ANALYSIS OF GENETIC VARIABILITY AND CHARACTER ASSOCIATION IN F_2 SEGREGATING POPULATION OF TOMATO (*Solanum lycopersicum* L.)

AFSANA HOSSAIN

DEPARTMENT OF GENETICS AND PLANT BREEDING

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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By
AFSANA HOSSAIN
REGISTRATION N0. 15-06840

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Approved by:

Prof. Dr. Naheed Zeba
Supervisor

Prof. Dr. Mohammad Saiful Islam
Co-Supervisor

Assoc. Prof Dr. Shahanaz Parveen
Chairman
Examination Committee

Prof. Dr. Naheed Zeba
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Dhaka-1207, Bangladesh
Phone: +8802-9180921-167 (Office)
Mobile: +88 01913-091772
E-mail: zeban@sau.edu.bd

CERTIFICATE

This is to certify that thesis entitled, "Analysis of genetic variability and character association in F_2 segregating population of tomato (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 AFSANA HOSSAIN, Registration Number15-06840 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, 2022
Place: Dhaka, Bangladesh

Prof. Dr. Naheed Zeba
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

Some commonly used abbreviations

Full word	Abbreviation	Full word	Abbreviation
Abstract	*Abstr.*	Information	*Inf.*
Advances/Advanced	*Adv.*	International	*Intl.*
Agriculture	*Agric.*	Journal	*J.*
Agricultural	*Agril.*	Kilogram	Kg
Agronomy	*Agron.*	Limited	*Ltd.*
And others	*et al.*	Ministry	*Min.*
Analysis of Variance	ANOVA	Muriate of Potash	MP
Applied	*Appl.*	Negative logarithm of hydrogen ion concentration (-log [H^+])	pH
Archives	*Arch.*		
Bangladesh Bareau of Statistics	BBS		
Biology	*Biol.*	Non-significant	^{ns}
Botany	*Bot.*	Mid parent	MP
Better parent	BP	Parts per million	ppm
Breeding	*Breed.*	Percentage	%
Centimeter	Cm	Proceedings	*Proc.*
Coefficient of variation	CV	Programme	*Prog.*
Cross between two dissimilar parents	X	Randomized Complete Block Design	RCBD
		Replication	*Rep.*
Degree Celsius	°C		
Ecology	*Ecol.*	Research	*Res.*
Economic	*Econ.*	Review	*Rev.*
Environment	*Environ.*	Science	*Sci.*
Etcetera	etc.	Serial	Sl.
Experimental	*Expt.*	Society	*Soc.*
Food and Agricultural Organization	FAO	Specific combining ability	SCA
Gazette	*Gaz.*	That is	*i.e.*
General	*Gen.*	The second generation of a cross between two dissimilar parents	F_2
General combining ability (GCA)	GCA		
		Triple Super Phosphate	TSP
Genetics	*Genet.*		
Gram	G	University	*Uni.*
Heredity	*Hered.*	Variety	*var.*
Horticulture Horticultural	*Hort.*	Vegetable	*Veg.*
		Videlicet (namely)	*viz.*
Incorporated	*Inc.*	Weight	wt.

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The Author

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ABSTRACT

An experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from September 2021 to February 2022 using twenty-eight genotypes of tomatoes (*Solanum lycopersicum* L.) to analyze the genetic variability and character association in F_2 population of tomato in a randomized complete block design with three replications. The analysis of variance revealed significant differences for various traits among the genotypes. For all of the characters, phenotypic variance was greater than the genotypic variance. The GCV values were lower than that of PCV values, indicating that the environment had an important role on the expression genes controlling these characters. The number of cluster per plant (35.033), number of fruits per cluster (47.347), number of fruits per plant (81.5), fruit diameter (41.008), single fruit weight (66.156), total soluble solid (53.131) and yield per plant (41.691) all had high genotypic co-efficient of variation (GCV). It indicated that selection may be effective based on these characters. High heritability with high genetic advance in percent of mean was observed in number of fruits per cluster (73.667 and 83.714 respectively), number of fruits per plant (85.669 and 89.897 respectively), fruit diameter (93.326 and 81.609 respectively), single fruit weight (96.603 and 79.649 respectively) and total soluble solid (72.553 and 93.227 respectively) indicating the most suitable condition for selection. It also indicates the presence of additive genes in these traits and reliable crop improvement through selection of such traits is possible. High heritability with low genetic advance in percent of mean was observed in plant height (87.719 and 30.99 respectively), days to 1^{st} fruiting (81.845 and 26.508 respectively), fruit length (88.531and 57.068 respectively) and shelf life (81.168 and 44.243, respectively) suggesting non-additive gene action for the expressions of these characters. The result revealed a highly significant positive correlation with days to 1^{st} fruiting (rg = 0.224, rp = 0.227), number of branches per plant (rg = 0.422, rp = 0.498), number of cluster per plant (rg = 0.231,rp = 0.244), number of flowers per plant (rg = 0.242,rp = 0.366), number of fruits per plant (rg = 0.418,rp = 0.447), fruit diameter (rg = 0.553,rp = 0.367), single fruit weight (rg = 0.734,rp = 0.524) and total soluble solid (rg = 0.332,rp = 0.266) indicating that a possible increase in these traits tends to increase in fruit yield per plant. In path analysis data on various parameters *viz*. plant height (0.183), days to 1^{st} flowering (0.764), days to maturity (0.305), number of cluster per plant (0.892), number of flowers per cluster (0.684), number of fruits per cluster (0.936), fruit length (0.753), fruit diameter (0.575), single fruit weight (0.75) and total soluble solid (0.178) had revealed positive direct effect on yield. Among these, number of cluster per plant, number of fruits per cluster, number of fruits per plant, fruit diameter, single fruit weight and total soluble solid had also significant positive correlation with yield per plant at genotypic level, indicating direct selection may be executed considering these traits as the main selection criteria to reduce indirect effect of the other characters during the development of high yielding tomato variety. Therefore, considering the agronomic and genetic performance the $G_1 \times G_4$ genotype for high yield, and $G_9 \times G_{10}$ genotype for short durated ripen fruits might be suggested for further selection in next generation.

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CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to the family Solanaceae and is normally a self-pollinated annual crop. Tomato is a universally known vegetable and is one of the widest grown vegetables in the world and ranked third in respect of vegetable production in the world next to potato and sweet potato (Yasmin *et al*., 2022). According to FAO (2022) 180.76 million tons of fresh and processed tomatoes were produced worldwide in 2021. Among the vegetables tomato is important for vitamin A, C and minerals (Collins *et al*., 2022). Nutritive elements are almost double compared to apple which proved superiority in regard to food values (Ibrahim *et al*., 2017). Due to its phytonutrients mainly antioxidant elements such as lycopene and β carotene, it prevents cancer and many human diseases (Islam *et al*., 2021). It occupies an area of 0.15 million hectares with annual production of about 0.45 million tons in Bangladesh (BBS, 2021). Although the total cultivated area and production of tomato in our country have been increased gradually over the last few years, the productivity is still very low (9.4 t ha^{-1}) compared to the average yield (26.29 t ha^{-1}) of the world (Mazed *et al*., 2015).

The present demand of tomato is based on the industrial requirement and consumer's preference (Jurkenbeck *et al*., 2019). So, there is an immediate need for further improvement in this crop through development of superior varieties/hybrids to meet the present day requirements. Now-a-days, cultivation of tomato is the focus of large horticultural industry in the world, economically exploited under controlled environmental conditions. In many countries, it is considered as poor man's orange because of its attractive appearance and nutritive value (Sadique *et al*., 2021). Considering the importance and scope of this crop, there is a need to develop tomato varieties suitable to specific agro ecological conditions and also for specific traits.

The estimates of different genetic parameters and the association of different characters are important for better understanding of the nature and the magnitude of genetic variability present in the breeding material. Information on genetic diversity among available genotypes is essential for development of promising variety (Pandey and Siraree, 2019). Nature and magnitude of total phenotypic variability and heritability for any quantitative and qualitative characters under improvement is of utmost importance to the breeder to proceed toward fruitful hybridization programme. Yield improvement would be facilitated only when genetic diversity exists in the material chosen for improvement (Swarup *et al*., 2020).

The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and the environment, in which it is growing (Potts and Hunter, 2021). Further, the genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance and include dominance and epistasis (non-allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic advance. Further, genetic advance can be used to predict the efficiency of selection. Hence, there above said parameters will give the information regarding the availability of genetic variability for different characters in germplasm.

The yield is a complex character being influenced by various component factors. Acknowledge of inter-relationship among these factors is necessary for indirect selection of higher fruit yielding genotype by giving appropriate emphasis for each of these characters. Such information can be obtained by correlation studies along with path coefficient analysis, which gives the cause and effective relationship between different pairs of variables. The path analysis also specifies the relative importance of direct influence of one variable upon another, besides portioning of the correlation coefficient into direct and indirect effects (Ashebr *et al*., 2020). Selection directly based on the performance of fruit yield may not be very effective but selection based on its component characters would prove more effective as reported in other plants (Labroo *et al*., 2021). In this context, Wright (1921) proposed concept of path coefficient analysis as an important tool in partitioning the correlation coefficient into direct and indirect effects which will be useful to the breeders in identifying important biometrical characters to achieve desirable goals.

Commercial F_1 hybrids are common in tomato and selection of new parents for higher heterosis is a continuous process. Generally diverse plants are expected to give high hybrid vigour (Avdikos *et al*., 2021). Hence, it necessitates the study of genetic divergence among the existing varieties and germplasm collection for identification of parents for hybridization programme. The information on genetic divergence of various traits particularly of those that contribute to yield and quality would be of most useful in planning the breeding programme. Such studies are also useful in selection of parents for hybridization to recover superior transgressive segregants and it can further result into release of improved open pollinated varieties for commercial cultivation.

Therefore, the present investigation have been undertaken with the following objectives-

i. to estimate the extent of genetic variability, heritability and genetic advance for fruit yield and other attributes,

ii. to investigate the amount and nature of association among different characters with fruit yield through correlation analysis and

iii. to workout path coefficient analysis for assessing the relative contribution of each yield component towards fruit yield, through their direct and indirect effects.

CHAPTER II
REVIEW OF LITERATURE

The breeding in vegetable is primarily concerned with the improvement of both qualitative and quantitative plant characters thus, complete knowledge of genetics is very much essential in formulating a vegetable breeding programme for obtaining desired results. The success of vegetable breeding depends on the extent and the magnitude of variability existing in the germplasm. Hence, genetic variability in relation to fruit yield and its attributes should be the main concern. Several earlier workers have carried out a number of studies on genetic variability, character correlation and path analysis in tomato. Keeping in view the objectives of the present investigation, such information reported by earlier workers has been reviewed, under following heads:

2.1 Genetic variability, heritability and genetic advance

2.2 Correlation coefficient

2.3 Path coefficient analysis

2.1 Genetic variability, heritability and genetic advance

Kumari *et al.* (2020) evaluated twenty-five tomato genotypes in 2018-19 at Vegetable Research Farm, Bihar Agricultural University, Bhagalpur (Bihar). They assessed the different variability parameters for important growth, morphological as well as yield, quality attributes. They concluded that the attributes viz. polar diameter, pericarp thickness, fruit weight, equatorial diameter, total fruit yield, per plant yield exhibited higher GCV and PCV estimates and higher heritability with genetic gain was reported for pericarp thickness, plant height, fruit weight, fruits per truss, TSS, fruits per plant and lycopene content.

Bindal *et al*. (2019) conducted an experiment to studied genetic and phenotypic variability in twenty seven tomato genotypes and revealed that the traits fruits per plant, yield per plant, weight of fruit and fruit cluster per plant showed highest PCV and GCV. Number of fruits per plant, fruit cluster per plant, plant height, yield per plant, fruit weight, fruit shape index and days to 50% flowering noted high heritability with genetic gain. Again Gillani *et al.* (2019) noted high heritability with genetic gain in tomato for some characters like cluster per plant, plant height, weight of fruit, protein content and vitamin-C.

Saravanan *et al.* (2019) studied variability, heritability and genetic advance for eighteen genotypes of tomato. Fruit yield per plant, locules per fruit and number of fruits per plant showed highest GCV, PCV and genetic advance. Similarly, Bajpai *et al.* (2018) revealed that highest GCV and PCV for locules per fruit and plant height, primary branches per plant, fruits per plant and fruit circumference exhibited higher heritability coupled with genetic advance.

Pandey *et al.* (2018) carried out an experiment at Nana Ji Deshmukh Agriculture Farm, Satna (M.P.) to analyzed variability, heritability along with genetic gain in thirty tomato genotypes. The result obtained that most of the characters investigated in present study showed high GCV and PCV estimates. Various attributes like fruit weight, plant height, fruit yield, days taken to maturity recorded high heritability and genetic gain. Kaushal *et al*. (2017) reported that, higher phenotypic and genotypic coefficients of variation (PCV and GCV) for average fruit weight and number of fruits per plant in tomato. They also reported that high heritability coupled with high genetic advance as per cent of mean were estimated for days required to 1st fruiting, average fruit weight, number of fruits per plant, percentage acidity, pericarp thickness and number of locules per fruit.

Singh *et al*. (2017) evaluated thirty-five genotypes of tomato for yield and yield attributing characters. He recorded high magnitude of phenotypic as well as genotypic coefficients of variation were observed in case of fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant. Days to 50 per cent flowering exhibited low level of variability. High heritability coupled with high genetic advance were estimated for all the traits except days to 50 per cent flowering indicating opportunity for selection response.

Somraj *et al.* (2017) studied genetic variability on twenty genotypes of tomato and revealed that the characters like primary branches per plant, average weight of fruit, number of clusters per plant, fruits per plant, yield per plant, plant height, fruit length and chlorophyll content showed high GCV and PCV.

Rai *et al.* (2016) studied coefficient of variation analysis which indicated that the magnitude of the PCV was slightly higher than the GCV for yield and quality traits. They revealed that high estimate of heritability and genetic advance in tomato for weight of fruit, fruits per plant, fruit yield per plant, lycopene content and locular wall thickness.

Hasan *et al.* (2016) investigated thirty tomato genotypes to study genetic variability for yield and quality traits. High heritability coupled with high genetic advance was recorded in characters like individual fruit weight and fruits per plant. High heritability but low genetic gain was noted for fruit cluster per plant, primary branches, total soluble solid, fruit diameter and ascorbic acid content.

Basavaraj *et al.* (2015) reported that genotypic coefficient of variation and phenotypic coefficient of variation were highest for yield per hectare, whereas days to first flowering showed the lowest ones. Highest heritability was observed for the character yield per hectare, whereas, the plant height showed least heritability. Phom *et al.* (2015) noted the highest PCV and GCV for number of fruits, per plant yield, fresh weight, vitamin C and number of branches in thirteen diverse tomato genotypes.

Prajapati *et al.* (2015) analyzed thirty nine genotypes of tomato and obtained high GCV and PCV for number of seeds per fruit and weight of fruit, while the lowest result was recorded for days to 50% fruit setting and highest heritability were noted for secondary branches and weight of fruit.

Taiana *et al*. (2015) evaluated a total 21 genotypes of tomato for variation. All the genotypes varied significantly with each other for all the characters studied which indicated the presence of inherent genetic variations among the genotypes. The phenotypic coefficient of variation were slightly higher than the respective genotypic coefficient of variation for all the characters under study indicating that the characters were less influenced by the environment.

Kathayat *et al*. (2015) studied genetic variability for 17 quantitative characters and revealed significant differences among the tomato genotypes for all the characters. High genotypic and phenotypic coefficient of variation was observed for number of fruit clusters per plant (49.84 and 51.16%, respectively) and lowest for days to first fruit picking (1.51 and 1.41% respectively).

Zhou *et al*. (2015) used morphological traits to assess the genetic diversity of 29 cultivated tomatoes, 14 wild tomatoes and seven introgression lines. Number of fruits per plant, average fruit weight, fruit length, plant height, fruit diameter and fruit width showed high heritability with high genetic gain.

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

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

Meitei *et al*. (2014) carried out an investigation to study the genetic variability for yield and yield attributes and to screen genotypes for resistance to early blight disease of tomato (*Solanum lycopersicum* L.). The pooled analysis of variance revealed significant variation among the genotypes studied for all the characters except primary branches plant. The genotype H-24 was found to be the best among the genotypes for yield (1309.50g plant) and fruit cluster plant(37.33) and ultimately resulted in highest yield/ha (401.64q). The genotype 2012/TOLCVRES-3 had significantly highest for single fruit weight (71.33g). Another genotype, NDT-3 was the best for fruit diameter (6.47cm). Sel.-35 had more fruits and fruit clusters plant. High GCV were observed for fruit cluster and fruits plant, single fruit weight, fruit
yield plant and fruit yield per ha.

Mukul *et al*. (2014) carried out an investigation to studied variability among 16 yield traits including yield on 30 genotype of tomato (15 exotic and 15 indigenous). Genotypic coefficient of variation played a major role for the expression of the traits and ranged from 9.35 (days to 50% flowering) to 42.02 (fruit yield per plant). Heritability in broad sense ranged from 66.00 (primary branches) to 90.10 (fruit per plant). High genetic advance was observed for Fruit yield per plant (81.95) coupled with high heritability (89.60).

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

Kumar *et al.* (2013) evaluated 26 genotypes of tomato for yield and yield contributing characters. The analysis of variance revealed highly significant differences among all genotypes for the characters. High phenotypic coefficient of variability (PCV), genotypic coefficient of variability (GCV) and heritability estimates coupled with high genetic gain were recorded for plant height, number of fruits per plant, yield per plant and fruit weight.

Patel *et al.* (2013) observed significant variation for all the characters studied except pericarp thickness and number of locules. Highest genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for fruit yield per plant and number of locules were observed while, lowest GCV was noticed for days to first harvest, days to 50 per cent flowering and pericarp thickness and low PCV for days to first harvest and days to 50 per cent flowering. High heritability with high genetic advance as per cent of mean was observed for fruit yield per plant and average fruit weight which could be improved by simple selection.

Ojo *et al*. (2013) studied 4 varieties of tomato with the objective of evaluating the performance of tomato varieties in the Southern Guinea Savanna ecology of Nigeria. Highly significant variety effect was observed for all the traits (days to flowering, fruit length, fruit diameter, number of fruits per plant, weight of fruits per plant and fruit yield) studied, indicating that the varieties evaluated are genetically diverse.

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

Buckseth *et al*. (2012) noted high genotypic coefficients variation for number of fruits per plant, average fruit weight and yield per plant, pericarp thickness and thousand seed weight in tomato.

Kumar *et al*. (2012) studied genetic variability in different genotypes of tomato and reported significant difference among the genotypes. The magnitude of genotypic and phenotypic coefficient of variation was higher for number of fruits per cluster and lycopene content. High values of heritability (broad sense) were observed for plant height, fruits per cluster, total soluble solids and lycopene content. High genetic advance was observed for plant height and average fruit weight.

Manna and Paul (2012) reported high and moderate to high genotypic coefficient of variation and phenotypic coefficient of variation in tomato for number of locules per fruit, fruit weight, total acid (%), number of fruits per plant, vitamin C (mg /100g), fruit yield per plant, fruit length and pericarp thickness.

Mohamed *et al*. (2012) noted that fruit weight showed the highest genotypic and phenotypic variance whereas fruit yield per plant showed the lowest in tomato. High genotypic variance was observed for most of the characters indicating more contribution of genetic component for the total variation. Genotypic coefficients of variations (GCV) and phenotypic coefficient of variation (PCV) were highest for fruit weight whereas the lowest ones were for days to 50% flowering. Higher GCV and PVC were recorded for most of the characters indicating higher magnitude of variability for these characters.

Rahaman *et al*. (2012) observed that phenotypic and genotypic coefficients of variation were high for fruit weight followed by fruit length, lowest for number of flowers per cluster and total acid (%). Moderate values (20 – 30%) of phenotypic and genotypic coefficients of variation were recorded for fruits per plant in tomato, while other characters displayed less than 20 per cent. Moderate to low estimates of phenotypic coefficients of variation was recorded against plant height, primary branches per plant, fruits per plant and yield per plant. However, days to first flowering, flowers per cluster, fruits per plant, fruit yield and average fruit weight recorded lower genotypic coefficients of variation values compared to their respective phenotypic coefficients of variation values. The estimates of phenotypic coefficients of variation and genotypic coefficients of variation values were close for days to 50per cent flowering, days to full flowering, number of primary and secondary branches, plant height of all the fruit and quality characters except average fruit weight.

Sahanur *et al.* (2012) evaluated 34 genotypes of tomato for genetic parameters, viz. variability, heritability and genetic advance and observed high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for fruit weight followed by fruit length and lowest for number of flowers per cluster and total acid. Moderate value of PCV and GCV were recorded for fruits per plant. Moderate to low estimates of PCV were recorded for plant height, primary branches per plant, fruits per plant and yield per plant. However, days to first flowering, flowers per cluster, fruits per plant, fruit yield and average fruit weight recorded lower GCV values compared to their respective PCV values. The estimates of PCV and GCV values were close for days to 50 per cent flowering, days to full flowering, number of primary and secondary branches, plant height, fruit and quality characters except average fruit weight. High heritability coupled with high genetic advance expressed in percentage of mean was observed for primary and secondary branches, plant height, fruits per plant, fruit length, fruit diameter and fruit weight.

Bernousi *et al*. (2011) studied 25 genotypes of tomato and observed maximum variability for number of fruit per plant and minimum variability for pH and found significant differences for all the characters except for fruit yield, total soluble solids, titratable acidity and number of tillers.

Dar and Sharma (2011) reported high values of phenotypic coefficient of variation for yield quintals per hectare, average fruit weight, number of fruits per plant in tomato whereas high genotypic coefficient of variation for beta-carotene.

Kaushik *et al*. (2011) evaluated ten genotypes of tomato and reported that maximum variation was observed for fruit yield and minimum was observed for fruit width. The magnitude of genotypic and phenotypic coefficient of variation was higher for number of leaves, fruit length (cm) and fruit yield. High values of heritability coupled with high genetic advance were observed for number of leaves at 60 days after transplanting and fruit yield.

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

Taisa *et al.* (2011) studied genetic variability in twenty three tomato genotypes for yield and yield components. Higher values of phenotypic coefficients of variation and genotypic coefficients of variation were observed for fruits per plant, seeds per fruit, flowers per cluster, unmarketable fruit yield per plot, fruit clusters per plant and plant height. Higher heritability estimates were recorded for fruits per plant, days to maturity, nodes on the main stem, flowers per cluster, plant height, shape index, days to flowering, seeds per fruit, fruit diameter and fruit clusters per plant. Higher values of expected genetic advance as per cent of mean was recorded for fruits per plant, seeds per fruit, flowers per cluster, plant height, fruit clusters per plant, nodes on the main stem, shape index, yield per plant and fruit diameter, indicating that selection would be more useful to improve these traits. High heritability values coupled with high genetic advance were observed in respect of seeds per fruit, fruits per plant, plant height and fruit clusters per plant.

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

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

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

Shashikanth *et al*. (2010) observed high genotypic coefficient of variation and phenotypic coefficient of variation for characters like number of branches per plant, number of fruits per plant, fruit yield per plant and number of locules per fruit in tomato indicating higher magnitude of variability for these traits.

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

Anjum *et al*. (2009) observed high values of genotypic coefficient of variability for juice-pulp ratio, fruit yield per plant, number of primary branches per plant, number of fruits per plant, average fruit weight and titrable acidity in tomato.

Rajaguru *et al.* (2009) studied that all traits *i.e*. plant height, flowering duration, number of fruits per plant, single fruit weight, dry matter accumulation and fruit yield per plant in F_2 generation exhibited higher phenotypic coefficient of variation than the genotypic coefficient of variation for tomato indicating environmental influence on the expression of characters.

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

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

Hedau *et al*. (2008) reported higher phenotypic coefficient of variation than genotypic coefficient of variation for pericarp thickness, skin firmness, TSS and other functional and nutritional traits in tomato.

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

Sharma and Thakur (2008) studied that number of fruits per plant and average fruit weight exhibited high genotypic and phenotypic coefficients of variation for tomato.

Golani *et al.* (2007) found high phenotypic and genotypic coefficient of variation with fruit weight, fruit girth, TSS (only at genotypic level), and number of locules per fruit in tomato while low genotypic and phenotypic coefficient of variability with plant height.

Haydar *et al*. (2007) observed that fruit yield had high positive phenotypic coefficient of variation and genotypic coefficient of variation with total number of fruits at harvesting period and number of fruits in three clusters per plant in tomato.

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

Ahmed *et al*. (2006) studied genetic variability, heritability and genetic advance for 14 traits in 60 genotypes of tomato and indicated considerable genetic variability for yield and yield components. High phenotypic (PCV) and genotypic (GCV) variances were observed for yield per plant, plant height, average fruit weight, number of fruits per plant, juice to pulp ratio and average fruit weight. High estimates of heritability were recorded for all characters except fruit pH. High heritability with high genetic advance as percent of mean was observed for juice to pulp ratio, yield per plant, average fruit weight, acidity, number of fruits per plant, fruit length, pericarp thickness, plant height and earliness.

Mahesha *et al.* (2006) observed significant differences among 30 diverse tomato genotypes for all the characters studied. A wide range of variation was observed for plant height, number of branches per plant, fruit weight, fruit length, fruit diameter, number of locules per fruit, fruit set percentage, fruits per plant, fruit yield per plant, ascorbic acid content and total soluble solids. Fruit weight, fruits per plant and plant height exhibited very high heritability values along with high genetic gain.

Singh *et al*. (2006) observed considerable range of genetic variability in 19 genotypes of tomato for yield, yield components and biochemical characters. Maximum genotypic coefficient of variation was recorded for number of leaves per plant, followed by number of clusters per plant. Heritability estimates were high for ascorbic acid content, average weight of fruits, number of leaves per plant, number of locules per fruit, number of fruits per plant, leaf area and dry matter content. High estimates of heritability with high genetic advance was recorded in case of number of leaves per plant, average weight of fruits, number of fruits per plant and plant height, whereas high heritability with low genetic advance was recorded for number of locules per fruit, dry matter content, pericarp thickness and yield per plant.

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

Singh and Cheema (2005) studied the variation and heritability of quality characteristics in tomato raised under normal and high temperature conditions (November and February plantings, respectively). Data were recorded for total soluble solids (TSS), pericarp thickness, fruit firmness, acidity, lycopene content and dry matter content. There were significant differences among the genotypes under normal conditions, whereas differences were not significant under high temperature conditions. The population mean was higher during November than February planting for all the characters except acid content and TSS. In general, the phenotypic coefficients of variation were higher than genotypic coefficients of variation indicating that the genotypic effect is least influenced by the given environment. Heritability estimates (in the broad sense) were high for all the characters for November planting except for lycopene content.

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

Singh and Narayan (2004) studied the genetic variability in 10 diverse genotypes of tomato for yield and yield attributing traits and observed a wide range of variability along with high estimates of genetic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) for plant height, fruit length, number of fruits per plant and number of branches per plant. Moderate to high values of heritability coupled with high GCV and genetic gain were observed for plant height, fruit length, number of fruits per plant, fruit yield and number of branches per plant.

Attree (2003) reported high genotypic and phenotypic coefficients of variation for number of fruits per plant, while moderate coefficient of variation for number of fruits per cluster, pericarp thickness, total soluble solids and low coefficient of variation for average fruit weight, yield per plant in tomato.

Mariame *et al.* (2003) studied genetic variability in 21 genotypes of tomato for fruit yield and other yield contributing characters and reported significant genotypic variation among the genotypes for fruit yield and other yield components in tomato. High heritability estimates coupled with high genetic advance as percent mean were observed for plant height, number of nodes on main stem, number of flowers per cluster, number of fruits per plant and number of seeds per fruit in tomato. The results suggested the existence of high genetic variability among the cultivars for all the characters studied.

Singh *et al*. (2002) evaluated 15 tomato cultivars for genetic variation in yield and quality parameters (days to anthesis, days from fruit setting to mature green stage, days from fruit setting to red ripe stage, average fruit weight, total yield, shelf life of mature green fruits and shelf life of ripe red fruits). Phenotypic and genotypic coefficients of variation were high for average fruit weight, shelf life of ripe red fruits, total yield and marketable yield, but were moderate for days from fruit setting to mature green stage and shelf life of mature green fruits. In all traits, genotypic coefficient of variation was lower than phenotypic coefficient of variation, indicating the role of environment in the expression of these characters. Heritability was high for all characters except days from fruit setting to red ripe stage. The highest genetic advance was predicted for average fruit weight, followed by shelf life of red ripe fruits.

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

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

2.2 Correlation coefficient

Kumar *et al.* (2020) revealed that fruit yield was significantly and positively correlated with fruit diameter, number of fruits per cluster and number of branches per plant at genotypic and phenotypic level.

Yadav *et al.* (2020) conducted an experiment at Acharya Narendra Deva University of Agriculture and Technology, Kumarganj during winter season of 2016-17 to study the association among fifty tomato genotypes for eleven yield attributing parameters. The result revealed that traits viz. number of fruits per plants, equatorial diameter, average fruit weight was positively associated with fruit yield, while, the traits days taken to 50 percent flowering and plant height showed negative association with fruit yield.

Alam and Paul (2019) reported that fruit yield per plant of tomato is positively and significantly correlated with fruit weight, primary branches per plant and number of fruits per plant.

Namdev and Dongre (2018) studied correlation and path coefficient in thirty three genotypes of tomato at Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur. They reported that positive significant association of fruit yield with plant height, number of fruits per plant, yield per hectare and yield per plot. Path coefficient showed that number of fruits per cluster, plant height (60 days after transplanting), days to 50% flowering and fruits per plant and fruit yield per hectare had maximum direct contribution for fruit yield in tomato.

Ashish *et al.* (2017) reported that the yield per hectare displayed positive correlation with periccarp thickness, ascorbic acid content, number of fruits per plant, number of locules per fruit, yield per plant and individual fruit weight.

Kaushal *et al*. (2017) has been studied on crop tomato that the yield per hectare displayed positive correlation with number of fruits per plant, pericarp thickness, number of locules per fruit, average fruit weight and yield per plant.

Naveen *et al.* (2017) studied on 30 genotypes of tomato, for fruit yield and yield attributes. Fruit yield had the positive and significant correlation with plant height, average fruit weight and fruit yield per hectare. It was observed that with an increase in plant height, there was the corresponding increase in average fruit weight and fruit yield per hectare.

Phom *et al.* (2015) used thirteen tomato genotypes to study correlation coefficient for yield and yield attributing characters. They found that crop duration, plant height, number of branches, fresh weight, yield per plant, number of leaves and fruit diameter have strong and positive association with fruit yield per hectare.

Ullah *et al*. (2015) evaluated twenty parental genotypes of tomato for yield and yield attributing traits. Significant positive genotypic and phenotypic correlation was observed for fruits per plant, fruit weight, fruit diameter and number of locules per fruit with fruit yield per plant. Fruit diameter showed the highest positive direct effect (3.25) on fruit yield per plant followed by fruits per plant (1.54).

Iqbal *et al*. (2014) analyzed the data on different morphological and reproductive traits of forty-seven tomato genotypes for correlation to select genotypes and traits for future breeding program. Correlation analysis revealed significant positive association between yield and yield components like fruit diameter, fruit weight and number of fruits per plant.

Meena and Bahadur (2014) determined association studies for yield and yield contributing traits in tomato and revealed that fruit yield per plant showed significantly positive correlation with fruit weight, number of fruits per plant, polar diameter and fruit setting percentage at both genotypic and phenotypic levels, respectively.

Mukul *et al*. (2014) observed that phenotypic correlation coefficient however, in few cases environment factors seem to play a major role to bring down the magnitude of phenotypic correlation coefficient compared to its genotypic contributions. Average fruit weight (0.74), fruits per plant (0.55), equatorial diameter (0.43) fruits per cluster (0.42), locule number (0.39) and cluster per plant (0.36), polar diameter (0.36) and flowers per cluster (0.18) were positively associated with fruit yield at phenotypic level, indicating improvement in these traits will increase the fruit yield in tomato.

Osekita and Ademiluyi (2014) observed highly significant and positive correlation of plant height with number of branches per plant and fruit shape index. However, highly significant and negative correlations were observed in number of fruits per plant, number of clusters per plant and number of fruits per cluster.

Mahapatra *et al.* (2013) found that fruit yield had positive and significant correlation with primary branches per plant, number of flower clusters per plant, plant height, fruit length, number of fruits per plant, fruit width, yield per plant, pericarp thickness, number of lucules per fruit and average fruit weight in tomato.

Patil *et al*. (2013) observed genotypic and phenotypic associations of yield per plant were significantly positive with harvesting duration. Average fruit weight was also positively correlated with yield per plant at genotypic level.

Reddy *et al*. (2013) conducted correlation studies for yield and quality traits on nineteen genotypes of tomato. Yield per plant had exhibited highly significant and positive correlation with fruit width and fruits per plant. Days to last fruit harvesting and self life showed significantly negative association with fruit yield per plant of tomato.

Buchseth *et al.* (2012) reported yield per plant expressed a highly significant positive correlation with pericarp thickness, shelf life, TSS, fruit shape index and number of fruits per plant.

Khan and Samadia (2012) revealed that fruit yield per plant was positively and significantly correlated with pericarp thickness, fruit length, fruit weight and number of fruits per plant indicating mutual association of these traits. Negative correlation of days to flowering and days to fruit harvest on yield per plant suggested indirect selection for earliness for yield improvement.

Narolia *et al*. (2012) reported that fruit yield per plant exhibited significantly positive association with average fruit weight and shelf life. Path analysis confirmed that maximum positive direct effect on fruit yield per plant was exhibited by fruit weight followed by number of fruits per plant.

Sharma and Singh (2012) studied tomato genotypes for twenty one qualitative and quantitative parameters for fruit and seed yield by correlation and path analysis at Pantnagar. This study showed that fruit yield was significantly and positively correlated with days to 50% flowering and weight of fruit. Seed yield per plant and fruit weight non- significantly but positively correlated with fruit yield.

Kaushik *et al.* (2011) analyzed ten tomato genotypes for genetics of yield improving characteristics and noted that fruit yield per hectare is positively associated with plant height, fruit length, number of leaves at 30 and 60 days after transplanting respectively.

Kumar and Dudi (2011) studied that total fruit yield (kg) per plant was correlated significantly and positively with number of fruits per plant, fruit weight and total sugar in tomato. The correlation of yield with most of the quality traits indicated that simultaneous improvement of yield and quality traits was not possible because of negative correlation of yield with such quality traits.

Vyas *et al.* (2011) studied phenotypic and genotypic correlation among twenty tomato genotypes and found that fruit yield showed positive and significant association with fruit weight, fruits per plant, ascorbic acid and reducing sugar at both level of correlation.

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

Islam *et al.* (2010) evaluated thirty nine genotypes of tomato for yield contributing characters and found that yield the number of flowers per plant, fruits per plant, fruit length, weight of fruit and fruit diameter was positively and significantly associated with per plant yield.

Rani *et al.* (2010) correlation studies on twenty three tomato hybrids showed that pericarp thickness, acidity, weight of fruit, lycopene content and ascorbic acid had positive significant association with per plant fruit yield. While fruits per plant showed negative association with per plant fruit yield.

Sharma *et al.* (2010) revealed that genotypic and phenotypic associations of fruit yield were significantly positive with average fruit weight and number of fruits per plant.

Shashikanth *et al*. (2010) revealed that fruit yield had a positive and highly significant association with number of fruits per plant and number of branches per plant at both genotypic and phenotypic levels.

Anjum *et al.* (2009) noted that the economically important trait fruit yield per plant in tomato exhibited high positive significant correlation with fruit size, plant height, number of fruits per plant and number of primary branches per plant at both phenotypic as well as genotypic levels.

Sengupta *et al*. (2009) revealed that fruit yield per plant had significant positive genotypic and phenotypic correlation with fruit clusters per plant, fruits per plant. Fruits per plant showed the highest positive direct effect on fruit yield per plant followed by individual fruit clusters per plant.

Asati *et al*. (2008) observed high significant and positive correlation of fruit yield with fruit diameter and pericarp thickness, while it was negative with plant height, number of locules per fruit and ascorbic acid in tomato.

Hedau *et al.* (2008) reported that the genotypic correlations were higher than the corresponding phenotypic for few important quality traits indicating inherent relationship among nutritional quality traits in tomato. Both positive and negative correlations were observed among traits under study.

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

Prashanth *et al.* (2008) conducted an experiment on sixty seven tomato genotypes using growth, earliness, quality and yield characters for correlation studies. They concluded that the weight of fruit, volume of fruit, early yield per plant, fruits per plant, equatorial diameter of fruit, polar diameter of fruit, plant height, fruit set percentage, number of seeds per fruit, number of locules per fruit, stem girth at 90 DAT and pericarp thickness was significantly positive correlated with per plant yield. However, flowers per cluster and number of fruits per cluster was showed negative significant association with per plant yield.

Singh *et al*. (2008) reported that fruit yield per plant is positively correlated with plant height, number of branches per plant, number of fruits per plant, average fruit weight, number of locules per fruit. The TSS and ascorbic acid content showed positive correlation while pericarp thickness and acidity are negatively correlated with yield.

Golani *et al.* (2007) evaluated that ten-fruit weight in tomato had significant and positive correlations with fruit length, fruit girth and number of locules per fruit at both levels.

Kumar and Thakur (2007) revealed that fruit weight followed by number of fruits per plant, fruit breadth and number of fruits per cluster had positive correlation with yield per plant. These traits also had highly positive correlation with yield per plant.

Singh *et al.* (2006) studied that per plant yield is positively significantly correlated with branches per plant, fruits per plant, plant height, locules per fruit and fruit weight. Whereas pericarp thickness, acidity percentage showed negatively association with yield.

Mohanty (2003) carried out an experiment on eighteen genotypes of tomato at Orrisa and revealed that the yield is positively and significantly correlated with days to first fruit harvest and fruit per plant. Weight of fruit, plant height and number of branches per plant showed negatively association with yield.

2.3 Path coefficient analysis

Maurya *et al.* (2020) investigated thirty genotypes of tomato during Rabi 2018-19 at Bihar. Path coefficient analysis revealed that plant height at maturity (0.1247), number of days to 50 percent fruit initiation (0.2136), number of fruits per cluster (0.4878), average fruit weight (0.6832), polar diameter of fruit (0.1379), equatorial diameter of fruit (0.6602) and total soluble solid (0.1153) had showed highest positive direct effect on yield per plant. This indicated that these traits play important role in yield improvement.

Alum and Paul (2019) conducted an experiment with twenty nine genotypes of tomato for determining direct and indirect effects of the various yield attributing traits and found that the fruit yield per plant had high direct effect on secondary branches per plant, number of fruits per plant, average fruit weight, days to 50% flowering and number of flower cluster per plant showed positive direct effects on yield per plant. However, primary branches per plant, days to first flowering and plant height had negative direct effects on yield per plant.

Anuradha *et al.* (2018) performed an experiment consisted of forty genotypes of tomato to during Kharif, 2017-18 and reported that the parameters such as number of fruits per plant and average fruit weight exhibited highest positive direct effect on fruit yield and thus these parameters should be considered for selection in yield improvement. Rojalin *et al.* (2018) analyzed that the path coefficient and reported that traits such as number of locules, average fruit weight, fruit set percentage, fruit length, flower cluster per plant, fruits per plant , primary branches per plant, days to fruit set and plant height at final harvest had positive direct effect on marketable fruit yield per plant.

Naveen *et al.* (2017) evaluated thirty genotypes of tomato to study path coefficient analysis of fruit yield and yield attributing traits in tomato during Rabi season 2015-16 at Hyderabad. Path coefficient analysis revealed that number of days to first flowering, number of branches per plant, days to 50% flowering, number of fruits per plant, average fruit weight, acidity, fruit yield per hectare and TSS: Acid ratio exhibited positive direct effects on fruit yield per plant. These characters play a major role in breeding programme and suggested that direct selection based on these traits will be important for crop improvement of tomato.

Rawat *et al.* (2017) analysed path coefficient on fifty nine tomato genotypes and revealed that average fruit weight and the number of fruits per plant had highest positive direct effect on fruit yield. Average fruit weight and number of fruits per plant both are important components that increases fruit yield. Hence these characters may be simultaneously selected for improving fruit yield in tomato. Rajolli *et al.* (2017) path analysis revealed that the number of fruits per plant, plant height, branches per plant, fruit length, average fruit weight, pericarp thickness, number of locules per fruit and ascorbic acid were showed direct positive effect on yield per plant while other parameters like fruit width, days to first anthesis, fruit firmness, total soluble solids and pH were showing direct negative effect.

Kumar and Singh (2016) evaluated 25 tomato genotypes and reported that positive direct effect on fruit yield was imposed by days taken to 50 per cent flowering at phenotypic level. However, at genotypic level, positive direct effect on fruit yield was imposed by plant height.

Thapa *et al*. (2016) conducted an experiment on 38 tomato genotypes and observed that the highest positive direct effects on fruit yield per plant was exhibited by average fruit weight followed by fruits per plant and pericarp thickness.

Nagaria *et al.* (2015) determined path coefficient analysis on twenty genotypes of tomato and revealed that parameters such as average fruit weight, number of flowers per cluster, plant height and days to first fruit set and had showed highest direct values on fruit yield per plant and thus these parameters should be considered for selection in yield improvement.

Prajapati *et al.* (2015b) conducted an experiment on 39 tomato genotypes and observed that average fruit weight had positive direct effect on fruit yield per plant followed by number of fruits per plant.

Rahman *et al.* (2015) carried out an experiment on fourty eight genotypes of tomato to know association and direct effect of yield attributing characters on fruit yield. Path coefficient analysis for yield and yield attributing characters on fruit yield confirmed that the number of fruits per cluster had highest positive direct effect on fruit yield per plant.

Chernet *et al.* (2014) conducted an experiment to evaluate performance of thirty six genotypes of tomato during 2010-11.They concluded that the average fruit weight and number of matured fruits per plant had positive direct effect to fruit yield. Based on these specified traits, direct selection will improve fruit yield, while, polar diameter of fruit and fruit set percentage exerted highest negative direct effect on fruit yield per hectare.

Kapte and Jansirani (2014) analysed path coefficient and revealed that average fruit weight and number of fruits per plant had positive direct effect on yield. Characters viz., fruit diameter, fruit index and fruit shape exhibited negative direct effect on fruit yield per plant. Most of the other characters showed indirect effect via fruit shape index, fruit weight, fruits per plant and fruit diameter. Hence, these characters should be important for selection of high yielding genotypes on any particular agro-climatic region.

Kumar *et al.* (2014) conducted an experiment with fifty genotypes of tomato in randomized complete block design with three replications at UP studies correlation and path coefficient at UP. Fruits per plant, pericarp thickness and fruit diameter were identified as most important traits which contributed considerable positive direct effect on fruit yield per plant. The negative direct effects on fruit yield per plant were exhibited by number of locules per fruit.

Premalakshmi *et al.* (2014) investigated fourteen genotypes of tomato to find out the variability, correlation and path coefficient effects. They revealed that number of fruits per plant had positively significant association and also have positively high direct effect on fruit yield per plant.

Kumar *et al.* (2013) carried out an experiment comprising twenty six genotypes of tomato for evaluating yield and yield attributing characters. Path analysis at genotypic level showed that fruit weight, number of fruits per cluster, fruit diameter and number of fruits per plant had highest positive direct effect on fruit yield. Direct selection on the basis of the parameters like fruit weight, number of fruits per plant, fruit diameter and number of fruits per cluster should be considered for yield improvement in tomato.

Patil *et al.* (2013) in a path coefficient analysis revealed that days to first harvest had the highest positive direct effect on fruit yield followed by pericarp thickness, number of locules, average fruit weight and plant height. It was suggested that characters viz., minimum days to first fruit harvest, pericarp thickness and average fruit weight should be given priority for selecting high yielding genotypes. Sharma *et al.* (2013) in their studies on path coefficient analysis revealed appreciable amount of direct effect of number of marketable fruits per plant, fruit shape index, gross yield per plant and plant height on marketable yield per plant at phenotypic and genotypic levels.

Basavaraj and Mallikarjun (2012) reported that number of branches per plant and number of flowers per cluster had the highest positive direct effect on fruit yield both at genotypic and phenotypic levels.

Sharma and Singh (2012) path analysis studies revealed that fruit weight, flower clusters per plant and number of fruits per plant had maximum direct effect on fruit yield. Thus fruit weight, flower clusters per plant and number of fruits are the most suitable characters for the improvement of tomato genotypes. Narolia *et al.* (2012) conducted an experiment with a set of fifty five tomato genotypes at Rajendranagar, Hyderabad. Correlation and path analysis was done for growth, yield and quality parameters. Path analysis confirmed that the number of fruits per plant and average fruit weight had maximum positive effect on fruit yield per plant.

Islam *et al*. (2010) studied on thirty nine exotic genotypes of tomato for yield associated characters and found that fruits per plant showed highest positive direct effect on fruit yield per plant followed by individual fruit weight. While days to first flowering showed highest negative direct effect on fruit yield per plant. Individual fruit weight and fruits per plant are the characters which showed high direct effect on yield which indicate that direct selection of these characters or trait for improving yield per plant.

Ara *et al.* (2009) analyzed path coefficient on thirty five genotypes of tomato. They revealed that fruit yield had higher positive direct effect on harvesting duration, days to first picking, number of flowers per cluster, fruit weight, plant height and number of fruits per plant.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to analyze the genetic variability and character association in F_2population of tomato crosses. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from September. 2021 to February, 2022 using different genotypes of tomatoes.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted both in the field of Sher-e-Bangla Agricultural University (SAU). The experimental site was geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anonymous, 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Madhupur Tract”, AEZ-28 (Anonymous, 1988 a). 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 hillocks of red soils as ‘islands’ surrounded by floodplain (Anonymous, 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix I.

3.2.3 Soil

The soil texture was silty clay with pH 5.6. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix III.

3.3 Planting materials

For the purposes of the current research, F_2 seeds of 28 cross combinations of tomato were used. The purity and germination percentage were leveled as around 100 and 80 respectively. The F_2 seeds of tomatoes were collected from the Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 (Table 1).

3.4 Seedbed preparation and raising of seedling

On October 24, 2021, the sowing was done in the seedbed. Seeds were mixed with Bavistin (Systemic fungicide) for five minutes prior to sowing. In the farm unit of the Sher-e-Bangla Agricultural University, Dhaka-1207, seedlings of all genotypes were raised in seedbeds. Rows of seeds were sown at a distance of 10 cm apart, and beds were regularly watered. Regular nursery procedures were used to raise the seedlings. Before and after planting the seeds, suggested cultural practices were adopted. The seedlings were transplanted into the main field after 22 days. Raising of seedlings is shown in Plate 1A.

3.5 Design and layout of the experiment

The experiment was laid out in Randomized Complete Block Design (RCBD). The F2 seeds obtained from 28 cross combinations, 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 2021. Land preparation and design and layout is shown in Plate 1(B-C).

Table 1. F_2 seeds from 28 different cross combinations of tomato used in the study

Sl. No.	F_2 seeds from different cross combinations of tomato	F_2 seeds from different cross combinations of tomato with their parental accession no./ variety name	Source of collection
1	G1×G3	SL 020 × SL 022	GEPB. SAU
2	G1×G4	SL 020 × SL 023	
3	G1×G5	SL 020 × SL 024	
4	G1×G6	SL 020 × SL 025	
5	G1×G7	SL 020 × BARI Tomato 16	
6	G1×G8	SL 020 × BARI Tomato 3	
7	G1×G9	SL 020 × BARI Tomato 14	
8	G1×G10	SL 020 × BARI Tomato 11	
9	G2×G3	SL 021 × SL 022	
10	G2×G7	SL 021 × BARI Tomato 16	
11	G2×G10	SL 021 ×BARI Tomato 11	
12	G3×G2	SL 022 × SL 021	
13	G3×G4	SL 022 × SL 023	
14	G3×G5	SL 022 × SL 024	
15	G3×G10	SL 022 × BARI Tomato 11	
16	G4×G1	SL 023 × SL 020	
17	G4×G5	SL 023 × SL 024	
18	G4×G6	SL 023 × SL 025	
19	G4×G7	SL 023 × BARI Tomato 16	
20	G4×G9	SL 023 × BARI Tomato 14	
21	G4×G10	SL 023 × BARI Tomato 11	
22	G5×G10	SL 024 × BARI Tomato 11	
23	G6×G2	SL 025 × SL 021	
24	G7×G10	BARI Tomato 16× BARI Tomato 11	
25	G8×G10	BARI Tomato 3 × BARI Tomato 11	
26	G9×G10	BARI Tomato 14 ×BARI Tomato 11	
27	G10×G2	BARI Tomato 11 × SL 021	
28	G10×G4	BARI Tomato 11 × SL 023	

Here, GEPB,SAU =Department of Genetics and Plant Breeding of Sher-e-Bangla Agricultural University, Dhaka.

3.6 Land preparation

The experiment plot was prepared by multiple ploughing and cross ploughing, followed by laddering and harrowing with a tractor and power tiller to create good tilth. Apply the recommended amount of fertilizers and farmyard manures during the land preparation process (FYM). The experimental plot's weeds and other stubbles were carefully removed and leveled. On November 13, 2021, the final land preparation was completed (Plate 1B).

3.7 Manure and fertilizers application

Before one day of transplanting, one-third of the urea, total TSP Triple Super Phosphate), half of the MoP (Muriate of Potash), total Boric acid, total Zinc, total Ghypsum, and cowdung were used Plate 2A. The remaining Urea and MoP were used between 15 days of transplanting and the first flowering. Table 2 shows the fertilizer and manure dosages.

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

SL.No	Fertilizer/Manure	Doses per ha
1	Urea	550 kg
2	TSP	450 kg
3	MoP	250 kg
4	Boric acid	10 kg
5	Zinc sulphate	12 kg
6	Ghypsum	120 kg
7	Cowdung	10000 kg

3.8 Transplanting of seedlings

The seedlings were raised in the seedbed, and on November 15, 2021, they were transplanted into the main field when they were 22 days old Plate 2B. The transplanted seedlings were given regular irrigation so that their roots and the soil around them would form a strong bond.

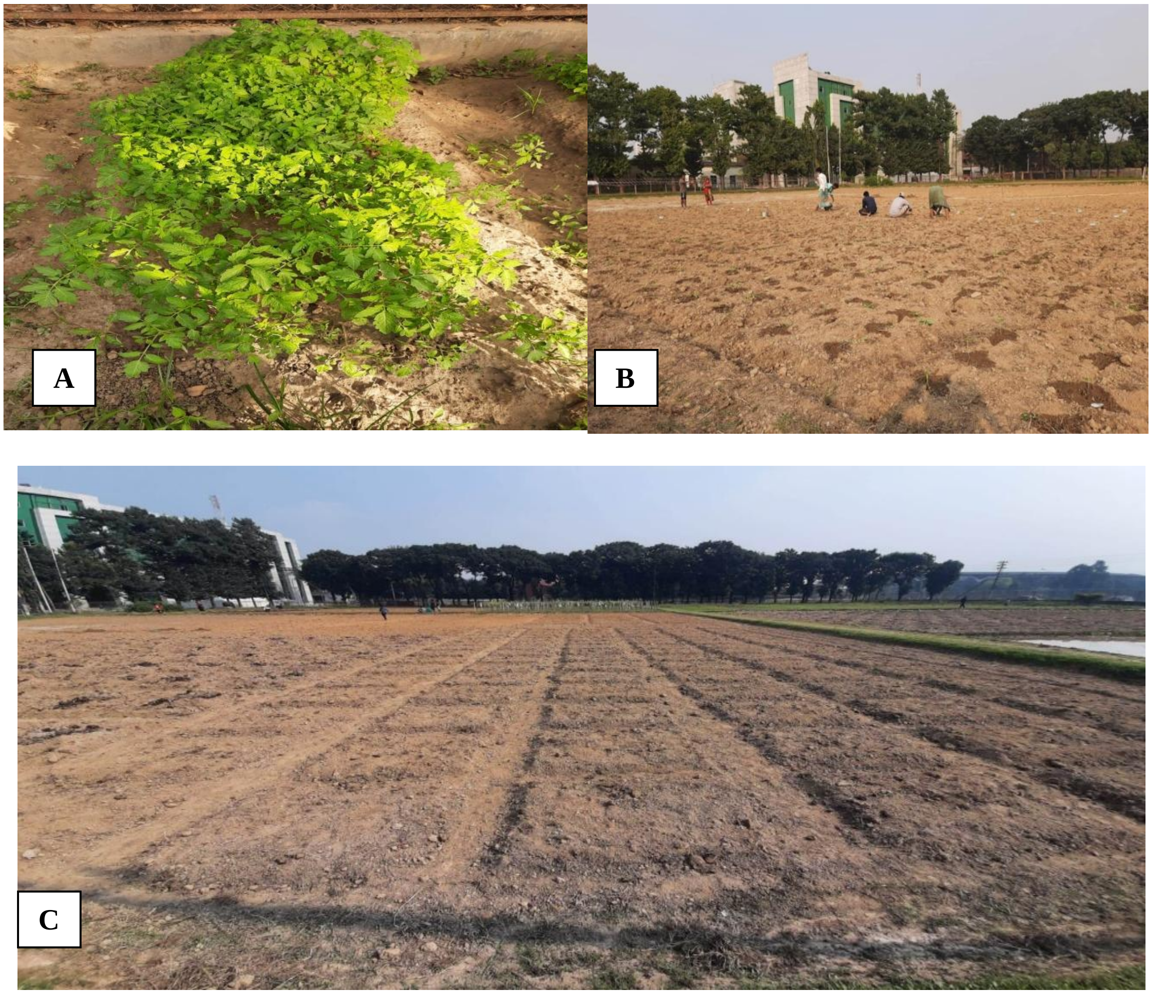

Plate 1. Seed bed and land preparation. A. Seedbed preparation and rising of seedling B. Land preparation C. Design and layout of the experimental field

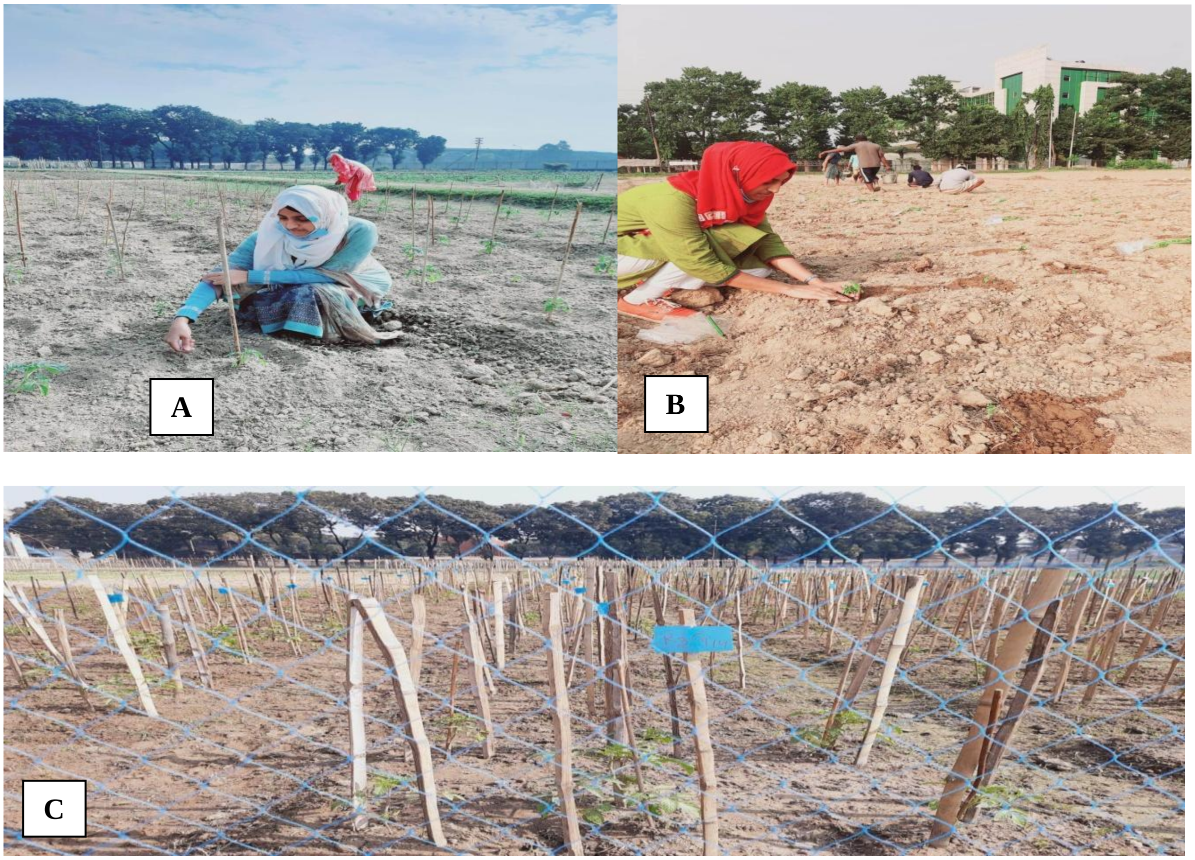

Plate 2. Manure and fertilizer application, transplanting and intercultural operation. A. Manure and fertilizer application B. transplanting of seedling C. Staking and tagging

3.9 Intercultural operations

After establishing of seedlings, 1st mulching and weeding were done. Then second weeding was done during the 2nd installment of urea after 15days. When the seedlings became large, bamboo sticks and ropes were used for supporting the plants Plate 2C. Some lateral branches and leaf were pruned out for obtaining proper sunlight and to reduce the infestation of insects. After some days of transplanting when the seedlings became established, some new plants were planted at the place of dead seedlings to fill up the gap. Thinning was done to avoid the crowded of seedlings. Weeding and mulching were done several times after transplanting in the main field. Mulching was done for proper aeration and weeding was done to reduce the competition with the tomato plant. Staking was done to keep the plants erect and for proper aeration. Staking was done by using bamboo stick and rope. At the time of cropping period, “Ripcord” was used about 7 times at 7 day’s interval during the sunny days in order to prevent the insect infestation. No herbicide was used to control the weeds, only hand weeding was done. The seedlings were properly irrigated for consecutive 7 days after transplanting. The flood irrigation was done at the time of urea application. Final irrigation was done during fruiting stage. Drainage were done at the time of requirements.

3.10 Harvesting and Processing

All of the tomato varieties used in this experiment were different. As a result, harvesting time differed for each variety, and it lasted about a month and a half because fruits from different lines matured at different times. The fruits were allowed to ripen before being collected and stored at $4^{o}C$ for future use. Harvesting began on February 19, 2022, and will be completed by April 6, 2022. Harvesting is shown in Plate 3A.

3.11 Data recording

Data were recorded on following parameters from the studied plants during the experiment (Plate 3B). The details of data recording are given below on individual plant basis.

Plate 3. Harvesting and data recording. A. Harvesting B. Data recording

3.11.1 Plant height (cm)

Five plants from each genotype were chosen at random from each plot, and plant height was measured at maturity stage after 75 days of transplanting. The plant height for each plot was determined by taking the mean of five plants.

3.11.2 Days to first flowering

The number of days from the date of sowing to the first flowering was counted. The days to first flowering for each plot were calculated using the mean value of five plants.

3.11.3 Days to first fruiting

The number of days from the date of sowing to the first flowering was counted. The days to first fruiting for each plot were calculated using the mean value of five plants.

3.11.4 Days to maturity

Number of days from the date of transplanting to the date when at least 80 % of fruits were matured in each replication were counted and mean values were worked out to estimate the fruit maturity of the genotype.

3.11.5 Number of branches per plant

During the maturity stage of each of the selected plants, the number of branches per plant was counted. The number of branches per plant for each plot was calculated using the mean value of five plants.

3.11.6 Number of cluster per plant

The number of clusters per plant was recorded at the time of harvesting. For each plot, the mean value of five plants was used to determine the number of clusters per plant.

3.11.7 Number of flowers per cluster

At the time of flowering, the number of flowers per plant was recorded. The number of flowers per cluster in each plot was calculated using the mean value of five plants.

3.11.8 Number of fruits per cluster

By randomly selecting five clusters from each plant, all fruits in one cluster were recorded. The number of fruits per cluster in each plot was calculated using the mean value of five plants.

3.11.9 Number of fruits per plant

The number of fruits per plant was counted during the maturity stage of five plants from each genotype in each plot at random. The number of fruits per plant for each plot was calculated using the mean value of five plants.

3.11.10 Fruit length (cm)

The length of the fruit was determined by measuring five representative fruits from each genotype from the neck to the bottom using a digital slide caliper, and taking the average of those measurements.

3.11.11 Fruit diameter (cm)

Fruit diameter was measured using digital slide calipers along the equatorial part of the same five representative fruits used for fruit length, and the average was taken as the diameter of the fruit.

3.11.12 Single fruit weight (g)

Picking a fruit from each genotype, weighing it using an electric precision balance, and calculating its mean value served as the method for measuring the weight of a single fruit..

3.11.13 Fruit pH

Fruit juice was collected from a single fruit of each genotype by blending it to measure fruit P^H using REX P^H meter model –PHS-3C. The electrode was inserted into the juice to get P^H value.

3.11.14 Total soluble solid

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

3.11.15 Shelf life

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

3.11.16 Yield per plant (kg)

Fruits ripped at different times in the same plant of the same genotype because all the genotypes were indeterminate types. As a result, the weight of each fruit and the number of fruits harvested from each plant were recorded each time they were harvested. Finally, after the last harvest, their average weight was calculated as the yield per plant.

3.12 Statistical analysis

All characters under examination underwent a univariate analysis of the individual character using the mean values (Singh and Chaudhury, 1985), which was estimated using the MSTAT-C computer program. To examine the differences between the genotype means, Duncan's Multiple Range Test (DMRT) was run on each character. Using MSTAT-C, it was also possible to estimate the mean, range, and co-efficient of variation (CV percent). Multivariate analysis was performed on the character mean data.

3.12.1 Analysis of variance

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	Variance ratio (V.R.)
Replication (r)	r-1	SSr	SSr/(r-1) =MSSr	MSSr/MSSe
Genotypes (g)	g-1	SSg	SSg/(g-1) = MSSg	MSSg/MSSe
Error (e)	(r-1) (g-1)	SSe	SSe/(r-1) (g-1) =MSSe	

Where,

r = Number of replications

g = Number of genotypes

SSr = Sum of squares due to replications

SSg = Sum of squares due to genotypes

SSe = Sum of squares due to error

MSSr = Mean sum of squares due to replications

MSSg = Mean sum of squares due to genotypes

MSSe = Mean sum of squares due to error

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

The standard error and critical differences were calculated as follows:

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

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

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

Where,

$SE(m)\pm$ = Standard error of mean

$SE(d)\pm$ = Standard error of difference

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

3.12.2 Mean performance and genetic variability

The genotypic and phenotypic coefficients of variability were calculated as per formulae given by Burton and De Vane (1953).

A) Genotypic Coefficient of Variation (GCV)

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

B) Phenotypic Coefficient of Variation (PCV)

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

3.12.3 Heritability (in broad sense)

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

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

Where,

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

Vp = Phenotypic variance [Vg + Ve]

3.12.4 Genetic advance (GA)

The expected genetic advance (GA) resulting from selection of 5% superior individuals was worked out as suggested by Allard (1960).

Genetic advance = H × σ p × K

Where,

K	=	2.06 (Selection differential at 5% selection index)
σ p	=	Phenotypic standard deviation
H	=	Heritability in broad sense

3.12.5 Estimation of genetic advance percentage of mean

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

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

3.12.6 Correlations

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

3.12.7 Analysis of variance and covariance

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

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

VeXY = MP_2

VgXY = $(MP_1-MP_2)/r$

VpXY = VgXY+VeXY

Where, VeXY = Environmental covariance between X and Y

Vg = Genetic covariance between X and Y Phenotypic

XYVpXY = Covariance between X and Y

3.12.8 Coefficients of correlation

3.12.8.1 Genotypic correlation coefficient between X and Y

$$r_g = \frac{VgXY}{\sqrt{(VgX \times VgY)}}$$

Where,

Vg XY = Genotypic covariance between X and Y

Vg X = Genotypic variance of X

Vg Y = Genotypic variance of Y

3.12.8.2 Phenotypic correlation coefficient between X and Y

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

Vp XY = Phenotypic covariance between X and Y

Vp X = Phenotypic variance of X

Vp Y = Phenotypic variance of Y

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

Phenotypic variance (Vp) = (Vg+Ve)

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

3.12.9 Path coefficient analysis

Path co-efficient analysis was done according to the procedure employed by Dewey and Lu (1959) also quoted in Singh and Chaudhary (1985) using simple correlation values. In path analysis, correlation co-efficient is partitioned into direct and indirect independent variables on the dependent variable. In order to estimate direct and indirect effect of the correlated characters, say x1, x2 and x3 yield y, a set of simultaneous equations (three equations in this example) is required to be formulated as shown below:

$$r_{yx1} = P_{yx1} + P_{yx2}r_{x1x2} + P_{yx3}r_{x1x3}$$

$$r_{yx2} = P_{yx1}r_{x1x2} + P_{yx2} + P_{yx3}r_{x2x3}$$

$$r_{yx3} = P_{yx1}r_{x1x3} + P_{yx2}r_{x2x3} + P_{yx3}$$

Where, r’s denotes simple correlation co-efficient and P’s denote path co-efficient (Unknown). P’s in the above equations may be conveniently solved by arranging them in matrix from. Total correlation, say between x1 and y is thus partitioned as follows:

P_{yx1}=The direct effect of x1 on y.

$P_{yx2}r_{x1x2}$=The indirect effect of x1 viax2 on y.

$P_{yx3}r_{x1x3}$=The indirect effect of x1 viax3 on y.

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

$P^2RY = 1- \Sigma P_{iy}.Riy$

Where,

$P^2RY = (R^2)$; and hence residual effect, $R= (P^2RY)^{1/2}$
Piy = Direct effect of the character on yield
Riy = Correlation of the character with yield.

CHAPTER IV

RESULTS AND DISCUSSION

Results obtained from the present study have been presented and discussed in this chapter with a view to analysis of genetic variability and character association in F_2 segregating population of tomato. The results have been discussed, and possible interpretations were given under the following headings.

4.1. Genetic variability

The results of the analysis of variance showed that there was significant genetic variation among the tomato genotypes. Table 3 displayed the mean, mean sum of squares, variance components, genotypic and phenotypic coefficients of variance, heritability, genetic advance, and genetic advance expressed as a percentage of the mean.

4.1.1. Plant height (cm)

The plant height of 28 genotypes of tomato showed significant variation. Significant mean sum of squares for plant height (880.65) suggested that the genotypes under study showed a great deal of variation (Table 3). The genotype G1×G7 had the tallest plants (138.00 cm), while G1×G3 had the shortest plants (74.67 cm), with a mean height of 104.26 cm (Appendix IV). The phenotypic variance (319.72) appeared to be higher than the genotypic variance (280.44). The phenotypic co-efficient of variation (PCV) 17.15% and the genotypic co-efficient of variation expression (GCV) 16.062% were rather close to one another. Moderately high PCV and GCV estimates indicated that these traits were under genetic control and are less affected by environment. The plant height showed the highest heritability with (87.719) with moderate genetic advance in percent of mean (30.99%) indicated that this trait is and additive genetic control. Thus the selection based on this character would be effective. Kumari *et al.* (2020) found a wide range of variation in the plant height of different tomato genotype.

Table 3. Estimation of genetic variability for yield contributing characters related to yield of tomato

Parameters	MS	Mean	CV (%)	σ^2p	σ^2g	σ^2e	PCV	GCV	h^2b	GA (5%)	GA (%) mean
PH	880.65**	104.26	6.01	319.72	280.44	39.27	17.15	16.062	87.719	32.311	30.99
DFF	187.05**	33.93	11.531	72.56	57.25	15.31	25.105	22.3	78.903	13.845	40.806
DFFr	157.95**	49.23	6.699	59.91	49.03	10.88	15.722	14.224	81.845	13.049	26.508
DM	264.86**	99.58	7.396	124.43	70.2	54.24	11.202	8.414	56.414	12.964	13.018
NBP	38.64**	10.94	25.862	18.22	10.21	8.01	39.014	29.21	56.057	4.929	45.052
NCP	253.81**	25.07	18.866	99.51	77.14	22.37	39.79	35.033	77.518	15.93	63.54
NFC	16.55**	7.63	20.333	7.12	4.71	2.41	34.972	28.454	66.198	3.639	47.691
NFrC	22.38**	5.45	28.308	9.034	6.66	2.38	55.165	47.347	73.667	4.564	83.714
NFP	49040.38**	152.69	33.334	18076.3	15485.9	2590.11	88.053	81.5	85.669	137.254	89.897
FL	682.43**	50.16	10.597	246.37	218.11	28.25	31.292	29.443	88.531	28.622	57.068
FD	1296.24**	50.09	10.967	452.1	421.93	30.18	42.449	41.008	93.326	40.882	81.609
SFW	4055.00**	55.25	12.406	1383.01	1335.99	46.99	67.31	66.156	96.603	44.006	79.649
FpH	0.20**	3.73	6.673	0.11	0.044	0.062	8.737	5.64	41.667	0.28	7.499
TSS	2.54**	1.63	32.679	1.03	0.75	0.284	62.377	53.131	72.553	1.52	93.227
SL	58.26**	17.81	11.483	22.21	18.03	4.18	26.46	23.839	81.168	7.879	44.243
YPP	21.93**	5.43	47.007	11.64	5.12	6.53	62.832	41.691	44.028	3.097	56.987

PH = Plant height (cm), DFF = Days to 1st flowering, DFFr = Days to 1st fruiting, DM = Days to maturity, NBP = Number of branches per plant, NCP = Number of cluster per plant, NFC = Number of flowers per cluster, NFrC = Number of fruits per cluster, NFP = Number of fruits per plant, FL = Fruit length (mm), FD = Fruit diameter (mm), SFW = Single fruit weight (g), FpH = Fruit pH, TSS = Total soluble solid, SL = Shelf life (days), YPP = Yield per plant(kg), PCV = Phenotypic Co-efficient of Variation, GCV = Genotypic Co-efficient of Variation, h^2b = Heritability, GA = Genetic advanced, GA(%) mean = Genetic advance in percent of mean** = significant at 1%, and * = significant at 5% level of probability, respectively.

4.1.2 Days to 1st flowering

Days to first flowering revealed highly significant variation among different tomato genotypes. G10×G4 required the longest duration (50.00) for the emergence of the first flower, while G1×G7 required the shortest duration (20.33), with a mean value of 33.93. (Table 3). There was a considerable difference between the phenotypic variance (72.56) and genotypic variance (57.25), suggested less influence of environment on the expression of the genes controlling this character (Table 3). The difference between phenotypic coefficient of variation (25.105%) and genotypic coefficient of variation (22.3) was comparatively larger in terms of days to first flowering. This character showed a moderately high heritability (78.903), genetic advance (13.845), and genetic advance in percent of mean (40.806). Osekita and Ademiluyi (2014) reported that genotypic coefficient of variation and phenotypic coefficient of variation was highest in days to first flowering of different genotypes of tomato.

4.1.3 Days to 1st fruiting

The mean sum of squares of the days to 1st fruiting revealed highly significant tomato genotype variation (157.95). With a mean value of 49.23, G3×G2 required the longest time (64.33) and G1×G7 required the shortest time (36.33), respectively, for the emergence of the first fruiting of tomato. (Table 3). The phenotypic variance (59.91) and genotypic variance (49.03) differed significantly, indicating that environmental factors may have influenced the traits expressed (Table 3). The phenotypic co-efficient of variation (15.722%), higher than the genotypic co-efficient of variation (14.224%) had significant effect due to phenotypic variation. Heritability was (81.845), genetic advance (13.049), and genetic advance in percent of mean (26.508), indicating that this character was influenced by additive gene effects. Similar result also observed by Kaushal *et al*. (2017) reported that, high heritability coupled with high genetic advance as per cent of mean were estimated for days required to 1st fruiting of tomato plant.

4.1.4 Days to maturity

Days to maturity of tomato genotypes mean square of sum was found to be significant (264.86). Among different genotypes, G2×G3 required the longest duration (115.67) for maturity of tomato, while G9×G10 required the shortest duration (80.67), with a mean value of 99.58 (Table 3). The phenotypic variance (124.43) and genotypic variance (70.2) differed significantly, indicating that environmental influences may have had an impact on how the traits were manifested (Table 3). Phenotypic variation had little impact as the phenotypic co-efficient of variation (11.202%) was only marginally greater than the genotypic co-efficient of variation (8.414%). Heritability was high (56.414), genetic advance (12.964) and genetic advance in percent of mean (13.018) indicating successful selection based on this feature as the character was governed by additive genes. The result was similar with the findings of Taisa *et al.* (2011) who studied genetic variability in twenty three tomato genotypes for yield and yield components founded higher values of heritability in days to maturity in different tomato genotypes.

4.1.5 Number of branches per plant

The mean sum of squares of the number of branches per plant of tomato was found to be significant (38.64) (Table 3). The mean number of branches per plant was 10.94, with G5×G10 having the highest number of branches per plant at 16.67 and G4×G10 having the lowest number of branches per plant at 5.00. The phenotypic variance (18.22) appeared to be larger than the genotypic variance (10.21), indicating that the environment had less influence on the expression of this gene controlling the trait. The PCV (39.014%) was higher than GCV (29.21%). The moderate heritability (56.057) with genetic advance in percent of mean (45.052) was found for this trait suggesting moderate additive gene effects. Thus the selection based on this character would be effective. Bajpai *et al.* (2018) reveled that highest GCV and PCV for primary branches per plant of tomato exhibited higher heritability coupled with genetic advance.

4.1.6 Number of cluster per plant

The mean sum of squares of the number of cluster per plant revealed highly significant variation among the tomato genotypes (253.81). G9×G10 genotype had the highest number of cluster per plant (41.67) while G1×G9 genotype had the lowest number of cluster per plant (10.67) with a mean value of 25.07 (Table 3). There was considerable difference between the phenotypic variance (99.51) and genotypic variance (77.14), suggested less influence of environment on the expression of the genes controlling this character (Table 3). The difference between phenotypic coefficient of variation (39.79%) and genotypic coefficient of variation (35.033) was comparatively larger in terms of days to first male flower. This character showed a high heritability (77.518), genetic advance (15.93), and genetic advance in percent of mean (63.54). Somraj *et al.* (2017) studied genetic variability on twenty genotypes of tomato and revealed that the characters like number of clusters per plant showed high GCV and PCV.

4.1.7 Number of flowers per cluster

The mean sum of squares of number of flowers per clusterof tomato was found to be highly significant (16.55). With a mean value of 7.63, the highest number of flowers per cluster(13.33) was found in G4×G10 genotype, while the lowest number of flowers per cluster (4.33) was found in G1×G8 genotype. The fact that the phenotypic variance (7.12) was greater than the genotypic variance (4.71). The genotypic and phenotypic co-efficients of variation were both 34.972% and 28.454% respectively. This character showed a moderate heritability (66.198) with genetic advance (3.639) and genetic advance in percent of mean (47.691) indicating that this traits was governed by additive genes. Therefore selection based on this character would be effective. The high value of genotypic and phenotypic coefficients of variability and heritability estimates were associated with greater value of genetic advance as percent of mean as observed for number of flowers per cluster in tomato plant (Vyas *et al.* (2011).

4.1.8 Number of fruits per cluster

The mean sum of squares of number of fruits per cluster of tomato was found to be highly significant (22.38). With a mean value of 5.45, the highest number of fruits per cluster (13.33) was found in G4×G10 genotype, while the lowest number of fruits per cluster (2.33) was found in G1×G5 and G1×G7 genotype. The fact that the phenotypic variance (9.034) was greater than the genotypic variance (6.66). The genotypic and phenotypic co-efficients of variation were both 55.165% and 47.347% respectively. This character showed high heritability (73.667) with high genetic advance in percent of mean (83.714) indicating that this traits was governed by additive genes. Therefore selection based on this character would be effective. Similar result was reported by Vyas *et al.* (2011) in tomato.

4.1.9 Number of fruits per plant

The number of fruits per plant of 28 population of tomato showed significant variation. Significant mean sum of squares for number of fruits per plant (49040.38) suggested that the genotypes under study showed a great deal of variation (Table 3). With a mean value of 152.69, the highest fruit number per plant (496 g) was found in G4×G10 genotype, while the lowest fruit number per plant (39.33) was found in G1×G9 genotype. The fact that the phenotypic variance (18076.3) was greater than the genotypic variance (15485.9). The genotypic and phenotypic co-efficients of variation were both 88.053% and 81.5% respectively. This character showed a high heritability (85.669) with high genetic advance in percent of mean (89.897) indicating that this traits was governed by additive genes. Therefore, selection based on this character would be effective. The result was similar with the findings of Rai *et al.* (2016) who studied coefficient of variation analysis which indicated that the magnitude of the PCV was slightly higher than the GCV for yield and quality traits. They revealed that high estimate of heritability and genetic advance in tomato for, fruits per plant.

4.1.10 Fruit length (mm)

The mean sum of squares of fruit length of different genotypes of tomato was discovered to be significant (682.43). The average fruit length was 50.16 mm, with G4×G5 genotype having the highest fruit length of 83.00 mm and G4×G10 having the lowest fruit length of 23.67 mm. The fact that the phenotypic variance (246.37) was slightly higher than the genotypic variance (218.11) indicated that the environment had less of an effect on the expression of the gene responsible for this feature (Table 3). The phenotypic and genotypic co-efficients of variation were respectively 31.292% and 29.443%. Heritability was found to be high (88.531%), with genetic advance (28.622) and a moderate genetic advance in terms of percent of mean (57.068), indicating that the character was controlled by an additive gene, so selection based on this character would be effective. Zhou *et al*. (2015) reported similar result in tomato.

4.1.11 Fruit diameter (mm)

It was discovered that the mean sum of squares of fruit diameter of tomato genotypes was significant (1296.24). The average fruit diameter was 50.09 mm, with G4×G9 genotype having the fruit diameter was 84.67 mm and G2×G10 and G1×G10 genotypes having the lowest fruit diameter (19.67 mm). The phenotypic variance (452.1) was slightly higher than the genotypic variance (421.93), indicating that the environment had less of an effect on the expression of the gene responsible for this feature (Table 3). The phenotypic and genotypic co-efficients of variation were respectively 42.449% and 41.008%. Heritability was found to be high (93.326%), with a moderate genetic advance (40.882) and high genetic advance in terms of percent of mean (81.609), indicating that the character was controlled by an additive gene, so selection based on this character would be effective. The result was similar with the findings of Hasan *et al.* (2016) who investigated thirty tomato genotypes to study genetic variability for yield and quality traits and founded high heritability but low genetic advance mean was noted for fruit diameter of tomato.

4.1.12 Single fruit weight (g)

A significant mean sum of squares of single fruit weight was recorded (0.30) in different genotype of tomato. The mean single fruit weight was 55.25 g, with the minimum single fruit weight of 9.67 g found in G5×G10 and the maximum single fruit weight of 138.00 g found G1×G4. The fact that the phenotypic variance (1383.01) was slightly greater than the genotypic variance (1335.99) suggested that the environment had less of an impact on the expression of the gene responsible for this feature (Table 3). The phenotypic and genotypic co-efficients of variation were 67.31% and 66.156%, respectively. Heritability was found to be high (96.603%), with a genetic advance (44.006) and highly genetic advance in percent of mean (79.649), indicating that the character was controlled by an additive gene, so selection based on this character would be effective. Somraj *et al.* (2017) studied genetic variability on twenty genotypes of tomato and revealed that the characters like average weight of fruit content showed high GCV and PCV.

4.1.13 Fruit pH

The mean sum of squares of fruit pH of different genotypes of tomato was found to be significant (0.20) (Table 3). The mean fruit pH was 3.73, with G6×G2 having the highest fruit pH at 4.17 and G1×G7 having the lowest fruit pH at 2.97. The phenotypic variance (0.11) appeared to be larger than the genotypic variance (0.044), indicating that the environment had less influence on the expression of this gene controlling the trait. The PCV (8.737%) was higher than GCV (5.64%). The moderate heritability (41.667) with genetic advance in percent of mean (7.499) was found for this trait indicating successful selection based on this feature as the character was governed by additive genes. Bernousi *et al*. (2011) reported similar result in tomato.

4.1.14 Total soluble solid

The mean sum of squares of total soluble solid of different genotypes of tomato was found to be significant (0.20) (Table 3). The average total soluble solid of different genotypes of tomato (1.63) where, the G2×G7 genotype had the highest total soluble solid (4.17 ºBrix) whereas the G4×G6 genotypes had the lowest total soluble solid (0.17 ºBrix). The phenotypic variance (1.03) appeared to be larger than the genotypic variance (0.75), indicating that the environment had less influence on the expression of this gene controlling the trait. The PCV (62.377%) was higher than GCV (53.131%). The moderate heritability (72.553) with low genetic advance (1.52) and genetic advance in percent of mean (93.227) was found for this trait indicating successful selection based on this feature as the character was governed by additive genes. Kumar *et al*. (2012) studied genetic variability in different genotypes of tomato and reported significant difference among the genotypes and founded high values of heritability (broad sense) were observed for total soluble solids.

4.1.15 Shelf life

It was discovered that the genotypes of tomato had a significant mean sum of squares of shelf life (58.26). The average shelf life was 17.81 days, with G1×G10 genotype having the longest shelf life of 28.67 days while the G7×G10 genotype having the shortest shelf life of 9.00 days. The phenotypic variance (22.21) was slightly higher than the genotypic variance (18.03), indicating that the environment had less of an effect on the expression of the gene causing this feature (Table 3). The phenotypic and genotypic co-efficients of variation were 26.46% and 23.839%, respectively. Heritability was discovered to be high (81.168%), with low genotypic advance (7.879) and moderate genetic advance in percent of mean (44.243), indicating that the character was controlled by an additive gene and that selection based on this character would be effective. The result was similar with the findings of Reddy *et al*. (2013).

4.1.16 Yield per plant (kg)

Significant mean sum of squares of yield per plant was found (21.93) in different genotypes of tomato. The mean yield per plant was 5.43, with the maximum yield per plant of 11.35 kg discovered in G1×G4 and the minimum yield per plant of 1.95 kg discovered in G6×G2. The fact that the phenotypic variance (11.64) was larger than the genotypic variance (5.12) suggested that the environment had an impact on the expression of the gene responsible for this feature (Table 3). Both the genotypic and phenotypic co-efficients of variance were 62.832% and 41.691%, respectively. Heritability was found moderate (44.028%) with a low genetic advance (3.097) and moderate genetic advance in percent of mean (56.987), revealed that the character was controlled by additive gene so the selection based on this character would be effective. Kumari *et al.* (2020) reported that the attributes viz. per plant yield exhibited higher GCV and PCV. Saravanan *et al.* (2019) reported that the fruit yield per plant, showed highest GCV, PCV and genetic advance.

4.2. Correlation coefficient

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). For clear understanding correlation coefficients are separated into genotypic and phenotypic level in (Table 4). The genotypic correlation coefficients in most cases were higher than their phenotypic correlation coefficients indicating the genetic reason of association. While phenotypic correlation coefficient were higher than genotypic correlation coefficient indicating suppressing effect of the environment which modified the expression of the characters at phenotypic level. The depicted of genotypic and phenotypic correlation coefficients among different pairs of yield and yield contributing characters for different genotypes of tomato are given in (Table 4).

4.2.1 Plant height (cm)

Plant height showed highly significant positive correlation with number of branches per plant (rg = 0.460, rp = 0.304), number of cluster per plant (rg = 0.491, rp = 0.411), Number of fruits per cluster (rg = 0.277, rp = 0.239) and fruit diameter (rg = 0.291, rp = 0.262) indicating that if plant height increase these parameters will also be increased (Table 4). Significant but negative correlation was found with days to 1^{st} flowering (rg = 0.812, rp = -0.700), days to 1^{st} fruiting (rg = -0.871, rp = -0.760), days to maturity (rg = -0.626, rp = -0.445), fruit length (rg = -0.313, rp = -0.296). Non-significant but positive correlation was found in number of cluster per plant (rg = 0.088, rp = 0.048), number of fruits per cluster (rg = 0.142, rp = 0.120), single fruit weight (rg = 0.020, rp = 0.021), total soluble solid (rg = 0.096, rp = 0.087) and yield per plant (rg = 0.175, rp = 0.101). Non-significant and negative correlation was found in fruit pH (rg = -0.168, rp = -0.122). Plant height was an important component of plant ecological strategy. It is strongly related to life span, seed mass, and maturity time, and it is a major determinant of a species' ability to compete for light. Naveen *et al.* (2017) found similar result which supported the present findings.

4.2.2 Days to 1st flowering

Days to 1st flowering of tomato plant showed highly significant positive correlation with days to 1st fruiting (rg = 0.742, rp = 0.730), Days to maturity (rg = 0.884, rp = 0.557), fruit

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

Character		DFF	DFFr	DM	NBP	NCP	NFC	NFrC	NFP	FL	FD	SFW	FpH	TSS	SL	YPP
PH	rg	-0.812**	-0.871**	-0.626**	0.460**	0.491**	0.088^{NS}	0.142^{NS}	0.277*	-0.313**	0.291**	0.020^{NS}	-0.168^{NS}	0.096^{N}S	-0.006^{NS}	0.175^{NS}
	rp	-0.700**	-0.760**	-0.445**	0.304**	0.411**	0.048^{NS}	0.120^{NS}	0.239*	-0.296**	0.262*	0.021^{NS}	-0.122^{NS}	0.087^{NS}	-0.004^{NS}	0.101^{NS}
DFF	rg		0.742**	0.884**	-0.304**	-0.622**	-0.402**	-0.420**	-0.513**	0.481**	0.162^{NS}	0.305**	0.291 ^{NS}	-0.253 ^{NS}	0.168^{NS}	0.086^{NS}
	rp		0.730**	0.557**	-0.271*	-0.491**	-0.321**	-0.365**	-0.443**	0.400**	0.129^{NS}	0.263*	0.149^{NS}	-0.136^{NS}	0.166^{NS}	0.011^{NS}
DFFr	rg			0.556**	-0.456**	-0.358**	0.055^{NS}	-0.046^{NS}	-0.154^{NS}	0.254*	-0.251*	-0.139^{NS}	0.199^{NS}	-0.102^{NS}	-0.201^{NS}	0.224*
	rp			0.349**	-0.335**	-0.284**	0.059^{NS}	-0.101^{NS}	-0.165^{NS}	0.219*	-0.231*	-0.110^{NS}	0.066^{NS}	-0.054^{NS}	-0.154^{NS}	0.227*
DM	rg				-0.138^{NS}	-0.776**	-0.791**	-0.758**	-0.816**	0.867**	0.191^{NS}	0.398**	0.050^{NS}	-0.022^{NS}	0.104^{NS}	-0.113^{NS}
	rp				-0.080^{NS}	-0.452**	-0.445**	-0.462**	-0.510**	0.634**	0.152^{NS}	0.277*	0.070^{NS}	-0.003^{NS}	0.041^{NS}	-0.028^{NS}
NBP	rg					0.005^{NS}	-0.403**	-0.287**	-0.248*	0.141^{NS}	0.352**	0.097^{NS}	-0.041^{NS}	0.172^{NS}	-0.117^{NS}	0.422**
	rp					0.067^{NS}	-0.268*	-0.128*	-0.111*	0.060^{NS}	0.285**	0.055^{NS}	-0.041^{NS}	0.080^{NS}	-0.122^{NS}	0.498**
NCP	rg						0.652**	0.725**	0.861**	-0.731**	-0.404**	-0.680**	-0.246*	0.057^{NS}	0.227*	0.231*
	rp						0.497**	0.560**	0.798**	-0.586**	-0.357**	-0.574**	-0.134*	0.088^{NS}	0.145*	0.244*
NFC	rg							0.776**	0.789**	-0.786**	-0.634**	-0.546**	-0.153^{NS}	0.090^{NS}	-0.139^{NS}	0.242*
	rp							0.562**	0.614**	-0.569**	-0.509**	-0.414**	-0.034^{NS}	0.056^{NS}	-0.119^{NS}	0.366**
NFrC	rg								0.970**	-0.841**	-0.641**	-0.650**	0.359**	0.006^{NS}	0.237*	-0.352**
	rp								0.923**	-0.701**	-0.526**	-0.549**	0.157*	0.056^{NS}	0.135*	-0.223*
NFP	rg									-0.837**	-0.601**	-0.689**	0.170^{NS}	-0.007^{NS}	0.227*	0.418**
	rp									-0.738**	-0.540**	-0.623**	0.072^{NS}	0.029^{NS}	0.140*	0.447**
FL	rg										0.347**	0.489**	-0.096^{NS}	-0.078^{NS}	-0.277*	-0.106^{NS}
	rp										0.305**	0.464**	0.019^{NS}	-0.050^{NS}	-0.226*	-0.071^{NS}
FD	rg											0.807**	-0.115^{NS}	0.071^{NS}	-0.127^{NS}	0.553**
	rp											0.765**	-0.161^{NS}	0.070^{NS}	-0.147^{NS}	0.367**
SFW	rg												0.068^{NS}	0.064^{NS}	-0.219*	0.734**
	rp												0.050^{NS}	0.049^{NS}	-0.207*	0.524**
FpH	rg													-0.580**	0.037^{NS}	0.209^{NS}
	rp													-0.420**	0.030^{NS}	0.036^{NS}
TSS	rg														-0.006^{NS}	0.332**
	rp														0.018^{NS}	0.266*
SL	rg															0.030^{NS}
	rp															0.035^{NS}

PH = Plant height (cm), DFF = Days to 1st flowering, DFFr = Days to 1st fruiting, DM = Days to maturity, NBP = Number of branches per plant, NCP = Number of cluster per plant, NFC = Number of flowers per cluster, NFrC = Number of fruits per cluster, NFP = Number of fruits per plant, FL = Fruit length (mm), FD = Fruit diameter (mm), SFW = Single fruit weight (g), FpH = Fruit Ph, TSS = Total soluble solid, SL = Shelf life (days), YPP = Yield per plant(kg), PCV = Phenotypic Co-efficient of Variation, GCV = Genotypic Co-efficient of Variation, h^2b = Heritability, GA = Genetic advanced, GA(%) mean = Genetic advance in percent of mean ** = significant at 1%, and * = significant at 5% level of probability, respectively.

length (rg = 0.481, rp = 0.400), single fruit weight (rg = 0.305, rp = 0.263) both at genotypic and phenotypic level indicating that if number of branches per plant increase, these parameters will also be increased (Table 4). Significant but negative correlation was found in number of branches per plant (rg = -0.304, rp = -0.271), Number of cluster per plant (rg = -0.622, rp = -0.491), number of flowers per cluster (rg = -0.402, rp = -0.321), number of fruits per cluster(rg = -0.420, rp = -0.365) and number of fruits per plant (rg = --0.513, rp = -0.443). Non-significant positive correlation was found in fruit diameter (rg = 0.162, rp = 0.129), fruit pH (rg = 0.291, rp = 0.149), shelf life (rg = 0.168, rp = 0.166) and yield per plant (rg = 0.086, rp = 0.011). Non-significant and negative correlation was found in total soluble solid (rg = -0.253, rp = -0.136). Ghosh *et al.* (2010) found similar result which supported the present findings.

4.2.3 Days to 1st fruiting

Days to 1st fruiting of tomato plant showed highly significant positive correlation with days to maturity (rg = 0.556, rp = 0.349), fruit length (rg = 0.254, rp = 0.219) and yield per plant (rg = 0.224, rp = 0.227) (Table 4) at both genotypic and phenotypic level indicating that the traits were governed by same gene and in that case, phenotypic selection would be effective. Significant but negative correlation was found in number of branches per plant (rg = -0.456, rp = -0.335), Number of cluster per plant (rg =-0.358, rp = -0.284), number of fruits per cluster(rg = -0.046, rp = -0.101), number of fruits per plant (rg = -0.154, rp = -0.165) and fruit diameter (rg = -0.251, rp = -0.231). Non-significant positive correlation was found in number of flowers per cluster (rg = 0.055, rp = 0.059) and fruit pH (rg = 0.199, rp = 0.066). Non-significant and negative correlation was found in total soluble solid (rg = -0.253, rp = -0.136) and Shelf life (rg = -0.253, rp = -0.136). Naveen *et al.* (2017) found similar result which supported the present findings. Hedau *et al.* (2008) reported that the genotypic correlations were higher than the corresponding phenotypic for few important quality traits indicating inherent relationship among nutritional quality traits in tomato.

4.2.4 Days to maturity

Days to maturity showed significant but positive correlation with fruit length (rg = 0.867, rp = 0.634), single fruit weight (rg = 0.398, rp = 0.277). Significant but negative correlation was found in number of cluster per plant (rg = -0.776, rp = -0.452), number of flowers per cluster (rg = -0.791, rp = -0.445), number of fruits per cluster (rg = -0.758, rp = -0.462) and Number of fruits per plant (rg = -0.816, rp = -0.510). Non-significant positive correlation was found in fruit diameter (rg = 0.191, rp = 0.152), fruit pH (rg = 0.050, rp = 0.070) and shelf life (rg = 0.104, rp = 0.041). Non-significant and negative correlation was found in number of branches per plant (rg = -0.138, rp = -0.080), total soluble solid (rg = -0.022, rp = -0.003) and yield per plant (rg = -0.113, rp = -0.028). Namdev and Dongre (2018) found similar result which supported the present findings.

4.2.5 Number of branches per plant

Number of branches per plant showed highly significant positive correlation with fruit diameter (rg = 0.352, rp = 0.285) and yield per plant (rg = 0.422, rp = 0.498) both at genotypic and phenotypic level indicating that if number of branches per plant increase, these parameters will also be increased (Table 4). Significant but negative correlation was found in number of cluster per plant (rg = -0.403, rp = -0.268), number of flowers per cluster (rg = -0.287, rp = -0.128), number of fruits per cluster (rg = -0.248, rp = -0.111) and shelf life (rg = -0.117, rp = -0.122). Non-significant positive correlation was found in number of cluster per plant (rg = 0.005, rp = 0.0067), fruit length (rg = 0.141, rp = 0.060), single fruit weight (rg = 0.097, rp = 0.055) and total soluble solid (rg = 0.172, rp = 0.080). Non-significant and negative correlation was found in fruit pH (rg = -0.041, rp = -0.041). Alam and Paul (2019) reported that fruit yield per plant of tomato is positively and significantly correlated with branches per plant.

4.2.6 Number of cluster per plant

Number of cluster per plant showed highly significant positive correlation with number of flowers per cluster (rg = 0.652, rp = 0.497), Number of fruits per cluster (rg = 0.725, rp = 0.560), number of fruits per plant (rg = 0.861, rp = 0.798), shelf life (rg = 0.227, rp = 0.145) and yield per plant (rg = 0.231, rp = 0.244) both genotypic and phenotypic data suggest that when the number of branches per plant increases, these characteristics will likewise rise (Table 4). Significant but negative correlation was found in fruit length (rg = -0.731, rp = -0.586), fruit diameter (rg = -0.404, rp = -0.357), single fruit weight (rg = -0.680, rp = -0.574) and fruit pH (rg = -0.246, rp = -0.246). Non-significant positive correlation was found in Total soluble solid (rg = 0.057, rp = 0.088). Osekita and Ademiluyi (2014) also found similar result which support the present findings.

4.2.7 Number of flowers per cluster

At both genotypic and phenotypic level, number of flowers per plant demonstrated a significant positive connection with number of fruits per cluster (rg = 0.776, rp = 0.562), number of fruits per plant (rg = 0.789, rp = 0.614) and yield per plant (rg = 0.242, rp = 0.366) indicating that number of fruits per cluster, number of fruits per plant and yield per plant increasing significantly if the Number of flowers per cluster increased. Significant but negative correlation was found in fruit length (rg = -0.786, rp = -0.569), fruit diameter (rg = -0.634, rp = -0.509) and single fruit weight (rg = -0.546, rp = -0.414). Non- significant positive correlation was found in total soluble solid (rg = 0.090, rp = 0.056). Non- significant and negative correlation was found in fruit pH (rg = -0.153, rp = -0.034) and shelf life (rg = -0.139, rp = -0.119). The result was similar with the findings of Mahapatra *et al.* (2013) who reported that fruit yield had positive and significant correlation with number of flower clusters per plant.

4.2.8 Number of fruits per cluster

Number of fruits per cluster demonstrated a highly significant and positive correlation with number of fruits per plant (rg = 0.970, rp = 0.923), fruit pH (rg = 0.359, rp = 0.157) and shelf life (rg = 0.237, rp = 0.135) at both genotypic and phenotypic level (Table 4). Significant but negative correlation was found in fruit length (rg = -0.841, rp = -0.701), fruit diameter (rg = -0.641, rp = -0.526), single fruit weight (rg = -0.650, rp = -0.549) and yield per plant (rg = -0.352, rp = -0.223) (Table 4). Non-significant positive correlation was found in Total soluble solid (rg = 0.006, rp =0.056).Kumar *et al.* (2020) revealed that fruit yield was significantly and positively correlated with number of fruits per cluster at genotypic and phenotypic level.

4.2.9 Number of fruits per plant

Number of fruits per plant showed highly significant positive correlation with shelf life (rg = 0.227, rp = 0.140) and yield per plant (rg = 0.418, rp = 0.447) both genotypic and phenotypic levels. Significant but negative correlation was found in fruit length (rg = -0.837, rp = --0.738), fruit diameter (rg = -0.601, rp = -0.540) and single fruit weight (rg = -0.689, rp = -0.623). Non-significant positive correlation was found in fruit pH (rg = 0.170, rp = 0.072). Non-significant and negative correlation was found in Total soluble solid (rg = -0.007, rp = -0.029). Ashish *et al.* (2017) reported that in different tomato genotypes the yield per hectare displayed positive correlation with number of fruits per plant.

4.2.10 Fruit length

Fruit length showed a highly significant and positive correlation with fruit diameter (rg = 0.347, rp = 0.305) and single fruit weight (rg = 0.489, rp = 0.464) at both the genotypic and phenotypic levels, indicating that if the fruit length was increased the fruit diameter and single fruit weight were increasing significantly (Table 4). Significant but negative correlation was found in Shelf life (rg = -0.277, rp = -0.226). Non-significant and negative correlation was found in fruit pH (rg = -0.096, rp = -0.019), total soluble solid (rg = -0.078, rp = -0.050) and yield per plant (rg = -0.106, rp = -0.071). Anjum *et al.* (2009)found similar result which supported the present findings.

4.2.11 Fruit diameter

Flash diameter demonstrated a highly significant and positive correlation with single fruit weight (rg = 0.807, rp = 0.765) and yield per plant (rg = 0.553, rp = 0.367) at both genotypic and phenotypic level (Table 4). Significant but positive correlation was found in total soluble solid (rg = 0.071, rp = 0.070). Significant but negative correlation was found in fruit pH (rg = -0.115, rp = -0.161) and shelf life (rg = -0.127, rp = -0.147). Phom *et al.* (2015) used thirteen tomato genotypes to study correlation coefficient for yield and yield attributing characters and found that fruit diameter have strong and positive association with fruit yield per hectare.

4.2.12 Single fruit weight

Single fruit weight showed highly significant and positive correlation with yield per plant(rg = 0.734, rp = 0.524) at both genotypic and phenotypic level indicating that if the single fruit weight was increased the yield per plant was increasing significantly (Table 4). Significant but negative correlation was found in Shelf life (rg = -0.219, rp = -0.207). Non-significant positive correlation was found in fruit pH (rg = 0.068, rp = 0.050) and total soluble solid (rg = 0.064, rp = 0.049). Rani *et al.* (2010) correlation studies on twenty three tomato hybrids showed that weight of fruit had positive significant association with per plant fruit yield.

4.2.13 Fruit pH

Fruit pH showed highly significant but negative correlation with total soluble solid (rg = 0.064, rp = 0.049). Non-significant but positive correlation was found in shelf life (rg = 0.037, rp = 0.030) and yield per plant (rg = 0.209, rp = 0.036). Singh *et al*. (2008) found similar result which supported the present findings.

4.2.14 Total soluble solid

Total soluble solid showed highly significant and positive correlation with yield per plant (rg = 0.332, rp = 0.266) at both genotypic and phenotypic level(Table 4). Non-significant and negative correlation was found in shelf life (rg = -0.006, rp = -0.018). Buchseth *et al.* (2012) reported that yield per plant expressed a highly significant positive correlation with Total soluble solid.

4.2.15 Shelf life

Shelf life showed positive non significant correlation with yield per plant (rg = 0.030, rp = 0.035) at both genotypic and phenotypic level (Table 4).

4.3 Path analysis

The path coefficient analysis technique was developed by Wright (1921) and demonstrated by Deway and Lu (1959) facilitates the portioning of correlation coefficients into direct and indirect contribution of various characters on yield. It is standardized partial regression coefficient analysis. As such, it measures the direct influence of one variable upon other. Such information would be of great value in enabling the breeder to specifically identify the important component traits of yield and utilize the genetic stock for improvement in a planned way. The direct and indirect effects of yield contributing characters on yield were worked out by using path analysis. Here yield per plant was considered as effect (dependent variable) and days of first flowering, days to 50% flowering, days to first fruiting, days to maturity, plant height (cm), number of branches per plant, number of clusters per plant, number of flowers per cluster, number of fruits per cluster, number of fruits per plant, fruit length (mm), fruit diameter (mm), skin diameter (mm), No. of locules per fruit, Total soluble solids, pH, Relative water content, Moisture percentage, Individual fruit weight (g) were treated as independent variables. Path coefficient analysis was showed direct and indirect effects of different characters on yield of tomato in Table 5.

4.3.1 Plant height (cm)

Plant height had a positive direct impact on yield (0.183) (Table 5). This character exhibited negative indirect effect on Days to 1st flowering (-0.946), days to maturity (-0.191), Number of branches per plant (-0.015), Number of fruits per plant (-1.125) and Fruit length (-0.236). The character also showed positive indirect effect on days to 1st fruiting (0.836), number of cluster per plant (0.732), number of flowers per cluster (0.060), number of fruits per cluster (0.643), fruit diameter (0.167), single fruit weight (0.015), fruit pH (0.031), total soluble solid (0.017) and shelf life (0.002). The cumulative effect produced a positive and non-significant correlation with yield (0.175). Rojalin *et al.* (2018) analyzed that the path coefficient and reported that traits such as plant height at final harvest had positive direct effect on marketable fruit yield per plant in tomato.

4.3.2 Days to 1st flowering

Days to 1st flowering had a positive direct impact on yield (0.764) (Table 5). This character exhibited negative indirect effect on plant height (-0.148), days to 1st fruiting (-0.713), number of cluster per plant (-0.928), number of fruits per cluster (-0.275), number of fruits per cluster (-1.907), fruit pH (-0.054), total soluble solid (-0.045) and shelf life (-

0.056). The character also showed positive indirect effect on days to maturity 0.270) and number of branches per plant (0.010), number of fruits per plant (2.084), fruit length (0.362), fruit diameter (0.094) and single fruit weight (0.229). The cumulative effect produced a positive and non-significant correlation with yield (0.086).The result was similar with Rajolli *et al.* (2017) who carried out path analysis in tomato.

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

Characters	Direct effect	PH	DFF	DFFr	DM	NBP	NCP	NFC	NFrC	NFP	FL	FD	SFW	FpH	TSS	SL	Genotypic correlation with Yield
PH	0.183		-0.946	0.836	-0.191	-0.015	0.732	0.060	0.643	-1.125	-0.236	0.167	0.015	0.031	0.017	0.002	0.175^{NS}
DFF	0.764	-0.148		-0.713	0.270	0.010	-0.928	-0.275	-1.907	2.084	0.362	0.094	0.229	-0.054	-0.045	-0.056	0.086^{NS}
DFFr	-0.961	-0.159	0.864		0.170	0.014	-0.535	0.038	-0.209	0.626	0.192	-0.145	-0.105	-0.037	-0.018	0.067	0.224*
DM	0.305	-0.114	1.029	-0.534		0.004	-1.158	-0.541	-3.436	3.318	0.653	0.110	0.299	-0.009	-0.004	-0.035	-0.113^{NS}
NBP	-0.032	0.084	-0.354	0.438	-0.042		0.008	-0.276	-1.302	1.010	0.106	0.203	0.073	-0.008	0.031	0.039	0.422**
NCP	0.892	0.090	-0.724	0.344	-0.237	0.000		0.446	3.289	-3.501	-0.551	-0.233	-0.510	0.046	0.010	-0.076	0.231*
NFC	0.684	0.016	-0.468	-0.053	-0.241	0.013	0.973		3.521	-3.209	-0.592	-0.365	-0.410	0.028	0.016	0.046	0.242*
NFrC	0.936	0.026	-0.489	0.044	-0.231	0.009	1.082	0.531		-3.942	-0.634	-0.369	-0.488	-0.067	0.001	-0.079	-0.352**
NFP	-0.965	0.051	-0.597	0.148	-0.249	0.008	1.285	0.540	4.398		-0.631	-0.346	-0.517	-0.032	-0.001	-0.076	0.418**
FL	0.753	-0.057	0.560	-0.244	0.265	-0.004	-1.091	-0.537	-3.815	3.403		0.200	0.367	0.018	-0.014	0.092	-0.106^{NS}
FD	0.575	0.053	0.189	0.241	0.058	-0.011	-0.603	-0.434	-2.906	2.445	0.262		0.606	0.021	0.013	0.042	0.553**
SFW	0.75	0.004	0.355	0.134	0.121	-0.003	-1.015	-0.373	-2.947	2.803	0.369	0.464		-0.013	0.011	0.073	0.734**
FpH	-0.186	-0.031	0.339	-0.191	0.015	-0.001	-0.367	-0.105	1.630	-0.692	-0.072	-0.066	0.051		-0.103	-0.012	0.209^{NS}
TSS	0.178	0.018	-0.294	0.098	-0.007	-0.005	0.085	0.061	0.029	0.028	-0.058	0.041	0.048	0.108		0.002	0.332**
SL	-0.334	-0.001	0.195	0.193	0.032	0.004	0.339	-0.095	1.074	-0.922	-0.208	-0.073	-0.164	-0.007	-0.001		0.030^{NS}

PH = Plant height (cm), DFF = Days to 1st flowering, DFFr = Days to 1st fruiting, DM = Days to maturity, NBP = Number of branches per plant, NCP = Number of cluster per plant, NFC = Number of flowers per cluster, NFrC = Number of fruits per cluster, NFP = Number of fruits per plant, FL = Fruit length (mm), FD = Fruit diameter (mm), SFW = Single fruit weight (g), FpH = Fruit Ph, TSS = Total soluble solid, SL = Shelf life (days), YPP = Yield per plant(kg)

** = significant at 1%, and * = significant at 5% level of probability, respectively.

4.3.3 Days to 1st fruiting

Days to 1st fruiting had shown negative direct impact on yield (-0.961) (Table 5). This character showed negative indirect effect on plant height (-0.159), number of cluster per plant (-0.535), number of fruits per cluster (-0.209), fruit diameter (-0.145), single fruit weight (-0.105), fruit pH (-0.037) and total soluble solid (-0.018). The character also showed positive indirect effect on days to 1st fruiting (0.864), days to maturity (0.170), Number of branches per plant (0.014), number of fruits per cluster (0.038), number of fruits per plant (0.626), fruit length (0.192) and shelf life (0.067) which finally made significant positive correlation with yield (0.224). The result was similar with Rajolli *et al.* (2017) who carried out path analysis in tomato.

4.3.4 Days to maturity

Days to maturity showed positive direct effect (0.305) on yield (Table 5). This character showed positive indirect effect on days to 1st flowering (1.029), number of branches per plant (0.004), number of fruits per plant (3.318), fruit length (0.653), fruit diameter (0.110), single fruit weight (0.299). This character also showed negative indirect effect on plant height (-0.114), days to 1st fruiting (-0.534), number of cluster per plant (-1.158), number of flowers per cluster (-0.541), number of fruits per cluster (-3.436), fruit Ph (-0.009), total soluble solid (-0.004) and shelf life (-0.035). The cumulative effect produced a non-significant negative correlation with yield (-0.113).

4.3.5 Number of branches per plant

Number of branches per plant showed negative direct effect on yield (-0.032) (Table5). This character produce negative indirect effect on days to 1st flowering (-0.354), days to maturity (-0.042), number of flowers per cluster (-0.276), number of fruits per cluster (-1.302) and fruit pH (-0.008). The character also showed positive indirect effect on plant height (0.084), days to 1st fruiting (0.438), number of cluster per plant (0.008), number of fruits per plant (1.010), fruit length (0.106), fruit diameter (0.203), single fruit weight (0.073), total soluble solid (0.031) and shelf life (0.039) which finally made significant positive correlation with yield (0.422). Naveen *et al.* (2017) evaluated thirty genotypes of tomato to study path coefficient analysis of fruit yield and yield attributing traits in tomato during revealed that number of branches per plant, exhibited positive direct effects on fruit yield per plant.

4.3.6 Number of cluster per plant

Number of cluster per plant showed positive direct effect on yield (0.892) (Table5). This character produce negative indirect effect on days to 1^{st} flowering (-0.724), days to maturity (-0.237), number of fruits per cluster (-3.501) fruit length (-0.551), fruit diameter (-0.233), single fruit weight (-0.510) and shelf life (-0.076). The character also showed positive indirect effect on plant height (0.090), days to 1^{st} fruiting (0.344), number of branches per plant (0.001), number of flowers per cluster (0.446), Number of fruits per cluster (3.289), fruit pH (0.046) and total soluble solid (0.010) which finally made significant positive correlation with yield (0.231). The result was similar with Rahman *et al.* (2015) who carried out path analysis in tomato.

4.3.7 Number of flowers per cluster

Number of flowers per cluster showed positive direct effect on yield (0.684) (Table5). This character produce negative indirect effect on days to 1^{st} flowering (-0.468), days to 1^{st} fruiting (-0.053),days to maturity (-0.241), number of fruits per plant (-3.209), fruit length (-0.592), fruit diameter (-0.365) and single fruit weight (-0.410). The character also showed positive indirect effect on plant height (0.016), number of branches per plant (0.013), number of cluster per plant (0.973), fruit pH (0.028) and total soluble solid (0.016) and shelf life (0.046) which finally made significant positive correlation with yield (0.242). The result was similar with Rahman *et al.* (2015) who carried out path analysis in tomato. Alam and Paul (2019) conducted an experiment with twenty nine genotypes of tomato for determining direct and indirect effects of the various yield attributing traits and found that the number of flower cluster per plant showed positive direct effects on yield per plant.

4.3.8 Number of fruits per cluster

Number of fruits per cluster showed positive direct effect (0.936) on yield (Table 5). This character showed positive indirect effect on plant height (0.026), days to 1^{st} fruiting (0.044), number of branches per plant (0.009), number of cluster per plant (1.082), number of flowers per cluster (0.531) and total soluble solid (0.001). This character produce negative indirect effect on days to 1st flowering (-0.489), days to maturity (-0.231), number of fruits per plant (-3.942), fruit length (-0.634), fruit diameter (-0.369) and single fruit weight (-0.488), fruit pH (-0.067) and shelf life (-0.079). The cumulative effect produced a negative but highly significant correlation with yield (-0.352). The result was similar with Kumar *et al.* (2013) who carried out path analysis in tomato.

4.3.9 Number of fruits per plant

Number of fruits per plant showed negative direct effect (-0.965) on yield (Table 5). This character produce negative indirect effect on days to 1st flowering (-0.597), days to maturity (-0.249), fruit length (-0.631), fruit diameter (-0.346), single fruit weight (-0.517), fruit pH (-0.032), total soluble solid (-0.001) and shelf life (-0.076). This character showed positive indirect effect on plant height (0.051), days to 1st fruiting (0.148), number of branches per plant (0.008), number of cluster per plant (1.285), number of flowers per cluster (0.540) and number of fruits per cluster (4.398).The cumulative effect produced a positive highly significant correlation with yield (0.418). Premalakshmi *et al.* (2014) investigated fourteen genotypes of tomato to find out the variability, correlation and path coefficient effects. They revealed that number of fruits per plant had positively significant association and also have positively high direct effect on fruit yield per plant.

4.3.10 Fruit length

Fruit length showed positive direct effect (0.753) on yield (Table 5). This character produce negative indirect effect on plant height (-0.057), days to 1st fruiting (-0.244), number of branches per plant (-0.004), number of cluster per plant (-1.091), number of flowers per cluster (-0.537), number of fruits per cluster (-3.815) and total soluble solid (-0.014). This character also showed negative indirect effect on days to 1st flowering (0.560), days to maturity (0.265), number of fruits per plant (3.403), fruit diameter (0.200), single fruit weight (0.367), fruit pH (0.018), and shelf life (0.092). The cumulative effect produced a non significant and negative correlation with yield (-0.106).

4.3.11 Fruit diameter

Fruit diameter showed positive direct effect (0.575) on yield (Table 5). This character produce positive indirect effect on plant height 0.053), days to 1st flowering (0.189), days to 1st fruiting (0.241), days to maturity (0.058), number of fruits per plant (2.445), fruit length (0.262), single fruit weight (0.606), fruit pH (0.021), total soluble solid (0.013) and shelf life (0.042). This character also showed negative indirect effect on number of branches per plant (-0.011), number of cluster per plant (-0.603), number of flowers per cluster (-0.434) and number of fruits per cluster (-2.906). The cumulative effect produced a significant positive correlation with yield (0.553). Maurya *et al.* (2020) reported that in thirty genotypes of tomato path coefficient analysis revealed that the polar diameter of fruit (0.1379), had showed highest positive direct effect on yield per plant.

4.3.12 Single fruit weight

Single fruit weight had shown positive direct effect (0.75) on yield (Table 5). This character produce positive indirect effect on plant height (0.004), days to 1st flowering (0.355), days to 1st fruiting (0.134), days to maturity (0.121), number of fruits per plant (2.803), fruit length (0.369), fruit diameter (0.464), total soluble solid (0.011) and shelf life (0.073). This character also showed negative indirect effect on number of branches per plant (-0.011), number of cluster per plant (-1.015), number of flowers per cluster (-0.373), number of fruits per cluster (-2.947) and fruit pH (-0.013). The cumulative effect produced a significant positive correlation with yield (0.734). Anuradha *et al.* (2018) performed an experiment consisted of forty genotypes of tomato to during Kharif, 2017-18 and reported that the parameters such as average fruit weight exhibited highest positive direct effect on fruit yield and thus these parameters should be considered for selection in yield improvement.

4.3.13 Fruit pH

Fruit pH had shown negative direct effect (-0.186) on yield (Table 5). This character produce negative indirect effect on plant height (-0.031), days to 1st fruiting (-0.191), number of fruits per plant (-0.001), number of cluster per plant (-0.367), number of flowers per cluster (-0.105), number of fruits per cluster (-0.692), fruit length (-0.072), fruit diameter (-0.066), number of flowers per cluster (-0.373), number of fruits per cluster (-2.947) and fruit pH (-0.013), total soluble solid (-0.103) and shelf life (-0.012). This character also showed positive indirect effect on days to 1st flowering (0.339), days to maturity (0.015), number of fruits per cluster (1.630) and single fruit weight (0.051). The cumulative effect produced a non significant but positive correlation with yield (0.209).

4.3.14 Total soluble solid

Total soluble solid had shown positive direct effect (0.178) on yield (Table 5). This character produce positive indirect effect on plant height (0.018), Days to 1st fruiting (0.098), number of cluster per plant (0.085), number of flowers per cluster (0.061), number of fruits per cluster (0.029), number of fruits per plant (0.028), fruit diameter (0.041), single fruit weight (0.048), fruit pH (0.108) and shelf life (0.002). This character also showed negative indirect effect on days to 1st flowering (-0.294), days to maturity (-0.007) and number of branches per plant (-0.005). The cumulative effect produced significant positive correlation with yield (0.332).

4.3.15 Shelf life

Shelf life had shown negative direct effect (-0.334) on yield (Table 5). This character produce negative indirect effect on plant height (-0.001), number of flowers per cluster (-0.095), number of fruits per cluster (-0.922), fruit length (-0.208), fruit diameter (-0.073), single fruit weight (-0.164), fruit pH (-0.007) and total soluble solid (-0.001). This character also showed positive indirect effect on days to 1st flowering (0.195), days to 1st fruiting (0.193), days to maturity (0.032), number of branches per plant (0.004), number of cluster per plant (0.339) and number of fruits per cluster (1.074). The cumulative effect produced non-significant positive correlation with yield (0.030).

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at Sher-e-Bangla Agricultural University Dhaka, during the period from September, 2021 to February, 2022 using 28 genotypes of tomatoes to analyze the genetic variability and character association in F_2 population of tomato in a randomized complete block design with three replications.

The analysis of variance revealed significant differences for various traits among genotypes. Mean performance revealed that G1×G4 had the highest fruit yield per plant (11.35 Kg). The lowest days to maturity was found in G9×G10 (80.67 days) followed by G2×G10 (81.33 days). The phenotypic variance (σ^2p) appeared to be higher than the genotypic variance (σ^2g) suggested considerable influence of environment on the expression of genes controlling these traits. The genotypic co-efficient of variation (GCV) was less than the phenotypic co-efficient of variation (PCV) for all the characters. The number of cluster per plant (35.033), number of fruits per cluster (47.347), number of fruits per plant (81.5), fruit diameter (41.008), single fruit weight (66.156), total soluble solid (53.131) and yield per plant (41.691) all had high genotypic co-efficients of variation (GCV). High heritability with high genetic advance in percent of mean was observed in number of fruits per cluster (73.667), number of fruits per plant (85.669), fruit diameter (93.326), single fruit weight (96.603) and total soluble solid (72.553) which indicated that these traits would be effective for genetic improvement. High heritability with low genetic advance in percent of mean was observed in plant height (87.719), days to 1st fruiting (81.845), fruit length (88.531) and shelf life (81.168).

The result revealed fruit yield per plant had a highly significant positive correlation with days to 1st fruiting (rg = 0.224, rp = 0.227), number of branches per plant (rg = 0.422, rp = 0.498), number of cluster per plant (rg = 0.231, rp = 0.244), number of flowers per plant (rg = 0.242, rp = 0.366), number of fruits per plant (rg = 0.418, rp = 0.447), fruit diameter (rg = 0.553, rp = 0.367), single fruit weight (rg = 0.734, rp = 0.524) and total soluble solid (rg = 0.332, rp = 0.266), indicating that a possible increase in these traits tends to increase in fruit yield per plant.

In path analysis data on various parameters *viz.*plant height (0.183),days to 1st flowering (0.764),days to maturity (0.305),number of cluster per plant (0.892), number of flowers per cluster (0.684), number of fruits per cluster (0.936), fruit length (0.753),fruit diameter (0.575), single fruit weight (0.75) and total soluble solid (0.178) had revealed positive direct effect on yield. Among these, number of cluster per plant, number of fruits per cluster, number of fruits per plant, fruit diameter, single fruit weight and total soluble solid had also significant positive correlation with yield per plant at genotypic level, indicating that these were the main contributors to yield per plant and there is a great extent of possibility of improving fruit yield through selection based on these characters. Days to 1st fruiting, number of branches per plant, fruit pH, and self life showed in direct effect indicating effectiveness of indirect selection.

Based on the findings of the study, it can be concluded that, G1×G4 is the highest yielder and could be recommended for further selection in next generation. G9×G10 could be selected for early maturity and further selection.

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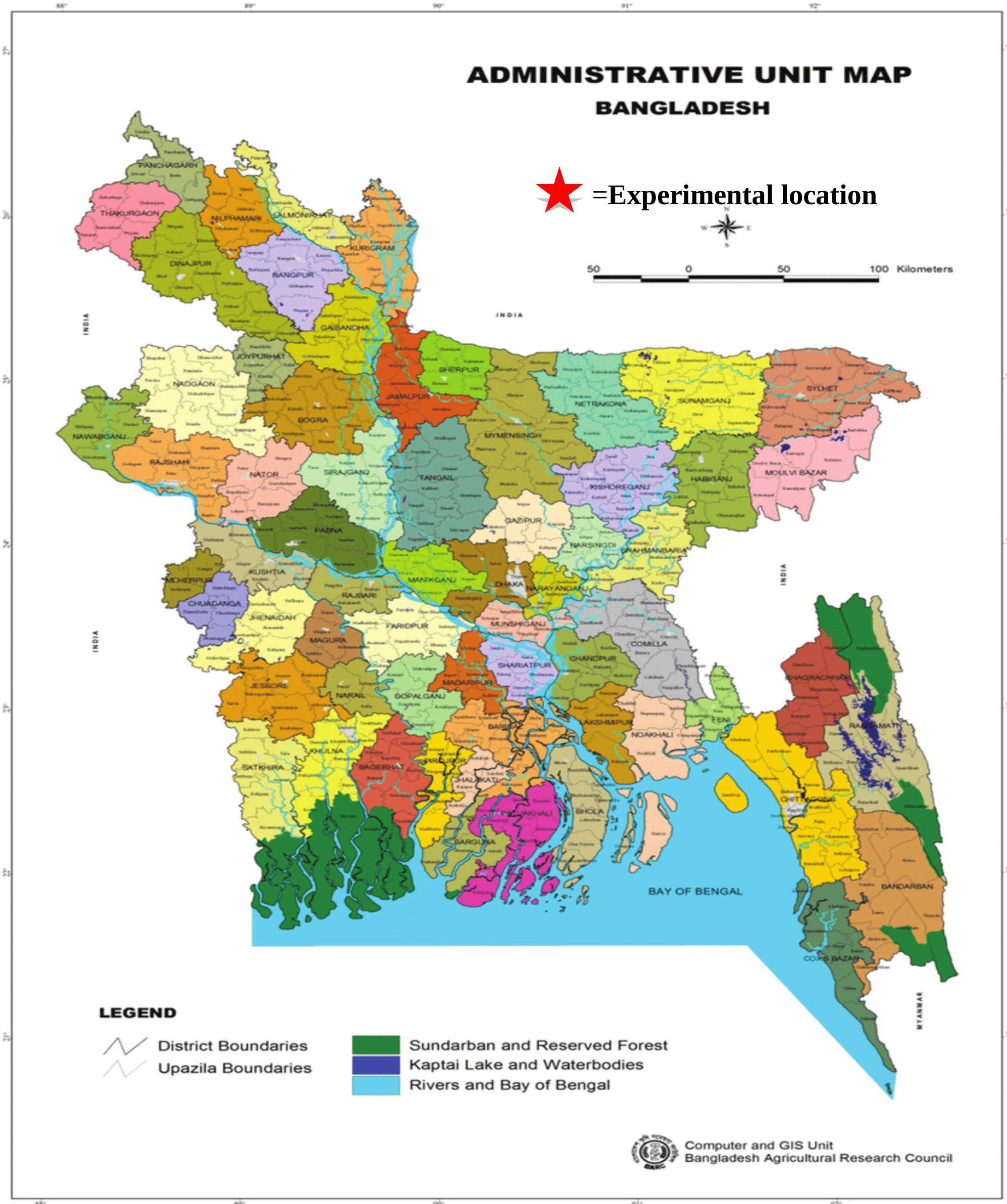
Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	**Characteristics**
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0- 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix III. Monthly meteorological information during the period from September 2021to February, 2022.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2021	September	32.4°C	25.7°C	80%.	86 mm
	October	31.2°C	23.9°C	76%.	52 mm
	October	31.2	23.9	76	52 mm
	November	29.6	19.8	53	00 mm
	December	28.8	19.1	47	00 mm
2022	January	25.5	13.1	41	00 mm
	February	25.9	14	34	7.7 m

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Mean performance for 16 different characters in 28 F_2 populations of tomato

Genotype	PH	DFF	DFFr	DM	NBP	NCP	NFC	NFrC	NFP	FL	FD	SFW	FpH	TSS	SL	YPP
G1×G3	74.67	48.67	60.33	107.00	5.67	14.67	8.33	4.67	68.33	48.67	65.33	79.00	3.90	1.67	13.67	5.40
G1×G4	129.00	28.67	43.00	94.00	15.67	19.33	8.33	4.33	83.33	56.67	80.00	138.00	4.07	2.17	11.00	11.35
G1×G5	78.33	39.00	55.33	109.00	9.00	21.00	5.67	2.33	47.67	68.33	41.67	66.67	3.63	1.40	12.67	3.10
G1×G6	98.33	39.00	51.00	101.33	10.00	20.00	7.33	4.33	87.00	46.67	64.33	55.33	3.37	2.50	23.33	4.93
G1×G7	138.00	20.33	36.33	96.00	12.33	37.00	8.00	2.33	84.67	57.00	69.33	56.67	2.97	3.03	17.00	4.78
G1×G8	130.00	28.33	47.00	96.00	16.33	36.33	4.33	5.67	204.00	45.67	71.67	16.00	3.90	1.30	18.67	3.33
G1×G9	120.00	32.00	41.00	102.33	7.00	10.67	5.00	3.67	39.33	54.67	67.33	100.67	3.80	1.77	21.67	3.93
G1×G10	107.67	37.67	46.33	95.33	10.00	41.00	10.67	9.33	383.00	27.33	19.67	14.67	4.07	1.50	28.67	5.67
G2×G3	104.33	38.67	55.33	115.67	10.33	19.33	6.67	5.00	102.33	55.33	38.67	51.00	3.87	1.57	15.67	5.14
G2×G7	102.67	35.00	52.67	101.00	10.00	25.33	9.00	6.33	167.00	47.00	45.67	60.33	3.47	4.17	18.67	10.10
G2×G10	102.00	25.67	50.33	81.33	11.00	25.67	12.33	6.67	174.67	24.00	19.67	13.00	3.67	1.50	15.00	2.23
G3×G2	86.00	46.33	64.33	109.00	10.33	22.67	8.67	2.67	62.00	63.67	51.00	42.33	3.47	1.17	16.00	2.77
G3×G4	112.67	38.67	45.33	96.00	14.33	20.67	4.67	3.00	65.33	49.67	81.00	79.00	3.67	0.83	21.00	5.32
G3×G5	110.00	34.33	42.00	101.67	15.33	19.00	5.67	4.67	84.00	49.33	64.67	99.33	4.10	0.37	20.33	8.19
G3×G10	90.00	37.67	49.67	104.67	10.67	22.33	7.33	3.33	72.67	55.33	30.00	29.33	3.60	0.33	21.67	2.08
G4×G1	98.67	33.00	45.67	99.00	13.67	18.33	4.67	5.33	93.33	42.67	79.33	98.00	3.63	3.13	22.33	9.20
G4×G5	102.00	32.67	49.67	108.33	7.00	15.33	5.67	2.67	44.67	83.00	38.67	63.00	3.73	1.40	17.00	2.81
G4×G6	104.67	40.67	51.33	108.67	5.67	18.33	6.67	4.00	69.00	60.00	64.67	93.33	3.87	0.17	16.67	6.28
G4×G7	107.33	23.67	44.33	93.67	7.00	36.33	11.00	9.33	341.00	29.00	24.67	13.67	3.93	1.23	19.33	4.67
G4×G9	118.67	28.33	39.33	92.67	15.33	22.00	7.33	3.33	76.00	61.33	84.67	115.67	3.63	1.00	9.33	9.30
G4×G10	98.33	27.00	56.00	83.67	5.00	37.67	13.33	13.33	496.00	23.67	21.67	14.00	3.60	1.83	15.33	6.91
G5×G10	127.00	24.33	39.33	96.67	16.67	37.67	8.00	7.67	288.67	39.00	40.33	9.67	3.53	2.20	19.00	2.78
G6×G2	80.00	41.33	56.67	107.67	14.00	14.00	5.33	6.67	97.33	72.00	30.00	19.33	4.17	0.83	19.67	1.95
G7×G10	86.33	38.00	61.67	105.33	14.00	16.33	7.00	3.33	56.00	62.67	47.33	52.67	3.87	2.17	9.00	2.94
G8×G10	115.67	27.67	46.00	83.00	7.33	37.33	9.67	10.67	403.00	29.67	27.33	13.67	3.97	1.00	18.00	5.55
G9×G10	125.33	20.67	43.67	80.67	12.33	41.67	10.33	8.33	337.00	32.00	39.33	13.67	3.67	1.17	15.67	4.63
G10×G2	91.00	32.67	46.33	108.00	13.67	25.00	6.33	5.33	132.33	62.00	30.67	48.67	3.60	3.03	19.00	6.40
G10×G4	80.67	50.00	58.33	110.67	6.67	27.00	6.33	4.33	115.33	58.00	64.00	90.33	3.77	1.23	23.33	10.43
SE(±)	3.618	2.259	1.904	4.252	1.634	2.731	0.896	0.891	29.383	3.069	3.172	3.957	0.144	0.308	1.181	1.475
CV(%)	6.01	11.53	6.67	7.40	25.86	18.87	20.33	28.31	33.334	10.60	10.97	12.41	6.67	32.68	11.48	47.01

PH = Plant height (cm), DFF = Days to 1st flowering, DFFr = Days to 1st fruiting, DM = Days to maturity, NBP = Number of branches per plant, NCP = Number of cluster per plant, NFC = Number of flowers per cluster, NFrC = Number of fruits per cluster, NFP = Number of fruits per plant, FL = Fruit length (mm), FD = Fruit diameter (mm), SFW = Single fruit weight (g), FpH = Fruit Ph, TSS = Total soluble solid, SL = Shelf life (days), YPP = Yield per plant(kg).

Appendix V. Visit of research supervisor in the experimental field