GENETIC ANALYSIS OF TOMATO (*Solanum lycopersicum* L.) GENOTYPES BASED ON NUTRITIONAL TRAITS

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BY

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CERTIFICATE

This is to certify that thesis entitled, "Genetic analysis of tomato (Solanum lycopersicum L.) genotypes based on nutritional traits".submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE in GENETICS AND PLANT BREEDING,*** *embodies the result of a piece of bona fide research work carried out by MD. MEZBAHUR RAHMAN, Registration No. 09-03433 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2016
Place: Dhaka, Bangladesh

(Prof. Dr. Naheed Zeba)
Supervisor

DEDICATED

TO

My beloved Parents and Sisters

SOME COMMONLY USED ABBRIVIATIONS

FULL NAME	ABREVIATIONS
Analysis of variance	ANOVA
and others (*at elli*)	*et al.*
Bangladesh Agricultural Research Institute	BARI
cm.	Centimeter
Degree Celcius	^{o}C
Environmental coefficient of variation	ECV
Environmental variance	σ^2 e
gram (s)	g
Genetic advance	GA
Genetic advance as percent mean	GAM
Genotypic coefficient of variation	GCV
Genotypic variance	σ^2g
Heritability	H %
Kilogram	Kg
Kilogram/hectare	Kg/ha
Least Significant Difference	LSD
Milli gram	mg
Nanometer	Nm
Negative log of the activity of the hydrogen ion	P^H
Percent	%
Phenotypic coefficient of variation	PCV
Phenotypic variance	σ^2p
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
ton/hectare	t/ha
Triple Super Phosphate	TSP

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GENETIC ANALYSIS OF TOMATO (*Solanum lycopersicum* L.) GENOTYPES BASED ON NUTRITIONAL TRAITS

BY

MD. MEZBAHUR RAHMAN

ABSTRACT

An experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during the months of October 2015 to April 2016 to study the genetic variability and inheritance in different agro-morphogenic and nutritional traits of tomato. Ten genotypes were used for the study. The genotypes were G1(SL-001), G2(SAU Tomato-1), G3(SAU Tomato-3), G4(SL-002), G5(SL-003), G6(SAU Tomato-4), G7(SAU Tomato-2), G8(BARI Tomato-3), G9(BARI Tomato-2) and G10(BARI Tomato-11). Data were recorded on (%) per cent of brix content, pH content, dry matter content, moisture content, vitamin C content, lycopene content at 472nm and 502nm. The genotype G7 showed the best performance for lycopene content, vitamin C content and brix content. In terms of pH content, dry matter content and moisture content genotype G1, G2 and G9 showed the best performance respectively. Narrow gap between PCV and GCV for lycopene content, vitamin C content, brix content, dry matter content and moisture content suggested that environmental influence was minor on the expression of the genes controlling these traits and selection based upon the phenotypic expression of these characters would be effective for the improvement of this crop. High heritability coupled with high genetic advance in percent of mean were observed in lycopene content, vitamin C content and dry matter content. Hence, these characters are highly heritable and there is a wide scope for improvement through selection of these traits. Most likely the heritability of these traits is due to additive gene effects and selection may be effective in early generations for these traits. In the phenotypic correlation coefficient, a high positive significant correlation of brix with vitamin C and lycopene content whereas, dry matter content significant and negatively correlated with moisture content and lycopene content. The genotypic correlation coefficient revealed positive and significant association of brix with vitamin C content, and lycopene content whereas, it had negative significant correlation with moisture content. Path analysis of direct and indirect effects revealed that lycopene content and brix exerted direct positive effect on moisture percentage whereas the direct effect of p^H, dry matter content and vitamin C content were negative direct effect on moisture percentage. G1(SL-001), G2(SAU Tomato-1), G7(SAU Tomato-2) and G9(BARI Tomato-2) genotypes could be recommended to the farmers for cultivation for nutrition and medicinal value, it will be possible to fulfill nutritional, food security and economic demand of Bangladesh and could also be used in future hybridization or other gene transfer programs.

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most major Solanaceous vegetable crops in the world in terms of both production and harvested area (FAOSTAT, 2005). Numerous varieties of tomato are widely grown in temperate climates across the world, with greenhouses allowing its production throughout the year and in cooler areas. Tomato species are diploid (2n = 2x = 24) and have the same chromosome number. It is one of the most important vegetables in the world because of its wider adaptability, high yielding potential and suitability for variety of uses in fresh as well as processed food industries (Meena and Bahadur, 2015). The cultivated tomato is the second most important vegetable crop in the world in terms of consumption per capita and it is the most popular garden vegetable. In addition to tomatoes that are eaten directly as raw vegetable or added as ingredient to other food items, a variety of processed products have gained popularity. In the U.S. diet, tomato ranks first among all fruits and vegetables as a good source of vitamins and minerals (Rick and Chetelat, 1995). Presently, Bangladesh is producing a good amount of tomatoes. It has great demand in Bangladesh throughout the year but it is available and cheaper during the winter season. The best growing areas of tomato in Bangladesh are Chittagong, Comilla and Rajshahi (Sharfuddin and Siddque, 1985) and it ranks fourth in respect of production and third in respect of area (BBS, 2006). In Bangladesh, it is cultivated as winter vegetable, which occupied an area of 23828 ha and total production was 190 thousand metric tons in 2009-10 (BBS, 2010).

It is a favorable food crop and is a self-pollinated annual crop. It is a good source of vitamins (A and C), fiber and minerals (Kalloo, 1989). More than 7% of total vitamin C of vegetable origin comes from tomato in Bangladesh. It contains 94 g water, 0.5 g minerals, 0.8 g fibre, 0.9 g protein, 0.2 g fat and 3.6 g carbohydrate and other elements like 48 mg calcium, 0.4 mg iron, 356 mg carotene, 0.12 mg vitamin B-1, 0.06 mg vitamin B-2 and 27 mg vitamin C in

100 g edible ripen tomato (Anonymous, 2010). It is a rich source of lycopene antioxidant that reduces the risk of prostate cancer (Hossain *et al*., 2004). As it consumed in various forms such as cooking, salad, soup, pickles, ketchup and sauces etc. it contributes largely to dietary intake of vitamins and minerals.

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). Crop improvement depends upon the magnitude of genetic variability and extent to which the desirable character is heritable. High heritability alone is not enough to make efficient selection in segregating generation, unless the information is accompanied for substantial amount of genetic advance (Johnson *et al*., 1955). Hybridization is one of the major tools for achieving variability aiming at the improvement of a crop. Before hybridization genetic diversity of the existing materials or entries needs to be known. Information about genetic diversity in available germplasm is important for optimal design of any breeding programme. This help to choose desirable parents for establishing new breeding population. Besides, better knowledge on genetic diversity could help to sustain long term selection gain (Chowdhury and Sharma, 2002).

The knowledge of association between yield and its contributing traits is of great values in planning a breeding programme. As yield is the main object of a breeder, so it is important to know the relationship between various characters that have direct and indirect effect on yield. According to Burton (1952), for the improvement of any character through breeding, it is essential to know the extent of variability present in that species, nature of association among the characters and the contribution of different characters towards yield. The efficiency of a plant breeding programme depends on the amount of genetic variability exist in nature or how much a plant breeder can create variability in the target population so as to perform effective selection.

Tomato contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). Food value of tomato is greatly dependent on its chemical composition such as dry matter, titrable acidity, total sugar, total soluble solids, ascorbic acid, moisture percentage etc. Studies indicate that flavor and taste of tomato are related to free sugars, organic acids and sugar acid ratios (Kader *et al*., 1978).

Tomatoes are very valuable for human health since they are low in fat and calories, free from cholesterol and rich in vitamins A and C, β-carotene, lycopene and potassium, as well as octadecadienoic acid (Kim *et al*., 2011). β-carotene is a provitamin a carotenoid and its deficiency can cause xerophthalmia, blindness and premature death (Li *et al*., 2012). It is very important for breeders to obtain the information on β-carotene content for developing cultivars with increased β-carotene levels. Spectrophotometry is widely used for the analysis of β -carotene but it has limitation such as exhaustive extraction methods, use of flammable, toxic solvents which pose personnel safety and environmental waste issues (Fish, 2012).

Information regarding genetic diversity and genetic relationships among different genotypes is very valuable in crop improvement. Analysis of genetic diversity of agro-morphogenic and nutritional traits is useful in selecting diverse parental combinations, reliable classification of accessions, and for exact identification of variety. Breeding and domestication has resulted in reduction of tomato genetic diversity. Therefore, it is important to know the genetic relationship between the tomato species. Considering the above information, the present study was therefore undertaken,

- to know the nature of association of traits, direct and indirect relation between antioxidant and nutritional traits,
- to compare the local and exotic genotypes of tomato based on their antioxidant and nutritional traits and
- to screen out the suitable parents which are likely to provide superior segregants on hybridization.

CHAPTER II

REVIEW OF LETERATURE

Tomato is one of the popular and most important vegetable crops of Bangladesh and as well as many countries of the world. It is a well-studied crop species for breeding, genetics and genomics in plants. Various resources are accessible now for its research, which can lead to uprising in evaluation of tomato biology (Barone *et al*., 2008). Many studies have been done using different genes to examine its genetic diversity (Asamizu and Ezura, 2009; Benor *et al*., 2008; Carelli *et al*., 2006; Martinez *et al*., 2006).

The crop has received much attention by the researchers on various aspects of its production under different adverse condition. Many studies on the genetic variability have been carried out in many countries of the world. The work so far done in Bangladesh is not adequate and conclusive. 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:

2.1Tomato

Currently 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, 2015). This name came into wide use, but was in violating of the plant naming rules. Genetic evidence has now shown from the "Natural History Museum" that Linnaeus was correct to put the tomato in the genus *Solanum*, making *Solanum lycopersicum* the correct name (Peralta and Spoonar, 2001). For some times both names might be used.

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 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 and 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 (Anonymous, 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.

2.2Nutritional analysis

In the present world, tomatoes are the most popular vegetable crop. It has an important source of antioxidants such as lycopene, vitamin C, phenolics and total soluble solids (% of brix) in human diet and has been linked with

decreases risk of heart diseases, diabetes, prostate and various forms of cancer. Lycopene, a precursor of beta-carotene with well-known antioxidant activity and powerful health properties. Current research for new anticancer drugs focuses more on the natural compounds such as physicochemical constituent from the regular human diet. Because of the lack of severe side effects yet efficiently can act on a wide range of receptors or molecular targets involved in carcinogenesis and cardiovascular diseases. *In vivo, in vitro* and clinical studies conducted in recent years have revealed an inverse association between the dietary intakes of lycopene with the risk of prostate cancer (PCa). L-Ascorbic acid (AsA), which is an essential nutrient component for human health and plant metabolism that plays key roles in diverse biological processes such as cell cycle, cell expansion, stress resistance, hormone synthesis, and signaling. Many scientists have studied quality character as well as anti-carcinogenic properties of tomato on human and many animals. Among them most relevant recent publications are reviewed below:

2.2.1 Lycopene

Lycopene (LYC) is the red pigment and a major carotenoid in tomatoes. Lycopene's antioxidant capacity is roughly twice that of β-carotene. Numerous epidermiological and intervention studies have demonstrated that dietary intake of LYC-rich foods result in decreased incidence of certain cancers, including the prostate, lung, mouth, and colon cancer, coronary heart diseases, cataracts and possibly macular degeneration. Although the tomato is the richest source of lycopene among all fruits and vegetables, its concentration in the fruit of commercial cultivars is rather low, on average ranging from 30 to 60 μg lycopene/g fresh tomato tissue. Using different traditional breeding techniques, Kinkade and Foolad recently (2013) has developed tomato breeding lines having fruit lycopene content from 100-200 μg lycopene/g fresh fruit tissue. Lycopene is an important intermediate in the biosynthesis of many carotenoids, including beta carotene, responsible for yellow, orange or red pigmentation, photosynthesis, and photo-protection. Like all carotenoids, lycopene is a

polyunsaturated hydrocarbon (an un-substituted alkene). Some of the previous reports on Lycopene experiment are discussed here (Datta *et al*., 2013; Dong *et al*., 2010; Alda *et al*., 2009; Moigrădean *et al*., 2007; Cucu and Loco, 2011). According to Datta *et al*. (2013), lycopene may lower the incidence of prostate cancer. This study aimed to evaluate the tolerance and acceptance of three different amounts (4, 8, or 12 oz) of tomato juice (TJ) and their effect on serum lycopene during radiotherapy in 20 men with localized prostate cancer. A significant positive correlation between serum lycopene, weight, and body mass index, and a negative correlation between serum lycopene and prior nutritional supplement use was detected. Panthee (2013) uses 44 vintage tomato varieties and evaluated them. Pearson's correlation analysis indicated that estimated lycopene content was negatively correlated with the other physicochemical traits whereas vitamin C, TSS and TTA were positively correlated with each other.

Dufera (2013) was conducted an experiment using twenty one tomato germplasm. Higher genotypic and phenotypic coefficients variation values was recorded for lycopene content. Mendelova *et al*. (2013) conducted a work to analyze the content of total carotenoids and lycopene in 8 varieties of tomato and to monitor dynamic changes after their different treatments (heating, drying). The experiment included following tomato varieties: Bambino F1, Darina F1, Diana F1, Denar, Milica F1, Orange F1 Paulina F1, Sejk F1. They found that processing of tomato fruits into juices and dried slices positively affected the presence of carotenoids and lycopene. Zhu *et al.* (2013) studied that lycopene, with its acyclic structure and large array of conjugated double bonds carries many distinct biological and physicochemical properties. Lycopene is among the most efficient singlet oxygen quenchers of the natural carotenoids without pro-vitamin A activity. It acts as a natural antioxidant in human serum and other tissues to protect the oxidative damage of lipids, proteins, and DNA.

Elumalai *et al.* (2013) conducted an experiment in human. Oxidative stress is recognized as one of the major contributors to the increased risk of cancer and lycopene being a potent antioxidant has been found to inhibit proliferation of several types of human cancer cells, including endometrial, prostate, breast, upper aero digestive tract and lung. Lycopene has tumor suppressor activity.

The lycopene content in fifteen varieties and three brands of tomato paste, three brands of ketchup and three brands of tomato hot sauce were determined by spectrophotometry and HPLC methods ranged from < 0.05 to 5.82 mg/100 g, and from 0.01 to 4.90 mg/100 g respectively (Bradbury *et al*., 2012). Dong *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 of fruit. 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 along with fruit quality characters such as lycopene, beta -carotene, ascorbic acid and titratable acidity. Kumari *et al*. (2007) recorded data for total soluble solids, dry matter content, reducing sugars, titratable acidity, ascorbic acid, lycopene and found there were insignificant differences for acidity, early yield, total yield, and days to flowering.

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. They 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. Jones

et al. (1983) studied inheritance and characterization of anthocyanin fruit (Aft) in tomato, to estimate the genetic potential for increased levels of this important class of phytonutrients in tomato fruit. They concluded that fruit of accession LA 1996 contained predominantly petunidine, followed by malvidine and delphinidinin, while the levels of lycopene, β-carotene, phytoene and phytofluene were similar to those of normal tomatoes and lower than those found in high pigmented tomatoes.

Davis *et al.* (2003) evaluated 13 tomatoes (four different cultivars) and 38 tomato products. They used absorbance method (PAM) and had linear correlation coefficients with lycopene content determined by hexane extraction/spectrophotometry of R^2=0.97 for fresh tomato, and 0.88 for tomato products. The fruits of 11 recent hybrids of processing tomato, grown under optimal conditions, were assessed for colour using Colorgard System 05 and for lycopene content examined by Siviero *et al*. (2000). Fresh DM regularly showed more mg lycopene/100 g than processed material.

2.2.2Vitamin-C

Tomatoes are excellent sources of vitamin C, with some varieties containing concentration comparable to those found in oranges. Although all tomatoes contribute to our vitamin C intake, there are different amounts of vitamin C in different genotypes. For example, raw green tomatoes contain 23.4 milligrams, orange tomatoes contain 16 milligrams and yellow tomatoes contain 9 milligrams per 100 grams, which is slightly more than half of a large, 3-inch tomato. Sun-dried tomatoes are much richer in vitamin C, containing 39.2 milligrams per 100 grams. Crushed, canned tomatoes and tomato juice contain smaller amounts, respectively contributing 9.2 and 18.3 milligrams of vitamin C to our daily intake (*Lee and Media, 2014)*. Borguini *et al.* (2013) were analyzed tomatoes regarding ascorbic acid (Vitamin C), lycopene content and antioxidant activity. Organic tomatoes presented higher content of ascorbic acid and total phenolics (641.39 and 4466.66 mg/100 g EAG on dry wt. basis) than did the conventional tomatoes (510.16 and 3477.50 mg/100 g EAG on dry

wt. basis, respectively). There was no difference in lycopene concentrations between the organic and conventional. Schwarz *et al.* (2013) evaluated ten tomato hybrids (Supera, Granadero, AP-529, AP-533, Katia, Laura, Fascinio, Tinto, Red Spring and Venus) for their quality, viz. soluble solids, ascorbic acid, lycopene and reducing sugars. The best performing hybrid for traits and for both segments was Granadero, but this hybrid showed low genotypic stability. So Venus and Tinto, despite lower yields, could be recommended because they presented good quality and stability.

Five tomato cultivars: four large-fruit (Rumba, Juhas, Kmicic, Gigant) and one cherry cultivar (Koralik) were selected for study by Hallmann *et al.* (2007). The organic tomato fruits contained more dry matter, total and reducing sugars, vitamin C, total flavones and beta-carotene, but less lycopene in comparison to conventionally grown tomatoes. The study done by Schulzova *et al.* (2007) to investigate the effects of tomato cultivation systems on the content of both health promoting and of toxic components represented by carotenoids (lycopene, beta -carotene), vitamin C and glycoalkaloids (alpha -tomatine, dehydrotomatine). The levels of biologically active compounds were shown to be strongly affected by the degree of fruit maturity. A study was conducted by Ramirez (2005) to test whether tomato fruits from a genotype with elevated levels of natural antioxidants produce seeds with a functionally greater total antioxidant capacity. The tomato genotype 'T4099', which produces elevated levels of lycopene and ascorbic acid, and the recurrent parent 'Flora-Dade' were grown in the field and greenhouse under standard agronomic practices. Harer *et al.* (2002) grew 37 tomato genotypes in a field experiment. Correlation studies showed that genotypic correlation was higher than phenotypic correlation for all characters examined. Among them the ascorbic acid content had negative direct effects and association with fruit yield.

2.2.3Total 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 %Brix only approximates the dissolved solid content. Various reports are available on variation of Brix % for different genotypes of tomato. 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. Krishna *et al.* (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). Seven tomato lines studied by Chen (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. 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*. (2002) 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.

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

2.2.4 Moisture Content

Accumulation of water accounts for more than 90%of the total weight of ripe tomato fruit; only 5-8% of the fruit weight is due to dry matter (Davies and Hobson, 1981; Ho *et al*., 1981).Therefore, factors affecting water accumulation may determine both the size and the quality of tomato fruit. Fruit grown at high salinity accumulated less water but not less dry matter than fruit grown at low salinity.

2.2.5 Dry matter content

Root restriction significantly decreased the dry weights of root, stem and leaves (about30%) and fruit (about 20%). Although root restriction has been reported to reduce dry matter production, it has been shown that this reduction was not a result of nutrient deficiency (Peterson and Krizek, 1992; Ruff *et al*.,1987; Carmi and Heuer, 1981). However, Bar-Tal *et al*. (1995) reported that root restriction reduced both dry matter production and K concentration in plant organs, indicating a possible K deficiency effect of restricting the roots. The increasing K and Ca concentrations in the solution did not significantly affect the dry weight of any plant organ and there was no significant interaction between root restriction and solution composition on any organ dry weight. The reduction in DM production following root restriction could not be compensated by elevating CCa above 3 mmol (+)· L–1 or increasing CK above 2.5 mmol·L–1.These results indicate that the reduction in plant growth under conditions of root restriction was not caused by nutrient deficiency, but it was probably related to hormone synthesis and metabolism in the root system (Jackson,1993; Carmi and Heuer, 1981; Richards and Rowe, 1977).

2.2.6 P^H

Acid concentration and pH are important quality and processing characteristics of tomatoes. Several studies have revealed that a proper sugar/acid ratio is paramount to good tomato flavor (Stevens, 1972; Simandle *et al*., 1966 Dennison, 1955). Both [H+] and potential acidity contribute to tartness (Harvey, 1920).The pH is important to process ability, as it should be lower than 4.4 to avoid problems with thermo phylic organisms (Rice and Pederson, 1954). Higher pH values necessitate longer processing times, increasing the difficulty of obtaining a high quality product. Total acidity and pH in a tomato should be closely related, but sometimes the relationship between these two factors is not good. Anderson (1957) found that pH and acidity are not always inversely related, and that in some varieties both values are relatively high. Lower and Thompson (1967) also found poor correlation between pH and acidity in

certain tomato lines and their progeny. Stevens (1972) found wide variation in the $[H^+]$/titratable acidity (TA) ratio among 55 divergent accessions and obtain edevidence indicating that variation in phosphorus concentration of the fruits is an important factor in the poor relationship between pH and acidity. It should be possible to explain the relationship between TA and pH using model systems, as the TA is equal to the sum of TAs contributed by the buffers in the fruit. These buffers also establish the pH.

CHAPTER III

MATERIALS AND METHODS

This chapter illustrates information concerning methodology that was used in execution 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, field preparation, fertilizing, transplanting of seedlings, intercultural operations, harvesting, data recording procedure, statistical and nutritional analysis etc., which are presented as follows:

3.1 Experimental site

The experiment was conducted at the experimental field and the laboratory of the department of Genetic and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh during the period from October 2015 to April 2016. The experimental site was under the Agro-ecological zone of Modhupur Tract, AEZ-28, situated at 23°41'N latitude and 90°22'E longitude at an altitude of 8.6 meter above the sea level (anonymous, 2004).

3.2 Planting materials

A total of ten genotypes of tomato originated from different places of Bangladesh were used in this experiment. The materials were collected from the research supervisor, department of Genetics and Plant Breeding, SAU and Plant Genetic Resource Centre (PGRC) at Bangladesh Agricultural Research Institute (BARI), Gazipur. The name and origin of these genotypes are presented in Table 1.

3.3 Climate and soil

Experimental site was located in the subtropical climatic zone, set aparted by plenty of sunshine and moderately low temperature prevails during October to April (Rabi season) which is suitable for tomato growing in Bangladesh. The soil was sandy loam in texture having pH 5.46- 5.62. Weather information and physicochemical properties of the soil are presented in (Appendix II and Appendix III respectively).

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

Sl. No.	Genotypes No.	Name/Acc No. (BD)	Source
1	G1	SL-001	GEPB, SAU
2	G2	SAU Tomato-1	
3	G3	SAU Tomato-3	
4	G4	SL-002	
5	G5	SL-003	
6	G6	SAU Tomato-4	
7	G7	SAU Tomato-2	
8	G8	BARI Tomato-3	PGRC, BARI
9	G9	BARI Tomato-2	
10	G10	BARI Tomato-11	

PGRC=Plant Genetic Research Centre, SAU=Sher-e-Bangla Agricultural University and BARI=Bangladesh Agricultural Research Institute

3.4 Seedbed preparation and raising of seedling

The sowing was carried out on 24 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. Seeds were sown in rows spaced at 10 cm apart, beds were watered regularly. Seedlings were raised using regular nursery practices. 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. The seedbed preparation and intercultural operation in the seedbed is shown in Plate 1.

3.5 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD). The number of genotypes was 10, number of replication was 3, spacing was 40 cm × 60 cm, plot size 180 cm × 120 cm and the date of transplanting was 15th November 2015.

3.6 Land preparation

The experimental plots were ploughed and brought into a fine tilth and raised the nursery bed, applied the recommended dose of fertilizers and farm yard manures (FYM). Weeds and other stubbles were removed carefully from the experimental plot and leveled properly. The final land preparation was done on 13 November 2015.

3.7 Transplanting of seedlings

The seedlings were raised in the seedbed and 22 days old seedlings were transplanted in the main field on 15 November 2015. The transplanted seedlings were watered regularly to make a firm relation with roots and soil to stand along. Transplanting of seedlings is presented in Plate 2(A-C).

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)

Plate 1. Seedbed preparation and weeding in the seedbed. A. Seedbed preparation B. Weeding in the seedbed

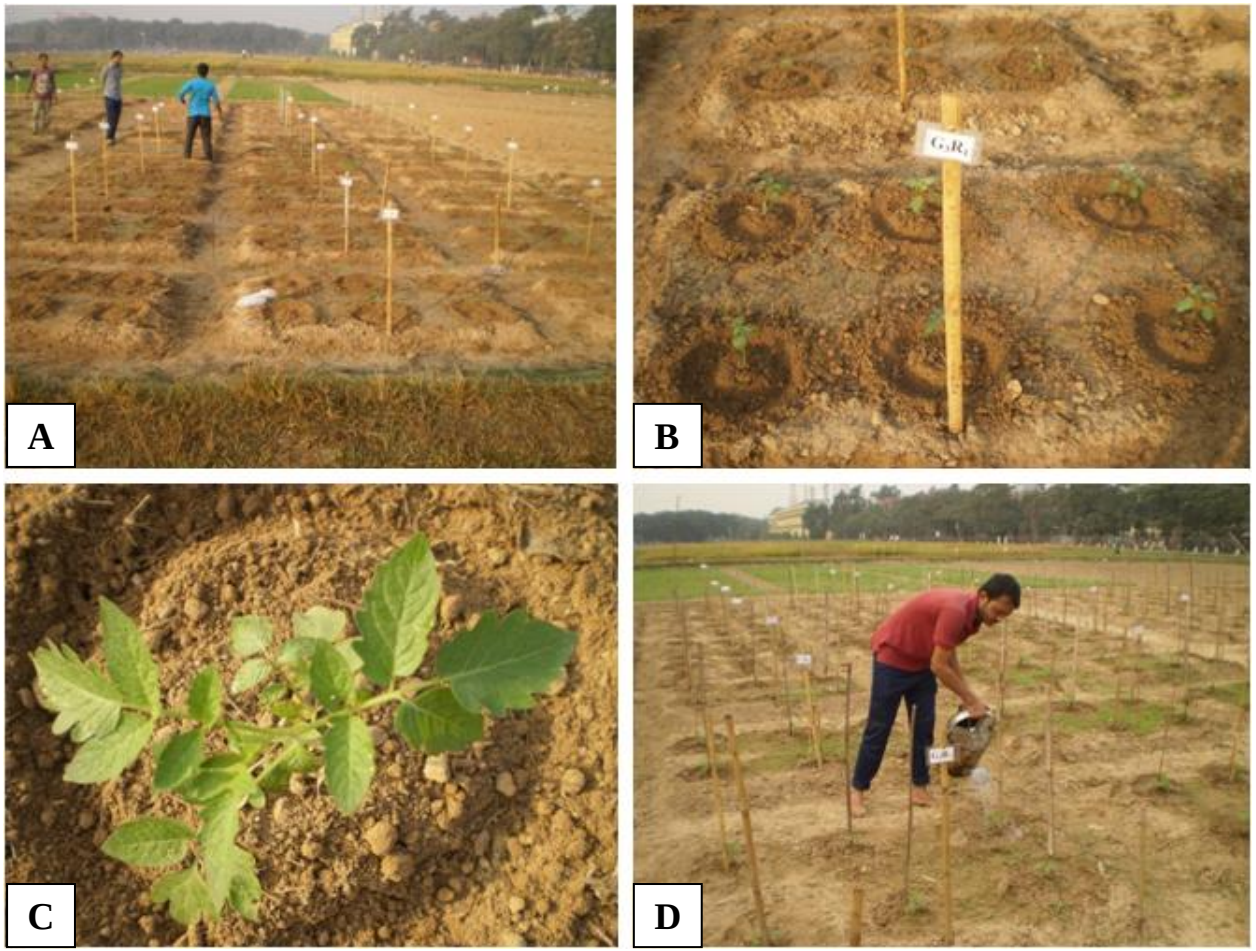

Plate 2. Transplanting and aftercare of seedlings in the experimental field. A. Transplanting in the main experimental field. B. Fertilizer application and labeling. C. Growing of transplanted seedling. D. Watering.

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.

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

Sl. No.	Fertilizers/ Manures	Dose	
		Applied in the plot	Quantity/ha
1.	Urea	10.5 kg	550 kg
2.	TSP	08 kg	450 kg
3.	MOP	4.5 kg	250 kg
4.	Cow dung	200 kg	10 ton

3.9 Intercultural operations

When the seedlings were well established, first weeding was done uniformly in all the plots. Second weeding was done after 20 days of the first one. Mechanical support was provided to the growing plants by bamboo sticks to keep them erect. During early stages of growth, pruning was done by removing some of the lateral branches to allow and plants to get more sunlight and to reduce the self-shading and incidence of increased insect infestation. Thinning and gap filling, staking, pesticide application, irrigation and after-care were also done as per requirement (Plate 2D).

3.10 Harvesting and processing

All of the tomato genotypes studied 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 2 March 2016 and completed by 26 April, 2016.

3.11 Data recording on Antioxidant and nutritional traits

Data were recorded on different antioxidant and nutritional traits using ripe fruits viz., Brix (%), Vitamin-C content (mg/100g) and Lycopene content (mg/100g), pH of the flesh, moisture content of flesh and dry matter content. Different steps of data recording are presented in Plate 3.

3.11.1 Determination of Brix percentage

Brix percentages were measured by Portable Refractometer (ERMA, Tokyo, Japan) at room temperature. Tomato juice was collected to measure brix %.

3.11.2 Determination of Vitamin-C

Vitamin-C was measured by Oxidation Reduction Titration Method (Tee *et al*., 1988). Tomato extract from single fruit was filtrated by Whatman No.1 filter paper. It was then mixed with 3% metaphosphoric acid solution. The titration was conducted in presence of glacial acetic acid and metaphosphoric acid to inhibit aerobic oxidation with dye solution (2, 6-dichlorophenol indophenol). The solution was titrated with dye. The observations mean gave the amount of dye required to oxidize definite amount of L-ascorbic acid solution of unknown concentration, using L-ascorbic acid as known sample.

3.11.3 Determination of Lycopene content

Absorption determination for lycopene content was estimated following the method of Alda *et al*. (2009) by using T60 UV-Visible Spectrophotometer. Lycopene in the tomato was extracted using hexane:ethanol:acetone (2:1:1) (v/v) mixture. One gram juice of the each sample were homogenized with 25 ml of hexane:ethanol:acetone, which were then placed on the orbital shaker for 30 min., adding 10 ml distilled water and was continued agitation for another two min. The solution was then left to separate into distinct polar and non-polar layers. The absorbance was measured at 472 nm and 502 nm, using hexane as a blank. The lycopene concentration was calculated using its specific extinction coefficient (E 1%, 1cm) of 3450 in hexane at 472 nm and 3150 at 502 nm. The lycopene concentration was expressed as mg/100g product.

$$\text{At } \lambda = 472\text{nm: lycopene content (mg/100g)} = \frac{E}{3.45} \cdot \frac{20}{m}$$

$$\text{At } \lambda = 502\text{ nm: lycopene content (mg /100g)} = \frac{E}{3.15} \cdot \frac{20}{m}$$

Where, m = the weight of the product (g), E = extinction coefficient

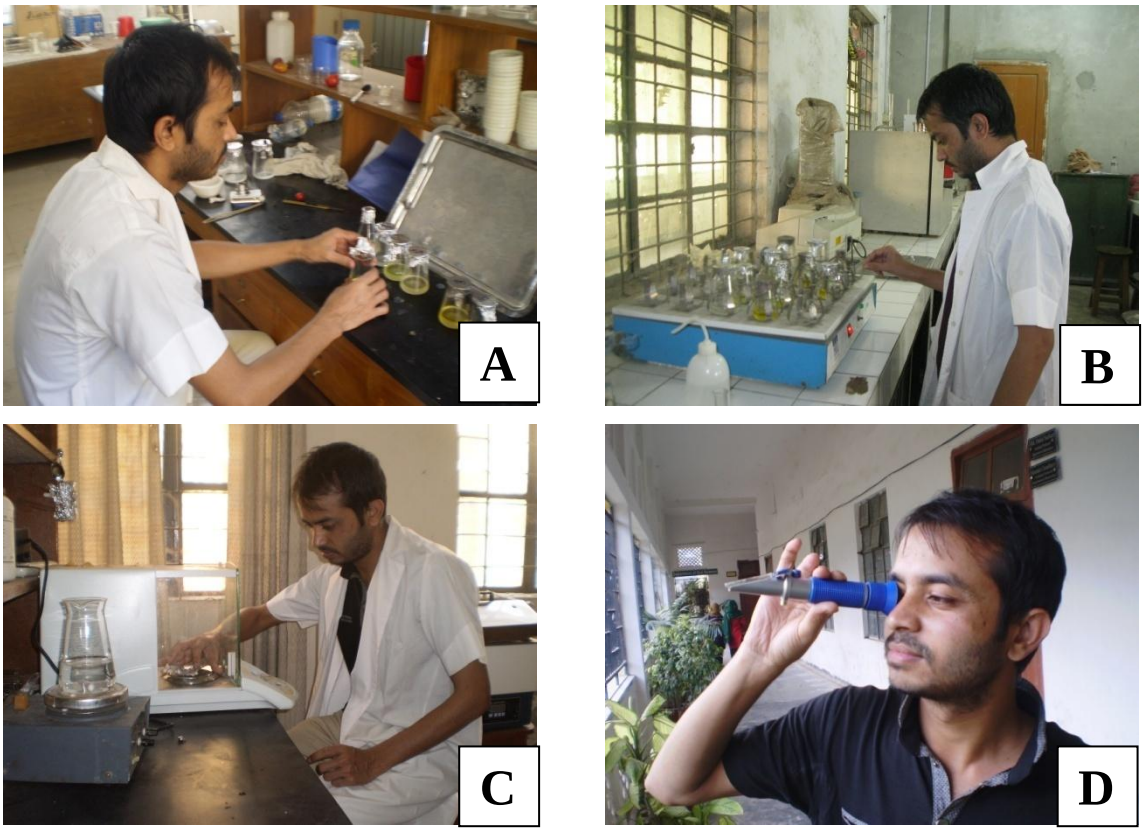

Plate 3. Different types of activities for data recording. A. Extraction of lycopene and B. Shaking for extraction of Vitamin-C. C. Solution preparation for extraction of vitamin-C D. Estimation of brix (%) using Portable Refractometer

3.11.4 Determination of pH of the flesh

Sample of 5gm each of the fresh mesocarp were homogenous in 5 ml of boil distill water and deionize water (pH 7) and the pH of the homogenate was measured with a pH meter.

3.11.5 Determination of moisture percentage

The moisture percentage was estimated as described by Isbat (1996) 5 g of pulp was taken in a procelain crucible and oven dried at 80^{o} C until the weight became constant. Three samples were used for each variety. Percent of moisture was calculated according to the following formula:

$$\% \text{ Moisture} = \frac{I-F}{I} \times 100$$

Where,

I= Initial weight of pulp

F= Final weight of pulp

3.11.6 Determination of dry matter

It was calculated from the data obtain from percent moisture contain (F).

3.12 Statistical analysis

Collected data were statistically analyzed using MSTAT-C computer package program. Mean for every treatments were calculated and analysis of variance for each character was performed by F-test (Variance Ratio). Difference between treatments was assessed by Least Significant Difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

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.

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).

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).

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

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 (Clarke, 1973; Singh and Chaudhary, 1985).

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

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), Johnson *et al.* (1955) and Hanson *et al.* (1956) were adopted. The genotypic co-variance component between two traits and have the phenotypic co-variance component were derived in the same way as for the corresponding variance components. The co-variance components were used to compute genotypic and phenotypic correlation between the pairs of characters as follows:

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

Where,

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

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

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

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

Where,

σ_{pxy} = Phenotypic covariance between the 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

It was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985), using phenotypic correlation coefficient values. In path analysis, correlation coefficients between yield and yield contributing characters were partitioned into direct and indirect effects on yield per hectare. In order to estimate direct and indirect effects of the correlated characters, i. e. 1, 2, 3….and 12 on yield y, a set of simultaneous equations (twelve equations in this example) is required to be formulated as shown below:

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

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

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

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

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

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

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

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

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

$r_{10.y} = r_{1.10} P_{1.y} + r_{2.10} P_{2.y} + r_{3.10} P_{3.y} + r_{4.10} P_{4.y} + r_{5.10} P_{5.y} + r_{6.10} P_{6.y} + r_{7.10} P_{7.y} + r_{8.10}$

$P_{8.y} + r_{9.10} P_{9.y} + P_{10.y} + r_{10.11} P_{11.y} + r_{10.12} P_{12.y}$

$r_{11.y} = r_{1.11} P_{1.y} + r_{2.11} P_{2.y} + r_{3.11} P_{3.y} + r_{4.11} P_{4.y} + r_{5.11} P_{5.y} + r_{6.11} P_{6.y} + r_{7.11} P_{7.y} + r_{8.11}$

$P_{8.y} + r_{9.11} P_{9.y} + r_{10.11} P_{10.y} + P_{11.y} + r_{11.12} P_{12.y} + r_{11.13} P_{13.y}$

$r_{12.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

$r_{13.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

$r_{14.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

$r_{15.y} = r_{1.12} P_{1.y} + r_{2.12} P_{2.y} + r_{3.12} P_{3.y} + r_{4.12} P_{4.y} + r_{5.12} P_{5.y} + r_{6.12} P_{6.y} + r_{7.12} P_{7.y} + r_{8.12}$

$P_{8.y} + r_{9.12} P_{9.y} + r_{10.12} P_{10.y} + r_{11.12} P_{11.y} + P_{12.y}$

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,….12)

1 = Plant Height

2 = Days to first flowering

3 = Days to 50% flowering

4 = Days to maturity

5 = Number of branches per plant

6 = Number of clusters per plant

7 = Number of fruit per cluster

8 = Number of fruits per plant

9 = Fruit weight (gm)

10 = Fruit length (cm)

11 = Fruit diameter (cm)

12 = Fruit yield per plant (kg)

13 = % of brix content

14 = Lycopene content

15 = Vitamin C content

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

$r_{1.13}\, P_{12.y}$ = indirect effect of 1 via 13 on y

$r_{1.14}\, P_{12.y}$ = indirect effect of 1 via 14 on y

$r_{1.15}\, P_{12.y}$ = indirect effect of 1 via 15 on y

Where,

$P_{1.y,}\, P_{2.y,}\, P_{3.y.}$ …… $P_{15.y}$ = Path coefficient of the independent variables 1, 2, 3,….,15 on the dependent variable y, respectively.

$r_{1.y,}\ r_{2.y,}\ r_{3.y,}$ …., $r_{15.y}$ = Correlation coefficient of 1, 2, 3,…., 15 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

$P^2_{RY} = 1- (r_{1.y}P_{1.y} + r_{2.y}P_{2.y} +\ldots\ldots\ldots\ldots\ldots..+ r_{15.y}P_{15.y})$

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.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study are to investigate of genetic analysis that means genetic variability, associations of characters and path coefficient analysis of tomato of native and exotic genotypes are presented and discussed here under the following sections. The gradual development of tomato plant from seedbed to fruiting stage is presented in Plate 4 and a close view of the experimental field is presented in Appendix V. The fruits showed different colour and shapes which are presented in Plate 5.

4.1 Mean, Range and Analysis of Variance

4.1.1 Fruit p^H

The calculated p^H of fruits was significantly varied in all the genotypes ranging from 4.5o to 5.20 (Table 3, Appendix IV). The CV value of fruit p^H was found 2.83%. The maximum p^H was recorded in genotype G1 (5.20) whereas the lowest p^H was observed in the genotype G8 (4.50) (Table 4). A schematic diagram of fruit p^H was presented in Figure 1.

4.1.2 Vitamin C

Another parameter vitamin C was observed from the result of the experiment that vitamin C contents of tomato fruit were significantly differed among the ten tomato genotypes. The mean value of vitamin C of fruit varied from 3.60 mg to 46.15 mg/100g (Table 4). The maximum amount of vitamin C (46.15 mg/100g) was found in G7 whereas minimum (3.60 mg/100g) from G_3 (Table 4). According to the present study maximum concentration of vitamin C was found in G7 tomato genotypes. High vitamin C in tomato not only improves the nutrition, it also aids in better retention of natural colour and flavour of the products (Thamburaj, 1998). A schematic diagram of vitamin C was presented in Figure 2.

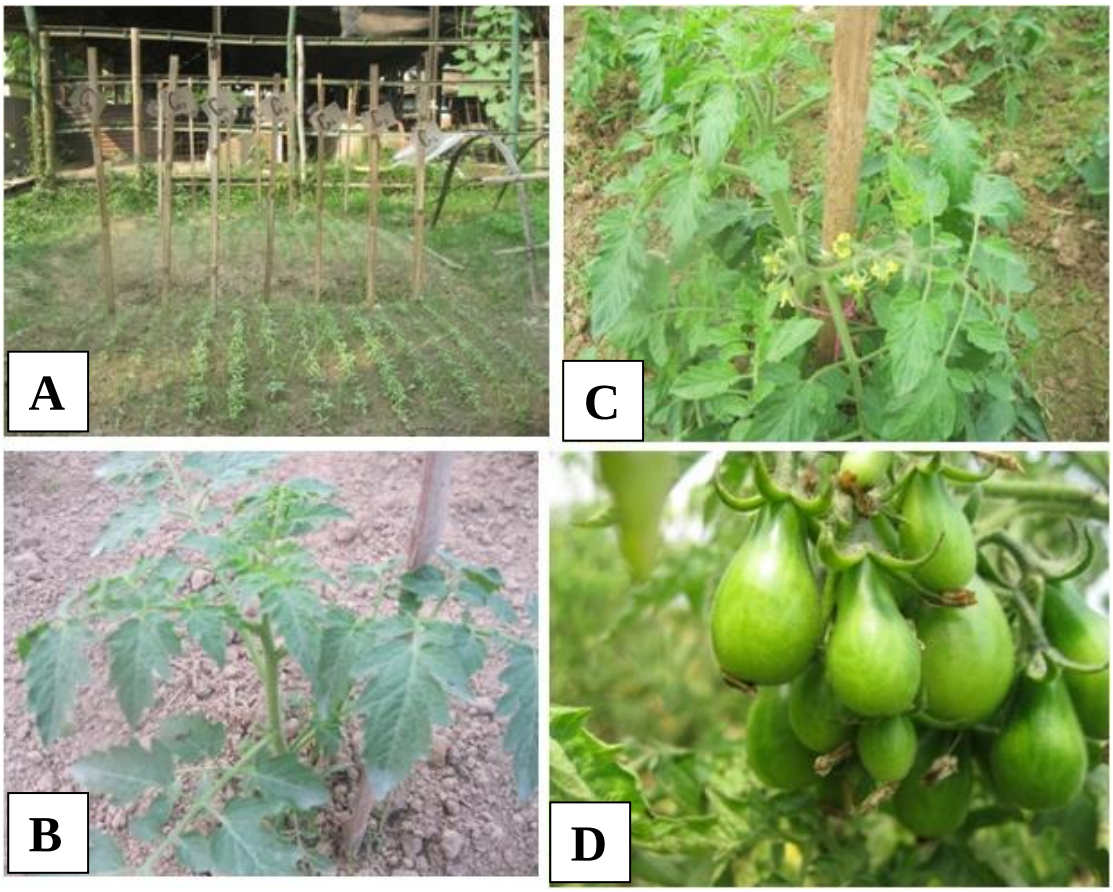

Plate 4. Different stages of tomato plant in the experiment field. A. Raising of tomato seedlings in the seedbed. B. Growing condition of tomato plant in the experimental field. C. Flowering stage of tomato plant. D. Fruiting stage of tomato plant.

Plate 5.Variation in studied genotypes. G1. (SL-001) G2. (SAU Tomato-1) G3. (SAU Tomato-3) G4. (SL-002) G5. (SL-003) G6. (SAU Tomato-4) G7. (SAU Tomato-2) G8. (BARI Tomato-3) G9. (BARI Tomato-2) G10. (BARI Tomato-11)

Table 3. Range, mean CV (%) and standard deviation of ten tomato genotypes.

Parameters	Range		Mean	CV (%)	SD	SE
	Min	Max				
p^H	4.50	5.20	4.79	2.83	0.14	0.05
Brix (%)	2.10	6.40	3.46	2.74	0.09	0.04
Dry matter content (g/100g)	0.23	2.37	0.58	12.17	0.07	0.03
Vitamin C (mg/100g)	3.60	46.15	17.63	1.78	0.31	0.12
Lycopene (mg/100g) at 472 nm	4.90	126.22	50.82	0.30	0.15	0.06
Lycopene (mg/100g) at 502 nm	2.10	89.70	35.43	1.56	0.55	0.21
Moisture (%)	52.67	95.33	88.47	1.59	1.40	0.53

Table 4. Mean performance of ten genotypes of tomato in respect of seven important characters.

Genotype	p^H	Brix (%)	Dry matter content (g/100g)	Vitamin C (mg/100g)	Lycopene (mg/100g) at 472 nm	Lycopene (mg/100g) at 502 nm	Moisture (%)
G1	5.20a	2.10g	0.43bc	5.500h	60.94d	44.14d	91.33bc
G2	4.90b	3.50d	2.37a	31.66b	4.900j	2.10j	52.67d
G3	4.76bc	3.20e	0.33bcd	3.600i	32.02f	9.84i	93.33abc
G4	4.90b	2.10g	0.43bc	15.67e	36.21e	24.15e	91.33bc
G5	4.60cd	3.10ef	0.37bc	3.640i	107.4b	79.14b	92.67bc
G6	4.80bc	5.00b	0.30cd	23.38c	78.70c	59.40c	94.00ab
G7	4.60cd	6.40a	0.43bc	46.15a	126.2a	89.70a	91.33c
G8	4.50d	3.00f	0.40bc	12.09g	25.63g	19.64f	92.00bc
G9	4.70bcd	2.10g	0.23d	14.87f	15.55i	11.89h	95.33a
G10	4.93b	4.10c	0.47b	19.70d	20.65h	14.24g	90.67c
LSD 0.05	0.2301	0.1627	0.1213	0.5370	0.2657	0.9489	2.408

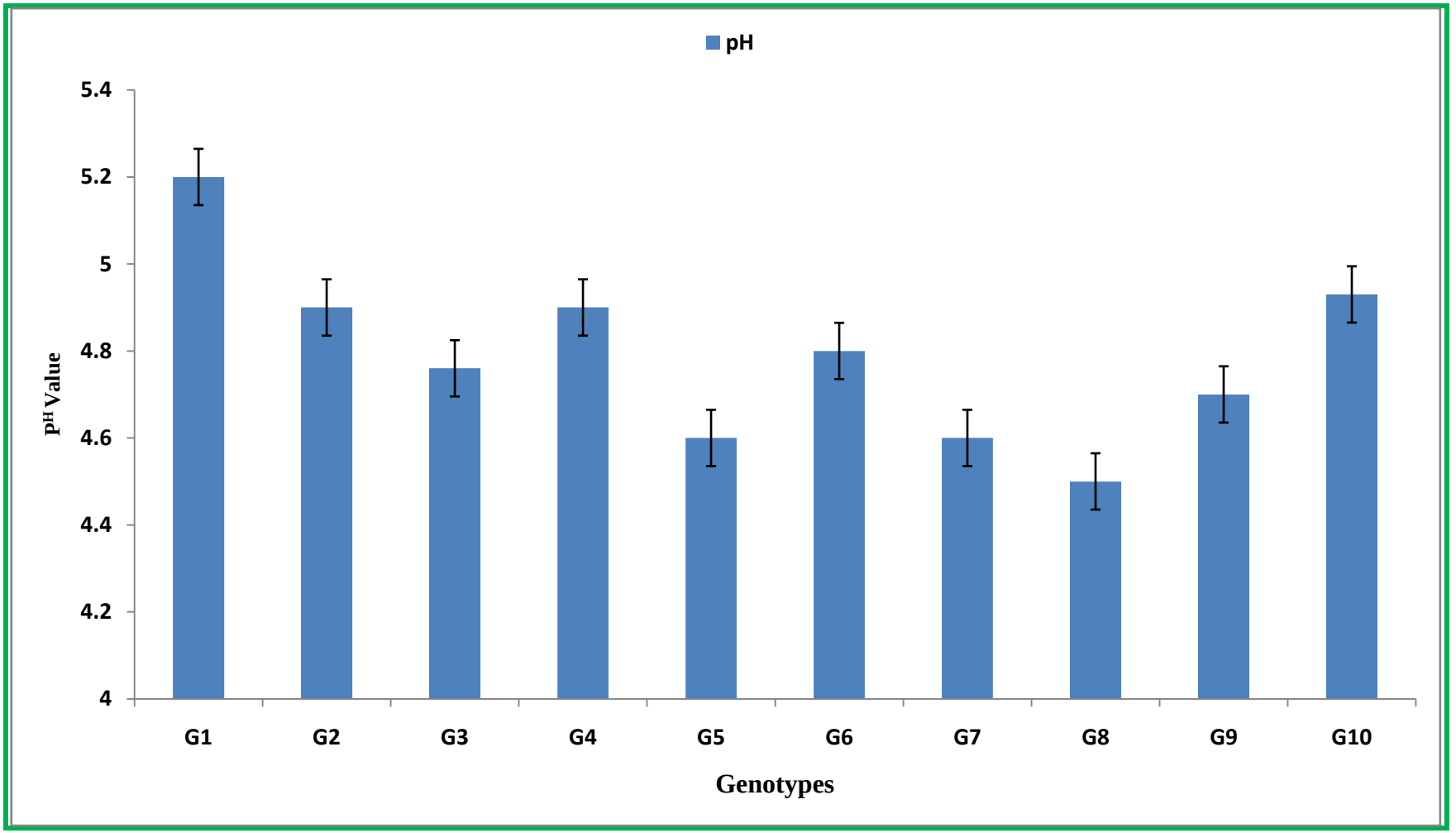

Figure 1. Variation in mean performance of ten genotypes on p^H of tomato.

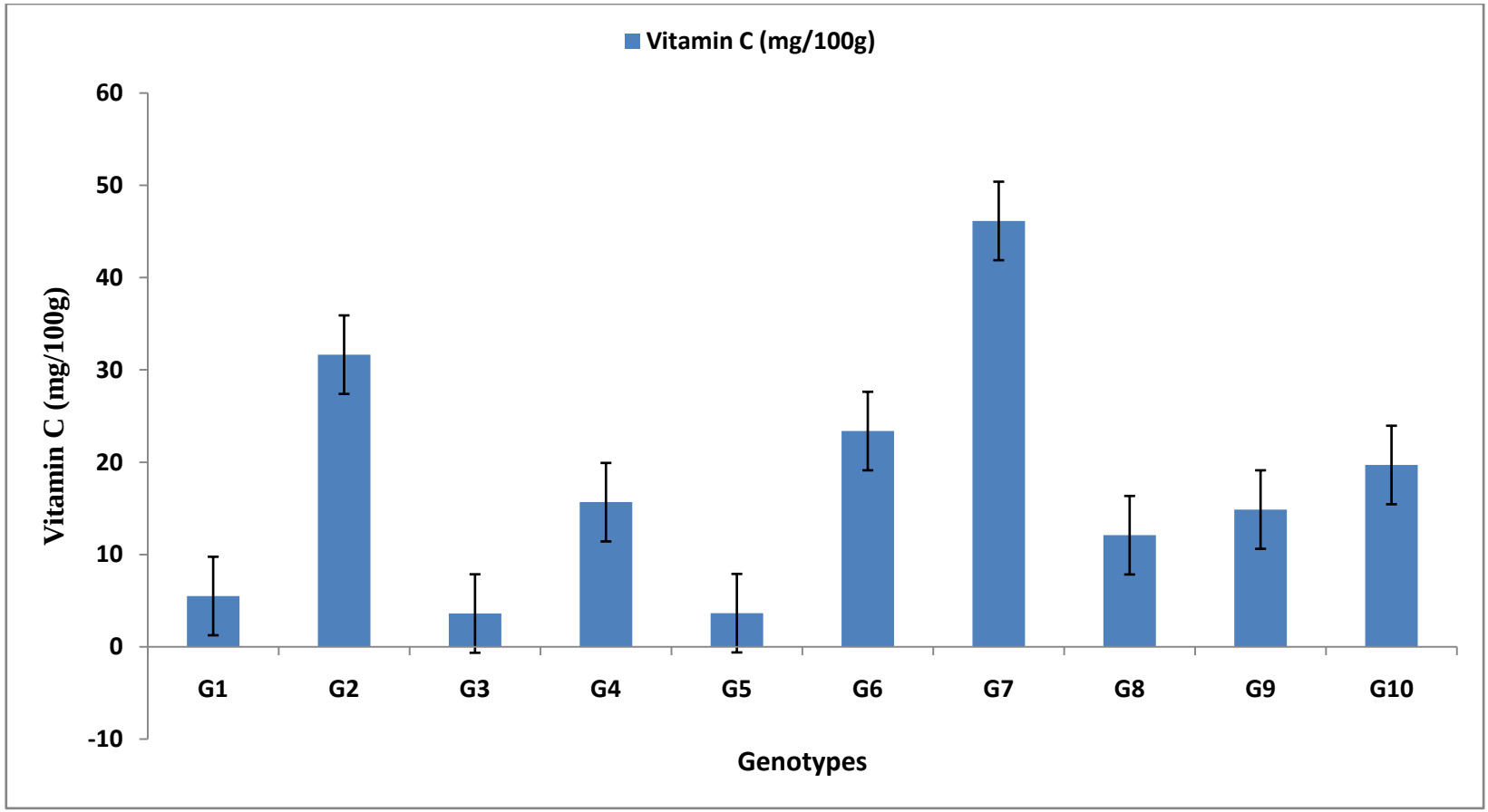

Figure 2. Variation in mean performance of ten genotypes of Vitamin C of tomato.

4.1.3 Dry matter content (g/100g)

Dry matter content varied from 0.23g to 2.37g with average of 0.58g (Table 3). The coefficient of variation of this trait was 12.17%. The maximum dry matter content was observed by the genotype G2 (2.37 g) and minimum in G9 (0.23 g) (Table 4). A graphical presentation of dry matter content was found in the Figure 3.

4.1.4 Brix (%)

From the result of the experiment it was observed that brix (%) of tomato fruit was varied significantly among the six tomato genotypes. The ranges of brix from 2.10% to 6.40% with the mean value of 3.46% (Table 3). Maximum brix (6.40%) was found in G7whereas minimum (2.10%) from G1, G4 and G9 (Table 4). According to the study G7 tomato genotypes have the highest brix (%). A graphical representation of brix of six genotypes was observed in Figure 4.

4.1.5 Lycopene

The genotype G7 recorded maximum lycopene content of the fruit (126.20 mg) followed by the genotypes G5 (107.40 mg) in case of 472 nm (Table 4), while the minimum was observed by the genotype G2 (4.90 mg) in case of 472 nm. In case of 502 nm highest lycopene content of fruit was observed in genotype G7 (89.70 mg) and the lowest was observed in the genotype G2 (2.10 mg) (Table 4). The variation in lycopene content is presented in Plate 6. Colour of fruit is an important quality parameter both for table purpose and processing varieties. Potaczek and Michalik (1998) have observed that environmental factors especially temperature and light intensity exerted a great influence on lycopene level than on carotene contents in tomato fruits. Red-fruiting cultivars also have higher lycopene content than yellow, orange and black- fruiting cultivars (Cox *et al.,* 2003). A schematic diagram of lycopene was presented in Figure 5 and Figure 6.

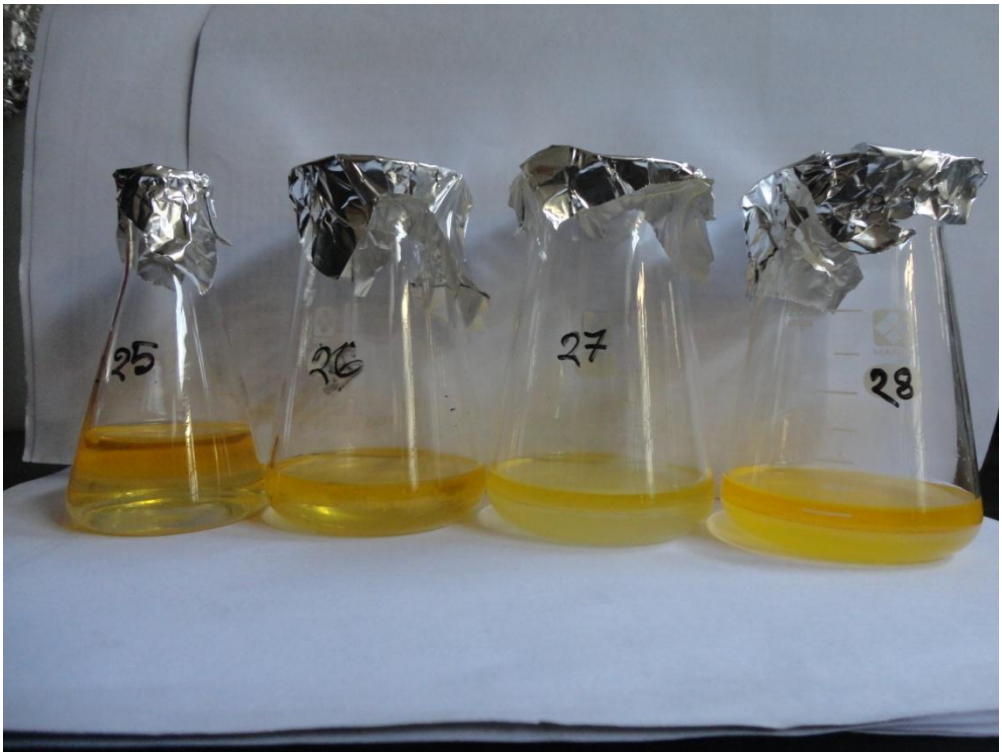

Plate 6. Extraction of lycopene content. The upper dark orange color layer is lycopene.

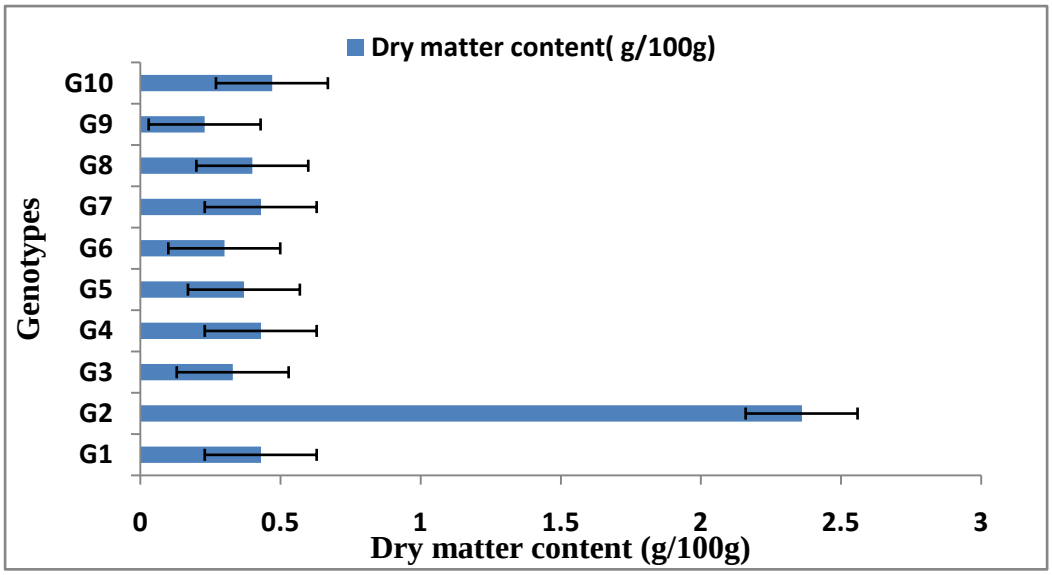

Figure 3. Variation in mean performance of ten genotypes of dry matter content (g/100g) of tomato.

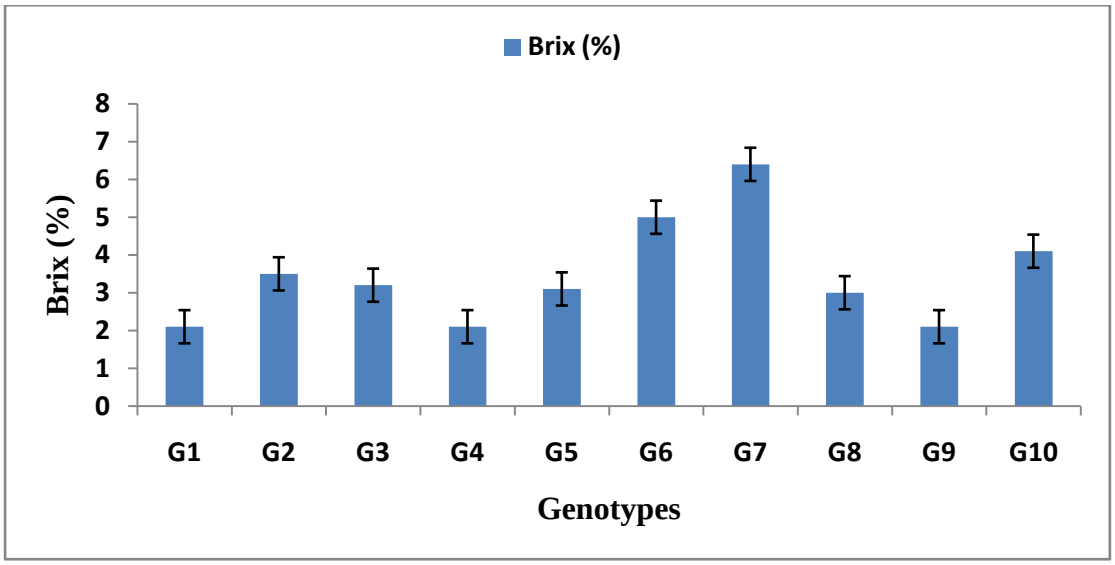

Figure 4. Variation in mean performance of ten genotypes of brix% of tomato.

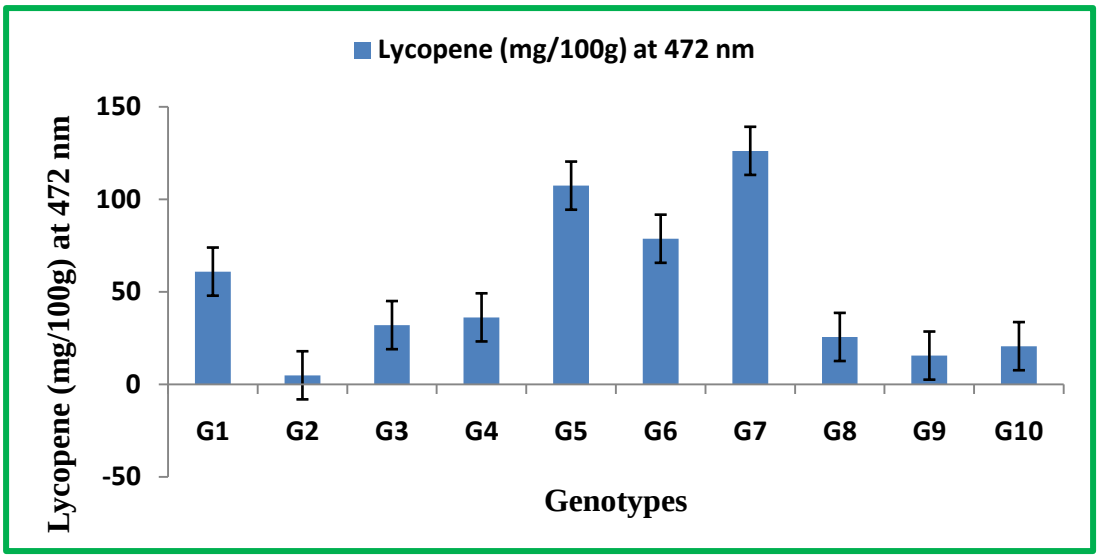

Figure 5. Variation in mean performance of ten genotypes of lycopene (mg/100g) at 472 nm in tomato.

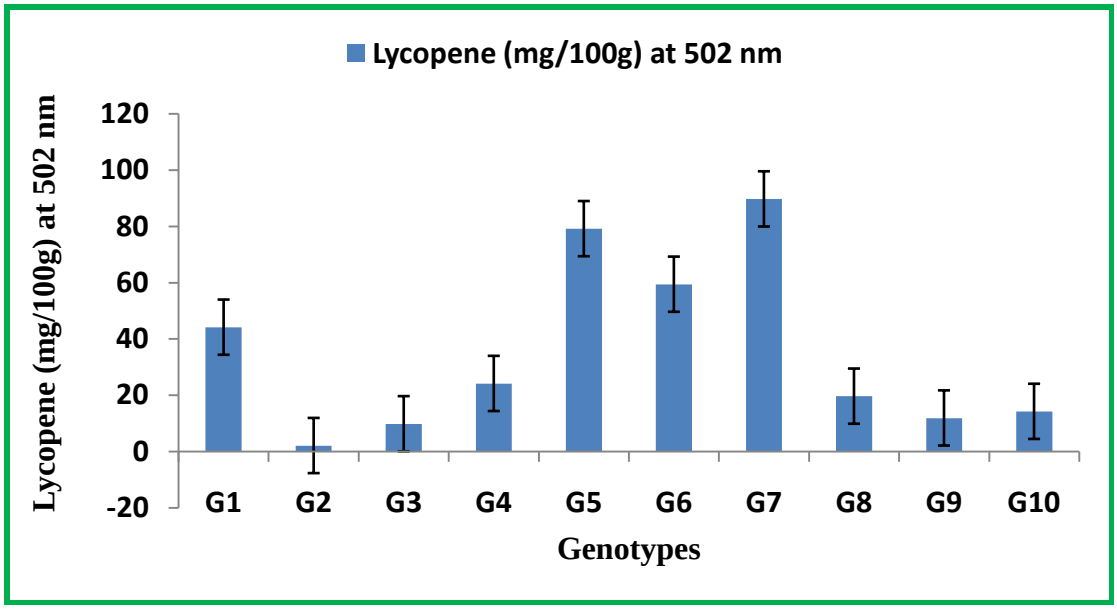

Figure 6. Variation in mean performance of ten genotypes of lycopene (mg/100g) at 502 nm in tomato.

4.1.6 Moisture

Moisture ranged was observed from 52.67% to 95.33% with the average of 88.47%. The coefficient of variation was 1.59%. Maximum moisture percentage was found by the genotype G9 (95.33%) and the minimum was observed from the genotype G2 (52.67%) (Table 4). A schematic diagram was presented in Figure 7.

4.2 Estimates of Genetic Parameters

The development of suitable plant type is of great importance for all the crops through planned design programme. Attempts have, therefore, been made by several scientists to analyse different chemical characters to provide meaningful information about the significance of characters in relation to tomato fruit. An ideal plant ideotype would only be defined if the different components of fruit of tomato are analysed and their relative importance can be assessed. In the present study, genetically diverse tomato genotypes collected from different sources were examined and quality component analyses were carried out to identify important fruit quality components.

Genetic variability Estimates including genotypic variance (σ^2_g) phenotypic variance (σ^2_p) environmental variance (σ^2_e) phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (H %), genetic advance (GA) and genetic advance as percent mean (GAM) were summarized in Table 5.

4.2.1Estimates of Variance Components

The variance components include genotypic variance, environmental variance and phenotypic variance which are presented in (Table 5) and discussed here. The highest environmental variance observed 1.97 was for moisture (%) which indicated that environmental component in total variation is high. The highest genotypic variance and phenotypic variance were 1692.54 and 1692.56 respectively both were for lycopene content (mg/ 100gm) at 472 nm; indicate the presence of high variation for this trait. The lowest environmental,

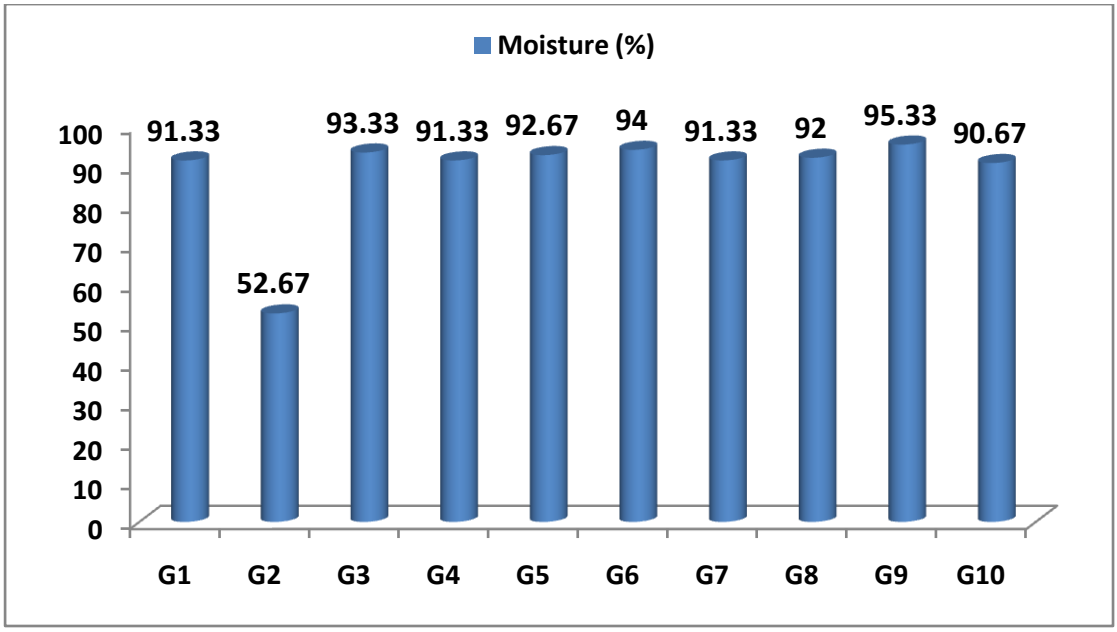

Figure 7. Variation in mean performance of ten genotypes of moisture in tomato.

Table 5. Estimation of genetic, phenotypic and environmental variance in seven traits.

Parameters	σ^2_p	σ^2_g	σ^2_e
p^H	0.05	0.04	0.02
Brix (%)	1.94	1.93	0.01
Dry matter content (g/100g)	0.40	0.40	0.00
Vitamin C (mg/100g)	181.08	180.98	0.10
Lycopene (mg/100g) at 472 nm	1692.56	1692.54	0.02
Lycopene (mg/100g) at 502 nm	961.50	961.20	0.31
Moisture (%)	161.61	159.64	1.97

σ^2p = Phenotypic variance, σ^2g = Genotypic variance and σ^2 e = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation.

genotypic and phenotypic variances were also 0.02, 0.04 and 0.05, respectively for p^H. This indicated the presence of low variation for this trait. All of the above results showed the potential of variation exist in different traits. According to Engida (2007) traits that showed the different genotypic, phenotypic and environmental values indicates the presence of variation.

4.2.2 Estimates of Genotypic and Phenotypic Coefficient of Variation

The highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were 109.55 and 110.23 which were recorded for dry matter content (g/100g) (Table 6). In this case, the PCV values of dry matter content (g/100g) were a little more than GCV values. This indicated that the environmental effect was small for the expression of these characters (Kassaye, 2006). The magnitudes of phenotypic and genotypic coefficient of variation were lowest for pH 4.86 and 3.95, respectively. In these cases, the PCV values were higher than GCV values across the environment. This indicated the presence of environmental influence on these characters (Sharma *et al*., 2009). PCV and GCV were classified as suggested by Shivasubramanian and Menon (1973) as follows, 0–10% -Low, 10-20 – Moderate, 20% and above - High.

High to moderate GCV and PCV values were shown by all the characters except pH that showed low GCV and PCV values (Table 6 and Figure 8). These observations find support from the previous workers (Islam *et al*., 2012; Samadia *et al.*, 2006; Mayavel *et al.*, 2005). The present result revealed that, higher genotypic coefficients of variations were recorded for dry matter content (109.55%), lycopene at 502 nm (87.52%), lycopene at 472 nm (80.95%), Vitamin C (76.33%), and brix (40.14%) (Table 6). Moisture (14.28%) had the moderate values. pH (3.95%) had the lowest GCV values. The highest phenotypic coefficient of variation value recorded for dry matter content (110.23%), lycopene at 502 nm (87.53%), lycopene at 472 nm (80.95%), Vitamin C (76.35%) and brix (40.23%) (Table 6). Moisture (14.37%) had the moderate PCV values. pH (4.86%) had the lowest PCV values.

Table 6. Estimation of phenotypic and genotypic coefficient variation.

Parameters	PCV (%)	GCV (%)	GCV:PCV
p^H	4.86	3.95	81
Brix (%)	40.23	40.14	100
Dry matter content (g/100g)	110.23	109.55	99
Vitamin C (mg/100g)	76.35	76.33	100
Lycopene (mg/100g) at 472 nm	80.95	80.95	100
Lycopene (mg/100g) at 502 nm	87.53	87.52	100
Moisture (%)	14.37	14.28	99

σ^2p = Phenotypic variance, σ^2g = Genotypic variance and σ^2 e = Environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation.

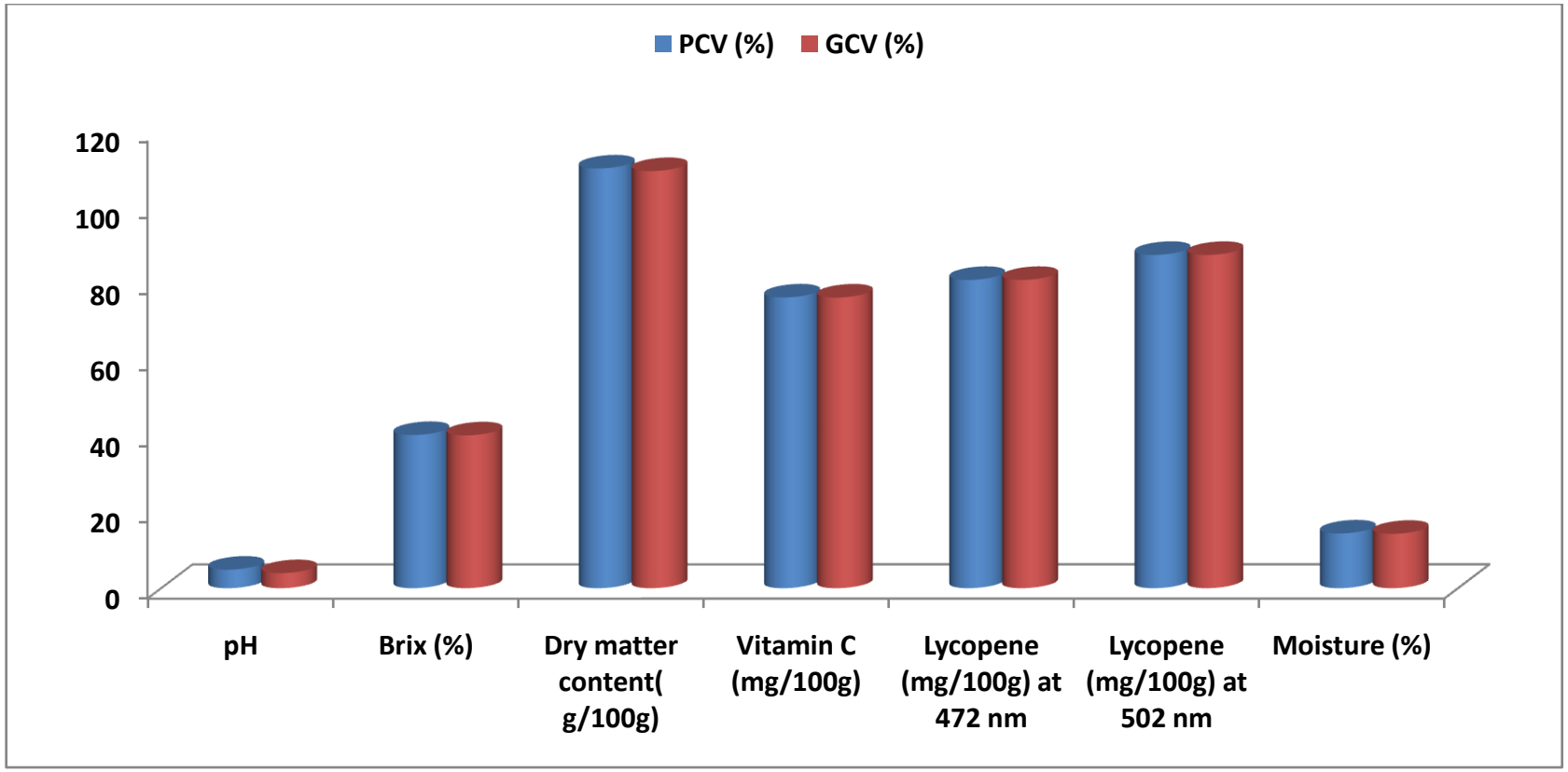

Figure 8. Genotypic and phenotypic coefficient of variability.

Phenotypic co-efficient of variation (PCV) agreed closely with the genotypic co-efficient of variation (GCV) (Table 7) which was well supported by Joshi *et al.*, 2004; Kumar *et al*., 2006; Golani *et al.*, 2007. In all cases, the difference between PCV and GCV values was low indicating the low effects of environment in all of these characters. The difference in genotypic coefficient of variation and phenotypic coefficient of variation values were closer indicates that there was a minimum influence of environment on these characters. In general, phenotypic coefficient of variation values were higher than their corresponding genotypic coefficient variation values in all of the characters. This result is also in line with the results reported by Sharma *et al.* (2009) who revealed that the magnitude of PCV was higher than GCV for all the characters. The present results further confirmed the finding of earlier researcher in tomato (Vani *et al.*, 2007).

High proportion of GCV to PCV is desirable in selection process because it depicts that the traits are much under the genetic control rather than the environment (Kaushik *et al.,* 2007). The proportion of GCV in PCV observed in this study ranged from 81.00% in pH to 100% in brix, vitamin C and lycopene content. The traits with high proportion of GCV in PCV are reliable for selection in quality genetic improvement of tomato genotypes. Trait (dry matter content) whose expression was environmentally dependent may not be reliable descriptor for quality characterization.

4.2.3 Estimates of Heritability and Genetic Advance

Broad sense heritability were higher (> 66.08%) for all the characters which collaborates the findings of earlier workers (Manna and Paul, 2012; Samadia *et al.*, 2006). Broad sense heritability ranged from 66.08% (pH) to 98.97 % (lycopene at 502 nm) (Table 7 and Figure 9). This broad sense heritability was likely to be over estimated as in this calculation it was not possible to exclude variation due to different genetic components and their interactions. The heritability was 66.08% for p^H, 97.69% for vitamin C, 97.95% for dry matter content, 98.78% for brix, 97.00% for

Table 7. Estimation of heritability and genetic advance.

Parameters	Heritability	Genetic advance (5%)	Genetic advance (% mean)
p^H	66.08	0.32	6.62
Brix (%)	98.54	2.85	82.49
Dry matter content (g/100g)	98.78	1.29	224.30
Vitamin C (mg/100g)	97.95	27.71	157.19
Lycopene (mg/100g) at 472 nm	97.00	84.75	166.75
Lycopene (mg/100g) at 502 nm	98.97	63.86	180.26
Moisture (%)	95.78	25.87	29.24

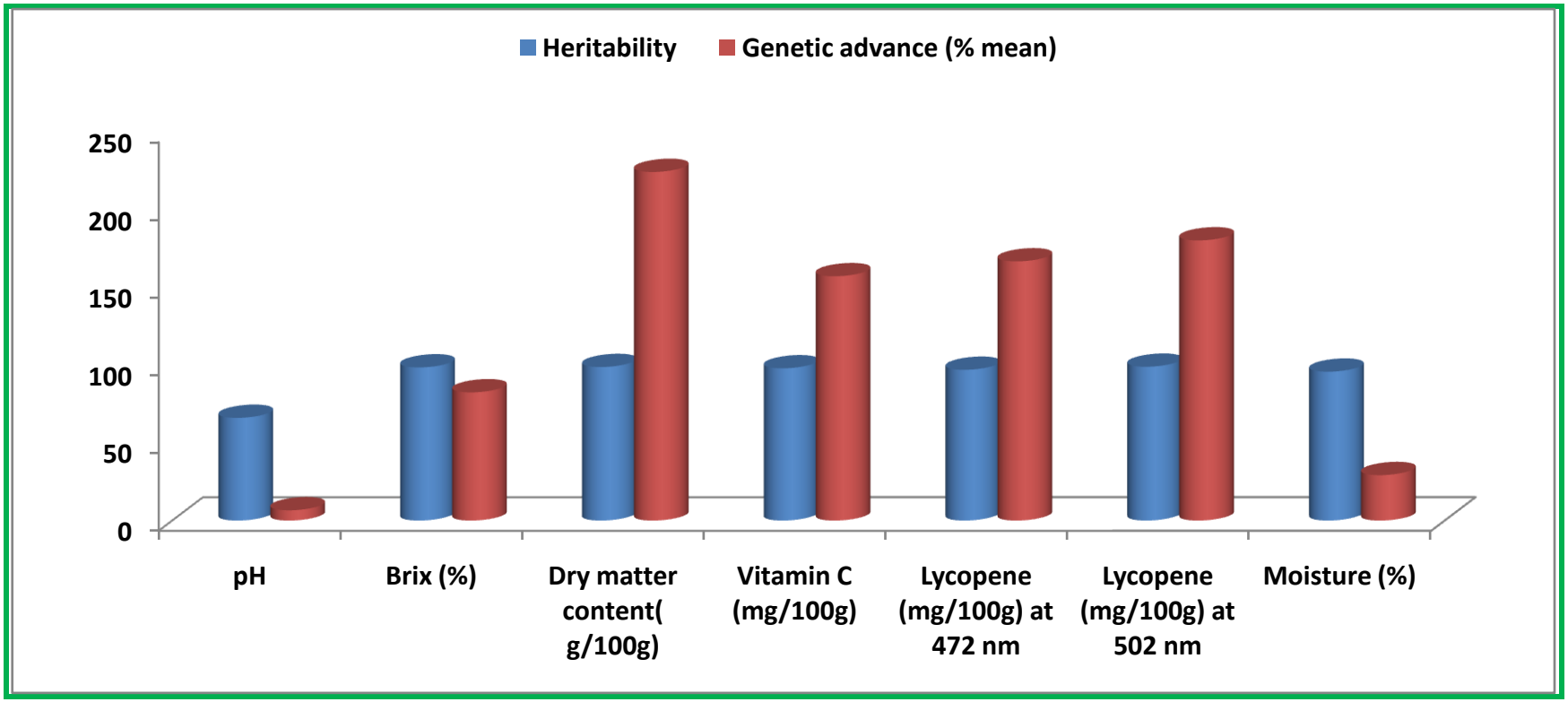

Figure 9. Heritability and genetic advance over mean.

lycopene at 472 nm, 98.97% for lycopene at 502 nm and 95.78% for moisture were higher. The heritability of the highest magnitude was noticed for lycopene at 502 nm (98.97%). Thus, it indicated that larger proportion of phenotypic variance has been attributed to genotypic variance and reliable selection could be made for almost all the traits on the basis of phenotypic expression. High estimates of heritability in broad sense indicate that substantial improvement can be made using standard selection procedures. In general, characters which exhibited high heritability suggest that the selection would be more effective whereas characters showing low heritability indicate that the selection would be affected by environmental factors. Based on the observation, in the present study, it can be surly concluded that selection of genotype based on p^H value, vitamin C, dry matter content, brix, lycopene at 472 nm, lycopene at 502 nm and moisture would be more satisfactory.

The heritability estimates were, therefore, to be considered with these limitations in view. However, genetic advance (GA) expressed as percentage of mean was high (>29%) for the characters like moisture, vitamin C, dry matter content, brix, lycopene at 472 nm and lycopene at 502 nm. Moderate genetic advance as percent of mean was shown by pH. The estimate of genetic advance as percent of mean was highest (224.30%) for dry matter content(g/100g) and lowest (6.62%) for pH. Most of the traits studied had high genetic advance as percent of mean though it was moderate for pH (6.62%). These results were in agreement with Singh *et al.* (2005). According to Johnson *et al*. (1955) high heritability estimates along with the high genetic advance is usually more helpful in predicting gain under selection than heritability estimates alone. The estimates of heritability accompanied by estimates of genetic advance as percent of means are more meaningful from the point of expected genetic gain. Genetic advance is the measure of improvement that can be achieved by practicing selection in a population.

The present study revealed high heritability coupled with high expected genetic advance as percent of means were observed in case of moisture (95.78% and

29.24%), vitamin C (97.95% and 157.19%), dry matter content (98.78% and 224.30%), brix (98.54% and 82.49%), lycopene at 472 nm (97.00% and 166.75%) and lycopene at 502 nm (98.97% and 180.26%) respectively indicating good response to selection for these characters. Therefore, it is clear that these traits were less influenced by environmental changes. Most of the variations are due to genetic factor and improvement in these traits would be more effective through selection owing to their additive gene action. Similar results were obtained by Singh *et al*. (2005). This suggested the presence of additive gene action and hence these characters are likely to respond better to selection. High heritability and high genetic advance for the above mentioned characters revealed that such characters are controlled additive gene action and selection based on these characters will be effective. These results find support with the observations of earlier workers (Prashant, 2003; Samadia *et al.*, 2006) irrespective of the genetic materials used and environments in which these experiments were conducted. The low heritability is being exhibited due to high environmental effects. Low heritability accompanied with low genetic advance for none of the character found. High heritability along with moderate genetic advance was observed for pH (66.08% and 6.62%) indicating that these traits are less amenable for selection, which may be attributed to both non-additive and additive gene effects and these traits can be improved through hybridization and use of hybrid vigour (Singhetal, 2005)

4.3 Character Association

Association analysis of different quality characters with moisture of tomato fruit and their interrelationships were investigated through the study of both phenotypic and genotypic correlation coefficients. Seven quality characters were recorded and their phenotypic and genotypic correlation coefficients were analyzed (Table 8 and Table 9 respectively and Figure 9).

Phenotypic and genotypic correlation co-efficients, in general, agreed very closely. However, the genotypic correlations were higher than phenotypic correlations in most of the cases. These could occur when the genes governing

Table 8. Phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype.

	p^H	**Brix (%)**	**Dry matter content (g/100g)**	**Vitamin C (mg/100g)**	**Lycopene (mg/100g) at 472 nm**	**Lycopene (mg/100g) at 502 nm**	**Moisture (%)**
p^H	1						
Brix (%)	-0.284	1					
Dry matter content(g/100g)	0.176	0.031	1				
Vitamin C (mg/100g)	-0.138	**0.763****	0.383*	1			
Lycopene (mg/100g) at 472 nm	-0.240	**0.570****	-0.372*	0.245	1		
Lycopene (mg/100g) at 502 nm	-0.239	**0.554****	-0.358	0.264	**0.990****	1	
Moisture (%)	0.176	-0.031	-0.650**	0.383*	0.372*	0.358	1

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

Table 9. Genotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotype.

	p^H	**Brix (%)**	**Dry matter content(g/100g)**	**Vitamin C (mg/100g)**	**Lycopene (mg/100g) at 472 nm**	**Lycopene (mg/100g) at 502 nm**	**Moisture (%)**
p^H	1						
Brix (%)	-0.34	1					
Dry matter content (g/100g)	0.251	0.028	1				
Vitamin C (mg/100g)	-0.168	0.766**	0.386*	1			
Lycopene (mg/100g) at 472 nm	-0.295	0.571**	-0.374*	0.245	1		
Lycopene (mg/100g) at 502 nm	-0.291	0.555**	-0.360	0.264	0.990**	1	
Moisture (%)	0.251	-0.028	-0.990**	0.386*	0.374*	0.360	1

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

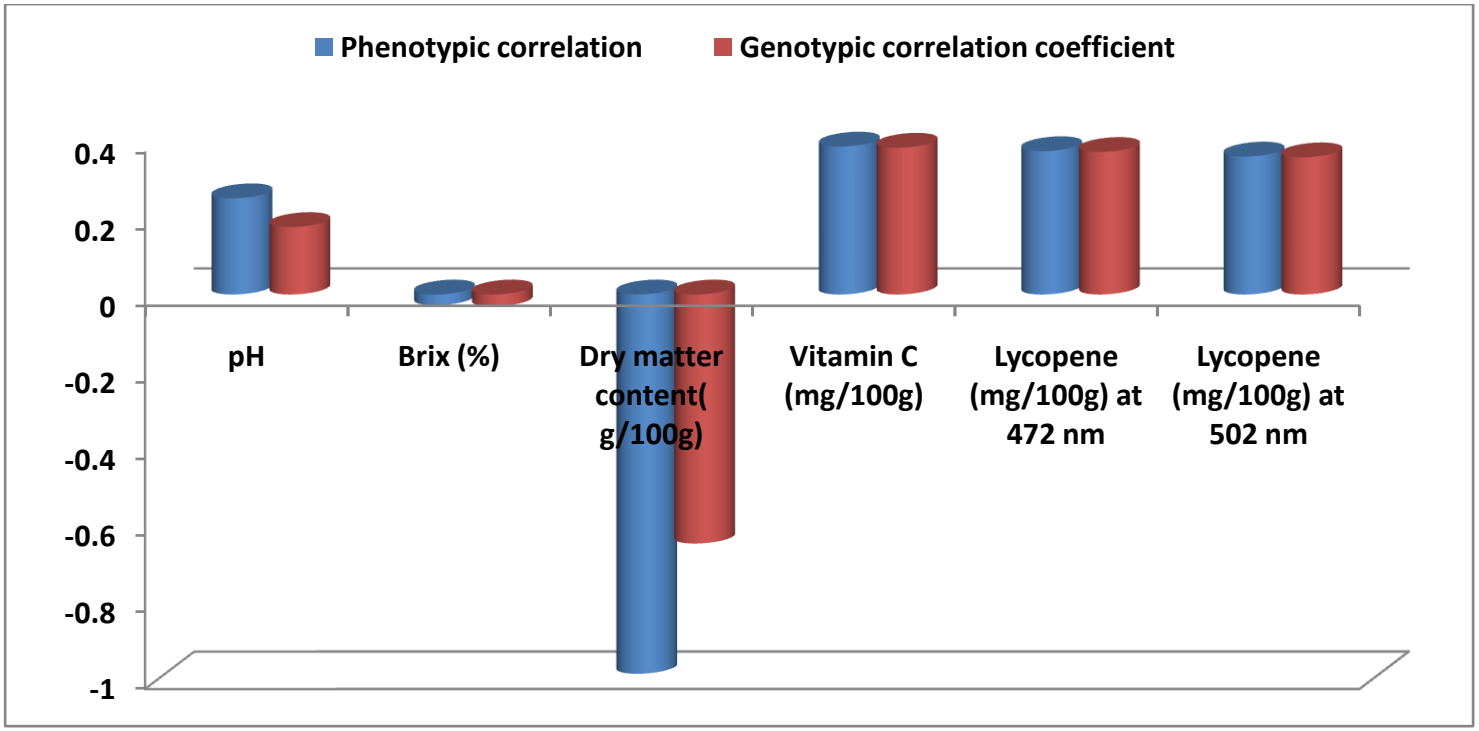

Figure 10. Genotypic and Phenotypic Correlation Coefficient of ten characters with moisture.

two traits were similar and environmental factors played a small part in the expression of these traits.

4.3.1 Phenotypic correlation

Phenotypic correlation among seven characters were computed and presented in the Table 8 and described below.

A high positive significant correlation of brix (r=0.763**) with vitamin C and lycopene at 472 nm (r = 0.570**) and lycopene at 502 nm(r=0.554**) and lycopene at 472 nm (r = 0.990**) with lycopene at 502 nm at 1% level of significant, suggested that more brix along with high lycopene and vitamin C would be an appropriate selection criterion to get high quality fruit of tomato (Table 8). Lycopene content was positively and significantly correlated with moisture (r = 0.372*). Dry matter content significant and negatively correlated with moisture (r = -0.650**) and lycopene at 472 nm (r = -0.372*). Brix had positively significant association with vitamin C (r = 0.763**), lycopene at 472 nm (r = 0.570**) and lycopene at 502 nm (r = 0.554**). This implies that lycopene and vitamin C increases with increasing of brix indicating that simultaneous selection of such traits are possible. Vitamin C had positively significant correlation with moisture (r = 0.383*).

The significant positive association of any character with the other character suggests that increase in any of these traits may results in increase in other trait.

4.3.2 Genotypic correlation

Genotypic correlations among seven characters were computed and presented in Table 9 and described below. The genotypic correlation coefficient revealed positive and significant association of brix with vitamin C (r = 0.766**), lycopene at 472 nm (r = 0.571**) and lycopene at 502 nm (r = 0.555**), whereas, it had negative significant correlation with moisture (r = -0.028). In the present study dry matter content had positive significant correlation with vitamin C (r = 0.386*) and negative significant correlation with moisture (r = -0.990**) and lycopene at 472 nm (r = -0.374*). From this result positive and significant correlation of vitamin C with moisture (r = 0.386*) indicating that

moisture will increase with increasing of vitamin C. Lycopene at 472 nm showed positive and significant association with moisture (r =0.374*). This indicates that if moisture content will increase the vitamin C and lycopene will increase as same degree because they were positively associated with moisture percentage.

4.4 Path Coefficient Analysis

The correlation values decide only the nature and degree of association existing between pair of characters. Yield is dependent on several mutually associated component characters and hence change in any one of the components is likely to affect the whole network of cause and effect. This in turn might affect the true association of component characters both in magnitude, direction and tend to vitiate the association of yield and yield attributes. Hence, it is necessary to partition the correlation of component characters into direct and indirect effects through components (Table 10).

Path analysis of direct and indirect effects revealed that lycopene at 472 nm (0.839) and brix (0.033) exerted direct positive effect on moisture percentage whereas the direct effect of p^H (-0.321), dry matter content (-0.143), vitamin C (-0.298) and lycopene at 502 nm (-0.828) were negative direct effect on moisture percentage (Table 10). Lycopene at 472 nm exerted the highest positive direct effect (0.839) on moisture percentage and exerted positive indirect effect through brix (0.018), dry matter content (0.021) and vitamin C (0.124). The residual (0.241) indicated that characters which included in these genotypic path analysis explained (99.75%) of the total variation in moisture or all other characters which are not included in this study have negative direct effect on moisture. The higher positive direct effect was observed in lycopene at 472 nm, thus lycopene at 472 nm can be used as either direct or indirect selection criteria to improve moisture percentage and other traits those are positively associated with it. Selecting plants with higher lycopene value of fruits will increase other associated qualitative traits specially fruit moisture.

Table 10. Partitioning of genotypic correlations into direct (bold) and indirect effects of seven important characters by path analysis

Characters	p^H	Brix (%)	Dry matter content (g/100g)	Vitamin C (mg/100g)	Lycopene (mg/100g) at 472 nm	Lycopene (mg/100g) at 502 nm	Genotypic correlation with moisture (%)
p^H	**-0.321**	0.018	0.079	0.136	0.626	-0.122	0.251
Brix (%)	-0.316	**0.033**	0.029	0.138	0.743	-0.129	-0.028
Dry matter content (g/100g)	0.184	-0.054	**-0.143**	-0.113	-0.523	-0.412	-0.990**
Vitamin C (mg/100g)	0.186	-0.061	-0.045	**-0.298**	-0.558	0.250	0.386*
Lycopene (mg/100g) at 472 nm	-0.224	0.066	0.021	0.124	**0.839**	-0.253	0.374*
Lycopene (mg/100g) at 502 nm	-0.058	0.019	-0.094	0.028	0.263	**-0.828**	0.360

Residual effect: **0.241**** = Significant at 1%. * = Significant at 5%.

CHAPTER V

SUMMARY AND CONCLUSION

The present study was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka-1207, Bangladesh with ten genotypes of tomato *(Solanum lycopersicum* L.) during October 2015 to April 2016. Seeds were sown in seed bed on 24 October, 2015 then transferred to the main field 0n 15 November, 2015 in Randomized Complete Block Design (RCBD) with three replications and harvesting was done on March 2, 2016 which was completed 26 April, 2016.Then quality traits were observed to study genetic variability in tomato. Ten tomato genotypes were used for the variability and correlation and path analysis. The experimental data was subjected to statistical analysis for elucidating the information on genetic variation existing for different component characters of quality trait. The genetic variability was assessed using the parameters like genotypic (GV) and phenotypic (PV) variance. Genotypic coefficient variation (GCV) and phenotypic coefficient of variation (PCV), heritability and genetic advance over mean (GAM) were studied. The inter character correlation and path coefficient analysis were also carried out to know the relationship among various quality. Analysis of variance indicated highly significant difference among all the accessions for all characters under study.

The maximum p^H was observed in genotype G1 (5.20) and the lowest p^H found in the genotype G8 (4.50). Maximum vitamin C (46.15 mg/100g) was found in G7 whereas minimum (3.60 mg/100g) from G3.The maximum dry matter content was observed by the genotype G2 (2.37 g) and minimum in G9 (0.23 g).Maximum brix (6.40%) was found in G7whereas minimum (2.10%) from G1, G4 and G9.The genotype G7 recorded maximum lycopene content of the fruit (126.20 mg) followed by the genotypes G5 (107.40 mg) in case of 472 nm, while the minimum was observed by the genotype G2 (4.90 mg) in case of 472 nm. In case of 502 nm highest lycopene content of fruit was observed in genotype G7 (89.70 mg) and the lowest was observed in the genotype G2 (2.10

mg). Maximum moisture percentage was found by the genotype G9 (95.33%) and the minimum was observed from the genotype G2 (52.67%).

Phenotypic coefficient of variation values was higher than their corresponding genotypic coefficient variation values in all of the characters. The highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were 109.55 and 110.23 respectively both of which were recorded for dry matter content (g/100g). Higher genotypic coefficients of variations were recorded for Vitamin C (76.33%), dry matter content (109.55%), brix (40.14%), lycopene at 472 nm (80.95%) and lycopene at 502 nm (87.52%). The highest phenotypic coefficient of variation value recorded for Vitamin C (76.35%), dry matter content (110.23%), brix (40.23%), lycopene at 472 nm (80.95%) and lycopene at 502 nm (87.53%). The proportion of GCV in PCV observed in this study ranged from 81% in pH to 100% in Vitamin C (mg/100g), brix, lycopene at 472 nm and lycopene at 502 nm. The traits with high proportion of GCV in PCV are reliable for selection in quality genetic improvement of tomato genotypes. Broad sense heritability ranged from 66.08% (pH) to 98.97 % (lycopene at 502 nm). The present study revealed high heritability coupled with high expected genetic advance as percent of means were observed in case of p^H (66.08% and 6.62%), vitamin C (97.95% and 157.19%), dry matter content (98.78% and 224.30%), brix (98.54% and 82.49%), lycopene at 472 nm (97.00% and 166.75%) and lycopene at 502 nm (98.97% and 180.26%) respectively indicating good response to selection for these characters.

In the phenotypic correlation coefficient, A high positive significant correlation of brix ($r=0.763^{**}$) with vitamin C and lycopene at 472 nm ($r = 0.570^{**}$) and lycopene at 502 nm($r=0.554^{**}$) and lycopene at 472 nm ($r = 0.990^{**}$) with lycopene at 502 nm. Lycopene content was positively and significantly correlated with moisture (r = 0.372*). Dry matter content significant and negatively correlated with moisture ($r = -0.650^{**}$) and lycopene at 472 nm (r = -0.372*). Brix had positively significant association with vitamin C (r =

0.763**), lycopene at 472 nm (r = 0.570**) and lycopene at 502 nm(r = 0.554**). This implies that lycopene and vitamin C increases with increasing of brix indicating that simultaneous selection of such traits are possible. Vitamin C had positively significant correlation with moisture (r = 0.383*).

The genotypic correlation coefficient revealed positive and significant association of brix with vitamin C (r = 0.766**), lycopene at 472 nm (r = 0.571**) and lycopene at 502 nm (r = 0.555**) whereas, it had negative significant correlation with moisture (r = -0.028). In the present study dry matter content had positive significant correlation with vitamin C (r = 0.386*) and negative significant correlation with moisture (r = -0.990**) and lycopene at 472 nm (r = -0.374*). Positive and significant correlation of vitamin C with moisture (r = 0.386*).

Path analysis of direct and indirect effects revealed that lycopene at 472 nm (0.839) and brix (0.033) exerted direct positive effect on moisture percentage whereas the direct effect of p^H (-0.321), dry matter content (-0.143), vitamin C (-0.298) and lycopene at 502 nm (-0.828) were negative direct effect on moisture percentage.

Tomato is the second popular vegetable in our country. The nutritional value is very high in tomato as raw or cooked food. Vitamin-A and vitamin-B, vitamin-C and lycopene are available in tomato which serves as antioxidant in human body and prevent cancer and cardiovascular disease. By producing quality tomatoes based on their nutrition and medicinal value, it will be possible to fulfill nutritional, food security and economic demand of Bangladesh. The result of the analysis of variance indicated that mean square due to accession of all traits were highly significant. The major qualitative traits of tomato was observed vitamin C, lycopene and dry matter content. Considering the quality performance of tomato genotypes, G7(SAU Tomato-2) could be selected for high vitamin C content, high lycopene and more brix% in the fruit. But for dry matter content genotype G2(SAU Tomato-1) and for pH genotype G1(SL-001) could be selected.

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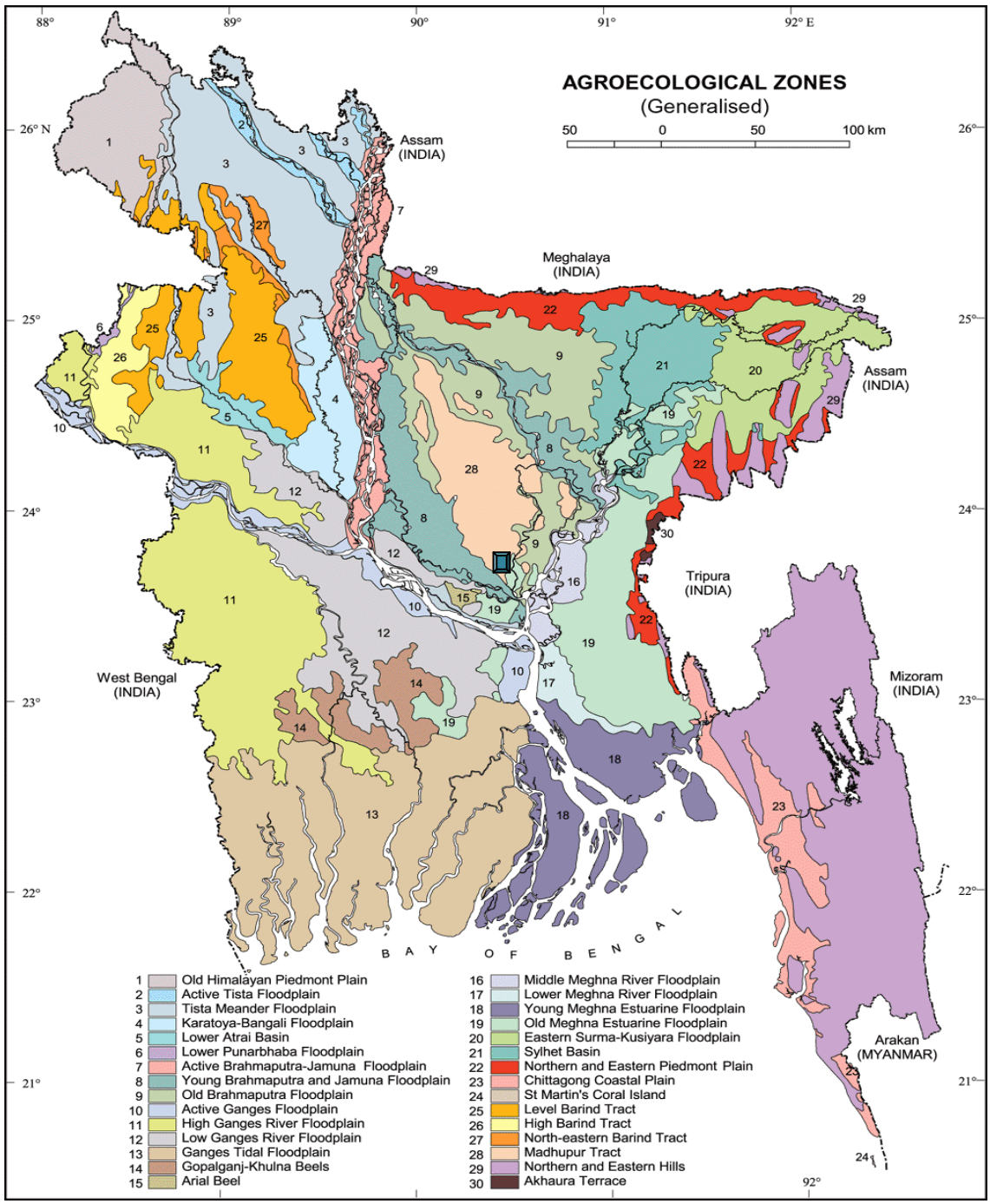
APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from October 2015 to April 2016

Month	Year	Monthly average air temperature (^{o}C)			Average relative humidity (%)	Total rainfall (mm)	Total sunshine (hours)
		Maximum	Minimum	Mean			
Oct	2015	29.36	18.54	23.95	74.80	Trace	218.50
Nov	2015	28.52	16.30	22.41	68.92	Trace	216.50
Dec.	2015	27.19	14.91	21.05	70.05	Trace	212.50
Jan.	2016	25.23	18.20	21.80	74.90	4.0	195.00
Feb.	2016	31.35	19.40	25.33	68.78	3.0	225.50
Mar.	2016	32.22	21.25	26.73	72.92	4.0	235.50
Apr.	2016	33.10	22.20	27.65	75.65	4.0	238.50

Appendix III. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0 - 15 cm depth)

Mechanical composition:

Particle size	Constitution
Sand	40%
Silt	40%
Clay	20%
Texture	Loamy

Chemical composition:

Soil characters	**Value**
Organic matter	1.44 %
Potassium	0.15 meq/100 g soil
Calcium	3.60 meq/100 g soil
Magnesium	1.00 meq/100 g soil
Total nitrogen	0.072
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Iron	262.6 µg/g soil
Manganese	164 µg/g soil
Zinc	3.32 µg/g soil

Appendix IV. Analysis of variance for different characters

Characters	Mean sum of square		
	Replication (r-1) = 2	**Genotype (g-1) = 9**	**Error (r-1)(g-1) = 18**
p^H	0.001	0.126	0.018
Brix (%)	0.019	5.795	0.009
Dry matter content(g/100g)	0.002	1.202	0.005
Vitamin C (mg/100g)	0.027	543.052	0.098
Lycopene (mg/100g) at 472 nm	0.211	5077.642	0.024
Lycopene (mg/100g) at 502 nm	0.088	2883.897	0.306
Moisture (%)	0.933	480.904	1.970

Appendix V. A close view of the research field