.022), NFP (-0.091), DF50% (-0.118), DM (-0.107), NCP (-0.088), FL (-0.030) and p^H (-0.086) (Table 7). 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 positive direct effects on fruit yield.

4.4.14 Dry weight of 5 g fresh fruit

Path analysis also revealed that dry fruit weight had direct positive effect (0.086) on yield per plant and non-significant negative correlation with yield per plant (-0.182). This trait had also indirect positive effect on PH (0.012), NBP (0.042), NFP (0.008), DFF (0.012), NFC (0.014), NCP (0.028), FFW (0.044), % Bx (0.027) and p^H (0.019). Further, fruit weight showed indirect negative effect on NLP (-0.036), DF50% (-0.060), DM (-0.018), NFrP (-0.032), FL (-0.022) and FD (-0.036) (Table 7). 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 positive direct effects on fruit yield.

4.4.15 % brix content

Percent (%) brix content had positive direct effect (-0.064) on yield per plant. It had also significant positive correlation with yield per plant (0.139). This trait had also indirect positive effect on NFP (0.012), DFF (0.004), DF50% (0.014), DM (0.018), FD (0.026), FFW (0.019) and FDW (0.028). % brix content showed indirect negative effect on PH (-0.044), NLP (-0.032), NBP (-0.004), NFrP (-0.022), NFC (-0.030), NCP (-0.025), FL (-0.031) and p^H (-0.022) (Table 7).

4.4.16 pH of tomato juice

pH of tomato had negative direct effect (-0.118) on yield per plant. It had also non-significant positive correlation with yield per plant (0.157). It showed positive indirect effect through DFF (0.028), NFrP (0.012), NFC (0.018), FL (0.008), FD (0.032), FFW (0.018), FDW (0.029) and % Bx (0.021). On the other hand, pH of Tomato showed negative indirect effect on yield per plant through, PH (-0.034), NLP (-0.061), NBP (-0.024), NFP (-0.016), DF50% (-0.007), DM (-0.009) and NCP (-0.032) (Table 7).

4.5 Multivariate Analyses

The genetic diversity of tomato advanced lines is presented in Table 8 to 11.

4.5.1 Principal Component Analysis (PCA)

Principal component analysis was carried out with fifteen genotypes of tomato which gives Eigen values of principal component axes of coordination of genotypes with the first axes totally accounted for the variation among the genotypes. First three Eigen values for three principal coordination axes of genotypes accounted for 47.76% variation (Table 11).

4.5.2 Non-Hierarchical Clustering

Fifteen *Solanum lycopersicum* L. genotypes were grouped into five different clusters non-hierarchical clustering (Table 8). These results confirmed the clustering pattern of the genotypes obtained through principal component analysis. Shashikanth *et al.* (2010) reported ten clusters, Mahesha *et al.* (2006) reported nine clusters, Sharma and Verma (2001) reported five clusters in tomato. Cluster I had highest number of 4 genotypes followed by cluster II, cluster IV and V constitute by three genotypes each respectively. On the other hand, cluster III constitute by 2 genotypes (Table 8).

Remarkably, cluster III have G10 and G12 whereas cluster II composed of G3, G5 and G7. Furthermore, cluster IV constitute with G9, G13 and G15. Cluster V represents 3 genotypes namely G6, G8 and G11. Last of all cluster I had 4 genotypes G1, G2, G4 and G14 (Table 8).

According to the cluster means (Table 9), cluster I had the highest cluster mean value for 8 characters namely NBP (18.75), DFF (25.75), DF50% (33.00), DM (61.25), NFP (121.92), NCP (25.34), FDW (4.80 g), FYP (2.51 g). This indicates that, genotype of cluster I could be used for parent in future hybridization program for NBP, DFF, DF50%, DM, NFP, NCP, FDW and FYP. Cluster IV had high

Table 8. Number, percent and name of genotypes in different cluster

Cluster number	No. of genotypes	Number of populations	Percent (%)	Name of genotypes
I	G1, G2, G4, G14	4	26.67	BARI tomato-2, BARI tomato-3, BARI hybrid tomato-5, BD-9960
II	G3, G5, G7	3	20	BARI hybrid tomato-4, BARI tomato-11, BARI tomato-15
III	G10, G12	2	13.33	BD-7287, BD-7278
IV	G9, G13, G15	3	20	BARI tomato-17, BD-7757, BD-7291
V	G6, G8, G11	3	20	BARI tomato-14, BARI tomato-16, BD-7290

Table 9. Cluster mean for seventeen morphological traits related to yield of fifteen tomato genotypes

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
PH	79.84	75.11	64.50	86.00	67.11
NLP	95.58	93.45	120.34	118.89	84.67
NBP	18.75	14.11	18.34	24.66	14.55
NFP	127.84	125.78	82.84	130.00	73.78
DFF	25.75	25.33	25.00	21.67	25.33
DF50%	33.00	30.33	27.50	25.00	28.33
DM	61.25	58.33	51.00	51.33	54.00
NFP	121.92	120.67	76.67	121.67	69.33
NFC	6.42	8.00	6.67	6.45	7.45
NCP	25.34	14.56	13.67	25.67	14.22
FL	41.46	38.74	41.58	38.33	35.94
FD	40.12	34.58	43.31	53.32	35.87
FFW	37.23	38.33	53.95	90.76	37.87
FDW	4.80	4.03	4.70	4.73	4.73
FYP	2.51	2.15	2.40	2.13	1.95
% Bx	2.85	3.67	2.60	3.03	2.43
p^H	4.70	4.97	4.70	4.90	4.93

Table 10. Intra-inter cluster distance among 15 tomato genotypes

Characters	Cluster I	Cluster II	Cluster III	Cluster IV	Cluster V
I	**782.64 (26.98)**	1214.88 (33.75)	1322.54 (38.30)	1823.37 (45.66)	1735.84 (43.14)
II		**658.38 (23.74)**	1588.64 (38.64)	1132.52 (31.19)	1378.27 (35.75)
III			**892.62 (28.82)**	2648.89 (47.56)	1957.48 (44.73)
IV				**768.26 (24.72)**	2125.63 (44.88)
V					**1018.38 (42.53)**

Values in bold illustrate the intra cluster distance and others show inter cluster distance

Table 11. Eigen values and yield percent contribution of seventeen characters of 15 genotypes

Principal component axis	Eigen value	% Variance	Cumulative (%) total variance
I	3.26	19.176	19.18
II	2.82	16.588	35.76
III	2.04	12.000	47.76
IV	1.40	8.235	56.00
V	1.27	7.471	63.47
VI	1.14	6.706	70.18
VII	1.02	6.000	76.18
VIII	0.93	5.471	81.65
IX	0.80	4.706	86.35
X	0.68	4.000	90.35
XI	0.48	2.824	93.18
XII	0.36	2.118	95.29
XIII	0.30	1.765	97.06
XIV	0.28	1.647	98.71
XV	0.12	0.706	99.41
XVI	0.08	0.471	99.88
XVII	0.02	0.118	100.00

value for PH (86.00 cm), NFP (130.00), FD (53.32 mm) and FFW (90.76 g) than other cluster. Highest cluster mean value was achieved for NFC (8.00), %Bx (3.67) and p^H (4.97) in cluster II. Cluster mean value was achieved high for NLP (120.34) and FL (41.58 mm) in cluster III. In cluster II, III and V had moderate mean value for all character. Genotype of cluster II, III and V could be used for parent in future hybridization program for all morphological character in this experiment studied.

4.5.3 Canonical variate analysis

Canonical Variate Analysis (CVA) was done to compute the inter-cluster distances. The intra and inter-cluster distance (D^2) values were shown in Table 10. In this experiment, the inter-cluster distances were higher than the intra-cluster distances thus indicating broader genetic diversity among the genotypes of different groups. Islam and Islam (2000) reported that the inter-cluster distances were larger than the intra-cluster distances.

The highest inter-cluster distance was observed between clusters III and IV (47.56), followed by between clusters I and IV (45.66), IV and V (44.88) and III and V (44.73). In contrast, the lowest inter-cluster distance was observed between cluster II and IV (31.19), followed by I and II (33.75).

However, the maximum inter-cluster distance was observed between the clusters III and IV (47.56) indicating genotypes from these two clusters, if involved in hybridization may produce a wide spectrum of segregating population.

On the other hand, the maximum intra-cluster distance was found in cluster V (42.53), which contained of 3 genotypes, while the minimum distance was found in cluster II (23.74) that comprises 3 genotypes. Inter and intra cluster distances were showed in table 10. Cluster I consists of nearest cluster with D^2 values cluster III (38.30) and farthest cluster with D^2 values V (43.14) (Table 12). Cluster II consists of nearest cluster with D^2 values cluster IV (31.19) and farthest cluster

with D^2 values III (38.64). Cluster III consists of nearest cluster with D^2 values cluster V (44.73) and farthest cluster with D^2 values IV (47.56). Cluster IV consists of nearest cluster with D^2 values cluster II (31.19) and farthest cluster with D^2 values III (47.56). Cluster V consists of nearest cluster with D^2 values cluster II (35.75) and farthest cluster with D^2 values IV (44.88) (Table 11).

4.5.4 Selection of genotypes as parent for hybridization programme

Selection of genetically diverse parents is the prime task for any plant breeding activities. So the genotypes were to be selected on the basis of specific objectives. A high heterosis could be produced from the crosses between genetically distance parents (Ghaderi *et al*., 1984). Considering the magnitude of cluster mean and agronomic performance the genotype G13 for maximum number of branches plant^{-1}, number of fruits plant^{-1}, G5 for maximum number of fruits cluster^{-1}, G14 for maximum number of clusters plant^{-1}, G9 for maximum Fresh fruit weight (single) and G4 for maximum fruit yield plant^{-1} (kg) were found promising. Therefore considering group distance and other agronomic performance the inter-genotypic crosses between G13, G5, G14, and G9 might be suggested for future hybridization program.

4.6.1 Percent (%) of brix

In this experiment, the % of Brix of fifteen genotypes of tomato was determined by refractometer. Very little variability was observed among the genotypes for percent of brix (Table 3 and Table 4). G5 contained high brix percentage (6.00).

CHAPTER V

SUMMARY AND CONCLUSION

The present study was undertaken at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh with fifteen genotypes of tomato *(Solanum lycopersicum* L.) during November 2015 to April 2016. Seeds were sown in seed bed then transferred to the main field in Randomized Complete Block Design (RCBD) with three replications. Data on various yield attributing characters such as, plant height, number of leaves plant^{-1}, number of branches plant^{-1}, number of flowers plant^{-1}, days to first flowering, days to 50% flowering, days to maturity, number of fruits plant^{-1}, number of fruits cluster^{-1}, number of clusters plant^{-1}, fruit length, fruit diameter, fresh fruit weight (single), dry weight of 5 g fresh fruit, fruit yield plant^{-1}, % of brix, p^H of tomato were recorded. Analysis of variance revealed significant differences among all the genotypes for all the characters under study.

The analysis of variances showed significant mean squares for different characters indicated the presence of sufficient variation among the genotypes for all the characters. The number of fruit yield plant^{-1} showed highest range of variation (3.75 kg - 1.05 kg) that means wide range of variation present for this character.

In case of plant height, number of leaves plant^{-1}, number of flowers plant^{-1}, number of fruits plant^{-1}, fruit yield plant^{-1}, showed higher influence of environment for the expression of these characters. On the other hand, number of branches plant^{-1}, days to first flowering, days to 50% flowering, days to maturity, fruit length, fruit diameter, dry weight of 5 g fresh fruit, % of brix, p^H of tomato showed least difference in phenotypic and genotypic variance suggesting additive gene action for the expression of the characters. All the characters under the present study exhibit the highest value of heritability.

Correlation coefficients among the characters were studied to define the association between yield and yield components. In general, most of the characters showed the genotypic correlation co-efficient were higher than the corresponding phenotypic correlation co-efficient suggesting a strong inherent association between the characters under study. The significant positive correlation with yield per plant was found in number of branches plant^{-1}, number of flowers plant^{-1}, fruit length, fruit diameter, fresh fruit weight (single) and % of brix at genotypic and phenotypic level. In addition, there were non-significant positive correlation with fruit yield per plant was also found in number of leaves plant^{-1}, days to first flowering, number of clusters plant^{-1} and p^{H} of tomato at genotypic and phenotypic level, respectively. On the other hand, the non-significant negative correlation with yield per plant was also found in plant height, days to 50% flowering and dry weight of 5 g fresh fruit while the significant negative correlation was found in days to maturity and number of fruits per cluster at genotypic and phenotypic level, respectively.

Path coefficient analysis showed that single fruit weight had the positive correlation with fruit yield per plant. Coherently, this trait contributes to the yield through direct effect (0.086) indicating selection will be judicious and more effective for these characters in future breeding program. It was also showed that number of fruits plant^{-1} had the highest positive correlation (0.053) with fruit yield per plant and this trait contributes to the yield through direct effect (0.382) indicating selection will be judicious and more effective for these characters in future breeding program. days to 50% flowering, days to maturity, number of fruits cluster^{-1} and % of brix had negative direct effect with fruit yield per plant where positive direct effect was also found in plant height, number of branches plant^{-1}, number of flowers plant^{-1}, days to first flowering, number of clusters plant^{-1}, fruit length, fruit diameter and dry weight of 5 g fresh fruit.

Genetic diversity among tomato genotypes was performed through Principal Component Analysis (PCA), Cluster Analysis, Canonical Variate Analysis (CVA) using GENSTAT computer program. The first three principal component axes accounted for 47.76% variation towards the divergence. Among five clusters; cluster I contained maximum number of genotypes (4) while cluster III had only 2 genotypes. According to PCA, D^2 and cluster analysis, the genotypes grouped into five divergent clusters obtained from principal component scores. The highest inter-cluster distance was observed between clusters III and IV (47.56) indicating genotypes from these two clusters, if involved in hybridization may produce a wide spectrum of segregating population while the lowest inter-cluster distance was observed between cluster II and IV (31.19). On the other hand, the maximum intra-cluster distance was found in cluster V (42.53), which contained of 3 genotypes, whereas the minimum distance was found in cluster II (23.74) that comprises 3 genotypes. Therefore, crossing between the genotypes belonging cluster I with cluster II, cluster II with cluster III, cluster III with cluster IV and cluster I with cluster V might produce high heterosis in respect of yield, single fruit weight and higher number of fruit per plant. So the genotypes belonging to cluster I and cluster II, cluster II and cluster III, cluster III and cluster IV and cluster IV and cluster V have been selected for future hybridization program.

Considering the magnitude of cluster mean and agronomic performance the genotype G13 for maximum number of branches plant^{-1}, number of fruits plant^{-1}, G5 for maximum number of fruits cluster^{-1}, G14 for maximum number of clusters plant^{-1}, G9 for maximum fresh fruit weight (single) and G4 for maximum fruit yield plant^{-1} (kg) were found promising. Therefore considering group distance and other agronomic performance the inter-genotypic crosses between G13, G5, G14, and G9 might 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 no. of clusters per plant, number of fruits per cluster, number of fruits per plant, fruit weight, fruit diameter % of brix content to develop high yielding varieties.

ii. Considering group distance and other agronomic performance the inter-genotypic crosses between G13, G5, G14 and G9 and also other improved variety and high yielding variety might be suggested for future hybridization program.

iii. G4 genotypes could be recommended to the farmers for cultivation for high agronomic performance.

REFERENCES

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

Aditya, P.M. and Phir, K. (1995). Studied on genetic variability in tomato. *Progr. Hort*. **32** (2): 172-182.

Aditya, T.L., Rahman, L., Alam, M.S. and Ghoseh, A.K. (1997). Correlation and path co-efficient analysis in tomato. *Bangladesh J. Agril. Sci.* **26**(1): 119-122.

Agong, S.G., Schittenhelm, S. and Friedt, W. (2001). Genotypic variation of Kenyan tomato (*Lycopersicon esculentum* L.) germplasm. *J. Food Technol. Afr*. **6**(1): 13-17.

Ahmed, S.U., Saha, H.K., Rahman, L. and Sharfuddin, A.F.M. (1986). Performance of some advance lines of tomato. *Bangladesh Hort.* **14**(1): 47-48.

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.

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

Anonymous. (2011). Agricultural statistics of Pakistan. Ministry of Food, Agriculture and Livestock, Islamabad.

Anonymous. (2014). "Solanaceae Source: Phylogeny of the genus *Solanum*". "Molecular phylogenetic analyses have established that the formerly segregate genera *Lycopersicon*, *Cyphomandra*, *Normania*, and *Triguera* are nested within *Solanum*, and all species of these four genera have been transferred to *Solanum*".

Anonymous. (2015). http://www.biodiversitylibrary.org/page/358204#page/6/mode 1up and "International Plant Name Index". (1753). Sp. Pl. **1:** 185. http://web.archive.org/web/20110606004439/http://www.ipni.org/ipni/id=146898.

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.Uni.* **14** (2): 249-252.

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

Arun, K., Veera, R. and Ragavathatham, K. (2004). Variability studies in tomato (*Solanum lycopersicum* L.) genotypes under green house and open conditions in different seasons. *South Indian Hort*. **53**(1-6): 18-24.

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

Baishya, K.C., Syamal, M.M. and Singh, K.P. (2001). Diallel analysis in tomato. *J. Agril. Sci. Soc. North East India.* **13**(2): 225-228.

Bernousi, I., Emami, A., Tajbakhsh, M., Darvishzadeh, R. and Henareh, M. (2011). Studies on genetic variability and correlation among the different traits in *Solanum lycopersicum* L. *Not Bot Hort Agrobot Cluj*. **39**(1):152-158.

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.

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., Chima, D.S. and Dhariwal, M.S. (2000). 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.

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

Burton, G.W. (1952). Quantitative interaction in grasses. In: Proc. Int. Grassland Congr. **1**: 277-283.

Chadha, S.I., Kumar, J. and Vidyasagar. (2001). Combining ability over environments in tomato. *Indian J. Agri. Res*. **35**(3): 171-175.

Cheema, D.S., Kumar, D. and Kaur, R. (2003). Diallel analysis for combining ability involving heat tolerant lines of tomato (*Lycopersicon esculentum* Mill). *Crop-Improvement*. **30**(1): 39-44.

Chen, X., Yang, D., Yang, Z., Li, Y. Y. and Zhang, H. (2009). The genetic analysis of quality of fruit of 7 tomato breeding lines. *J. Yunnan Agril. Univ.* **19**(5): 518-523.

Chishti, S.A.S., Khan, A.A., Sadia, B. and Khan, I.A. (2008). Analysis of combining ability for yield, yield components and quality characters in tomato (*Lycopersicon esculentum* Mill). *J. Agric. Res.* **46**(4): 325-332.

Comstock, R.E. and Ribinson, H.F. (1952). Genetic parameters, their estimation, and significance. Proc. 6th intercropping. **1**: 284-291.

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.

Dev, H., Rattan, R.S., and Thakur, M.C. (1994). Heterosis in tomato. *Hort. J.* **7** (2): 125-132.

Dewey, D.R. and Lu, K.H. (1959). A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agron. J.* **51**: 515-518.

Dhaliwal, M.S., Singh S., Badhan, B.S. and Cheema, D.S. (1999). Diallel analysis for total soluble solids content, pericarp thickness and locule number in tomato. *Veg. Sci*. **26**(2): 120-122.

Dhaliwal, M.S., Singh, S. and Cheema, D.S. (2002). Estimating combining ability effects of the genetic male sterile lines of tomato for their use in hybrid breeding. *J. Genet. Breed*. **54**(3): 199-205.

Dhaliwal, M.S., Singh, S. and Cheema, D.S. (2003). Line × tester analysis for yield and processing attributes in tomato. *J. Res*. **40**: 49-53.

Dhankar, S.K., Dhankar, B.S. and Sharma, N.K. (2001). Correlation and path analysis in tomato under normal and high temperature conditions. *Haryana J .Hort. Sci*. **30** (1-2): 89-92.

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.

Digby, P., Galway, M. and Lane, P. (1989). GENSTAT 5 A secind course. Oxford Science Publications, Oxford. pp. 103-108.

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

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

Dufera, J.T. (2013). Evaluation of agronomic performance and lycopene variation in Tomato (*Lycopersicon esculantum* Mill.) genotypes in Mizan, southwestern Ethiopia. *World App. Sci. J*. **27**(11): 1450-1454.

FAO (Food and Agriculture Organization). (2010). Plant genetic ressource for food and agriculture. Rome, Food and Agriculture Organisation of the United Nations.

FAOSTAT. (2013). Food and Agricultural Commodities Production; Available online: http://faostat. fao. org (accessed 14 February 2013).

Farkas, J. (1993). Current problems in heterosis breeding of tomato. *Zoldsegtermesztes-Kutato-Intezet-Bulletinje*. **25**: 23-36.

Farzaneh, A., Nemati, H., Arouiee, H. and Kakhki, A.M. (2013). Genetic analysis of traits associated with yield and earliness in nine tomato (*Lycopersicon esculentum* Mill.) lines using diallel crossing method. *J. Seed Pl. Improvement.* **29**(4): 693-710.

Filippone, P.T. (2014). Tomato History - The history of tomatoes as food. Once considered poisonous. The tomato is now a favorite food. Home Cooking Expert. (http:// homecooking.about.com/ od/ foodhistory/a/ tomatohistory. htm.

Foolad, M.R. (2007). Genome mapping and molecular breeding of tomato. *Int. J. Plant Genomics.* **45**: 64-58.

Gentilcore, D. (2010). A History of the Tomato in Italy Pomodoro. New York, NY: Columbia University Press, ISBN 023115206X.

Geogieva, A.K., Dhanesh and Kulal, P.K., (1969). Path analysis in tomato. *J. Maharashti agric. Univ.* **14**: 114-116.

Ghadheri, A., Shishegar, M., Regai, A. and Edaie, B. (1979). Multivariate analysis of genetic diversity for yield and morphological traits in dry edible bean and faba bean. *Crop Sci.* **24**: 37-42.

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. *Ind. 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.

Gopalan, C., Sastri, V.R., Balasubramanium, S.C., Rao, B.S.N., Dosthale, Y.G. and Pant, K.C. (1999). Nutritive value of Indian foods. Indian Council of Medical Research Technological Bulletin. National Institute of Nutrition, Hyderabad.

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

Hannan, M.M., Ahmed, M.B., Razvy, M.A., Karim, R., Khatum, M., Hayder, A., Hussain, M. and Roy, U.K. (2007*). Heterosis* **45** (2):146-150.

Hanson, C.M., Robinsen, R.R. and Comstock, R.R. (2002). Biometrical studies on yield in segregating population of Kotean. *Lespedeza. Agron. J*. **48**: 268-272.

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.

Hernandez, L.E., Lobato, O.R., Garcia, Z.J.J., Lopez, D. and Hernandez, B.A. (2013). Agronomic performance of F_2 populations from tomato hybrids (*Solanum lycopersicum* L.). *Rev. Fit. Mexicana*. **36**(3): 209-215.

Hotelling, H. (1933). Analysis of a complex of statistical variable into principal components. *J. Educ. Psych.* **24**: 417-441.

Hu, X., Wang, H., Chen, J. and Yang, W. (2012). Genetic diversity of Argentina tomato varieties revealed by morphological traits, simple sequence repeat, and single nucleotid polymorphism markers. *Pak. J. Bot.* **44**(2): 485-492.

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

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

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.

Jackson, J. (1991). A User's Guide to Principal Components. John Wiley & Sons.

Johnson, H.W., Robinson, H.F. and Comstock, R.E. (1955). Estimates of genetic and environmental variability in soyabean. *Agron. J.* **47**: 314-318.

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

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

Joshi, A., Vikram, A. and Thakur, M.C. (2004). Studies on genetic variability, correlation and path analysis for yield and physico- chemical traits in stomato (*Solanum lycopersicum* L.). *Progr. Hort*. **36** (1): 51-58.

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.

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

Khule, A.A., Tikka, S.B.S., Jadhav, D.J. and Kajale, D.B. (2011). Genetic variability and heritability studies in local collections of sponge gourd *(Luffa cylindrica.). Asian J. Bio. Sci.* **6**(1): 119-120.

Krishna, B.E. and Allolli, T.B. (2005). Influence of cropping system and source of nutrients in Leucaena-based alley cropping system on yield and quality of tomato. *Karnataka J. Agril. Sci*. **18**(2): 464-468.

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

Kumar, R., Ameta, K.D., Dubey, R.B. and Pareek, S. (2013). Genetic variability, correlation and path analysis in sponge gourd *(Luffa cylindrica* Roxb.) *African Journal of Biotechnology*. **12**(6): 539-543.

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

Kumar, S., Kumar, M., Singh, M., Banerjee, K. and Rai, M. (2003). Hybrid seed production of Solanaceous vegetables. A Practical Manual, II VR Technical Bulletin. **9**: 1-34.

Kumar, S., Singh, R. and Pal, A.K. (2007). Genetic variability, heritability, genetic advance, correlation coefficient and path analysis in bottle gourd *(Legenaria siceraria* L.). *Indian J. Hort.* **64**(2):163-168.

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., Nandan, R., Srivastava, K., Sharma, S.K., Kumar, R. and Kuma, A. (2013). Genetic parameters and correlation study for yield and quality traits in tomato (*solanum lycopersicum* L.). *Plant Archives*. **13** (1): 463-467.

Kumar, V.R.A., Thakur, M.C. and Hedau, N.K. (2001). Correlation and path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Ann. Agric. Res*. **24**(1): 170-177.

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

Lush, J.L. (1943). Heritability of qualitative characters in farm animals. Pro. of 8th Cong. Genetics and Heriditasd Supplement.pp.356-375.

Mahalanobis, P.C. (1936). On the generalized distance in statistics. *Proc. Nat. inst. Sci. India.* **2**: 49-55.

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

Mahesh, D.K., Apte, Y.B. and Jadhav, B.B. (2006). Studies on genetic divergence in tomato (*Lycopersicon esculentum* Mill.). *Crop Res.*, **32** (2): 401-402.

Mallik, A.K. (1985). Study on genetic parameters and character association of tomato. M.S. Thesis, BAU, Mymensingh.

Manivannan, K., Natarajan, J. and Irulappan, I. (2005). Correlation studies in tomato. *South Indian Hort*. **34**: 70-73.

Matin, K. and Kuddus, M. (2001). Varietal resistance to bacterial wilt in tomato. *Plant Disease. Rep.* **60**: 120-123.

Mayavel, A., Balakrishnamurthy, G. and Natarajan, S. (2005). Variability and heritability studies in tomato hybrids. *South Indian Hort*. **53**(1-6): 262-266.

McGiffen, M.E., Pantone, J. and Masiunas, J.B. (1994). Path analysis of tomato yield components in relation to competition with black and eastern black nightshade. *J. American Soc. Hort. Sci.* **119**(1): 6-11

Meena, O.P. and Bahadur, V. (2015). Genetic associations analysis for fruit yield and its contributing traits of indeterminate tomato (*Solanum lycopersicum*

L.) Germplasm under open field condition. *Journal of Agricultural Science.* **7**(3):148-163.

Megha, U., Singh, J.P., Singh, A. and Joshi, A. (2006). Studies on genetic variability in tomato (*Solanum lycopersicum* L.). *Progr. Hort*. **3**(2): 463-465.

Meitei, K.M., Bora, G.C., Singh, S.J. and Sinha, A.K. (2014). Morphology based genetic variability analysis and identification of important characters for tomato (*Solanum lycopersicum* L.) crop improvement. *American-Eurasian J. Agric. and Environ. Sci.* **14**(10): 1105-1111.

Millar, P.A., Williams, J.C. Robinsen, H.F. and Comstock, R.E. (1958). Estimates of genotypic and environmental variance and covariance and their implication in selection. *Agron J*. **50**:126-131.

Miller, J.C. and Tanksley, S.D. (1990). RFLP analysis of phylogenetic relationships and genetic variation in the genus *Lycopersicon*. *Theor. Appl. Genet*. **80**: 437-448.

Mohammadi, S.A. and Prasanna, B.M. (2003). Analysis of genetic diversity in crop plants-salient statistical tools and considerations. *Crop Sci.* **43**: 1235-1248.

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

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

Monamodi, E.L., Lungu, D.M. and Fite, G.L. (2013). Analysis of fruit yield and its components in determinate tomato (*Lycopersicon lycoperscicum*) using correlation and path coefficient. *Bots. J. Agric. Appl. Sci*. **9**(1): 29-40.

Naidu, D.Y. (1993). Study of segregating populations in tomato (*Solanum lycopersicum* L.). M.S. (Agril.) Thesis, Uni. Agric. Sci., Dharwad (India).

Nalla, M.K., Rana, M.K., Singh, S.J., Sinha, A.K., Reddy, P.K. and Mohapatra, P.P. (2014). Assessment of genetic diversity through D^2 analysis in tomato (*Solanum lycopersicon* .L). *Intl. J. Innovation and App. Studies*. **6**(3) 431-438.

Nandpuri, K.S., Singh, S. and Tarsemlal, L. (1974). Studies on the genetic variability and correlation of some economic characters in tomato. *J. Res. Punjab Agric. Univ*. **10** (3): 36-321.

Nardar, C.R., Muthukrishnan, C.R., Irulappan, I. and Shanmugusubramanian, A. (2007). Variability studies in tomato (*Solanum lycopersicum* L.). *South Indian Hort.* **28**: 123-127.

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

Naz, S., Zafrullah, A., Shahzadhi,K. and Munir, N. (2013). Assessment of genetic diversity within germplasm accessions in tomato using morphological and molecular markers. *J. Animal Plant Sci.* **23**(4):1099-1106.

Nesgea, S., Krishnappa, K.S. and Raju, T.B. (2002). Correlation coefficient analysis in tomato. *Current Res. Univ. Agric. Sci*. **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. (2007). Genotypic and phenotypic variabilities and correlations in quality characters of tomato (*Solanum lycopersicum* L.). *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, A., Rai, V. and Bal, S. (2010). Combining QTL mapping and transcriptome profiling of bulked RILs for identification of functional polymorphism for salt tolerance genes in rice (*Oryza sativa* L.). *Mol. Genet. Genomics.* **284**:121-36.

Panthee, D.R., Labate, J.A., McGrath, M.T., Breksa, A.P. and Robertson, L.D. (2013). Genotype and environmental interaction for fruit quality traits in vintage tomato varieties. *Euphytica*. **193** (2): 169-182.

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

Patil, A.A. and Bojappa, K.M. (1993). Studies on phenotypic and genotypic correlation on growth, yield and quality attributes in tomato (*Lycopersicon esculentum* Mill.). Karnataka *J. Agric. Sci*. **6**:133-136

Paul, M.R.R., Majumder, R.R., Khatun, H., Ali, L. and Roy, R.K. (2014). Genetic variability and character association in tomato (*Solanum lycopersicum*). *J. Eco-friendly Agril*. **7**(10): 100-104.

Pearson, K. (1901). "On Lines and Planes of Closest Fit to Systems of Points in Space" (PDF). *Philosophical Magazine* **2**(11): 559-572.

Peralta, I.E., Spooner, D.M. (2001). Granule-bound starch synthase (GBSSI) gene phylogeny of wild tomatoes (*Solanum* L. section *Lycopersicon* (Mill.) Wettst. subsection *Lycopersicon*)". *Amer. J. Bot.* **88** (10): 1888–1902.

Phookan, D. B., Talukdar, P., Shadeque A. and chakravarty, B.K. (1998). Genetic Variability and heritability in tomato (*Lycopersicon esculentum* Mill.)

genotypes during summer season under plastic house condition. *Indian J. Agril Sci*. **68**(6): 304-306.

Ponnusviamy, V. and Muthukrishnan, E.R.. (2010). A study of inter and intra generation correlation coefficients in F_2 and F_3 generation of tomato. *South Indian Hort*. **25**: 39-43.

Pradeepkumar, T., Joy, D.B.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.

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

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

Prashanth, S.J. (2003). Genetic variability and divergence study in tomato (*Lycopersicon esculentum* Mill). M. Sc. (Agri.) Thesis, Univ. Agric. Sci., Dharwad (India). 595-598.

Pujari, C.V. and Kale, P.N. (1994). Heterosis studies in tomato. *J. Mah. Agric. Univ.* **19**(1): 83-85.

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

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

Rao, C.R. (1952).Advanced statistical methods in biometrics research, John Wiley and Sons, New York. pp.357-369.

Ravindra, M., Aravinda, S. and Kumar, J.S. (2003). Stability analysis for growth and earliness in tomato. *Ind. J. Hort*. **60**(4): 353-356.

Raychaudhuri, S., Stuart, J.M. and Altman, R.B. (2000). Principal components analysis to summarize microarray experiments: Application to sporulation time series. Pacific Symposium on Biocomputing.

Reddy B.R., Reddy, M.P., Begum, H. and Sunil, N. (2013). Genetic diversity studies in tomato (*Solanum lycopersicum* L.). *J. Agric. Vet. Sci*. **4**(4): 53-55.

Reddy, M.L.N. and Gulshanlal, K. (1990). Genetic variability and path co-efficient analysis in tomato. *Progr. Hort*. **19**: 284-288.

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

Robinson, H.F., Comstock, R.E. and Harvey, V.H. (1949). Estimates of heritability and degree of dominance in corn. *Agron. J*. **41**:353-359.

Sachan, M.N. (2001). Heterosis, combining ability, RAPD analysis and resistance breeding to leaf curl viruses and bacterial wilt in tomato (*Solanum lycopersicum* L). M.S. (Agri.) Thesis, Uni. Agric. Sci., Dharwad (India).

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.

Saleem, M.Y., Iqbal, Q. and Asghar, M. (2013). Genetic variability, heritability, character association and path analysis in f_1 hybrids of tomato. *Pak. J. Agri. Sci.* **50** (4): 649-653.

Salunkhe, D.K., Jadhav, S.J. and Yu, M.H. (1974). Quality and nutritional composition of tomato fruit as influenced by certain biochemical and physiological changes. *QuaI. Plant. - H.Fds.hum.Nutr*. **XXIV**(1/2): 85-113.

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.

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, K.C. and Verma, S. (2000). Path coefficient analysis in tomato (*Lycopersicon esculentum* Mill.). *Indian J. Agri. Sci*. **70**(10): 700-702.

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

Sharma, S. K. and Rastogi, K. B. (1993). Evaluation of some tomato cultivars for seed production under mid hill condition of Himachal pradesh. *Annals. Agril. Res*. **14** (4): 494-496.

Shashikanth, P., Das, K. and Mulal, K. (2010). Studies on tomato leaf curl virus. *Ind. J. Virol*. **15**: 115-117.

Shravan, K., Biswash, C. and Mollik, P. (2004). Heterosis and inbreeding depression in tomato. *Utter Pradesh Ind. J.* **60**: 139-144.

Shuaib, M., Alam, Z., Zahir,A., Waqar, A., Taufiq, A. and Ikhtiar, K. (2007). Characterization of wheat varieties by seed storage protein electrophoresis. *Afr. J. Biotechnol*. **6:** 497-500.

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

Silva, P.F., Silva, A.C., Tavares, K.N. and Santos, D.P. (2012). Production and brix degrees content of tomato irrigated with water of different saline concentrations. *Rev. Verde Agroe. Des. Sust*. **7**(4):85-89.

Singh, A.K. (2005). Genetic variability, correlation and path coefficient studies in tomato (*Solanum lycopersicum* L.) under cold arid region. *Progr. Hort*. **37** (2): 437-443.

Singh, B.D. (2009). Plant Breeding Principles and Methods, Kalyani Publisher, New Delhi India.

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

Singh, R.R. and Singh, H.N. (1980). Correlation Studies in tomato. *Indian. J. Agric. Sci*. **50** (8): 23-45.

Singh, R.K. and Chaudhary, B.D. (1985). Biometrical methods in quantitative genetic analysis. Kalyani Publishers, New Delhi, India.

Singh, R.K. and Choudhary, B.D. (1985). Biometrical methods of quantitative genetic analysis. *Haryana J. Hort. Sci*. **12**(2):151-156.

Singh, R.K. and Singh, V.K. (1993). Heterosis breeding in tomato. *Ann. Agric. Res.* **14**(4): 416-420.

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

Singh, R.V., Verman, T.S. and Thakur, P.C. (2002). Characters association in cucumber. *Hariyana J. Hort. Sci.* **31**(1&2): 91-93.

Smith, A.F. (1994). The Tomato in America: Early History, Culture, and Cookery. Columbia SC, USA: University of South Carolina Press. ISBN 1-57003-000-6.

Sonone, A.H., More, D.C. and Thombre, M.V. (1986). Path analysis in tomato. *J. Maharashtra Agric. Univ*. **12**: 115-116.

Srivastava, J.P., Srivasta, B.P., Verma, H.P.S. and Singh, H. (1998). Heterosis in relation to combining ability in tomato. *Veg. Sci.* **25**(1): 43-47.

Sudre, C.P., Leonardecz E., Rodrigues, R., Junior, A.T.D.A., Moura, M.D.C.L. and Goncalves, L.S.A. (2007). Genetic resources of vegetable crops: a survey in the Brazilian germplasm collections pictured through papers published in the journals of the Brazilian Society for Horticultural Science. *Hortic. Bras.* **25**: 496-503.

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. and 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.

Thakur, B.S. (2009). Adaptability of tomato genotypes under mid-hill conditions of Himachal Pradesh. *Haryana J. Hort. Sci*. **38**(1/2): 93-95.

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

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

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

Verma, S. K. and Sarnaik, D.A. (2000). Path analysis of yield components in tomato (*Lycopersicon esculentum* Mill). *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.* **32**(1): 29-31.

Weber, C.R. and Moorthy, H.R. (2010). Heritable and non-heritable relationship and variability of oil content and agronomic characters in the F2 generation of soybean crosses. *Agron. J.* **44**: 202-209.

Willcox, J.K., Catigani, G.L. and Lazarus, S. (2003). Tomatoes and cardiovascular health. Critical reviews: Food Sci. Nut. **43**:1-18.

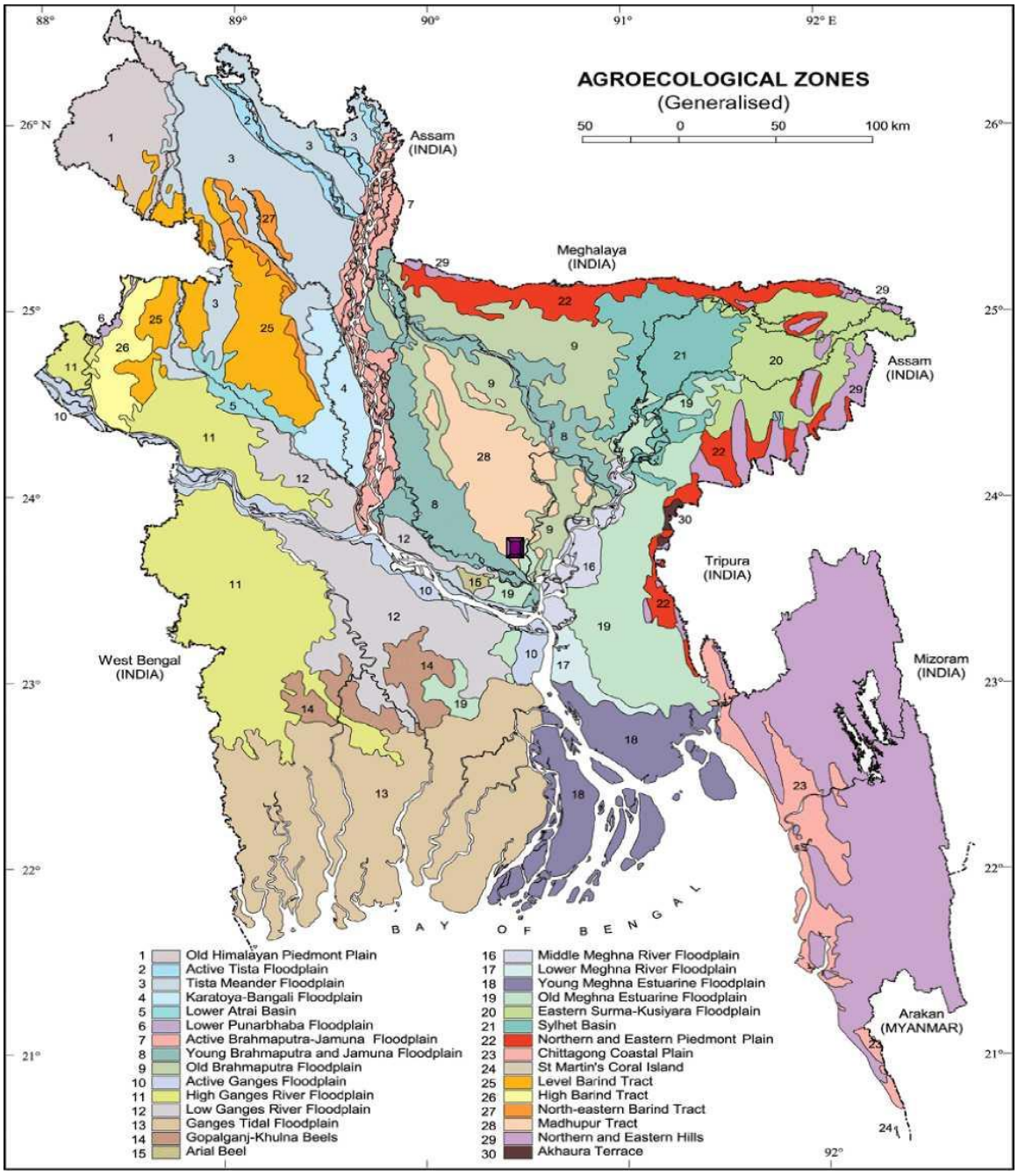
Wright, S. (2007). Correlation and causation. *J. Agric. Res*. **20**: 202-209.

YaDong, S., Yan, L., JiangMin, W., Lei, L. and XiaoJing W. (2010). Correlation analysis on quantitative traits of tomato germplasm resources. *China Veg.* **15**(6): 74-76.

Yi, S.S., Jatoi, S.A., Fujimura, T., Yamanaka, S. and Watanabe, K.N. (2008). Potential loss of unique genetic diversity in tomato landraces by genetic colonization of modern cultivars at a non-center of origin. *Plant Breed*. **127**: 189-196.

APPENDICES

Appendix I: Experimental site showing in the map under the present study



The experimental site under study

Appendix II: Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2015 to February 2016

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
2015	October	33.1	18.0	25.6	77	130	5.4
2015	November	32.0	15.0	23.5	67	14	7.8
2015	December	28.2	13.5	20.9	79	8	3.8
2016	January	24.5	11.5	18.0	72	6	5.7
2016	February	33.1	12.9	23.0	55	10	8.1
2016	March	33.6	15.3	24.5	63	43	7.5
2016	April	36.0	21.20	28.6	65	86	9.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207

Appendix III: The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (µ gm/gm)	:	18.49
Exchangeable K (µ gm/gm)	:	0.07
Available S (µ gm/gm)	:	20.82
Available Fe (µ gm/gm)	:	229
Available Zn (µ gm/gm)	:	4.48
Available Mg (µ gm/gm)	:	0.825
Available Na (µ gm/gm)	:	0.32
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix IV: Analysis of variance for different plant traits of 15 tomato genotypes

Source of variation	df	Mean square									
		Plant height	Number of leaves plant^{-1}	Number of branches plant^{-1}	Number of flowers plant^{-1}	Days to first flowering	Days to 50% flowering	Days to maturity	Number of fruits plant^{-1}	Number of fruits cluster^{-1}	Number of clusters plant^{-1}
Replication	2	1.822	4.467	1.756	2.156	6.067	6.089	13.156	3.600	0.156	1.267
Factor A	14	8.21*	9.96*	7.51*	9.95*	27.14*	61.71*	96.37*	15.11*	4.26**	9.89*
Error	28	5.203	5.229	2.494	5.156	0.138	0.137	0.179	6.005	1.108	3.719

* 5% level of significance

** 1% level of significance

Appendix IV (Cont'd)

Source of variation	df							
		Fruit length (mm)	Fruit diameter (mm)	Fresh fruit weight (g)	Dry weight of 5g fresh fruit	Fruit yield plant^{-1}	% of Brix	pH of tomato
Replication	2	3.467	0.272	6.465	2.484	0.029	1.717	1.850
Factor A	14	7.67*	10.06*	12.97*	0.68**	1.23**	4.05*	0.15**
Error	28	2.824	3.022	5.609	0.077	0.019	0.145	0.106

* 5% level of significance

** 1% level of significance

Appendix V: A view of Brix and pH determination

Brix Determination

p^H Determination

Appendix VI: Experiment in the farm of Sher-e-Bangla Agricultural University and Experiment in the Genetics and Plant Breeding Laboratory

Experiment in the farm of Sher-e-Bangla Agricultural University

Appendix VI (Cont'd)

Experiment in the Genetics and Plant Breeding Laboratory