Variability studies for growth, yield and quality characters of tomato (*Lycopersicon esculentum* Mill.)

By

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2017A67M

Thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University in partial fulfilment of the requirements for the degree of

Master of Science (Agriculture) in Horticulture-Vegetable Science

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE CCS HARYANA AGRICULTURAL UNIVERSITY HISAR - 125004 (HARYANA)

2019

CERTIFICATE – I

This is to certify that this thesis entitled "**Variability studies for growth, yield and quality characters of tomato (*Lycopersiconesculentum* Mill).**" submitted for the degree of **Master of Science (Agriculture)** in the subject of **Horticulture-Vegetable Science** to the **CCS Haryana Agricultural University**, is a bonafide research work carried out by **Ms.Vidya R**. **Admn. No. 2017A67M** under my supervision and that no part of this dissertation has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that this thesis entitled **"Variability studies for growth, yield and quality characters of tomato (*Lycopersiconesculentum* Mill.)"** submitted by **Miss. Vidya R.**Admn. No. **2017A67M** to the **ChaudharyCharan Singh Haryana Agricultural University, Hisar,** in partial fulfillment of the requirements for the degree of **Master of Science (Agricuture)** in the subject of **Horticulture-Vegetable Science** has been approved by the Student's Advisory Committee after an oral examination on the same, in collaboration with an external examiner.

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DEAN, POST-GRADUATE STUDIES

ACKNOWLEDGEMENT

I am beholden to the highly benevolent and merciful almighty God whose grace bestows upon us. The very idea of this work makes me amused in thanking to all who have helped me in achieving this milestone of my academic success. My heart full acknowledgement and deep sense of gratitude from the core of my heart to each and everyone who have been there with me helping to overcome the difficulties which crossed my way in the accomplishment of this Endeavour.

A precious debt as that of learning is the only liability that is difficult to repay except perhaps through gratitude. It is my proud privilege to express my heartfull of thanks and indebtness to my Major advisor, ***Dr. V.K,Batra****, Professor and Head, Department of Vegetable Science, COA, CCSHAU, Hisarfor his sustained guidance and constant encouragement and empathy in planning and execution of my research work, which helped me to successfully complete the research in time and also for his constant support, care and co-operation through the hard times and entire period of my presence in the University*

I feel privileged and express my deep sense of gratefulness and indebtedness to my Co- Major advisor ***Dr. D.S. Duhan****, Assistant Scientist, Department of Vegetable Science, for his unceasing encouragement, noble inspiration, planning, ever willing, meticulous suggestions in the preparation of this manuscript and judicious guidance throughout the course of this investigation enabled me in executing my research workand other members of advisory committee, Dr. S.K. Pahuja. Professor and Controller of examination,Department of Genetics & Plant Breeding, Dr.AxayBhukar, Asst. Scientist, Dept. of SST, Dr.Raj Pal Dalal, Asst. Horticulturist, Dept. of Horticulture, for their cooperation and sagacious guidance rendered during the course of investigation.*

Distinctive words of thanks to Dr. M.K,Rana, Dr. Virendra Singh, Dr. Kuldeep Singh, Dr.Vijay Pal Panghal and other faculty members, all non-teaching staff that provided timely help at various stages of study.

I am highly beholden to the benevolent and merciful Almighty who bestows his grace upon me,I express my gratitude and affection to the pillars of my life, ever supporting father ***Shri. RajuS.C.****, loving mother* ***Smt. Chandramathi.G****,dearest sister****Varsha.R*** *and all the members of my family for their unconditional love and all time support, without them it would have never been possible for me to reach this success.*

Words are scarce to express my ardent sentiments to my Seniors PavanGowdar, SantoshKorav, Jayanth. S, NavyaBhat, Jaslam P.K. and Pradeep Kumar for their timely help and moral support.

A special recognition should always be given to some special persons such as Mamatha, Athira, Praveen, Tanvi, Bicchinnamaîtri, Khyathi, Uma, Anjukumari, Sumayya ,Karthik, Bhanuprakash and Manjunath for their help during my M.Sc. degree programme. I Lastly, I would like to convey my whole hearted thanks to all my well-wishers who assisted and supported me directly or indirectly

It is a matter of great inclination to thank the ***Indian Council of Agricultural Research*** *for financial assistance through* ***Junior Research Fellowship*** *during my Master's degree programme.*

Above all, I thank the ALMIGHTY, without whose grace this work could never have been accomplished.

Place: Hisar *Vidya R.*

Dated: July 2019

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CHAPTER-I

INTRODUCTION

India is the second largest producer of vegetables in the world, next to China with an annual production estimated around 179.7 million tones from an area of 10.38 million hectare (Horticulture Statistics at a Glance, 2017-18).

Tomato is one of the most important and widely grown vegetable crops, belongs to a family Solanaceae. In many countries, it ranks second in importance to potato. Wider adaptability, high yield potential and usage of varieties in fresh and processed food industries increases its importance to all over the world. Tomato is a rich source of vitamins, minerals and organic acids, made it universally considered as 'Protective food'. It is known as Love apple. It can also be grown in the greenhouses during the off-season as a forcing crop.

In India, Tomato ranks second among vegetables in area and production in India. It occupies an area of 0.88 million hectares with 18.70 million tones of production with an average yield of 21.2 tons per hectares. In India, during 2017-18 this crop occupies an area of 0.80 milliion hectares and production of 22.337 million tonnes. (Horticulture Statistics at a Glance 2017-18).

In Haryana, during 2017-18, its area and production was 789 ha and 4900 metric tons, respectively. The major tomato growing districts are Karnal, Mewat, Gurgaon, Ambala, Sonipat, Yamuna Nagar, Kurukshetra and Faridabad in the state. (Horticulture Statistics at a Glance 2017-18).

Tomato fruits are used as both fresh as well as processed form. Ripe fresh fruits are consumed as raw in sandwiches, salads etc. It ranks first in the list of vegetables used in the 7 processing industry. Fruits are utilized in the preparation of processed products such as puree, paste, powder, ketchup, sauces, soups etc. Green fruits are used for the preparation of pickles and chutney while fully ripened whole fruits are canned.

In many countries, it is considered as *poor man's orange* because, fruits are a good source of lycopene (an antioxidant), ascorbic acid and β – carotene thus add color and flavor. Epidemiological studies have proven that lycopene has great beneficial effects on human health and it has been shown to protect against damage caused by oxidative stress. It may also inhibit the oxidation of low –density lipoprotein (bad cholesterol). Increased lycopene has proven nutritional value as an antioxidant that is associated with a low incidence of certain forms of human cancer

Due to its nutritional value, it protects the human body from several ailments, useful for reducing cardiovascular risks, weight losses and controlling obesity, eye disorders, night blindness, urinary tract infection, liver disorders and diabetes. It acts as an intestinal antiseptic and blood purification, as it helps in cleansing toxic compounds from the body. It also

promotes gastric secretion, cures mouth cancer, sour throat and improve the quality of the prepared food.

The prime objective of the breeder is to improve the plant characters both qualitatively and quantitatively. Hence, adequate knowledge of genetics for various traits is essential to obtaining desirable results. For a successful crop improvement programme, the magnitude of genetic variability and the degree of transmission is of immense importance. Phenotypic plant characters are controlled by the genetic makeup of a plant and its prevailing environment conditions. By considering the parameters such as phenotypic genetic variability, genotypic genetic variability, heritability and genetic advance, phenotypic variability present in the population can be divided into heritable and non-heritable components

Heritability denotes the proportion of phenotypic variation due to genotype. An effective breeding programme involves the improvement of both yield and quality parameters. Likewise, heritability and genetic advance both are important considerations for a selection than heritability alone because, though high heritability helps the breeder to select the desirable genotype for a character based on phenotype but does not mean genetic gain for a particular character.

Genetic advance denotes the improvement in the genotypic values of the selected population over the base. Breeding programme aim at plant production requires not only of yield but also the direct and indirect effect of its components. Yield is the combined effect of all its individual components. Yield and quality both are important components of a breeder. Therefore, it is important to know the relationship between various components that affects the yield and quality. Correlation studies between the different quantitative characters' give the degree of relationship between these components. Direct and indirect contributions of various components towards total yield can be made understand by path coefficient techniques

The selection of new parents for a higher degree of heterosis is of prime importance. For a hybridization programme, a study of genetic divergence among the germplasm for the selection of parents is necessary. It is because genetically diverse plants are expected to give high hybrid vigor. Hence, for successful breeding programme knowledge on genetic diversity of various traits contributing to yield and quality would be of most importance. The path coefficient analysis helps in determining the direct and indirect contribution of various components towards yield. These studies facilitate the selection programme based on the quantum importance of individual characters

The selection of new parents is of prime importance for achieving better heterosis since; commercial F_1 hybrids are common in tomato. Generally, plants that are genetically diverse are expected to give high hybrid vigor. Hence, the study of genetic divergence among the existing varieties necessitates the identification of parents for the hybridization programme.

Planning of a successful breeding programme requires the information on genetic divergence of various traits particularly of those contribute towards yield and quality

Tomato is a day-neutral and self-pollinated crop. Being a warm-season crop, it can be cultivated under a wide range of soil and climatic conditions. Crop production is highly influenced by environmental factors such as temperature, relative humidity, light and carbon dioxide present in the atmosphere. The crop requires a temperature of 20-24° C for its optimum production. Day and night temperature difference should be 6-8º C for getting a higher yield. The temperature of 21-24° C is required for lycopene synthesis

The potentiality of this crop made its need for improvement and to develop varieties suitable for cultivation under specific agro-climatic conditions. Plant productivity requires the consideration of both yield and quality parameters for the breeding programme. Existence of genetic variability among the parents for specific characters is prerequisite for crop improvement. Evolution of germplasm is an imperative hence breeder will have to create the genetic variability through hybridization, mutation and polyploidy breeding

Considering the above themes, the research has been planned with the following objectives:

1. To study the extent of genetic variability in tomato genotypes for growth, yield and quality parameters
2. To study the correlation and path analysis of different parameters with the yield of tomato genotypes.

CHAPTER-II

REVIEW AND LITERATURE

Breeding of vegetable crops is primarily concerned with the improvement quantitative as well as qualitative plant characters; hence, absolute knowledge of genetics in the vegetable breeding programme is essential to get desired results. The extent of variability existing in the germplasm is pre-requisite for a successful vegetable breeding programme. Hence, genetic variability present in the fruit yield and its contributing characters should be the main concern Number of studies has been carried out by earlier research workers regarding genetic variability, correlation and path analysis.

Keeping in sight the objectives of the present study, adequate literature information as reported by earlier workers has been reviewed, compiled and presented here in this chapter under the following headings:

2.1 Genetic variability

2.2 Heritability and Genetic advance

2.3 Correlation studies

2.4 Path analysis

2.5 Genetic diversity

2.1 Genetic variability

The information on genetic variability is prerequisite to carry out any breeding programme. Hence, the study of the degree of variability and its genetic components are the most important aspects of breeding material. Considerable knowledge has been generated on genetic variability of various components of tomato genotypes. Generally, variability can be studied by measuring the genotypic coefficient of variability and phenotypic coefficient of variability of genotypes

Literature, which has a reference to the genetic variability and its components on tomato, has been comprised and reviewed below

In the tomato genotypes, high genotypic coefficient of variation and phenotypic coefficient for the number of fruits per plant but low genotypic coefficient of variation for plant height. (Dudi *et al.*, 1983) while Sonone *et al.* (1986) reported high GCV and PCV for a growth character, plant height. In tomato genotypes, low G and PCV for total number of branches which was observed by Patil,(1996), while high GCV and PCV for growth and yield contributing characters of plant indicating high magnitude of variability for these traits in tomato. (Anandgowda, 1997)

Mohanty, (2003) elucidated that the phenotypic coefficient of variation and genotypic coefficient of variation were recorded maximum for average weight of fruit , total number of branches, total number of fruits per plant and other growth charcters

Lakshmikanth and Mani (2004) observed the higher magnitude of variability for the traits like total number of branches per plant, the number of fruits per plant, yield per plant and number of locules per fruit and these characters were exhibited the highest GCV and PCV.

Ahmed *et al.* (2006) reported that among the 60 genotypes of tomato including F_1 hybrids fruit yield per plant, plant height and average fruit weight, number of fruits per plant and juice to pulp ratio exhibited high genotypic and phenotypic variance

Golani *et al.* (2007) elucidated the highest phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for the number of locules per fruit, average fruit weight, fruit yield and plant height. Haydar *et al*. (2007) observed that GCV and PCV were reported maximum for fruit weight per plant, while it was recorded minimum for the number of leaves per plant. Saeed *et al.* (2007) observed the wider variation between genotypes for yield contributing as well as growth characters.

Abhay and Kori (2008) revealed that magnitude of PCV and GCV was high for mean weight of fruits, flower clusters per plant, plant height, fruit yield per hectare and seeds per fruit. Sengupta *et al.* (2009) stated that maximum PCV and GCV were recorded for the fruits per plant, the weight of fruit and fruit yield per plant. Vyas *et al.* (2011) reported the high genotypic and phenotypic coefficient of variation was observed for fruit yield and its contributing characters. Prema *et al*. (2011) studied 6 cherry tomato genotypes and elucidated high GCV and PCV for average fruit weight, pericarp thickness of fruit firmness, storability of fruit, yield per plant, lycopene content, fruit length and fruit width. Dar and Sharma (2011) recorded the highest value of PCV for yield quintals per hectare, weight of fruits and the total number of fruits per plant whereas; high GCV has recorded for β carotene

Among the 13 genotypes, Narolia *et al*. (2012) reported that variability was high for most of the characters studied except total number of branches per plant and days to 50% flowering for which variability is moderate and low. (Ahirwar and Prashad 2013) noted that the traits like average height of plants, total number of branches per plant, days to flowering , fruits per plant, average fruit weight, number of fruit trusses per plant, fruit set percent and radial and a polar diameter of fruit exhibited highest environmental influence for an expression. Kumar *et al.* (2013) reported that higher values of genotypic and phenotypic coefficient of variation were recorded for growth and yield contributing characters indicating that these characters are under the influence of additive gene action and more reliable for effective selection

Saleem *et al.* (2013) observed the greater PCV for all the traits under the studies than the GCV. Reddy *et al.* (2013) revealed the magnitude of PCV was higher than GCV for all the characters under the study. In a study on tomato, Sindya *et al.* (2014) elucidated that greater amount of genetic variability was present among the character number of seeds /fruit which exhibits the highest GCV and PCV values

On the other hand, Manna and Paul (2014) observed GCV and PCV were high for number locules per fruit followed by fruit weight. Kathayat *et al.* (2015) observed the highest GCV and PCV for the number of fruit clusters/ plant and lowest for days to first fruit picking. Kumar *et al*. (2015) reported the maximum GCV and PCV were recorded for plant height and the minimum was recorded for titrable acidity

On the other hand, Nagariya *et al.* (2015) stated that the highest GCV and PCV recorded for fruits/ plant and fruit yield per plant. Kumar *et al*. (2016) estimated the highest PCV and GCV for fruit growth, yield and quality characters

Satyendra *et al*. (2017) found the highest GCV and PCV for the fruit width, number of flowers/plant, number of fruits per plant, plant height, days to first flower opening, days to 50% flower opening, number of clusters per plant. In tomato, Lekshmi and Celine (2017) recorded PCV and GCV were highest for plant height, truss per plant, fruit weight, fruits per truss, fruits per plant and yield per plant

2.2 Heritability and Genetic advance

The most important parameters for the selection in breeding programme include heritability as well as genetic advance. The portion of a phenotypic variation, which is heritable known as heritability. It also represents the characters, which are transmitted from parents to their offspring

For an assortment of elite genotypes from a diverse genetic population, estimates of heritability are of prime requisite. The rate of progress that could be expected in a character through a selection is known as genetic advance studies. Johnson *et al.* (1955) stated that the characters, which are having high heritability, are does not exhibit high genetic advance. However, Characters that are exhibited high heritability coupled with high genetic advance could be improved by a simple selection method

Kumar *et al.* (1980) showed moderate heritability estimates for fruit yield and its contributing characters.and suggested that these traits as the reliable indices for selection in tomato based on heritability studies. Dudi *et al.* (1983) and Sonone *et al.* (1986) reported high heritability for plant growth character in tomato genotypes

In several crosses of tomato, Natarajan, (1991) observed the maximum heritability along with genetic advance for yield per plant, number of days required for a fruit maturity, fruit weight and area of leaf. Padmini and Vadivel, (1997) studied the heritability in second generation progenies of six tomato crosses and noted maximum heritability for yield and its contributing character.. Brar *et al*. (2000) reported the characters total number of fruits per plant, total yield per plant and marketable yield exhibited low to moderate heritability and genetic advance

Singh *et al*. (2000) and Aradhana and Singh (2003) reported the maximum heritability and genetic advance for plant growth, yield contributing and quality characters. Mohanty, (2003)

found that high heritability along with high GCV and genetic advance was noticed for fruit weight, average plant height, number of fruits and branches per plant. Haydar *et al*. (2007) exhibited that in tomato, high genetic advance was observed for fruit weight per plant followed by the number of fruits in a trusses and number of flowers in a clusters per plant.

Golani *et al*. (2007) elucidated that traits like for fruit weight, number of locules per fruit and fruit yield had shown high heritability and genetic gain, which could be improved by simple selection. Singh, (2009) reported that the number of fruits per plant, average fruit weight, fruit length, plant height, fruit diameter and fruit width showed high heritability with high genetic gain. While the number of branches/plant showed moderate heritability and genetic gain.

Sengupta *et al*. (2009) observed the high heritability for growth, yield and qulity chatacters in a tomato genotypes.. Dar *et al.* (2011) elucidated that maximum heritability was recorded for the characters β-carotene, ascorbic acid and lycopene.

Kaushik *et al.* (2011) reported the extent of the genotypic and phenotypic coefficient of variation was higher for yield contributing characters and high values of heritability coupled with high genetic advance were observed for total number of leaves at 60 days after transplanting, and fruit yield.

Khan and Samadia (2012) reported that high heritability was observed for fruit yield per plant (93.2%) as also for average fruit weight (92.8%), total number of fruits per plant (73.4%) and plant height (50.1%). Narolia, (2012) recorded that high heritability was estimated in days to 50% flowering, growth and quality characters.

Reddy, (2013) recorded the high heritability for the characters acidity, shelf life and fruit weight. Agarwal *et al.* (2014) reported the maximum heritability, genetic coefficient of variation and genetic advance were observed for total number of fruits per plant and average fruit weight of fruits. Khapte and Rani (2014) elucidated that the high heritability has been observed for the growth, morphological and yield contributing characters. The estimates of heritability and expected genetic advance were high for plant height, fruit weight, total number of fruits per cluster, yield per plant and severity of *Alternaria* blight, concluded by Sharma and Paul (2014). Meena and Bahadur (2014) reported the maximum heritability accompanied with genetic advance were noted for fruit yield per plant, plant height, number of leaves per plant and leaf curl incidence percent. Premalakshmi *et al.* (2014) estimated that the characters number of branches per plant, average fruit weight and the number of fruits per plant exhibited high heritability as well genetic advance and genotypic coefficient of variation and they were controlled by additive gene action, indicating the possibility of selection to improve these characters.

Inheritability studies, Sherpa *et al.* (2014) found that all growth, yield contributing and quality characters were exhibited high heritability coupled with high genetic advance and which

were controlled by additive gene effects, indicating good response to selection for these characters.

In several crosses of tomato, Phom *et al.* (2015) reported that high estimates of heritability and genetic advance were obtained for fresh weight and fruit diameter.

Kumar *et al*. (2016) reported the high heritability estimates for all the characters except number of flowers per clusters showed low heritability and days to 50% flowering, pericarp thickness and the number of primary branches per plant, which showed moderate heritability and. Kumar *et al*.(2016) indicated the high heritability coupled with high genetic advance was observed in characters plant height, length and width of fruit, average weight of fruit, fruit yield per plant, pericarp thickness, total soluble solids, acidity, ascorbic acid content, total soluble sugars, reducing sugars and lycopene content.

Chada and Walia (2016) reported the maximum heritability along with high genetic advance was observed for total fruits per plant, total number of fruits per plant and marketable yield per plant. Kavyashree *et al*. (2017) observed that high heritability coupled with high genetic advance for all growth as well as yield contributing characters.

Dixit and Pandey (2017) reported that, the high estimates of heritability were recorded for plant height, number of primary branches per plant, length of fruit, thickness of pericarp, total soluble solid, titrable acidity, number of fruits per plant, average weight of fruit, early yield per plant and total yield per plant.

Lekshmi and Celine (2017) reported that, maximum heritability along with high genetic advance found maximum for plant height, pollen viability, trusses per plant, fruit weight, fruit girth, number of fruits per truss, fruits per plant, lycopene content and fruit yield per plant.

Satyendra *et al.* (2017) high heritability estimates were observed for quality and yield contributing characters. Meena *et al*. (2017) reported that high heritability was observed for plant growth , yield contributing as well as quality characters.

2.3 Correlation studies

Inclusion of economically important quantitative characters has been useful as a basis of selection, which can be determined statistically by the correlation coefficient. Correlation studies reveal that selection of one-character results in progress for all correlated characters. Thus, correlation studies improve the multiple characters in the selection of a single character, which is correlated to them. Reviews regarding correlation among different traits are presented below:

Dudi and Kallo (1982) reported that total fruit yield was positively correlated with early yield, fruit number per plant and fruit weight. Supe and Kale (1992) and Sonone *et al*. (1986) reported that the major yield-contributing trait for enhancing the fruit yield was the number of primary branches per plant, which had direct and positive effects on yield contributing traits. Nevertheless, Patil, (1998) noticed that the number of branches per plant had an indirect

effect on yield. Brar and Singh (1998) stated that fruit weight had a significant and positive association with number of locules and Total soluble solids, while total soluble had a negative association with juice content of fruit and locule number.

Mohanty, (2003) reported that positive and significant correlation of yield per plant with the growth and morphological characters whereas, days to 50% flowering had a negative significant association with fruit yield per plant both at the genotypic and phenotypic level.

Singh *et al*. (2004) noted that all yield contributing characters exhibited a positive correlation with fruit yield, however, the number of primary branches per plant exhibited negatively correlated with fruit yield.

Mayavel *et al.* (2005) reported that the growth and yield contributing characters had shown positive correlation with fruit yield of tomato. In correlation studies, Raut *et al.* (2005) found that the total number of branches, number of flowers per plant, number of fruits per plant, fruit setting percentage and average fruit weight had a positive correlation with fruit yield and plant height have a positive correlation with all these traits. Kumar,(2006) reported that yield per plant was positively correlated with total number of fruits, average weight of fruit, number of branches and plant height The number of fruits per plant and fruit weight, were correlated negatively with each other and also had a positive association with fruit yield.(Pradeep *et al*., 2007)

Abhay *et al*. (2008) recorded that significant positive correlation between the number of branches per plant and yield and negative and significant association of plant height and yield. Ara *et al*. (2009) Correlation studies revealed that fruit yield per plant exhibited positive and highly significant correlation with all yield contributing characters at both phenotypic as well as genotypic levels. Sengupta, (2009) reported that fruit yield per plant showed a highly positive correlation with fruit number per plants, primary branches and percentage of fruit set whereas, yield showed negative but significant correlation with seeds per plant. Singh, (2009) correlation studies, revealed that average fruit weight positively and significantly correlated with fruit width and fruit diameter. On the other hand, the number of fruits per plant exhibited significant negative correlation with fruit width, fruit diameter and average fruit weight at both genotypic as well as phenotypic level.

Islam *et al*. (2010) reported that number of fruits per plant showed the direct positive effect on yield per plant followed by individual fruit weight. Rani *et al.* (2010) studies on Correlation in twenty three tomato hybrids revealed that average fruit weight and its quality characters were positively and significantly associated with yield per plant, while the total number of fruits per plant was associated negatively at genotypic and phenotypic levels. On the other hand, days to first flowering had showed the highest negative direct effects on fruit yield per plant.

Tiwari and Upadhya (2011) revealed that fruit weight had a direct effect and significant positive correlation with the fruit yield per plant. Vinod *et al.* (2012) reported that the total number of fruits had significant and positively correlated with yield.

In correlation studies at both phenotypic and genotypic level, Ahirwar and Prashad (2013) found that quality characters had showed a positive correlation with fruit yield per hectare, whereas, plant height, days to 50% flowering showed negative correlation with fruit yield per hectare. Chernet *et al.* (2013) revealed that fruit yield per hectare had the highest positive and significant correlation with average fruit weight per plant, number of fruits per plant and fruit set percentage at phenotypic level. While it showed negative and highly significant correlation with days to 50% fruiting and days to maturity at phenotypic level. Saleem *et al.* (2013) noticed that growth and yield contributing characters had showed significant positive effect on fruit yield per plant. Kumar *et al*. (2013) Correlation studies, indicated that fruit yield had highly significant and positive correlation with the number of fruit per plant and number of fruits per cluster.

Kumar *et.al*. (2015) reported that a positive and significant association of yield per plant with growh and morphological characters whereas, number of days taken for 50% flowering was correlated negatively with yield per plant. Basavraj *et.al* (2015) reported that fruit yield was found significantly and positively correlated with fruit yield contributing characters. whereas, the number of fruits per cluster, TSS, polar diameter and equatorial diameter were found negatively correlated with total fruit yield.

Phoom *et al.* (2015) reported that fruit yield per hectare exhibited positive significant association with plant height, number of branches, number of leaves, crop duration, fruit diameter and fresh weight of fruit. Bernousi *et al*. (2011) reported that total soluble solids had a negative correlation with average fruit weight per plant, fruit length, fruit diameter, pericarp thickness and the number of carpels and positive correlation with the number of fruit per plant.. Kaushik *et al.* (2011) reported that significant and positive association of yield per hectare observed with the number of leaves at 60 days after transplanting followed by the number of leaves at 30 days after transplanting, fruit length and plant height. Khan and Samadia (2012) correlation studies revealed that fruit yield had a significant positive correlation with fruit morphological characters, fruit weight and total number of fruits per plant. A negative association with number of days taken to flowering and number of days taken to first harvest on total fruit yield per plant.

Srivastava *et al.* (2013) correlation studies on exotic tomato genotypes observed that yield per plant had positive association with number of days taken to 50% flowering, number of days to 50% fruiting and other growh and yield contributing characters. Mahapatra *et al*. (2013) reported that total fruit yield had significant positive association with plant growth and its yield contributing characters. Kumar *et al*. (2015) evaluated tomato genotypes and found that

significant positive association of fruit yield per plant with the plant height, primary branches per plant, total number of fruits per plant, average fruit weight and fruit shape whereas, days to 50% flowering had negative significant correlated with yield per plant at both the levels.

Jogi *et al*. (2018) reported that yield per plant exhibited a significant and positive association with the yield contributing as well as morphlological characters, indicating the possibility of simultaneous incorporating of these traits in improving total fruit yield per plant.

Path coefficient analysis

Direct and indirect effects of an independent variable on the dependent variable to retrieve the importance of various yield components are successfully examined by the path coefficient analysis. It was developed by Wright in 1921. The concept of path coefficient analysis was originally used by Dewey and Lu (1959) in crested wheatgrass. Dudi and Kalloo (1982) reported that characters like dry matter content, fruit yield per plant, average fruit weight and the total number of fruits per plant had a high direct effect on yield.

Gonzalez, (1985) reported that the character fruit weight was affected directly by the equatorial and polar diameters of the fruits. Gorbatenko and Gorbatenko (1985) investigated that total number fruits per plant and weight of a single fruit directly affect the yield per plant. The weight of a single fruit was indirectly affected by pericarp thickness and yield per plant. Bhutani and Kallo (1989) suggested that the number of fruits per plant dry matter content contributed directly towards the yield.

Sindhu and Singh (1989) reported that total number of fruits per plant had direct effect on total fruit yield per plant followed by the number of fruit yielding clusters per plant, early yield, height and, pericarp thickness, total number of branches per plant and total number of fruits per cluster. Singh *et al.* (1989) reported the number of number of fruit per plant, length and weight of fruit had a direct influence on fruit yield.

Path coefficient analysis was carried out by Vikram and Kohli (1998) indicated that the most important yield-attributing trait was the average fruit weight followed by total number fruits per plant. The total number of fruits per plant had the maximum direct effect on fruit yield per plant followed by other fruit morphological and yield characters.(Sharma and Verma 2000).

Path analysis study was undertaken by Joshi and Singh (2003) reported that the total number of fruits per plant and average fruit weight had a direct effect on fruit yield. Joshi *et al.* (2004) the trait the number of fruits should be given more importance while selecting the genotypes in tomato followed by fruit morphological characters since they contributed directly towards fruit yield. Path analysis confirmed that the total number of branches per plant and mean weight of fruit exerted a high positive direct association on yield and high positive indirect effect with each other. (Mohanty, 2002) Joshi *et al.* (2004) reported that the total number of fruits per plant had direct influence on fruit yield followed by other morphological characters of fruit. Total fruit yield was positively increased by the number of fruits per plant followed

by other fruit morphological and yield contributing characters.(Singh *et al*. 2004). Lakshmikant and Mani (2004) concluded that all the yield contributing characters had the highest direct effects towards total fruit yield.

Singh, (2005) reported that the total number of fruits per plant had the higest positive direct effect on yield followed by mean weight of fruit. while the total number of fruits per plant exhibited positive and indirect effect towards fruit yield *via* the total number of branches per plant and it was negative *via* plant growth character and number of days taken for flowering of 50% plants.Kumar and Thakur, (2007) concluded that fruit weight had a direct contribution towards yield followed by other fruit yield contributing characters.

Golani *et al*. (2007). Path analysis studies on tomato genotypes, found that mean weight of fruit followed by the number of locules per fruit had the maximum positive direct effect on yield. Haydar *et al*. (2007) reported that for increasing yield, selection should be based on fruit morphological and yield contributing characters since they contributed towards total fruit yield directly.

Mehta and Asati (2008) concluded that plant height, mean weight of fruit, number of days to first fruiting and total number of days to 50% fruiting had a direct influence on the major yield contributing traits in tomato. From path coefficient analysis, Ara *et al*. (2009) concluded that fruit yield was directly influenced by number of taken for days to first harvesting, duration of harvest and other yield contributing characters. In a path analysis study, Ghosh *et al*. (2010) concluded fruit yield per plant had a direct positive influence on fruits per plant. Thus, selection should be carried out by considering these traits as the main selection criteria.

As per the findings of Rani *et al*. (2010) while, selecting high yielding genotypes, the character like fruit weight could be reliably looked for important selection criteria. Since, it has the highest positive direct influence on total fruit yield per plant.

Path analysis indicated that direct selection based on fruit morphological and yield contributing characters could be reliable for yield improvement in tomato at genotypic level, and these characters had the most positive direct influence on total fruit yield per plant, (Kumar *et al*., 2013). Mahapatra *et al*. (2013) reported all fruit yield contributing exhibited positive direct effects towards total fruit yield.

Monamodi *et al*. (2013) reported that total number of fruits and weight of each fruit were related directly to yield with direct effects.

Saleem *et al*. (2013) studies on path analysis, reported that average height of plant, total number of fruits per plant and mean weight of fruit had a significant direct positive effect on fruit yield per plant.

Srivastava, (2013) revealed that The characters which were exhibited maximum direct effect on fruit yield per plant mean weight of fruit and other yield contributing characters had showed negative direct effects.

Estimates of genotypic direct and indirect effects of various characters on fruit yield showed that the number of fruits per plant and average fruit weight had the highest positive direct contribution to fruit yield. This indicated direct selection based on these characters will result in improve the fruit yield. On the contrary, fruit set percentage and a polar diameter of fruit had maximum negative direct effect on fruit yield hectare (Chernet *et al*., 2014)

Jogi *et al*. (2018) studies on path analysis reported that total number of fruits per plant, mean weight of fruit and fruit width had maximum positive direct effect on yield per plant hence, indicating their true positive and significant association with yield per plant and reported that direct selection for these characters could be effective and there is a possibility of improvement in yield per plant.

CHAPTER-III

MATERIAL AND METHODS

An investigation entitled "Variability studies in growth, yield and quality parameters in tomato genotypes (*Lycopersicon esculentum* Mill.)" was carried out at Research Farm and Laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during a spring-summer season of the year 2018. The materials used for this study and statistical methods adopted in this study are presented in this chapter.

3. Details of experiments

3.1 Location of the experimental site and climate

The experiment was conducted at Research Farm and Laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar.

The area was situated at 29º 10'N latitude and 75 46'E longitude at an altitude of 215.2 meter above the sea level on southwestern border of the Rajasthan state and at a distance of about 175 km in west of the national capital city New Delhi. The experimental field belongs to the Agro-ecological zone –VI, which is called "Trans-Gangetic plains region".

3.2 Climate and weather conditions

The experimental area has semi-arid and subtropical climate characterized by hot and dry winds during summer months, warm humid in monsoon and cold dry weather in winter. The temperature ranges from 44 to 48℃ during summer and falls low as to freezing point with frost during winter. Both winter and summer are harsh to bear upon.

Table 3.1: Agro-meteorological data during the period of experimentation from May 2018

Month	Temperature (ºC)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Morning	Evening	
January	20.3	4.8	96	56	10.9
February	24.5	7.9	91	55	1.2
March	30.9	12.2	80	36	0.0
April	36.7	19.5	60	33	14.0
May	40.6	23.7	57	29	0.0

Source: Department of Agricultural Meteorology, CCS HAU, Hisar

3.3 Properties of the soil of the experimental plot

The selected field for conducting the experiment was uniform with respect to fertility gradient. A composite sample of soil from 0 to 30 cm of soil depth was taken randomly from 15 places of the field before preparing the layout of the experiment.

The soil samples so collected were mixed thoroughly, dried and subjected to mechanical and chemical analysis. The soil analysis data revealed that the soil of the experimental field was

sandy loam in texture, non-saline, medium inorganic carbon, low in available nitrogen, high in available phosphorus and rich in available potassium.

The physicochemical properties of the soil of the experimental field are presented below in Table 3.2:

Table 3.2 Physico-chemical properties of soil of the experimental field

Sr. No.	Parameters	Values observed
1.	Soil texture and its	Sandy Loam
2.	pH	8.10
3.	EC(dS/m)	0.38
4.	Organic carbon (%)	0.46
5.	Available nitrogen (kg/ha)	140.50
6.	Available phosphorus (kg/ha)	32.00
7.	Available potassium (kg/ha)	554.00

3.4 Experimental details

The particulars of the present experiment are given below:

Total number of genotypes investigated : 13

Experimental Design : Randomized block design

Replications : 3

Spacing (row x plant) : 60 x 45 cm

Number of rows per genotype : 2

Number of plants per row : 6

Crop season : Spring-summer

3.5 Observation recorded

3.5.1 Observations recorded

1.	Days to 50% flowering	11.	Number of locules per fruit
2.	Number of branches per plant	10.	Pericarp thickness
3.	Number of flowers per cluster	13.	Plant height (cm) at 60, 90 and 120 DAT
4.	Number of trusses per plant	14.	Leaf area index
5.	Number of fruits per truss	15.	Marketable yield (q/ha)
6.	Number of fruits per plant	16.	Total soluble solids (°Brix)
7.	Days to the first harvest	17.	Acidity (%)
8.	Average fruit weight (g)	18.	Ascorbic acid (mg/100 g)
9.	Polar diameter (cm)	19.	Chlorophyll a:b ratio
10.	Equatorial diameter (cm)	20.	Test weight (g)

DAT-Days after transplanting

3.6 Raising of crop nursery

The seeds of all thirteen tomato genotypes were collected from different sources (Table 3.3). Before sowing, all the seeds were treated with Capton @2g/kg of seed. The seedlings were raised in outdoor nursery beds in the field. Seedlings were sown during the first week of December 2017. Nursery beds were covered with fine compost and were watered regularly. Beds should be kept moist to enhance the germination. Beds were covered with transparent polythene sheet to protect the seedlings from frost and cold waves. Soon after the emergence of seedlings, proper care was taken to ensure the proper growth of seedlings in the nursery. Seedlings became ready for transplanting in the last week of January 2018.

Table 3.3 List of germplasm lines included in the study.

Sr. No.	Genotype	Source	Sr. No.	Genotype	Source
1.	16/TODVAR-1	IIVR,Varanasi	8.	16/TODVAR-8	IIVR,Varanasi
2.	16/TODVAR-2	IIVR,Varanasi	9.	16/TODVAR-9	IIVR,Varanasi
3.	16/TODVAR-3	IIVR,Varanasi	10.	16/TODVAR-10	IIVR,Varanasi
4.	16/TODVAR-4	IIVR,Varanasi	11.	16/TODVAR-11	IIVR,Varanasi
5.	16/TODVAR-5	IIVR,Varanasi	12.	16/TODVAR-12	IIVR,Varanasi
6.	16/TODVAR-6	IIVR,Varanasi	13.	Sel-7	HAU,Hisar
7.	16/TODVAR-7	IIVR,Varanasi			

3.7 Field preparation

The experimental field is brought to a fine tilth by repeated ploughing and applied the recommended dose of farm yard manure along with full dose of phosphorous and potassium and one-third dose of nitrogen. The remaining dose of nitrogen was applied in two split doses, one at the time of earthing up *i.e.* 20 days after transplanting and second at 45 days after transplanting. The entire field was divided into small experimental blocks and ridges and furrows were made at a distance of 60 cm.

3.8 Transplanting of seedlings

The seedlings were transplanted in the main field on 24th January 2018 in a randomized block design with three replications. Seedlings were transplanted during the early morning on both sides at the base of ridges to at the spacing of 45cm apart and light irrigation was applied followed by all the cultural operations as per package of practices to raise a healthy crop.

3.9 Collection of data and recording of observations

Random selection of five plants in each block was carried out and selected plants were tagged. These tagged plants were used for recording observations for the following characters:

3.9.1 Days to 50% flowering

The days taken to 50% flowering were worked out for each genotype, based on date and replication wise. The number of days was counted to the date of flowering in 50% of plants from the date of transplanting.

3.9.2 Number of branches per plant

The number of branches was counted on randomly selected five plants of every genotype at 30, 60 and 90 days after transplanting and an average number of branches per plant were calculated.

3.9.3 Number of flowers per cluster

The number of flowers per cluster was counted in five randomly tagged clusters on each of the randomly selected five plants of every genotype. The total numbers of flowers were counted and then, an observation was calculated by taking the mean of the recorded values.

3.9.4 Number of trusses per plant

The number of trusses per plant was counted on each of five randomly selected plants at the time of harvesting and the number of trusses per plant was calculated by taking the mean of the observed values.

3.9.5 Number of fruits per truss

By dividing the observed total number of fruits per plant with the number of fruit trusses per plant, the number of fruits per truss was calculated.

3.9.6 Number of fruits per plant

The total numbers of fruits harvested at the marketable stage of each picking were counted from five randomly selected plants and average number of fruits per plant were calculated.

3.9.7 Days to first harvest.

In each experimental plot, the total number of days taken from the date of planting to the first fruit maturity was counted on randomly selected five plants for each harvest.

3.9.8 Average fruit weight (g)

The total numbers of harvested marketable size fruits were weighed and the average fruit weight was calculated and expressed in gram.

3.9.9 Equatorial diameter of fruit (cm)

Fruits were halved horizontally, the equatorial diameter was measured from one end to another with the help of scale and the value was noted down.

3.9.10 Polar diameter of fruit (cm)

Fruits were halved vertically, the polar diameter was measured from stalk end to blossom end with the help of scale and the value was noted down.

3.9.11 Number of locules per fruit

The number of locules per fruit was counted from the five individual fruits. Fruits were halved transversely and number of locules present in each fruit, an average of these values has given the number locules per fruit.

3.9.12 Pericarp thickness (mm)

Pericarp thickness of fruit was measured from randomly selected five fruits in each genotype in the equatorial section of fruit by using verneire caliper and then the average was calculated.

3.9.13 Plant height (cm)

Readings were taken from the randomly selected five plants from each block and the plant height was measured from the base just above the soil surface to the top of the plant by using scale and recorded at 60 days after transplanting, 90 days after transplanting and 120 days after transplanting. The average plant height of five randomly selected genotypes was added on replication wise and average value of plant height was expressed in percentage.

3.9.14 Leaf area index (m^2/ m^2)

Maximum width (W) and length (L) of each sampled leaf were measured with a ruler. In tomato, the length was measured as the distance between the insertion of the first leaflet on the rachis to the distal end, whereas the width was measured on the widest leaflet and leaf area of each leaf was calculated. In each experimental plot, the number of plants was counted in order to calculate the LAI using the formula.

LAI = LA- Np- 100

Where: LAI is leaf area index (m^2 leaf 100 m^2 soil)

LA is leaf area (m^2 plant)

Np is the number of plants per soil surface (number of plant m^2 soil)

3.9.15 Marketable yield (q/ha)

Fruit yield of all the selected and tagged plants of each genotype was taken replication wise from total pickings during the entire harvesting season and summed up. Yield per plant, expressed in gram, was thus obtained and converted into q/ha.

3.9.16 Total soluble solids content of fruit (°Brix)

Well-developed red ripe fruits were selected and the juice was extracted from the selected fruits. A drop of juice was placed over the prism presented in the hand refractometer. For TSS analysis, a digital ATAGO, Sanco, pocket refractometer having a reading range of 0 to 50□ Brix was used. TSS was recorded for the five fruits for each genotype separately and total soluble solids content of fruit was calculated by averaging these values.

3.9.17 Acidity (%)

Acidity was calculated by following the titration method. Tomato juice was extracted from red ripe fruits and the extracted juice was titrated against N/10 NaOH using phenolphthalein as an indicator.

Reagents used

NaOH 0.1 N

4g of NaOH was dissolved in distilled water with final volume was made up to one litre. Phenolphthalein indicator (%) was prepared in 80% ethyl alcohol.

Procedure

(i) Preparation of juice sample: The freshly harvested red-ripened fruits were used for juice extraction and the juice was extracted by squeezing it.

Extracted juice sample was added with five gram of activated charcoal, and then it was filtered using the muslin cloth. A 25 ml of prepared juice was taken in a conical flask and the volume was made up to 250 ml by adding distilled water.

(ii) Titration of juice sample: Five ml of extracted fruit juice was pippeted in 250 ml conical flask. It was added with 75 ml boiling water and 5 drops of phenolphthalein indicator.

NaOH was taken in the burrete and added slowly to the sample until the final drop gave a pink colour lasting for a minute or longer and readings were noted. Acidity was expressed in per cent and citric acid was estimated using the following formula:

$$\text{Titrable acidity (mg / 100 ml juice)} = \frac{\text{Volume of NaOH x N}}{\text{Volume of juice sample}} \text{x } 100$$

Where,

N = Normality of NaOH, *i.e.*, 1/10N

Percent citric acid = T.A. x 0.06404

3.9.18 Ascorbic acid content (mg/100 g of fresh fruit weight)

The ascorbic acid content in tomato fruits was determined by following the 2, 6 dichlorophenol indophenols titration method (A.O.A.C., 1975) and it was expressed in mg per 100 g of the fresh fruit weight.

Reagents used

(i) Metaphosphoric acid-acetic acid solution:

Metaphosphoric acid 15 g was dissolved in distilled water and 40 ml glacial acetic acid was added to it and the final volume was made up to 500 ml.

(ii) Indophenols standard solution:

50 mg of 2,6 dichlorophenol indophenols and 42 mg of $NaHCO_3$ was dissolved in distilled water and filtered, and the final volume was made to 100 ml with distilled water.

iii) Ascorbic acid standard solution (1 mg/ml):

50 mg of ascorbic acid was dissolved in a small quantity of metaphosphoric acid solution in a desiccator and final volume was made up to 50 ml by adding metaphosphoric acid. Desiccator was kept away from sunlight.

Procedure for extraction

Tomato fruit juice: The juice of tomato was extracted by squeezing the freshly harvested red-ripened fruits, and then, it is filtered by using a muslin cloth.

The filtered juice was added to an equal volume of metaphosphoric acid (acetic acid) and the total volume was made up to 100 ml.

Determination

About 2.0 ml of the ascorbic acid standard was transferred to 50 ml conical flask containing 5 ml of metaphosphoric acid solution. It was titrated rapidly against the indophenols solution until distinct rose colour persisted for more than five seconds and readings were noted down.

3.9.19 Chlorophyll a:b ratio

Chlorophyll content was estimated according to the method of Hiscox and Israelstam (1979) using dimethyl sulfoxide (DMSO)

Procedure

The third leaf was detached from the top of a plant, weighed, and was kept into a test tube containing 5 ml of DMSO. The test tube was then placed into an oven for about 2 hours at 60 ℃ to facilitate the extraction of pigment. After 2 hours the absorption was read at 645 and 665 nm on a computer added spectrophotometer. Calculations for different pigments were made according to Welburn (1994).

Chlorophyll 'a' (µg/ml) = $12.19\ A_{665} - 3.45\ A_{645}$

Chlorophyll 'b' (µg/ml) = $21.99\ A_{645} - 3.32\ A_{665}$

Total chlorophyll = Chl 'a' + Chl 'b'

Quantity of pigment was calculated in µg/gm tissue dry weight expressed as µmole g^{-1} tissue dry weight by using following relationship.

µmole of Chl 'a' = mg Chl 'a' × 1.119

µmole of Chl 'b' = mg Chl 'b' × 1.102

µmoles of total chlorophyll = Chl 'a'(µmoles) + Chl 'b'(µmoles)

3.9.20 Test weight of seed (g)

Five ripe fruits of the tagged plant were harvested were chosen randomly from each genotype, crushed well in a plastic container by hand, and left for two days for fermentation. After two days, seeds were extracted by stirring, washing with running water, and drying in the sun. The bold seeds were settled down in the bottom. From the entire seed lot, one thousand seeds were counted and weighed. Seed weight was expressed in grams.

3.10 Statistical Analysis

The genotypic and phenotypic variances and coefficient of variation were estimated by following the method as suggested by Burton (1952).

Heritability and genetic advance were analysed by the method as suggested by Burton and De Vane (1953), and the correlation among various variables and the path coefficient were

estimated by following the procedure of Deway and Lu (1959). The Data was analysed by the following methods:

3.10.1 Analysis of variance

Analysis of variance (ANOVA) of the observations recorded on different characteristics was carried out as per the standard procedure is given by Panse and Sukhatme (1978).

The following model was adopted for the analysis of variance of various characters.

$Y_{ij} = \mu + \alpha j + \beta j + e\,ij$

Where,

Y_{ij} = observation of i^{th} treatment and j^{th} block

μ = General mean

$\alpha j = i^{th}$ treatment effect

$\beta j = j^{th}$ block effect

eij = random error associated with the ith treatment and j^{th} block

The assumptions of the model adopted were:

i. All the observations should be independent.
ii. The different effects in the model should be additive.
iii. The error involved in the population should be distributed normally and independently with mean zero and variance

Analysis of variance tables for all characters under study was constructed as follows:

Sources of variation	Degrees of freedom	Sum of squares	Mean sum of squares	Expected mean squares	F calculated value
Replication	r-1	SSr	MSr	$\sigma^2 e + g\sigma^2 r$	MSr/MSe
Genotypes	g-1	SSg	MSg	$r\sigma^2 e + r\,\sigma^2 g$	Msg/MSe
Error	(r-1) (g-1)	SSe	Mse	$\sigma^2 e$	
Total	rg-1				

Where,

r = Number of replications

g = Number of genotypes

MSr = Mean sum of squares due to replications

MSg = Mean sum of squares due to genotypes

MSe = Mean sum of squares due to the error

$\sigma^2 g$ = Genotypic variance of the character

$\sigma^2 r$ = Variance due to replication

$\sigma^2 e$ = Error variance of character

The standard error of mean (S.E.m)

Standard error of mean was calculated with the help of error mean square from the analysis of variance table given as under:

Standard error mean = $\sqrt{MSe/r}$

S.E. = Standard error

MSe = Error mean sum of squares

R = Number of replications

Critical difference (CD)

For every character, the critical difference as the difference of any two mean values in order to compare the treatment means was calculated using the following formula and tabulated't' value at error degree of freedom and at 5 or 1% level of significance

S.E. (d) ± = $\frac{\sqrt{2MSe}}{r}$

CD at 5 or1% = $\frac{\sqrt{2MSe}}{r}$ ×'t'

Where, 't' is the tabulated value at error degree of freedom and at 5 and 1% level of significance

3.10.2 Parameters of variability

i) Mean ($\bar{x}$)

The mean value of each character was worked out by dividing the total sum of values with the corresponding number of observations.

$\overline{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$ ….

Where,

$\overline{X}$ = Sample mean

X_i = Individual value

n =Number of observations

ii) Range

The lowest and highest values of each character were recorded.

3.11 Estimation of genetic variability parameters

i. Components of variance

The variance due to genotype, phenotype and environmental was computed by using the following formulae:

$$\text{Genotypic variance}(\sigma^2 g) = \frac{\text{Treatment MSS} - \text{Error MSS}}{r}$$

$$\text{Phenotypic variance}(\sigma^2 p) = \sigma^2 g + \sigma^2 e \text{ ……}$$

Where,

'r' is a number of replications.

ii. Coefficient of variability

The coefficient of variation being a standardized form of variance is useful for comparing the extent of variance between different characters with different scales (Singh and Choudhary, 1979)

Genotypic and phenotypic coefficients of variation were estimated according to Burton and Devane (1953) based on the estimate of genotypic and phenotypic variance

$$\text{Genotypic coefficient of variability (GCV \%)} = \frac{\sigma^2 g \text{ X } 100}{\overline{X}}$$

$$\text{Phenotypic coefficient of variability (PCV \%)} = \frac{\sigma^2 p \text{ X } 100}{\overline{X}}$$

Where,

$\overline{X}$= General mean

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

The genotypic and phenotypic coefficients of variation were categorized as per the method suggested by Shivasubramanian and Menon (1973)

0-10% = Low

10-20% = Moderate

>20% = High

iii. Heritability

Heritability in broad sense was calculated as the ratio of genotypic variance to the phenotypic variance and it was expressed in percentage (Falconer, 1981)

$$\text{Heritability } (h^2) = \frac{\sigma^2 g}{\sigma^2 p} \text{X } 100$$

The calculated heritability was classified into three groups as suggested by Johnson *et al.* (1955)

0-30% = Low

30-60% = Moderate

> 60% = High

iv. Expected genetic advance (GA)

Genetic advance as per cent mean of each character was worked out by adopting the following formula given by Johnson *et al.* (1955)

$GA = k \times h^2 \times \sigma p$

Where,

h^2 = Heritability in broad sense

k = Selection differential (which is equal to 2.06 at 5% intensity of selection)

σp = Phenotypic standard deviation

v. Genetic advance as per cent of mean (GAM)

Genetic advance (GA) as a percentage over mean was worked out as per by Johnson *et al.* (1955)

$$\text{GAM} = \frac{\text{GA}}{\overline{X}} \text{ x } 100$$

Where,

GA = Genetic advance

$\overline{X}$ = General mean

Genetic advance as per cent of mean was categorized as per the formula suggested by Johanson *et al*. (1955).

0-10 % = Low

10-20 % = Moderate

>20 % = High

3.12 Correlation Studies

The correlation coefficients among all possible character combinations at phenotypic (rp) and genotypic (rg) level were estimated by employing the formulae given by Al-Jibourie *et al.* (1958).

Genotypic correlation r_{xy} (G) $= \frac{Cov_{xy}\ (G)}{V_x(G)\ x\ V_y\ (G)}$

Phenotypic correlation r_{xy} (P) $= \frac{Cov_{xy}\ (P)}{V_x(P)\ x\ V_y\ (P)}$

Where,

Cov_{xy}(G) = Genotypic coefficient of variance between 'x' and 'y'

Cov_{xy}(P) = Phenotypic coefficient of variance between 'x' and 'y'

V_x (G) = Genotypic variance of character 'x'

V_x (P) = Phenotypic variance of character 'x'

V_y (G) = Genotypic variance of character 'y'

V_y (P) = Phenotypic variance of character 'y'

The significance of correlation was tested by comparing estimated 'r' values with the tabulated value at 5 and 1% level of significance.

3.13 Path coefficient analysis

The path coefficient analysis was performed as per the formula given by Wright (1921) and adopted by Deway and Lu (1951).

The following set of simultaneous equations were formed and solved for estimating direct and indirect effects

$r_1y = r_{11}\ a + r_{12}b + r_{13}c\ldots\ldots + r_{11}i$

$r_2y = r_{21}a + r_{22}b + r_{23}c + \ldots\ldots + r_{21}i$

$r_3y = r_{31}a + r_{32}b + r_{33}c + \ldots\ldots + r_{31}i$

$r_ny = r_{n1}a + r_{n2}b + r_{n3}c + \ldots\ldots + r_{n1}\ i$

Where,

'r_1y' to 'r_ny' = Correlation coefficients between causal factors 1 to n on dependent character 'y'

r_{12}, r_{21}, 4_{31},….r_ni = correlation coefficient among the causal factor 1 to n a, b, c, …. i = direct effects of characters ‘a’ to ‘i’ on dependent character ‘y’

Residual effect (R) = $1 - \sqrt{(a^2 + b^2 + c^2 + ….. + i^2 + 2abr_{12} + 2acr_{13} + ……...)}$

CHAPTER-IV

EXPERIMENTAL RESULTS

The observational data were recorded as per the materials and methods discussed in the previous chapter. The experimental data for different characters were arranged and analyzed by following the Randomized Block Design. The results obtained are presented under the following headings:

4.1 Analysis of variance

4.2 Mean performance and range

4.3 Components of variation and estimates of genetic parameters

4.4 Correlation coefficient analysis

4.5 Path coefficient analysis

Table 4.1: Analysis of variance (mean sum of square) for growth, yield and quality parameters in different tomato genotypes

Sr. No.	Characters	Mean sum of square		
		Replications (df=2)	Genotypes (df=12)	Error (df=24)
1	Plant height at 60 DAT (cm)	10.230	229.55*	36.30
2	Plant height at 90 DAT (cm)	14.021	133.38*	3.000
3	Plant height at 120 DAT (cm)	19.560	335.88*	10.670
4	Number of branches per plant	1.022	19.03**	0.600
5	Days to 50% flowering	22.480	90.16*	1.980
6	Leaf area index (m^2/m^2)	0.013	0.07**	0.013
7	Number of flowers per cluster	0.058	0.44**	0.028
8	Number of trusses per cluster	1.789	3.58**	0.485
9	Number of fruits per truss	0.023	0.02**	0.020
10	Number of fruits per plant	3.266	136.37**	3.700
11	Days to first harvest	1.333	13.11**	2.300
12	Average fruit weight (g)	0.487	15.26*	1.570
13	Marketable yield (q/ha)	57.970	2122.19**	40.840
14	Polar diameter (cm)	0.021	0.01**	0.086
15	Equatorial diameter (cm)	0.085	0.46**	0.030
16	Number of locules per fruit	0.011	0.438**	0.027
17	Pericarp thickness (mm)	0.001	0.038**	0.004
18	Total soluble solids (°Bx)	0.102	0.49**	0.016
19	Acidity (%)	0.013	0.03*	0.004
20	Ascorbic acid(mg/100g)	0.907	9.39**	0.715
21	Chlorophyll a:b ratio	1.823	4.57**	1.150
22	Test weight of seed (g)	0.007	0.07**	0.011

**Significant at 1%, * Significant at 5%
DAT-Days after transplanting

4.1 Analysis of variance

The analysis of variance indicated a significantly higher amount of variability among the genotypes for all the characters studied *viz*., plant height at 60, 90 and 120 days after transplanting, number of branches per plant, leaf area index, days to 50% flowering, number of flowers per cluster, number of trusses per plant, number of fruits per truss, number of fruits per plant, average fruit weight, equatorial diameter of fruit, polar diameter of fruit, number of locules per fruit, total soluble solids, ascorbic acid content, acidity, chlorophyll a:b ratio, days to first harvest, test weight of seed, days to first harvest and marketable yield. (Table 4.1).

4.2 Mean performance

The mean performance of thirteen tomato genotypes for different characters and their grand mean are presented in Table 4.2(a) to 4.2(g). The details of characters recorded during the research work are given below

4.2.1 Plant height at 60 days after transplanting (cm)

The range of plant height at 60 days after transplanting was from 50.33 to 76.33 cm, with average plant height 60 cm (Table 4.2.a). The maximum plant height was recorded in genotype 16/TODVAR-10 (76.33 cm) and the minimum plant height in 16/TODVAR-11 (50.33 cm). (Fig. 1)

4.2.2 Plant height at 90 days after transplanting (cm)

The plant height at 90 days after transplanting was recorded maximum in the genotype 16/TODVAR-10 (84.33cm) and the minimum plant height in 16/TODVAR-5 (63.33 cm) with the average plant height of 72.49cm (Table 4.2.a). (Fig.1)

4.2.3 Plant height at 120 days after transplanting (cm)

The plant height at 120 days after transplanting was in the range of 81-105cm with the average of 85.94 cm (Table 4.2.a).The maximum plant height was recorded in genotype 16/TODVAR-10 (105cm) and the lowest plant height in 16/TODVAR-8 (81 cm). The six genotypes showed maximum plant height more than mean value. (Fig. 1)

4.2.4 Number of branches per plant

The number of branches per plant ranged from 7.43 to 13.30, with a mean value of 10.52(Table 4.2.b). The maximum number of branches per plant was recorded in16/TODVAR-11 (13.30) and a minimum number of branches in 16/TODVAR-3 (7.43). The other varieties with the number of branches per plant above twelve were, 16/TODVAR-4, 16/TODVAR-5, 16/TODVAR-7, 16/TODVAR-8 and 16/TODVAR-9. (Fig. 2)

4.2.5 Leaf area index (m^2/m^2)

The leaf area index was ranged between 2.96 and 3.47 with a mean value of 3.16 (Table 4.2.b). The 2 genotypes have (16/TODVAR-2 and 16/TODVA–5) showed maximum leaf area index (3.47), while it was minimum It was minimum in the genotype 16/TODVAR-10 (2.96). (Fig. 4)

Table 4.2(a): Mean performance of different tomato genotypes for plant height at 60, 90 and 120 days after transplanting

Genotypes	Plant height at 60 DAT (cm)	Plant height at 90 DAT (cm)	Plant height at 120 DAT (cm)
16/TODVAR-1	69.33	74.33	87.33
16/TODVAR-2	53.67	68.00	82.00
16/TODVAR-3	68.67	80.33	96.33
16/TODVAR-4	47.33	66.67	77.00
16/TODVAR-5	51.00	63.33	75.33
16/TODVAR-6	59.67	74.67	83.67
16/TODVAR-7	58.33	69.33	79.00
16/TODVAR-8	62.33	71.00	81.00
16/TODVAR-9	61.33	67.67	75.33
16/TODVAR-10	76.33	84.33	105.00
16/TODVAR-11	50.33	65.00	77.33
16/TODVAR-12	68.00	81.40	104.33
SEL- 7	53.67	76.33	93.67
SE(m)	3.48	1.00	1.89
C.D. at 5%	10.16	2.92	5.51
General Mean	60.00	72.49	85.94

4.2.6 Days to 50% flowering

A significant difference was recorded among the entries with respect to days to 50% flowering (Table 4.2.b). The average number of days taken to flowering in 50% plants was 63.33 days, with a range from 56 to 72.67 days. The minimum number of days were taken to flower in 50% plants by two genotypes namely,16/TODVAR-4 and 16/TODVAR-5 (56.00 days), whereas, the maximum number of days were taken to flower in 50% plants by the genotype 16/TODVAR- 10 (72.67 days). (Fig. 3)

4.2.7 The number of flowers per cluster

The highest and lowest values for the number of flowers per cluster were recorded in genotype 16/TODVAR-5 (7.30) and 16/TODVAR-10(6.50), respectively with the average value ranged between 6.50 and 7.30 with a mean value of 6.85 (Table 4.2.c) The genotypes 16/TODVAR-2, 16/TODVAR-4, 16/TODVAR-7 closely followed the highest number of flowers per cluster, 16/TODVAR-8 and 16/TODVAR-11. (Fig. 5)

4.2.8 The number of trusses per plant

The number of trusses per plant ranged from 13.47 to 17.20, with a mean value of 16.14(Table 4.2.c). The genotypes 16/TODVAR- 4 and 16/TODVAR-8 (17.20) recorded with the highest number of trusses per plant, whereas, the genotype 16/TODVAR-3 (13.47) exhibited the minimum number of trusses per plant. Among all the genotypes studied, eight genotypes were having the number of trusses per plant above mean value and the remaining five genotypes were lower than the mean value. (Fig. 6)

Table 4.2(b): Mean performance of tomato genotypes for number of branches per plant, leaf area index and days to 50% flowering

Genotypes	Number of branches per plant	Leaf area index (m^2/ m^2)	Days to 50% flowering
16/TODVAR-1	8.17	3.12	65.33
16/TODVAR-2	10.43	3.47	59.00
16/TODVAR-3	7.43	3.10	67.00
16/TODVAR-4	13.00	3.25	56.00
16/TODVAR-5	13.60	3.47	56.00
16/TODVAR-6	8.83	3.08	67.00
16/TODVAR-7	12.10	3.17	59.33
16/TODVAR-8	12.60	3.11	57.00
16/TODVAR-9	12.97	3.05	65.67
16/TODVAR-10	7.73	2.96	72.67
16/TODVAR-11	13.70	3.20	67.33
16/TODVAR-12	7.63	2.99	69.33
SEL 7	8.63	3.14	61.67
SE(m)	0.45	0.07	0.81
C.D. at 5%	1.31	0.20	2.38
General Mean	10.52	3.16	63.33

4.2.9 The number of fruits per truss

The number of fruits per truss varied significantly among the genotypes investigated (Table 4.2.c). The number of fruits per truss ranged from 2.80 to 3.93, with a mean value of 3.14. The maximum number of fruits per truss was recorded in genotype 16/TODVAR-5 (3.93) and minimum in genotype 16/TODVAR-3(2.80). The other genotypes, *i.e.*, 16/TODVAR-4, 16/TODVAR-7 and 16/TODVAR-11, showed a good number of fruits per truss. (Fig. 7)

4.2.10 The number of fruits per plant

A wide variation was found among the different tomato genotypes for the number of fruits per plant, which significantly varied from 45.67 to 63 among the genotypes, with an overall mean of 54.12 (Table 4.2.d). The genotype 16/TODVAR-5 had the highest number of fruits per plant (63.00) which was followed by 16/TODVAR-4 (61.00) and 16/TODVAR -11 (60.00). The genotype16/TODVAR-10 showed the lowest number of fruits per plant (45.67). (Fig. 8)

4.2.11 Days to first harvest

Significant differences were recorded among the entries with respect to days to first harvest. The average days taken to first harvest were 83.14, value ranging from 80.67 to 87.33 days (Table 4.2d). The minimum days was taken to first harvest in genotype 16/TODVAR -12 (80.67) and maximum in genotype 16/TODVAR -11(87.33). (Fig.19)

Table 4.2(c): Mean performance of tomato genotypes for the number of flowers per cluster, the number of trusses per plant and the number of fruits per truss

Genotypes	The number of flowers per cluster	The number of trusses per plant	The number of fruits per truss
16/TODVAR-1	6.38	14.99	3.43
16/TODVAR-2	7.03	17.00	3.43
16/TODVAR-3	6.07	13.47	2.80
16/TODVAR-4	7.17	17.20	3.57
16/TODVAR-5	7.30	16.13	3.93
16/TODVAR-6	6.88	16.67	3.47
16/TODVAR-7	7.03	16.70	3.53
16/TODVAR-8	7.10	17.20	3.47
16/TODVAR-9	7.23	16.32	3.53
16/TODVAR-10	6.50	15.47	2.97
16/TODVAR-11	7.10	17.03	3.67
16/TODVAR-12	6.47	15.20	3.09
SEL 7	6.80	16.53	3.47
SE(m)	0.10	0.40	0.08
C.D. at 5%	0.29	1.18	0.24
General Mean	6.85	16.14	3.41

Table 4.2(d): Mean performance of tomato genotypes for number of fruits per cluster days to first harvest and average fruit weight

Genotypes	The number of fruits per plant	Days to first harvest	Average fruit weight (g)
16/TODVAR-1	49.00	83.67	60.00
16/TODVAR-2	57.74	81.00	53.33
16/TODVAR-3	39.67	81.00	55.67
16/TODVAR-4	61.00	82.00	51.67
16/TODVAR-5	63.00	81.67	52.33
16/TODVAR-6	54.67	83.00	54.33
16/TODVAR-7	56.67	84.00	53.67
16/TODVAR-8	56.67	85.33	54.33
16/TODVAR-9	57.00	84.67	55.67
16/TODVAR-10	45.67	86.00	51.67
16/TODVAR-11	60.00	87.33	52.00
16/TODVAR-12	47.59	80.67	53.00
SEL 7	55.00	84.00	53.67
SE(m)	1.11	0.88	0.72
C.D. at 5%	3.24	2.56	2.11
General Mean	54.12	83.41	53.94

4.2.12 Average fruit weight (g)

The average fruit weight of various tomato genotypes varied significantly from one another. It ranged from 51.67 to 60.00 g, with a mean value of 53.94g (Table 4.2.d). The maximum average fruit weight was recorded by the genotype 16/TODVAR -1 (60.00g) and minimum by 16/TODVAR -10 (51.67 g). The other six genotypes ranging above average fruit weight from the mean were 16/TODVAR -3, 16/TODVAR -6, 16/TODVAR -7, 16/TODVAR -8, 16/TODVAR -9 and Sel-7. The remaining seven genotypes were having the average fruit weight lower than the mean. (Fig. 18)

4.2.13 Marketable yield (q/ha)

The marketable yield of tomato genotypes evaluated varied significantly among 13 genotypes, ranging from 235 to 318.33 q/ha. The general mean of genotypes was 287.06q/ha (Table 4.2e). The maximum marketable fruit yield was recorded in genotype 16/TODVAR-5 (318.33 q/ha), while the minimum was recorded in genotype 16/TODVAR -3 (235q/ha). The most promising genotypes having fruit yield greater than general mean were 16/TODVAR -6, 16/TODVAR -7, 16/TODVAR -8, 16/TODVAR -9, 16/TODVAR -11 and Sel-7, whereas, the remaining genotypes were found to have yielded lower than the general mean. (Fig.9)

Table 4.2(e): Mean performance of tomato genotypes for marketable yield, polar diameter and equatorial diameter of fruit

Genotypes	Marketable yield (q/ha)	Polar diameter (cm)	Equatorial diameter (cm)
16/TODVAR-1	291.10	4.30	5.07
16/TODVAR-2	296.97	4.40	4.73
16/TODVAR-3	235.00	4.63	5.60
16/TODVAR-4	306.70	4.10	4.63
16/TODVAR-5	318.33	4.10	4.40
16/TODVAR-6	291.73	4.30	5.20
16/TODVAR-7	296.37	4.20	4.57
16/TODVAR-8	308.00	4.53	4.63
16/TODVAR-9	293.33	4.67	4.70
16/TODVAR-10	245.00	4.20	5.41
16/TODVAR-11	308.90	4.37	4.40
16/TODVAR-12	249.00	4.73	5.30
SEL 7	291.47	4.37	4.70
SE(m)	3.69	0.17	0.10
C.D. at 5%	10.77	0.50	0.29
General Mean	287.06	4.37	4.87

4.2.14 Polar diameter of fruit (cm)

The maximum polar diameter of fruit was recorded in genotype 16/TODVAR -12 (4.73 cm) and the minimum was recorded in 16/TODVAR -4 and 16/TODVAR -5 (4.10 cm) ,which

were ranged from 4.10 to 4.73 cm, with a mean value of 4.37 cm (Table 4.2e). The other genotypes showed polar diameter above the mean value were 16/TODVAR -2, 16/TODVAR -3,16/TODVAR -8 and 16/TODVAR -9, whereas, the remaining genotypes had the polar diameter of fruit below mean value. (Fig. 10)

4.2.15 Equatorial diameter of fruit (cm)

Significant differences were observed among the genotypes for an equatorial diameter of the fruit. It was ranged from 4.4 to 5.60 cm, with a mean value of 4.87cm (Table 4.2.e). The maximum equatorial diameter of fruit was recorded in genotype 16/TODVAR -3 (5.60 cm) and minimum in genotypes 16/TODVAR -5 and 16/TODVAR -11 (4.40 cm). The other genotypes were having wide equatorial diameter above the mean were 16/TODVAR -1, 16/TODVAR -6 and 16/TODVAR -12. (Fig. 11)

4.2.16 Number of locules per fruit

The number of locules per fruit ranged from 4.10 to 5.13, with a mean value of 4.71 (Table 4.2 f). The maximum number of locules was observed with genotype 16/TODVAR -11 (5.13), while the minimum with the genotype 16/TODVAR -10 (4.10). The other genotypes having the number of locules per fruit above mean value were 16/TODVAR -4, 16/TODVAR -5, 16/TODVAR -6, 16/TODVAR -7 and 16/TODVAR -8. (Fig. 12)

4.2.17 Pericarp thickness (mm)

Pericarp thickness of tomato varied significantly among the genotypes. It ranged from 0.43 to 0.78 mm, with a mean value of 0.68 mm (Table 4.2 f). The maximum pericarp thickness was recorded by the genotype 16/TODVAR-8 (0.78mm) and minimum by 16/TODVAR -3 (0.43mm). The other genotypes ranging above the mean were 16/TODVAR -1, 16/TODVAR -2, 16/TODVAR -4, 16/TODVAR -5, 16/TODVAR -6, 16/TODVAR-7, 16/TODVAR-9 and 16/TODVAR-11. (Fig. 13)

4.2.16 Total soluble solid content of fruit TSS (°Brix)

A significant difference was noticed among genotypes for total soluble solids content of fruit at marketable stage.TSS of fruit ranged from 6.13 to 7.31 (°Bx), with a mean value of 6.56 (°Bx) (Table 4.2.f). The maximum total soluble solids content of fruit was recorded with the genotype 16/TODVAR-3 (7.31°Bx), while the genotype 16/TODVAR -5 (6.13 °Bx) showed the low TSS content. The genotypes showed TSS greater than mean value were 16/TODVAR -1, 16/TODVAR -3, 16/TODVAR -6 and 16/TODVAR -10, whereas, the remaining eight genotypes had a total soluble solids content of fruit juice less than the general mean. (Fig. 14)

4.2.17 Acidity (%)

The general mean of the population in relation to acidity content of the fruit at the marketable stage was 0.66. The acidity of the fruits at the marketable stage ranged from 0.53 to 0.83% (Table 4.2.f). The highest acidity was recorded in fruits of genotype 16/TODVAR-3(0.83%), it was observed less in fruits of 16/TODVAR-8 (0.53%). Among the other tomato genotypes

studied, 16/TODVAR-1, 16/TODVAR-6, 16/TODVAR -9, 16/TODVAR -10 and 16/TODVAR -12 had the acidity content of fruit more than general mean and the remaining six genotypes, *i.e.*, 16/TODVAR -2, 16/TODVAR -4, 16/TODVAR -5, 16/TODVAR -7 16/TODVAR -11 and Sel -7had the acidity content of fruit less than general mean (Table 4.2.h). (Fig. 15)

Table 4.2(f): Mean performance of tomato genotypes for a number of locules per fruit pericarp thickness, TSS and acidity

Genotypes	Number of locules per fruit	Pericarp thickness (mm)	TSS (°Brix)	Acidity (%)
16/TODVAR-1	4.53	0.70	6.57	0.70
16/TODVAR-2	5.00	0.76	6.22	0.64
16/TODVAR-3	4.11	0.43	7.31	0.83
16/TODVAR-4	5.01	0.76	6.26	0.59
16/TODVAR-5	5.07	0.77	6.13	0.57
16/TODVAR-6	4.87	0.72	6.70	0.73
16/TODVAR-7	4.97	0.75	6.43	0.61
16/TODVAR-8	5.02	0.78	6.27	0.53
16/TODVAR-9	4.60	0.73	6.53	0.67
16/TODVAR-10	4.10	0.52	7.17	0.77
16/TODVAR-11	5.13	0.76	6.20	0.59
16/TODVAR-12	4.17	0.56	7.21	0.82
SEL 7	4.71	0.68	6.43	0.63
SE(m)	0.10	0.04	0.07	0.04
C.D. at 5 %	0.28	0.12	0.21	0.11
General Mean	4.71	0.68	6.56	0.66

4.2.18 Ascorbic acid (mg/100g)

A significant difference was observed among the genotypes for ascorbic acid content of fruit at marketable stage. The ascorbic acid content of fruit at marketable stage ranged from 21.50 to 26.63mg/100mg. The general mean of the population in relation to the ascorbic acid content of fruit was 24.81 (Table 4.2g). The highest ascorbic acid was recorded in fruits of genotypes 16/TODVAR- 4 and 16/TODVAR- 5(26.63 mg/100g), while it was noticed minimum in fruits of 16/TODVAR -3 (21.50 mg/100g). Among the genotypes studied, eight genotypes had the ascorbic acid of fruit more than general mean, and the remaining five genotypes had the ascorbic acid of fruit less than general mean(Table 4.2i). (Fig. 16)

4.2.19 Chlorophyll a:b ratio

Chlorophyll a:b ratio was ranged from 2.2:1 to 1:1, with a mean value of 24.74(Table 4.2.g). The highest chlorophyll ratio was recorded in the genotype 16/TODVAR-4 (2.2:1), while the genotype Sel-7 (1:1) showed the lowest chlorophyll ratio.

4.2.20 Test weight of seed (g)

Test weight of hundred tomato seeds noted at dry stage varied significantly among the genotypes. It ranged from 3.67 to 4.27 g, with a mean value. (Table 4.2g). The maximum of hundred test weight was recorded by the genotype 16/TODVAR -11 (4.27 g) and minimum by 16/TODVAR -3 (3.67 g). The other nine genotypes ranging above the mean value. (Fig. 17)

Table 4.2(g): Mean performance of tomato genotypes for ascorbic acid, chlorophyll a:b ratio and test weight of seed

Genotypes	Ascorbic acid (mg/100g)	Chlorophyll a:b ratio	Test weight of seed (g)
16/TODVAR-1	24.27	2:1	4.07
16/TODVAR-2	26.00	2:1	4.23
16/TODVAR-3	21.50	2:1	3.67
16/TODVAR-4	26.63	2.2:1	4.20
16/TODVAR-5	26.63	1:1	4.30
16/TODVAR-6	24.23	2:1	4.23
16/TODVAR-7	25.00	2:0.5	4.23
16/TODVAR-8	25.97	2:1.5	4.20
16/TODVAR-9	25.90	2:1	4.23
16/TODVAR-10	21.63	2.1.5	4.13
16/TODVAR-11	26.33	2:1	4.27
16/TODVAR-12	23.17	2:1	4.20
SEL 7	25.30	1:1	4.23
SE(m)	0.49	0.62	0.06
C.D. at 5%	1.43	1.81	0.18
General Mean	24.81	24.74	4.16

4.3 Components of variation and estimates of genetic parameters

The estimates of components of variances, coefficients of variation, minimum, maximum values and the genetic parameters like. genotypic variance, phenotypic variance, genotypic coefficient of variation, phenotypic coefficient of variation, heritability (broad sense), and genetic advance as percent of mean along with mean and the range of various characters investigated in the present study had been mentioned in Table 4.3

The mean values for different parameters under study were already explained previously under subheading mean performance of respective characters. However, the remaining estimates have been explained below:

In general, the magnitude of phenotypic variances, as well as coefficients of variation, was higher than their respective genotypic estimates, indicating the environment influence on the expression of these characters.

The highest estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was recorded for number of branches per plant (23.54 and 23.93%), pericarp thickness (15.42 and 16.46%), acidity (14.79 and 15.8%), plant height 60 DAT (13.37 and 14.57%), number of fruits per plant (12.28 and 12.45%), plant height 120 DAT(12.11 and 12.31%), marketable yield (9.175 and 9.266%) plant height 90 DAT(9.09 and 9.19%), and whereas, the lowest estimates of GCV and PCV was observed for traits like days to first harvest (2.27 and 2.5%), polar diameter (2.82 and 4.8%), test weight of seed (3.57 and 3.88%), average fruit weight (3.96 and 4.18%), chlorophyll a:b ratio(4.31 and 4.98%), leaf area index (4.49 and 4.97%)

Moderate PCV and GCV was estimated for, number of flowers per cluster (5.41 and 5.59%), total soluble solids (6.09 and 6.19%),number of trusses per plant (6.297 and 6.77%), ascorbic acid (6.85 and 7.13%), equatorial diameter of fruit (7.83 and 8.09%), number of locules per fruit (7.84 and 8.1%) and days to 50% flowering (8.56 and 8.656%.), number of fruits per truss (8.41 and 8.74)

The high estimates of heritability (broad sense) were noticed in almost all characters *viz*, marketable yield (98.08%), days to 50% flowering (97.80%), plant height at 90 DAT (97.75%), number of fruits per plant (97.29%), plant height at 120 DAT (96.82%), number of branches per plant (96.81%), total soluble solids (96.74%),number of locules per fruit (93.68%) equatorial diameter of fruit (93.55%), number of flowers per cluster (93.49%) number of fruits per truss (92.42%), ascorbic acid(92.38%), average fruit weight (89.71%), number of trusses per plant (89.47%), pericarp thickness (87.78%), acidity (87.50%), test weight of seed (84.83%), plant height at 60 DAT (84.16%), days to first harvest (82.43%), leaf area index (81.48%),chlorophyll a:b ratio (74.79%).

Estimates of genetic advance as percent of mean were recorded very high for number of branches per plant (47.72%) followed by pericarp thickness (29.77%), acidity (28.53%), plant height at 60 DAT (25.27), number of fruits per plant (24.96%) plant height at 120 DAT(24.55). while ,the estimates of genetic advanceas per cent of mean for marketable yield (18.72%), plant height at 90 DAT (18.52%), days to 50% flowering (17.43%) and number of fruits per truss (16.65%) were in average range and found very low for polar diameter of fruit (3.42%), days to first harvest (4.25), test weight of seed (6.74), chlorophyll a:b ratio (7.68%), average fruit weight (7.74%), leaf area index (8.35%), number of flowers per cluster (10.77%), number of trusses per plant (12.06%), total soluble solids (12.35%), ascorbic acid (13.56%), equatorial diameter of fruit (15.63%), number of locules per fruit (15.64%).

4.4 Correlation among yield components

The correlation coefficients among the characters were analyzed at phenotypic and genotypic levels, which give the information on nature of association of characters with tomato fruit yield and aids the selection process more effective

Both the genotypic and phenotypic estimates of correlations were tested for their significance against the tabulated value of correlation coefficient at five and one per cent levels of significance. Correlation analysis studied the association of different traits with fruit yield at genotypic and phenotypic level and results have been mentioned in (Table 4.4)

Plant height at 60 DAT was found highly significant but negative association with number of branches per plant (-0.804 and -0.582), leaf area index (-0.857 and -0.559), number of flowers per cluster(-0.848 and -0.638), number of trusses per plant(-0.827 and -0.538), number of fruits per truss (-0.852 and -0.676), number of fruits per plant (-0.938 and -0.755), number of locules per fruit (-0.948 and -0.697), pericarp thickness 0f fruit (-0.782 and -0.514), ascorbic acid (-0.950 and -0.733), chlorophyll a:b ratio (-0.979 and -0.604), test weight of seed (-0.595 and -0.438), and marketable yield (-0.869 and -0.669) at both genotypic and phenotypic level (Table 4.4). It was found significant but positively correlated with plant height at 90 DAT (0.918 and 0.689), plant height at 120 DAT (0.826 and 0.603), days to 50% flowering (0.750 and 0.742), equatorial diameter of fruit (0.923 and 0.652), total soluble solids (0.898 and 0.710), acidity (0.901 and 0.613). It highly significant but positively correlated with polar diameter of fruit (0.714) and average fruit weight (0.524) at a genotypic level.

Table 4.3: Estimation of variability, heritability and expected genetic advance for 22 characters

Sr. No.	Characters	Range Min-Max	General Mean	Phenotypic variance	Genotypic variance	Phenotypic coefficient of variation	Genotypic coefficient of variation	Heritability in broad sense (h^2b) in %	Genetic advance as % of mean
1	Plant height at 60 DAT (cm)	50.33 -76.33	60.00	76.51	64.39	14.57	13.37	84.16	25.27
2	Plant height at 90 DAT (cm)	63.33 - 84.33	72.49	44.46	43.46	9.19	9.09	97.75	18.52
3	Plant height at 120 DAT (cm)	81.00 – 105.0	85.94	111.96	108.41	12.31	12.11	96.82	24.55
4	Number of branches per plant	7.43 - 13.30,	10.52	6.34	6.14	23.93	23.54	96.81	47.72
5	Days to 50% flowering	56.00 -72.67	63.33	30.05	29.39	8.65	8.56	97.80	17.43
6	Leaf area index	2.96 - 3.47	3.16	0.024	0.02	4.97	4.49	81.48	8.35
7	Number of flowers per cluster	6.50 -7.30	6.85	0.14	0.13	5.59	5.41	93.49	10.77
8	Number of trusses per plant	13.47 -17.20	16.14	1.19	1.03	6.77	6.29	89.47	12.06
9	Number of fruits per truss	2.80 - 3.93	3.41	0.09	0.08	8.74	8.41	92.42	16.65
10	Number of fruits per plant	45.67 – 63	54.12	45.45	44.22	12.45	12.28	97.29	24.96
11	Days to first harvest	80.67 - 87.33	83.41	4.37	3.604	2.5	2.27	82.43	4.25
12	Average fruit weight (g)	51.67 - 60.00	53.94	5.08	4.56	4.18	3.96	89.71	7.74
13	Marketable yield (q/ha)	235.0 - 318.33	287.06	707.39	693.78	9.26	9.17	98.08	18.72
14	Polar diameter (cm)	4.10 -4.73	4.37	0.045	0.015	4.8	2.82	34.66	3.42
15	Equatorial diameter (cm)	4.4 -5.60	4.87	0.15	0.14	8.09	7.83	93.55	15.63
16	Number of locules per fruit	4.10 - 5.13	4.71	0.14	0.13	8.1	7.84	93.68	15.64
17	Pericarp thickness (mm)	0.43 - 0.78	0.68	0.01	0.02	16.46	15.42	87.78	29.77
18	Total soluble solids (%)	6.13 - 7.31	6.56	0.16	0.16	6.19	6.09	96.74	12.35
19	Acidity (%)	0.53 - 0.83	0.66	0.01	0.009	15.8	14.79	87.50	28.53
20	Ascorbic acid(mg/100g)	21.50 - 26.63	24.81	3.13	2.89	7.13	6.85	92.38	13.56
21	Chlorophyll a:b ratio	2.2:1 - 1:1	24.74	1.52	1.14	4.98	4.31	74.79	7.68
22	Test weight (g)	3.67 - 4.27	4.16	0.02	0.022	3.88	3.57	84.83	6.74

Correlation studies on Plant height was taken at 90 DAT recorded highly significant and positive correlation with plant height at 120 DAT (0.971 and 0.932), days to 50% flowering (0.669 and 0.720), polar diameter of fruit (0.642 and 0.184), equatorial diameter of fruit (0.924 and 0.840) total soluble solids (0.921 and 0.869), acidity (0.902 and 0.799), at both genotypic and phenotypic level. It was found highly significant but negative association with number of branches per plant (-0.935 and -0.874), leaf area index (-0.814 and -0.612), number of flowers per cluster (-0.882 and -0.800), number of trusses per plant (-0.731 and -0.551), number of fruits per truss (-0.922 and -0.830), number of fruits per plant (-0.920 and -0.855), , number of locules per fruit (-0.898 and -0.863), pericarp thickness 0f fruit (-0.910 and -0.806), ascorbic acid (-0.955 and -0.862), chlorophyll a:b ratio (-0.983 and -0.715), test weight of seed (-0.546 and -0.506), and marketable yield (-0.911 and -0.873) at both genotypic and phenotypic level (Table 4.4)

Correlation studies regarding the plant height revealed that plant height at 120 DAT was recorded significant but negative association with number of branches per plant (-0.903 and -0.838),leaf area index (-0.665 and -0.504), number of flowers per cluster (-0.864 and -0.755), number of trusses per plant (-0.715 and -0.534), number of fruits per truss (-0.884 and -0.765), number of fruits per plant (-0.865 and -0.778), number of locules per fruit (-0.896 and -0.814), pericarp thickness of fruit (-0.938 and -0.780), ascorbic acid (-0.899 and -0.790), chlorophyll a:b ratio (-0.851and -0.597), test weight of seed (-0.484 and -0.392) and marketable yield (-0.903 and -0.846) at both genotypic and phenotypic level (Table 4.4).

It was noted highly significant but positively correlated with days to 50% flowering (0.694 and 0.634), polar diameter of fruit (0.595 and 0.179), equatorial diameter of fruit (0.846 and 0.747) total soluble solids (0.886 and 0.788), acidity (0.899 and 0.712), at both genotypic and phenotypic level.

Among all the plant characters studied, the number of branches per plant recorded significant and positive association with leaf area index (0.574 and 0.423), number of trusses per plant (0.758 and 0.590), number of fruits per truss (0.831 and 0.737), number of fruits per plant (0.885 and0.820), number of flowers per cluster (0.915 and 0.854), number of locules per fruit (0.820 and 0.772), pericarp thickness of fruit (0.821 and 0.757), ascorbic acid (0.866 and 0.820), chlorophyll a:b ratio (0.847 and 0.712), test weight of seed (0.588 and 0.490), and marketable yield (0.813 and 0.798) at both genotypic and phenotypic level (Table 4.4)

It was noted highly significant but negatively correlated with days to 50% flowering (-0.651 and -0.581), equatorial diameter of fruit (-0.913 and -0.841) total soluble solids (-0.810 and -0.787), acidity (-0.911 and -0.790), at both genotypic and phenotypic level, it had significant positive association with days to first harvest (0.277) at genotypic level and non significant positive association with days to first harvest (0.337) at phenotypic level.

It had a significant but negatively correlated polar diameter of fruit (-0.534) and average fruit weight (-0.352) at a genotypic level and non-significant negative association with a polar diameter of fruit (-0.153) and average fruit weight (-0.305) at a phenotypic level.

Correlation studies on plant characters revealed that leaf area index recorded significant and positive association at both genotypic and phenotypic level with number of flowers per cluster (0.617 and 0.395), number of fruits per truss (0.755 and 0.440), number of fruits per plant (0.760 and 0.465), number of locules per fruit (0.759 and 0.569), pericarp thickness of fruit (0.627 and 0.432), ascorbic acid (0.723 and 0.544), chlorophyll a:b ratio (0.818 and 0.404), and marketable yield (0.698 and 0.518) at both genotypic and phenotypic level (Table 4.4). It was recorded highly significant but negatively correlated at both genotypic and phenotypic level with polar diameter of fruit (-0.824 and -0.255), equatorial diameter of fruit (-0.709 and -0.481) total soluble solids (-0.813 and -0.594), acidity (-0.710 and -0.466).Significant negative correlation with days to first harvest (-0.469) at a genotypic level.

For a character, Days to 50 % flowering, characters like leaf area index (-0.811 and -0.613), number of flowers per cluster (-0.656 and -0.595), number of trusses per plant (-0.586 and -0.480), number of fruits per truss (-0.684 and -0.582), number of fruits per plant (-0.711 and -0.665), number of locules per fruit (-0.768 and -0.690), pericarp thickness of fruit (-0.676 and -0.553), ascorbic acid (-0.784 and -0.686), chlorophyll a:b ratio (-0.725 and -0.477) and marketable yield (-0.747 and -0.699) had shown highly significant but negative association at both genotypic and phenotypic level and the characters like polar diameter of fruit (0.581 and 0.309), equatorial diameter of fruit (0.727 and 0.667) total soluble solids (0.792 and 0.732), acidity (0.859 and 0.709) had shown highly significant but negative association at both genotypic and phenotypic level.

Table 4.4: Genotypic correlation coefficient among marketable yield and its component characters in tomato

	PLHT 1	PLHT 2	PLHT 3	NBR	DFF	LAI	NFCL	NTPL	NFPT	NFPL
PLHT 1	1.000									
PLHT 2	0.918**	1.000								
PLHT 3	0.826**	0.971**	1.000							
NBR	-0.804**	-0.935**	-0.903**	1.000						
DFF	0.750**	0.720**	0.694**	-0.651**	1.000					
LAI	-0.857**	-0.814**	-0.665**	0.574**	-0.811**	1.000				
NFCL	-0.848**	-0.882**	-0.864**	0.915**	-0.656**	0.617**	1.000			
NTPL	-0.827**	-0.731**	-0.715**	0.758**	-0.586**	0.470**	0.964**	1.000		
NFPT	-0.852**	-0.922**	-0.884**	0.831**	-0.684**	0.755**	0.908**	0.843**	1.000	
NFPL	-0.938**	-0.920**	-0.865**	0.885**	-0.711**	0.760**	0.995**	0.933**	0.966**	1.000
AFW	0.524**	0.155NS	0.002NS	-0.352*	0.131NS	-0.303NS	-0.485**	-0.547**	-0.117NS	-0.392*
PDF	0.714**	0.642**	0.595**	-0.534**	0.581**	-0.824**	-0.557**	-0.585**	-0.878**	-0.821**
EDF	0.923**	0.924**	0.846**	-0.913**	0.727**	-0.709**	-0.911**	-0.875**	-0.953**	-0.968**
NLFR	-0.948**	-0.898**	-0.896**	0.820**	-0.768**	0.759**	0.862**	0.952**	0.915**	0.956**
PTF	-0.782**	-0.910**	-0.938**	0.821**	-0.676**	0.627**	0.885**	0.959**	0.933**	0.958**
TSS	0.898**	0.921**	0.886**	-0.810**	0.792**	-0.813**	-0.855**	-0.888**	-0.934**	-0.946**
ASDY	0.901**	0.902**	0.899**	-0.911**	0.859**	-0.710**	-0.858**	-0.923**	-0.918**	-0.953**
ASAD	-0.950**	-0.955**	-0.899**	0.866**	-0.784**	0.723**	0.917**	0.891**	0.964**	1.001**
CHL	-0.979**	-0.983**	-0.851**	0.847**	-0.725**	0.818**	0.816**	0.827**	0.975**	0.993**
TW	-0.595**	-0.546**	-0.484**	0.588**	-0.366*	0.370*	0.876**	1.026**	0.794**	0.886**
DFH	-0.004NS	-0.097NS	-0.158NS	0.277NS	0.252NS	-0.469**	0.218NS	0.416**	0.220NS	0.204NS
MYD	-0.869**	-0.911**	-0.903**	0.813**	-0.747**	0.698**	0.872**	0.861**	0.992**	0.952**

	AFW	PDF	EDF	NLFR	PTF	TSS	ASDY	ASAD	CHL	TWS	DFH	MYD
AFW	1.000											
PDF	0.141^{NS}	1.000										
EDF	0.250^{NS}	0.291^{NS}	1.000									
NLFR	-0.196^{NS}	-0.306^{NS}	-0.862**	1.000								
PTF	-0.076^{NS}	-0.184^{NS}	-0.758**	0.873**	1.000							
TSS	0.119^{NS}	0.281^{NS}	0.894**	-0.911**	-0.854**	1.000						
ASDY	0.142^{NS}	0.317*	0.882**	-0.890**	-0.779**	0.895**	1.000					
ASAD	-0.140^{NS}	-0.174^{NS}	-0.883**	0.867**	0.839**	-0.916**	-0.864**	1.000				
CHL	-0.163^{NS}	-0.037^{NS}	-0.696**	0.694**	0.801**	-0.723**	-0.642**	0.800**	1.000			
TW	-0.358*	-0.175^{NS}	-0.637**	0.616**	0.641**	-0.607**	-0.528**	0.621**	0.566**	1.000		
DFH	-0.017^{NS}	-0.051^{NS}	-0.265^{NS}	0.216^{NS}	0.273^{NS}	-0.225^{NS}	-0.320*	0.173^{NS}	0.114^{NS}	0.255^{NS}	1.000	
MYD	-0.065^{NS}	-0.285^{NS}	-0.868**	0.916**	0.891**	-0.957**	-0.858**	0.916**	0.730**	0.619**	0.255^{NS}	

**Significance at 5 % level *Significance at 1 % level

PLHT 1- Plant height at 60,90 and 120 days after transplanting, NBR – The number of branches per plant, PDF- Polar diameter of fruit, CHL- Chlorophyll a : b ratio, LAI - Leaf area index, NTPL – The number of trusses per plant, EQD - Equatorial diameter of fruit, TW- Test weight, TSS - Total soluble solids, NFPT – The number of fruits per truss, PTF- Pericarp thickness of fruit DFH- Days to first harvest, ASDY- Acidity, DFF-Days to 50% flowering, NFPL - Number of fruits per plant, MYD- Marketable yield, AFW- Average fruit weight, ASDD- Ascorbic acid, NFCL – The number of flowers per cluster, NLFR- The number of locules per fruit

Table 4.4: Phenotypic correlation coefficient among marketable yield and its component characters in tomato

	PLHT1	PLHT2	PLHT3	NBR	DFF	LAI	NFCL	NTPL	NFPT	NFPL
PLHT1	1.000									
PLHT2	0.689**	1.000								
PLHT3	0.603**	0.932**	1.000							
NBR	-0.582**	-0.874**	-0.838**	1.000						
DFF	0.631**	0.669**	0.634**	-0.581**	1.000					
LAI	-0.559**	-0.612**	-0.504**	0.423**	-0.613**	1.000				
NFCL	-0.638**	-0.800**	-0.755**	0.854**	-0.595**	0.395*	1.000			
NTPL	-0.538**	-0.551**	-0.534**	0.590**	-0.480**	0.257NS	0.745**	1.000		
NFPT	-0.676**	-0.830**	-0.765**	0.737**	-0.582**	0.440**	0.775**	0.533**	1.000	
NFPL	-0.755**	-0.855**	-0.778**	0.820**	-0.665**	0.465**	0.898**	0.783**	0.894**	1.000
AFW	0.262NS	0.132NS	0.004NS	-0.305NS	0.131NS	-0.105NS	-0.334*	-0.292NS	-0.169NS	-0.355*
PDF	0.225NS	0.184NS	0.179NS	-0.153NS	0.309*	-0.255NS	-0.251NS	-0.272NS	-0.277NS	-0.266NS
EDF	0.652**	0.840**	0.747**	-0.841**	0.667**	-0.481**	-0.833**	-0.654**	-0.825**	-0.869**
NLFR	-0.697**	-0.863**	-0.814**	0.772**	-0.690**	0.569**	0.824**	0.683**	0.811**	0.851**
PTF	-0.514**	-0.806**	-0.780**	0.757**	-0.553**	0.432**	0.828**	0.658**	0.797**	0.804**
TSS	0.710**	0.869**	0.788**	-0.787**	0.732**	-0.594**	-0.816**	-0.678**	-0.862**	-0.884**
ASDY	0.613**	0.799**	0.712**	-0.790**	0.709**	-0.466**	-0.806**	-0.637**	-0.743**	-0.791**
ASAD	-0.733**	-0.862**	-0.790**	0.820**	-0.686**	0.544**	0.858**	0.701**	0.837**	0.881**
CHL	-0.604**	-0.715**	-0.597**	0.712**	-0.477**	0.404**	0.738**	0.468**	0.696**	0.727**
TW	-0.438**	-0.506**	-0.392*	0.490**	-0.261NS	0.185NS	0.683**	0.576**	0.690**	0.695**
DFH	0.151NS	-0.095NS	-0.145NS	0.337*	0.254NS	-0.192NS	0.254NS	0.262NS	0.123NS	0.126NS
MYD	-0.669**	-0.873**	-0.846**	0.798**	-0.699**	0.518**	0.837**	0.716**	0.898**	0.908**

	AFW	PDF	EDF	NLFR	PTF	TSS	ASDY	ASAD	CHL	TWS	DFH	MYD
AFW	1.000											
PDF	0.596**	1.000										
EDF	0.301NS	0.574**	1.000									
NLFR	-0.275NS	-0.780**	-0.892**	1.000								
PTF	-0.101NS	-0.824**	-0.872**	0.932**	1.000							
TSS	0.156NS	0.791**	0.962**	-0.966**	-0.913**	1.000						
ASDY	0.277NS	0.718**	0.989**	-0.944**	-0.873**	0.997**	1.000					
ASAD	-0.222NS	-0.538**	-0.974**	0.925**	0.913**	-0.979**	-0.949**	1.000				
CHL	-0.336*	-0.648**	-0.958**	0.844**	0.821**	-0.861**	-0.820**	0.981**	1.000			
TW	-0.462**	-0.680**	-0.760**	0.656**	0.810**	-0.685**	-0.639**	0.760**	0.802**	1.000		
DFH	-0.098NS	-0.294NS	-0.325*	0.174NS	0.169NS	-0.204NS	-0.319*	0.097NS	-0.210NS	0.307NS	1.000	
MYD	-0.095NS	-0.805**	-0.938**	0.965**	0.956**	-0.980**	-0.981**	0.971**	0.877**	0.744**	0.222NS	1.000

**Significance at 5 % level *Significance at 1 % level

PLHT 1- Plant height at 60,90 and 120 days after transplanting, NBR – The number of branches per plant, PDF- Polar diameter of fruit, CHL- Chlorophyll a : b ratio, LAI - Leaf area index, NTPL - Number of trusses per plant, EQD - Equatorial diameter of fruit, TW- Test weight, TSS - Total soluble solids, NFPT – The number of fruits per truss, PTF- Pericarp thickness of fruit DFH- Days to first harvest, ASDY- Acidity, DFF-Days to 50% flowering, NFPL - Number of fruits per plant, MYD- Marketable yield, AFW- Average fruit weight, ASDD- Ascorbic acid, NFCL – The number of flowers per cluster, NLFR- The number of locules per fruit

Highly significant positive association was found in the number of flowers per cluster with the characters like number of trusses per plant (0.964 and 0.745), number of fruits per truss (0.908 and 0.775), number of fruits per plant (0.995 and 0.898), number of locules per fruit (0.862 and 0.824), pericarp thickness of fruit (0.885 and 0.828), ascorbic acid (0.917 and 0.858), chlorophyll a:b ratio (0.816 and 0.738), test weight of seed (0.876 and 0.683), and marketable yield (0.872 and 0.837) at both genotypic and phenotypic level (Table 4.4)

The highest significant negative association with average fruit weight (-0.485 and -0.334) equatorial diameter of fruit (-0.911 and-0.833), total soluble solids (-0.855 and -0.816), acidity (-0.858 and -0.806), at both genotypic and phenotypic level. It had non-significant but positive correlated with days to first harvest (0.218 and 0.254) at both genotypic and phenotypic level. It had significant but negative correlated polar diameter of fruit (-0.557) at a genotypic level. The characters like number of fruits per truss (0.843 and 0.533), number of fruits per plant (0.933 and0.783), number of locules per fruit (0.952 and 0.683), pericarp thickness of fruit (0.959 and 0.658), ascorbic acid (0.891 and 0.701), chlorophyll a:b ratio (0.827 and 0.468), test weight of seed (1.026 and 0.576) and marketable yield (0.861 and 0.716) were found highly significant positive association with number of trusses per plant at both genotypic and phenotypic level (Table 4.4). The characters like equatorial diameter of fruit (-0.875 and -0.654), days total soluble solids (-0.888and -0.678), acidity (-0.923 and -0.637) were found highly significant but negatively correlated with Number of trusses per plant at both genotypic and phenotypic level. It had highly significant but negatively correlated with average fruit weight (-0.547) and polar diameter of fruit (-0.585) at genotypic level.It had highly significant but positive correlated with days to first harvest (0.416) at genotypic level.

Number of fruits per truss, a major yield contributing character was recorded highly significant positive association with, number of fruits per plant (0.966 and0.894), number of locules per fruit (0.915 and 0.811), pericarp thickness of fruit (0.933 and 0.797), ascorbic acid (0.964 and 0.837), chlorophyll a:b ratio (0.975 and 0.696), test weight of seed (0.794 and 0.690) and marketable yield (0.992 and 0.898) at both genotypic and phenotypic level (Table 4.4) Highly significant but negatively correlated were recorded with an equatorial diameter of fruit (-0.953 and -0.825), days total soluble solids (-0.934 and -0.862) and acidity (-0.918 and -0.743) at both genotypic and phenotypic level. It had significant but negatively correlated with polar diameter of fruit (-0.878) at a genotypic level and non-significant but negatively correlated with polar diameter of fruit (-0.277) at phenotypic level.

Among all the yield contributing characters studied, it was found that the character number of fruits per plant had highly significant positive association with number of locules per fruit (0.956 and 0.851), pericarp thickness 0f fruit (0.958 and 0.804), ascorbic acid (1.001 and 0.881), chlorophyll a:b ratio (0.993 and 0.727), test weight of seed (0.886 and 0.695), and

marketable yield (0.952 and 0.908) at both genotypic and phenotypic level (Table 4.4) and highly significant but negatively correlated with average fruit weight (-0.392 and -0.355), equatorial diameter of fruit (-0.953 and -0.869), days total soluble solids (-0.946 and -0.884), acidity (-0.953 and -0.791) at both genotypic and phenotypic level.

Correlation studies on average fruit weight revealed that average fruit weight had highly significant but positively correlated with polar diameter of fruit (0.596) at a genotypic level and non-significant positively correlated with polar diameter of fruit (0.141) at a phenotypic level.

Among all fruit characters, Polar diameter of fruit found highly significant negatively associated with number of locules per fruit (-0.780), pericarp thickness of fruit (-0.824), ascorbic acid (-0.538), chlorophyll a:b ratio (-0.648), test weight of seed (-0.680), days to first harvest (-0.294) and marketable yield (-0.805) at genotypic level and non significant negative association with number of locules per fruit (-0.306), pericarp thickness of fruit (-0.184), ascorbic acid (-0.174), chlorophyll a:b ratio (-0.037) , test weight of seed (-0.175), days to first harvest (-0.051) and marketable yield (-0.285) phenotypic levels (Table 4.4). It was found highly significant but positively correlated with equatorial diameter of fruit (0.574), total soluble solids (0.791) and acidity (0.718) at genotypic level.

Correlation studies on fruit characters revealed that, equatorial diameter of fruit had highly significant negative association with, number of locules per fruit (-0.892 and -0.862), pericarp thickness 0f fruit (-0.872 and -0.758), ascorbic acid (-0.974 and -0.883), chlorophyll a:b ratio (-0.958 and -0.696),test weight of seed (-0.760 and -0.637) and marketable yield (-0.938 and -0.868) at both genotypic and phenotypic levels (Table 4.4).

It was noted highly significant but positively correlated with days total soluble solids (0.962 and 0.894) and acidity (0.989 and 0.882), at both genotypic and phenotypic level. It has a significant negative correlation with days to first harvest (-0.325) at a genotypic level .

Number of locules per fruit was recorded significant positive association with, pericarp thickness of fruit (0.932 and 0.873), ascorbic acid (0.925 and 0.867), chlorophyll a:b ratio (0.844 and 0.694),test weight of seed (0.656 and 0.616) and marketable yield (0.965 and 0.916) at both genotypic and phenotypic level (Table 4.4). It was recorded highly significant but negatively correlated with days total soluble solids (-0.966 and -0.911) and acidity (-0.944 and -0.890) at both genotypic and phenotypic level.

Pericarp thickness of fruit, a major fruit character had significant positive correlation with ascorbic acid (0.913 and 0.839), chlorophyll a:b ratio (0.821 and 0.801), test weight of seed (0.810 and 0.641) and marketable yield (0.956 and 0.891) at both genotypic and phenotypic level (Table 4.4). It had highly significant but negatively correlated with days total soluble solids (-0.913 and -0.854) and acidity (-0.874 and -0.779), at both genotypic and phenotypic level.

Correlation studies on quality characters, revealed that total soluble solids were observed a highly significant positive association with, acidity (0.997 and 0.895) and at both genotypic and phenotypic level (Table 4.4). It was noted highly significant but negatively correlated with ascorbic acid (-0.979 and 0.916) chlorophyll a:b ratio (-0.861 and -0.723), test weight of seed (-0.685 and -0.607), and marketable yield (-0.980 and -0.957) at both genotypic and phenotypic level.

Acidity, a major fruit quality character was observed highly significant negative correlation with ascorbic acid (-0.949 and 0.864) chlorophyll a:b ratio (-0.820 and -0.642), test weight of seed (-0.639 and -0.528), days to first harvest (-0.319 and -0.320) and marketable yield (-0.981 and -0.858) at both genotypic and phenotypic level.

Among all the fruit quality characters, ascorbic acid content was observed highly significant positive association with chlorophyll a:b ratio (0.981 and 0.800), test weight of seed (0.760 and 0.621), and marketable yield (0.971 and 0.916) at both genotypic and phenotypic level.

Correlation studies on yield contributing characters revealed that chlorophyll a:b ratio revealed highly significant positive association with a test weight of seed (0.802 and 0.566), and marketable yield (0.877 and 0.730) at both genotypic and phenotypic level and non-significant negative association with days to first harvest (-0.210) at a genotypic level

Test weight of seed was recorded a highly significant positive association with marketable yield (0.744 and 0.619) and non-significant positive association with days to first harvest (0.307and 0.114) at both genotypic and phenotypic level

4.5 Path analysis

Path analysis studies give an idea about the actual effects of a character on yield. For a dependent character like yield, many independent characters affect directly and indirectly. Hence, for an improvement of a character, even it is showing significance with yield may not be considered for improvement as its correlation with yield may be due to the indirect effects of this trait through other characters.In such cases, it is always more appropriate to split the correlation value into direct and indirect effects through path coefficient analysis. By partitioning the genotypic correlations, the direct effect of a chosen trait on fruit yield per plant and its indirect effect through other characters were analysed and the data related to direct and indirect effects are presented in (Table 4.5).

Out of twenty-two, nine characters showed a positive direct effect on fruit yield per plant at a genotypic level. The characters, which had a positive direct effect on fruit yield were leaf area index (0.262), number of flowers per cluster (1.7023), number of trusses per plant (1.5905), number of fruits per truss (1.1916), polar diameter of fruit (0.1765), pericarp thickness of fruit (2.6478), total soluble solids (2.8474), chlorophyll a:b ratio (0.5033) and days to first harvest (0.8384). Among the positive direct effects, leaf area index,(0.6980), number of flowers per cluster (0.8719), number of trusses per plant (0.8610), number of fruits per truss (0.9920),

number of fruits per plant (0.9516), number of locules per fruit (0.9652), pericarp thickness of fruit (0.9561), ascorbic acid (0.9710), chlorophyll a:b ratio (0.8769), test weight of seed (0.7438) and days to first harvest (0.2218) were highly significant and positive direct effect, and plant height at 60 DAT (-0.8685), plant height at 90 DAT (-0.911) and plant height at120 DAT(-0.9031) , average fruit weight (0.0949), polar diameter of fruit (0.8053) , equatorial diameter of fruit (0.9376), total soluble solids (0.9798) and acidity (0.9710) was found significant but negative direct effect, The characters, which had a negative direct effect on fruit yield per plant, were plant height at 60 DAT (-2.4875), plant height at 90 DAT(-1.3762), plant height at 120 DAT days (-3.8108), days to 50% flowering (-1.8605), number of branches per plant (-5.528), number of fruits per plant (-0.4849), average fruit weight (-0.6567), equatorial diameter of fruit (-0.53908), number of locules per fruit (-3.6583), acidity (-0.0244), ascorbic acid content (-4.37354) and test weight of seed (-0.0534) respectively.

4.5.2 Indirect effect

Plant height at 60 DAT (Table 4.5) had showed positive indirect effect *via* the number of branches per plant (4.44375), number of fruits per plant (4.55107), number of locules per fruit (3.46837), total soluble solids (2.5568), and It had high negative indirect effect *via* height at 90 DAT (-1.37619) plant height at 120 days after transplanting (-3.14604), days to 50 % flowering (-1.39453), leaf area index (-0.22536), number of trusses per plant (-1.31557) average fruit weight(-0.34434), equatorial diameter of fruit (-4.97585), number of fruits per truss (-1.01558), pericarp thickness of fruit (-2.07084), acidity (-0.02193), ascorbic acid (-4.1543), chlorophyll a:b ratio (-0.49251)test weight of seed(0.03173), days to first harvest (-0.00312). and marketable yield (-0.86852)

The effect of number of branches towards yield had an indirect positive effect *via* plant height at 60 DAT (1.99957), plant height at 120 DAT (3.4399), plant height at 90 (1.2873), number of trusses per plant (1.20528), days to 50% flowering (1.21175), leaf area index (0.1508), equatorial diameter of fruit (4.92258) number of flowers per cluster (1.5584), average fruit weight (0.23136), ,pericarp thickness of fruit (2.17369) ,acidity (0.02219), ascorbic acid (-3.78813), chlorophyll a:b ratio (0.4265) and days to first harvest (0.23211) and marketable yield (0.81266). >It had a high negative indirect effect *via* a number of fruits per plant (-4.29143), number of locules per fruit (-3.00048), total soluble solids (-2.30502) and test weight of seed (-0.03139).

Path analysis study on Days to 50% flowering had confirmed that it had indirect positive effect *via*, number of branches per plant (3.60049), number of locules per fruit (2.80834), polar diameter of fruit (0.10249) total soluble solids (2.25548), days to first harvest (0.21094), pericarp thickness of fruit (-1.79047), ascorbic acid (3.42954) and test weight of seed (0.0195). It had indirect negative effect *via* plant height at 60 DAT (-1.8645), plant height at 90 DAT(-0.99125), plant height at 120 DAT (- 2.6436), leaf area index (-0.21323), number of

trusses per plant (-0.93182), number of fruits per truss (-0.8154),number of flowers per cluster (-1.11658), average fruit weight (-0.08612), equatorial diameter of fruit (-3.9202), acidity (-0.02091), chlorophyll a:b ratio (-0.36487) and marketable yield (-0.74688)

The characters like plant height at 120 DAT (2.253533), number of flowers per cluster (1.0509), had indirect positive effect on leaf area index and *via* the number of branches per plant (-3.17094), total soluble solids (-2.3136) ascorbic acid (-3.16332) and days to first harvest (-0.39313) had indirect negative effect on leaf area index.

Path analysis on yield contributing characters recorded the number of flowers per cluster had an indirect positive effect *via* plant height at 60 DAT (2.11008), days to 50% flowering (1.22036), average fruit weight (0.31852), pericarp thickness of fruit (2.3435), acidity (0.02088) and days to first harvest (0.18303) and it had an indirect negative effect *via* number of trusses per plant (1.53311), number of fruits per plant (-4.82603), total soluble solids (-2.43571) and test weight of seed (-0.04672).

The characters like plant height at 120 DAT (3.29791), days to 50 % flowering (1.32191), number of trusses per plant (1.48435) average fruit weight (0.25713), acidity (0.02321) and days to first harvest (0.17062) had an indirect positive influence on number of fruits per plant and the number of branches per plant (-4.89173), number of locules per fruit (-3.49802), total soluble solids (-2.69495) and test weight of seed (-0.04729) had an indirect negative influence on number of fruits per plant.

The most important yield contributing character, average fruit weight was recorded an indirect positive effect *via* the number of branches per plant (1.94761), total soluble solids (0.44536) and test weight of seed (0.02464) and negative indirect effect *via*, plant height at 120 DAT (-0.00805), number of fruits per truss (-0.13987), equatorial diameter of fruit (-1.62355), acidity (-0.00675) and days to first harvest (-0.08257).

Path analysis study on fruit characters revealed the Polar diameter of fruit was found indirect positive effect *via* the number of locules per fruit (2.85182), ascorbic acid (2.35143). It had an indirect negative effect *via*, the number of trusses per plant (-0.93081), acidity (-0.01749) and days to first harvest (-0.2464). Equatorial diameter of fruit was found an indirect positive effect *via* the ascorbic acid(4.425379) and test weight of seed (0.04057). It had an indirect negative effect *via* acidity (-0.02409), the number of fruits per truss (-1.13518) and days to first harvest (-0.2722).

Total soluble solids, a major fruit quality character was found an indirect positive effect *via* number of branches per plant (4.47504),number of locules per fruit (3.53352), ascorbic acid (4.27966). It had an indirect negative effect *via* plant height at 60 DAT (-1.26776), days to 50%flowering (-1.47371), number of trusses per plant (-1.41241), average fruit weight (-0.010271), acidity (-0.02427), chlorophyll a:b ratio (-0.43348) and days to first harvest (-0.17079). Acidity had an indirect positive effect *via*, number of branches per plant (5.03798),

number of flowers per plant (0.458999), total soluble solids (2.83774) and test weight of seed (0.03409). It had an indirect negative effect *via*, average fruit weight (-0.18214), pericarp thickness of fruit (-2.31179), and days to first harvest (-0.26747).

The characters days to 50% flowering (1.45892), leaf area index (0.19016) number of trusses per plant (1.41642), average fruit weight (0.1455), pericarp thickness of fruit (2.41755) contributed an indirect positive effect on ascorbic acid content of fruit and days to first harvest (0.08165). It had an indirect negative effect *via the* number of branches per plant (-4.78817), acidity (0.0231) and test weight of seed (-0.04057) contributed an indirect negative effect on ascorbic acid.

Test weight of seed affects indirectly on the number of trusses per plant (1.6322), acidity (0.01556) and days to first harvest (0.25698).

Days to first harvest was recorded indirect positive effect *via* acidity (0.0077) recorded an indirect negative effect *via* days to 50 % flowering (-0.46809), number of branches per plant (-1.53043), ascorbic acid (-0.42592) and test weight of seed (-0.01635).

Table 4.5: Genotypic path coefficient analysis for Marketable yield and its component characters in tomato

	PLHT 1	PLHT 2	PLHT 3	NBR	DFF	LAI	NFCL	NTPL	NFPT	NFPL
PLHT 1	**-2.4875**	-1.2634	-3.1460	4.4438	-1.3945	-0.2254	-1.4440	-1.3156	-1.0156	4.5511
PLHT 2	-2.2837	**-1.3762**	-3.6989	5.1710	-1.3401	-0.2141	-1.5020	-1.1624	-1.0986	4.4597
PLHT 3	-2.0536	-1.3358	**-3.8108**	4.9902	-1.2906	-0.1749	-1.4702	-1.1376	-1.0536	4.1970
NBR	1.9996	1.2873	3.4400	**-5.5281**	1.2118	0.1508	1.5584	1.2053	0.9900	-4.2914
DFF	-1.8645	-0.9913	-2.6436	3.6005	**-1.8605**	-0.2133	-1.1166	-0.9318	-0.8154	3.4458
LAI	2.1323	1.1208	2.5353	-3.1709	1.5091	**0.2629**	1.0509	0.7468	0.9002	-3.6861
NFCL	2.1101	1.2143	3.2913	-5.0609	1.2204	0.1623	**1.7023**	1.5331	1.0821	-4.8260
NTPL	2.0575	1.0058	2.7256	-4.1892	1.0900	0.1234	1.6409	**1.5905**	1.0046	-4.5261
NFPT	2.1201	1.2688	3.3696	-4.5928	1.2731	0.1986	1.5459	1.3410	**1.1916**	-4.6850
NFPL	2.3343	1.2655	3.2979	-4.8917	1.3219	0.1998	1.6940	1.4844	1.1511	**-4.8497**
AFW	-1.3043	-0.2133	-0.0081	1.9476	-0.2440	-0.0795	-0.8257	-0.8693	-0.1399	1.8989
PDF	-1.7765	-0.8835	-2.2687	2.9541	-1.0804	-0.2168	-0.9477	-0.9308	-1.0458	3.9834
EDF	-2.2960	-1.2721	-3.2240	5.0479	-1.3529	-0.1864	-1.5516	-1.3913	-1.1352	4.6950
NLFR	2.3583	1.2360	3.4152	-4.5340	1.4282	0.1996	1.4676	1.5136	1.0906	-4.6372
PTF	1.9454	1.2524	3.5756	-4.5382	1.2581	0.1648	1.5066	1.5249	1.1119	-4.6481
TSS	-2.2336	-1.2678	-3.3769	4.4750	-1.4737	-0.2136	-1.4561	-1.4124	-1.1131	4.5900
ASDY	-2.2403	-1.2410	-3.4249	5.0380	-1.5978	-0.1866	-1.4600	-1.4674	-1.0933	4.6231
ASAD	2.3628	1.3139	3.4273	-4.7882	1.4589	0.1902	1.5618	1.4164	1.1481	-4.8549
CHL	2.4341	1.3530	3.2421	-4.6844	1.3487	0.2150	1.3896	1.3159	1.1614	-4.8174
TW	1.4796	0.7519	1.8433	-3.2527	0.6800	0.0974	1.4907	1.6322	0.9460	-4.2989
DFH	0.0092	0.1335	0.6024	-1.5304	-0.4681	-0.1233	0.3716	0.6615	0.2618	-0.9869

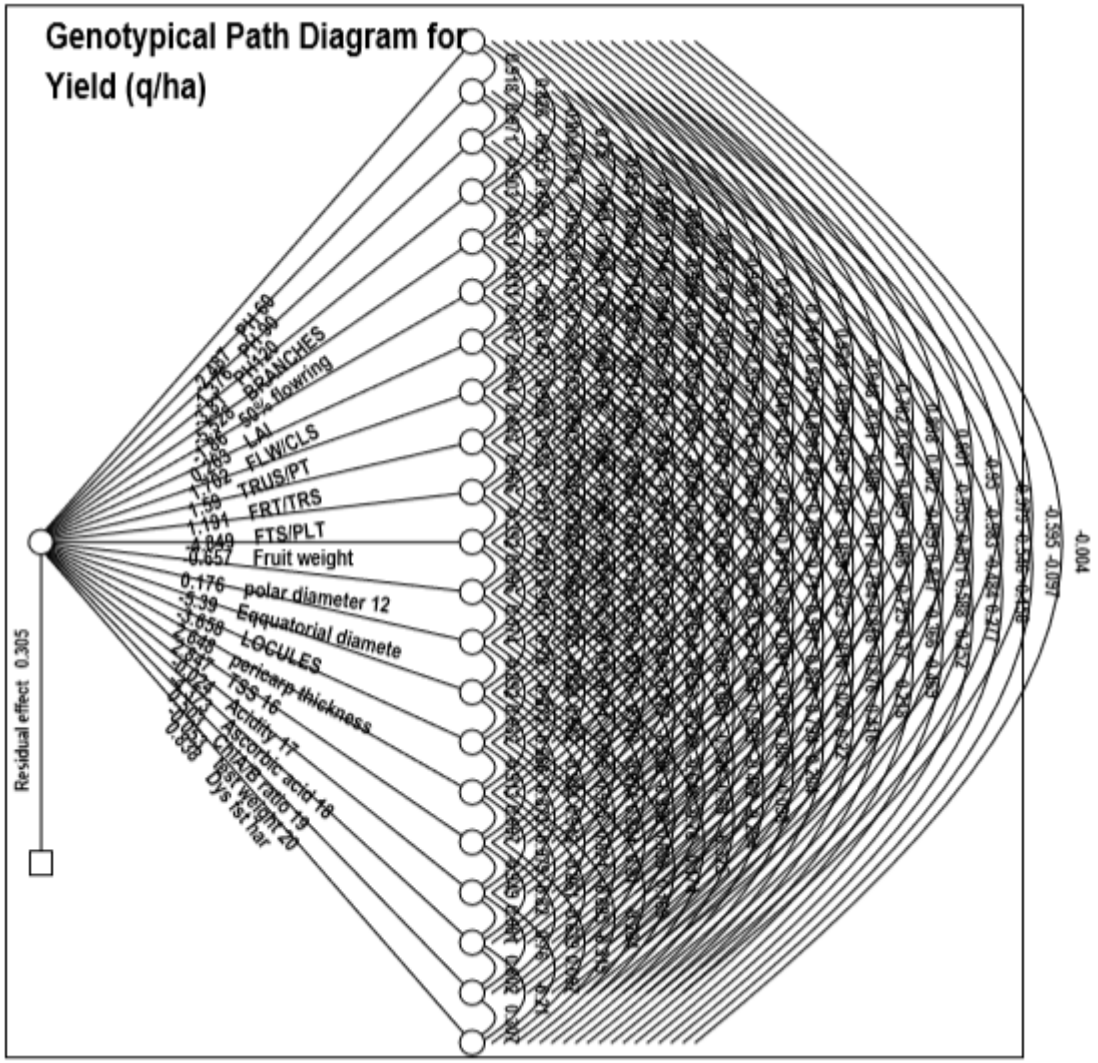
	AFW	PDF	EDF	NLFR	PTF	TSS	ASDY	ASAD	CHL	TWS	DFH	MYD
PLHT 1	-0.3443	0.1261	-4.9759	3.4684	-2.0708	2.5568	-0.0219	4.1543	-0.4925	0.0317	-0.0031	**-0.8685****
PLHT 2	-0.1018	0.1133	-4.9829	3.2856	-2.4097	2.6231	-0.0220	4.1757	-0.4948	0.0292	-0.0813	**-0.9111****
PLHT 3	-0.0014	0.1051	-4.5607	3.2785	-2.4844	2.5232	-0.0219	3.9334	-0.4282	0.0258	-0.1325	**-0.9031****
NBR	0.2314	-0.0943	4.9226	-3.0005	2.1737	-2.3050	0.0222	-3.7881	0.4265	-0.0314	0.2321	**0.8127****
DFF	-0.0861	0.1025	-3.9202	2.8083	-1.7905	2.2555	-0.0209	3.4295	-0.3649	0.0195	0.2109	**-0.7469****
LAI	0.1987	-0.1455	3.8222	-2.7773	1.6597	-2.3136	0.0173	-3.1633	0.4115	-0.0198	-0.3931	**0.6980****
NFCL	0.3185	-0.0983	4.9135	-3.1540	2.3435	-2.4357	0.0209	-4.0126	0.4109	-0.0467	0.1830	**0.8719****
NTPL	0.3589	-0.1033	4.7156	-3.4815	2.5387	-2.5286	0.0225	-3.8949	0.4164	-0.0548	0.3487	**0.8610****
NFPT	0.0771	-0.1549	5.1357	-3.3483	2.4707	-2.6599	0.0223	-4.2141	0.4905	-0.0424	0.1842	**0.9920****
NFPL	0.2571	-0.1450	5.2189	-3.4980	2.5378	-2.6950	0.0232	-4.3782	0.5000	-0.0473	0.1706	**0.9516****
AFW	**-0.6567**	0.1052	-1.6236	1.0044	-0.2670	0.4454	-0.0068	0.9690	-0.1693	0.0246	-0.0826	**-0.0949****
PDF	-0.3913	**0.1765**	-3.0964	2.8518	-2.1829	2.2517	-0.0175	2.3514	-0.3260	0.0363	-0.2464	**-0.8053****
EDF	-0.1978	0.1014	**-5.3908**	3.2645	-2.3097	2.7393	-0.0241	4.2598	-0.4820	0.0406	-0.2722	**-0.9376****
NLFR	0.1803	-0.1376	4.8104	**-3.6583**	2.4674	-2.7503	0.0230	-4.0434	0.4246	-0.0350	0.1462	**0.9652****
PTF	0.0662	-0.1455	4.7024	-3.4090	**2.6478**	-2.5990	0.0213	-3.9931	0.4132	-0.0432	0.1416	**0.9561****
TSS	-0.1027	0.1396	-5.1861	3.5335	-2.4169	**2.8474**	-0.0243	4.2797	-0.4335	0.0365	-0.1708	**-0.9798****
ASDY	-0.1821	0.1268	-5.3337	3.4542	-2.3118	2.8377	**-0.0244**	4.1486	-0.4129	0.0341	-0.2675	**-0.9812****
ASAD	0.1455	-0.0949	5.2507	-3.3822	2.4176	-2.7863	0.0231	**-4.3735**	0.4936	-0.0406	0.0817	**0.9710****
CHL	0.2209	-0.1143	5.1626	-3.0865	2.1738	-2.4523	0.0200	-4.2893	**0.5033**	-0.0428	-0.1762	**0.8769****
TW	0.3033	-0.1200	4.0988	-2.4003	2.1454	-1.9504	0.0156	-3.3256	0.4039	**-0.0534**	0.2570	**0.7438****
DFH	0.0647	-0.0519	1.7502	-0.6379	0.4472	-0.5801	0.0078	-0.4259	-0.1058	-0.0164	**0.8384**	**0.2218****

RSQUARE=0.9070, RESIDUALEFFECT=0.3050

**Significance at 5 % level *Significance at 1 % level

PLHT 1- Plant height at 60,90 and 120 days after transplanting, NBR – The number of branches per plant, PDF- Polar diameter of fruit, CHL- Chlorophyll a : b ratio, LAI - Leaf area index, NTPL – The number of trusses per plant, EQD - Equatorial diameter of fruit, TW- Test weight, TSS - Total soluble solids, NFPT – The number of fruits per truss, PTF- Pericarp thickness of fruit DFH- Days to first harvest, ASDY- Acidity, DFF-Days to 50% flowering, NFPL – The number of fruits per plant, MYD- Marketable yield, AFW- Average fruit weight, ASDD- Ascorbic acid, NFCL - Number of flowers per cluster, NLFR- Number of locules per fruit

Genotypic path diagram for yield (q/ha)



CHAPTER-V

DISCUSSION

The results of the present investigation entitled "Variability studies for growth, yield and quality characters of tomato (*Lycopersicon esculentum* Mill.)" have been well explained in the earlier chapter. In view of available literature information on the subject, the results so interpreted are discussed here in this chapter

For a successful crop improvement programme, the extent of genetic variability present in the population or germplasm is of prime importance. The amount of genetic improvement through selection or hybridization followed by selection can be determined by the magnitude of genetic variability present in the population. The magnitude of variation arises due to phenotypic values, can be measured by phenotypic variance, while variation arises due to a difference in genotypic values can be measured by genotypic variance.

Heritability value does not provide any indication of the amount of best individual. The character showing high heritability needs not to exhibit high genetic advance (Johnson *et al.*, 1955). Ramanujam and Tirumalachar (1967) also reported that estimates of heritability in broad sense accompanied with genetic advance would be more reliable in nature. High heritability coupled with high genetic advance indicates that the improvement could be made for a character by simple selection. Grafius (1964) stated that that the fruit yield can be improved through its components rather than directly would be more efficient. Hence, the study of yield components and their direct and indirect contribution to yield and their inter-relationship along with yield of immense importance. Deway and Lu (1959) studied the path analysis and gives cause and an effective relationship critically breaking up different direct and indirect effects, which finally make up correlation coefficient.

It is important to evaluate a large number of germplasm, varieties and hybrids, to increase the production of this crop, to increase the yield per unit area and to enhance the quality of tomato, which is capable of increasing yield and consistent performance in a given environment. For genotypes with desirable characters, selection of genetically distant parents for hybridization is of basic need. Genetic diversity between genotypes indicates the difference in gene frequencies.

In the present investigation, an attempt was made to characterize the germplasm accessions for the estimation of variability, heritability (broad sense), genetic advance, GCV and PCV with respect to twenty-two traits. The association among these characters and their direct and indirect effect on fruit yield has also been studied using correlation and path analysis.

The results presented in the previous chapter are discussed under following headings:

5.1 Genetic variability, heritability and genetic advance

5.2 Correlation studies

5.3 Path analysis

5.1 Genetic variability, heritability and genetic advance

The reports of analysis of variance investigated during the study indicated a significantly higher amount of variability among the genotypes for all the characters studied (Table 4.1) They clearly indicate that the presence of high variability existed for yield and yield components among all the genotypes studied. Hence, there is a scope for selection or hybridization followed by selection for the majority of the traits in the genotypes for their further improvement. The earlier workers (Mehta and Asati, 2008; Dar *et al*., 2012; Kumar *et al*., 2013; Ramzan *et al.*,2014; Singh *et al.,* 2014; Prajapati *et al.,* 2015) also reported a large and exploitable variation in different tomato germplasm.

The genotypes showed a wide range of variation, which helps in the selection of desired genotypes for further improvement and exploitation through selection, hybridization, heterosis and combination breeding (Table 4.1).

The analysis of variance investigated during the study indicated a significantly higher amount of variability among the genotypes for all the characters studied *viz*., plant height at 60, 90 and 120 DAT, number of branches per plant, days to 50% flowering, leaf area index, number of flowers per cluster, number of trusses per plant, number of fruits per truss, number of fruits per plant, equatorial diameter of fruit, polar diameter of fruit, number of locules per fruit, average fruit weight, pericarp thickness, total soluble solids ascorbic acid content, acidity, chlorophyll a:b ratio, test weight of seed, marketable yield and days to first harvest. These results indicate that there is plenty of scope for the improvement of germplasm through selection and utilization in heterosis breeding.

Based on variability assessed in present study and that assessed by earlier workers like (Aradhana and Singh, 2003; Joshi *et al.*, 2004; Ahmed *et al.*, 2006; Haydar *et al*., 2007; Sharma *et al*., 2009; Shasikant *et al*., 2010; Khan and Samadia, 2012; Ahirwar and Prashad, 2013; Kumar *et al*., 2013; Reddy *et al.*, 2103; Meena and Bahadur, 2014; Kumar *et.al.*, 2015)…, In tomato, it could be stated that there ample scope of variation in traits that could be utilized for improvement through selection for the traits investigated in the present material. Further, based on fruit yield per plant in the present investigation, the tomato genotypes 16/TODVAR-5 followed by 16/TODVAR-8, 16/TODVAR-11 and 16/TODVAR-4 appeared to be most promising for their exploitation and utilization for the incorporation of fruit yield potential in other promising materials. Thus, the materials assessed possessed ample scope of their improvement through selection and utilization of heterosis breeding for higher yield and quality. The high estimates of heritability for twenty-two traits were noticed (Table 4.3).

Further, genetic advance as per cent of mean observed for most of the characters under study showed that the number of branches per plant. pericarp thickness, number of fruits per plant, marketable yield, plant height, ascorbic acid, total soluble solids, average fruit weight,

number of trusses per plant, number of locules per fruit had moderate to high magnitude, indicating that the improvement of these through selection as well as their exploitation through combination breeding

However, the estimates of high heritability coupled with high genetic advance observed for most of the characters except days to first harvest, polar diameter of fruit, chlorophyll a:b ratio and leaf area index, suggesting that simple selection could be done for the improvement of most of the traits in the existing material. Results of the present investigation are also in agreement with previous studies carried out on tomato crop by several workers (Ahmed *et al.*, 2006; Asati, *et al*., 2008; Ara, *et al.*,2009 ; Ghosh *et al*., 2010; Dar *et al*., 2012; Kumar *et al*., 2013; Meena and Bahadur, 2014; Sharma and Paul, 2014; Khapte and Jansirani, 2014).

5.2 Correlation studies

The resultant yield is the combined effect of several yield contributing characters and environment. Studies on the interaction of characters among themselves with the environment have been of great use in plant breeding programme.

Correlation studies give the information on nature and extent of association between two pairs of characters. From this, it would be possible to create genetic up-gradation in one character by a selection of other pair of character. Obviously, the knowledge about character associations will help in identifying the characters to select for higher yield with a view to determining the extent and nature of relationship existing among yield contributing characters. Hence, an attempt has been made to study the association of characters in the tomato accessions at both genotypic and phenotypic level.

In the present investigation, the genotypic correlation was higher than the phenotypic correlations, indicating the high heritable nature of the characters. (Table 4.4). However, based on phenotypic values, one can make their selection closer. In the present study, through correlation analysis, yield and yield contributing components were investigated and their relationship with fruit yield per plant as well as among themselves was determined

The characters number of branches per plant, number of fruits per plant, number of fruits per truss and number of flowers per cluster, number of trusses per plant, average fruit weight, number of locules per fruit had a highly significant and positive correlation with fruit yield per plant at both genotypic and phenotypic level.

Therefore, selection for any of these highly associated characters with fruit yield per plant will indirectly help in the selection of plants with high yield. Hence, it is worthwhile to have genotypes with the higher number of fruits per plant, the number of fruits per truss and number flowers per cluster to get a higher yield. Similar results were reported by Mohanty, 2002; Ghosh *et al.*, 2010; Lakshmikant and Mani, 2004 and Meitei *et al.*, 2014), who noticed positive association of the number of fruits per plant with yield.

The plant height at 90 DAT was found highly and positively correlated with average fruit weight, total soluble solids of fruit, while it was negatively correlated with marketable yield and ascorbic acid. (Table 4.4) These results are in agreement with the findings Lakshmikant and Mani, 2004; Raut *et al.*, 2005; Mehta and Asati, 2008; Ghosh *et al.*, 2010; Srivatsava *et.al*., 2013; Kumar *et al*., 2015; Kumar *et al.*, 2013.

Days to 50% flowering was positively correlated with plant height, average fruit weight, total soluble solids and acidity and negatively correlated with the number of branches per plant, average fruit weight, number of fruits per plant, number of fruits per trusses, pericarp thickness and marketable yield (Table 4.4) Similar results were noticed by Patil, 1996; Dhankar *et al*., 2001; Mohanty, 2002; Mehta and Asati, 2008; Srivatsava *et al*.,2013; Kumar *et al*., 2015 Singh *et al*., 2017, Jogi *et.al*.,2018. The number of flowers per cluster was positively correlated with the number of trusses per plant, marketable yield, number of locules per fruit, and days to harvesting. The similar results were obtained by Sherpa *et al.* (2014). The average fruit weight of the plant was found positively correlated with days to 50% flowering and TSS negatively correlated with the number of branches, days to first harvest and marketable yield (Table 4.4). The present results are in accordance with the results of Brar and Singh, 1998; Vikram and Kohli, 1998; Kumar and Tewari, 1999; Joshi *et al.*,2004; Rani *et al*.,2008; Tewari and Upadhyay, 2011; Jogi *et.al*., 2018.

The number of fruits per plant, which was a major yield contributing character, showed a positive association with the number of trusses per plant, ascorbic acid and marketable yield. Significant and positive correlation with yield per plant was also reported by Singh *et al*., 2004; Mahesh *et al*., 2006; and Tiwari and Upadhyay, 2011.

A total soluble solid of fruit was found positively correlated with plant height (Table 4.4). Similar results were also reported by Kumar *et.al* (2012). The ascorbic acid content of fruits was found positively correlated with the number of branches, number of fruits per plant and pericarp thickness and negatively correlated with average fruit weight. Similar results were also reported by Kumar *et al*. (2013). Pericarp thickness of fruit was found a positive correlation with the number of branches per plant, number of fruits per cluster and marketable yield. Similar results were also reported by Kumar *et al.* (2013).

5.3 Path coefficient analysis

The technique of path coefficient analysis developed by Wright,(1921) and demonstrated by Deway and Lu,(1959). Path coefficient analysis partitioning the correlation coefficients into components of a direct and indirect effect. It is standardized partial regression coefficient analysis *per se* it involves measurement of influence of one trait upon the set of other traits. Such information would be of great value in enabling the breeder to identify the important component traits of yield and utilize the genetic stock for improvement in a planned way.

Path coefficient simply a standardized partial regression analysis, where total correlation values were subdivided into individual causal factors. The path analysis of genotypic correlations of fruit yield per plant with its component traits presented diagonally represents the direct effects of the characters towards their correlation with marketable yield per plant, while all other off-diagonal estimates depicted indirect effects of the characters towards their correlation with yield per plant (Table 4.5).

The characters, which had a positive direct effect on fruit yield, were the number of branches, number of flowers per cluster, number of trusses per plant, number of fruits per plant, equatorial diameter of fruit, number of locules per fruit and days to first harvest.

Similarly (Mohanty, 2002; Joshi and Singh, 2003; Kumar *et al*., 2003; Golani *et al*.,2007; Rani *et al*.,2008; Ghosh *et al*., 2010; Tiwari and Upadhyay, 2011 and Kumar *et al*.,2013) they have proved number of fruits per plant, average fruit weight are the major contributors of yield in tomato. The characters, which had a negative direct effect on fruit yield, were plant height, a polar diameter of fruit, equatorial diameter of fruit acidity and ascorbic acid content. Joshi and Singh, (2003), obtained similar results.

Among indirect contributions of component traits through each other, it was observed that plant height had a high positive indirect effect *via*, number of fruits per plant, total soluble solids and high indirect negative effect through, days to 50% flowering and acidity of fruit (Table 4.5).

The number of branches had a high positive indirect effect on yield through the number of flowers per cluster and a negative indirect effect on yield through plant height. Days to 50% flowering had a high positive indirect effect on yield *via*, number of branches per plant whereas, negative indirect effect through the number of fruits per truss and number of fruits per plant. The similar result was found by Patil, 1998; Islam *et al*., 2010; Kumar *et al.,* 2011; Srivatsava, 2013

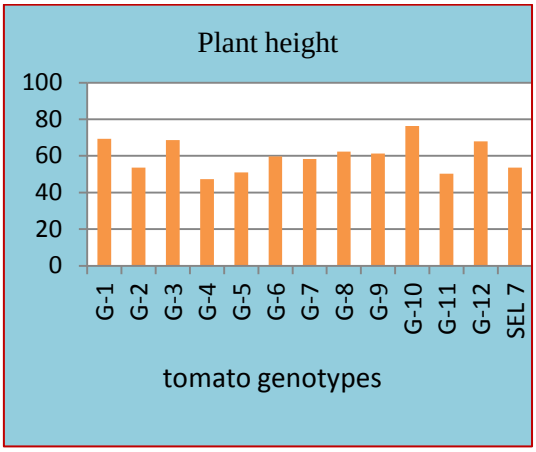
Path analysis study on yield contributing characters had shown the number of fruits per plant had an indirect positive effect through plant height, days to 50% flowering, average fruit weight, and ascorbic acid content of fruit.

The number of fruits per plant had a negative indirect effect *via* the number of branches, polar diameter and total soluble solids and this was in accordance with the findings of Joshi and Singh, 2003 and Srivatsava, 2013. The role of negative contributors *via* each other was important only if the variation in either of the associated contributory traits was much of a positive effect than the negative one. In other words, if the characters were associatively complementary, only then such combinations of characters for the improvement of yield potential of material being assessed could be exploited effectively

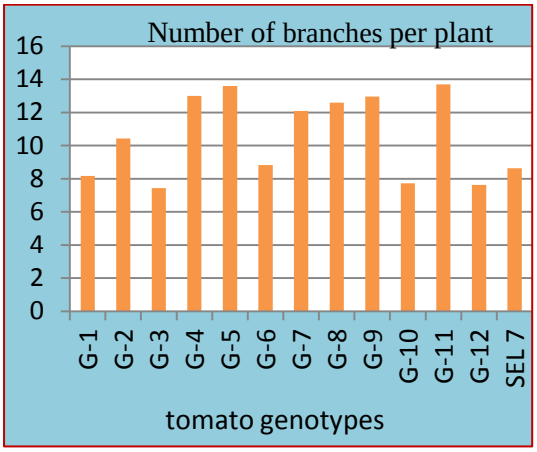
Table 4.6 Summary of superior genotypes based on mean performance in desired directions for marketable yield and fruit yield contributing characters

S. No.	Characters	Superior Genotypes
1	Plant height at 60 DAT (cm)	16/TODVAR-10, 16/TODVAR-1, 16/TODVAR-3
2	Plant height at 90 DAT (cm)	16/TODVAR-10, 16/TODVAR-12, 16/TODVAR-3
3	Plant height at 120 DAT (cm)	16/TODVAR-10, 16/TODVAR-12, 16/TODVAR-3
4	Number of branches per plant	16/TODVAR-11, 16/TODVAR-4, 16/TODVAR-5
5	Days to 50% flowering	16/TODVAR-4, 16/TODVAR-5, 16/TODVAR-8
6	Leaf area index	16/TODVAR-2, 16/TODVAR-5, 16/TODVAR-4
7	Number of flowers per cluster	16/TODVAR-5, 16/TODVAR-9, 16/TODVAR-8
8	Number of trusses per cluster	16/TODVAR-4, 16/TODVAR-8, 16/TODVAR-11
9	Number of fruits per truss	16/TODVAR-5, 16/TODVAR-4, 16/TODVAR-7
10	Number of fruits per plant	16/TODVAR-5, 16/TODVAR-4, 16/TODVAR-11
11	Average fruit weight (g)	16/TODVAR-1, 16/TODVAR-2, 16/TODVAR-9
12	Polar diameter (cm)	16/TODVAR-12, 16/TODVAR-9, 16/TODVAR-8
13	Equatorial diameter (cm)	16/TODVAR-3, 16/TODVAR-10, 16/TODVAR-12
14	Number of locules per fruit	16/TODVAR-11, 16/TODVAR-5, 16/TODVAR-4
15	Pericarp thickness (mm)	16/TODVAR-8, 16/TODVAR-5, 16/TODVAR-4,
16	Total soluble solids (°Bx)	16/TODVAR-12, 16/TODVAR-3, 16/TODVAR-10
17	Acidity (%)	16/TODVAR-3, 16/TODVAR-12, 16/TODVAR-10
18	Ascorbic acid(mg/100g)	16/TODVAR-4, 16/TODVAR-5, 16/TODVAR-11
19	Chlorophyll a:b ratio	16/TODVAR-4, 16/TODVAR-3, 16/TODVAR-2
20	Test weight (g)	16/TODVAR-11, 16/TODVAR-9, Sel-7
21	Days to first harvest	16/TODVAR-12, 16/TODVAR-2, 16/TODVAR-3
22	Marketable yield (q/ha)	16/TODVAR-5, 16/TODVAR-8, 16/TODVAR-11

Mean performance of different tomato genotypes for plant height and number of branches per plant

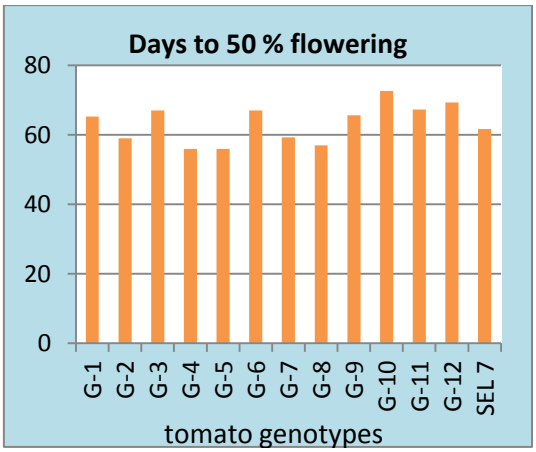


(Fig-1)

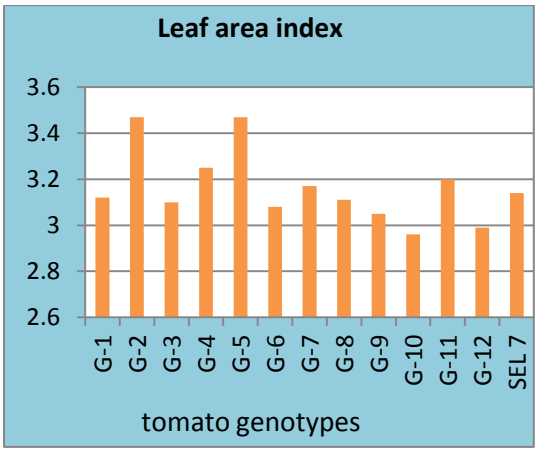


(Fig-2)

Mean performance of different tomato genotypes for days to 50% flowering and leaf area index

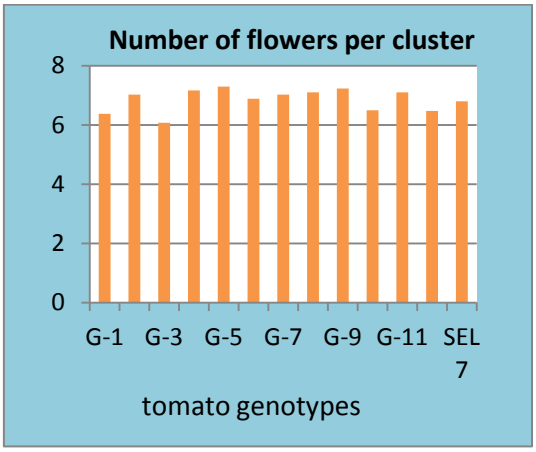


(Fig -3)

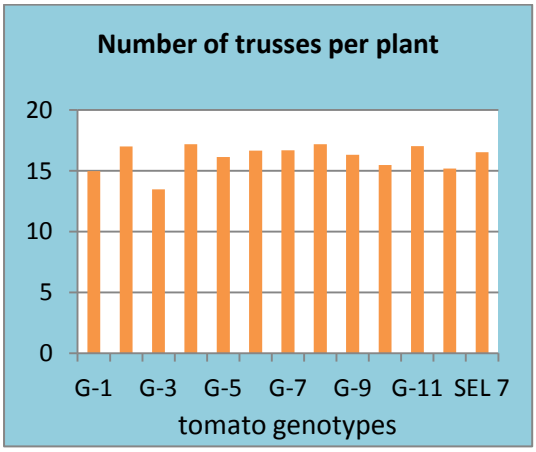


(Fig-4)

Mean performance of different tomato genotypes for the number of flowers per cluster and number of trusses per plant

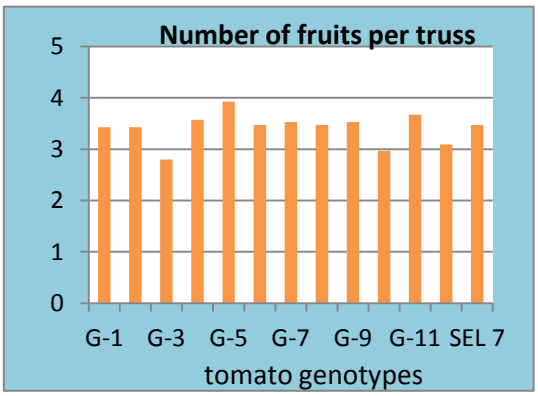


(Fig-5)

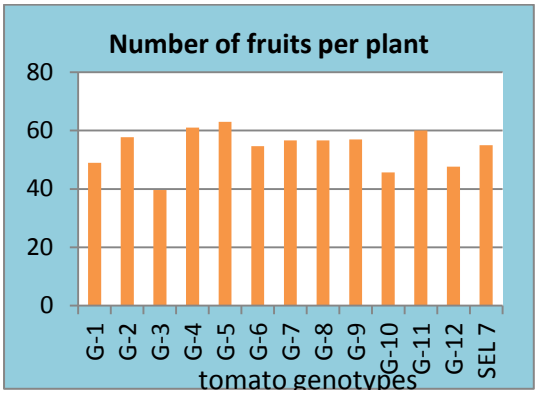


(Fig-6)

Mean performance of different tomato genotypes for number of fruits per truss and number of fruits per plant

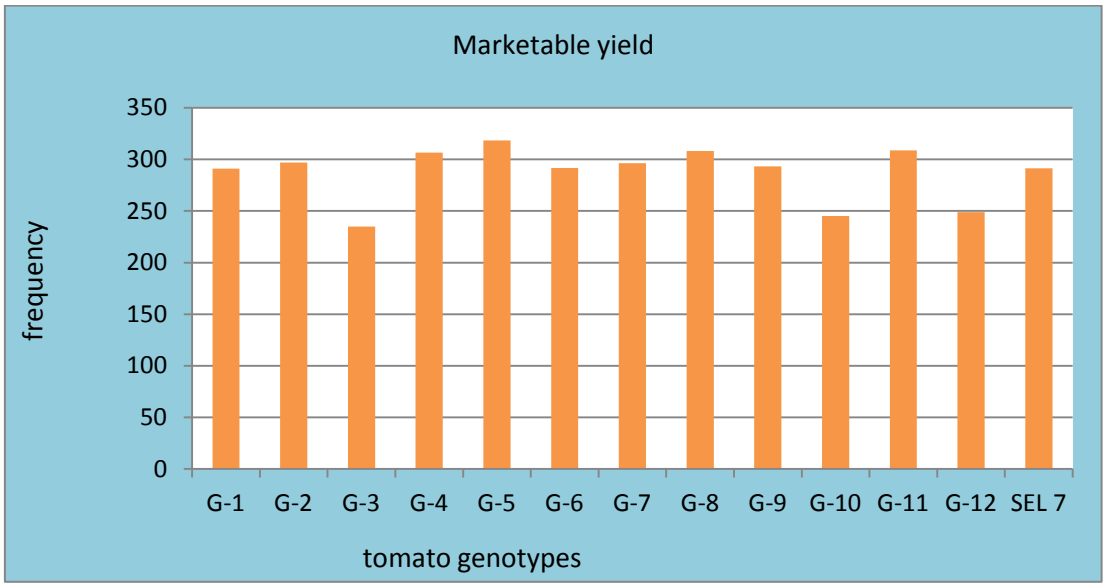


(Fig-7)



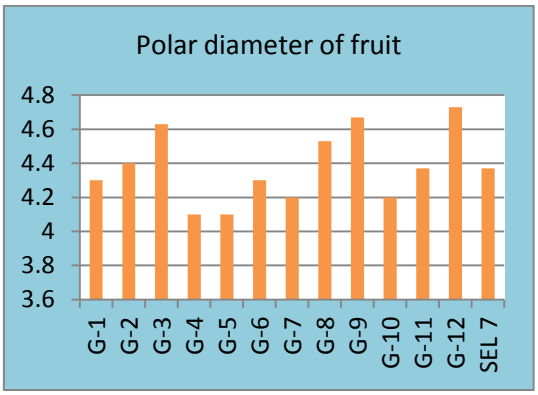
(Fig-8)

Mean performance of different tomato genotypes for marketable yield

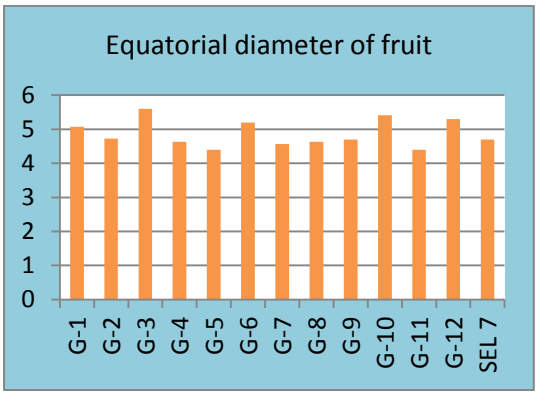


(Fig-9)

Mean performance of different tomato genotypes for a polar diameter of fruit and equatorial diameter of fruit

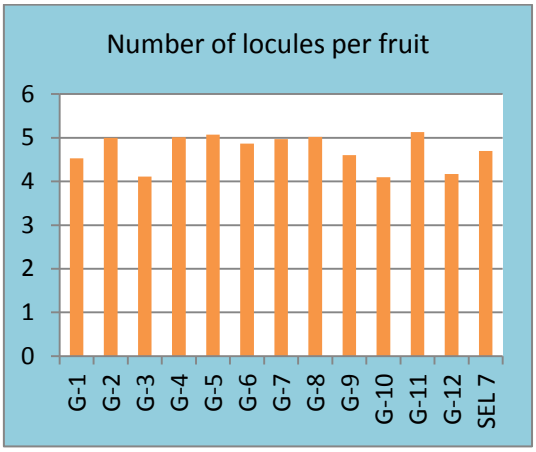


(Fig-10)

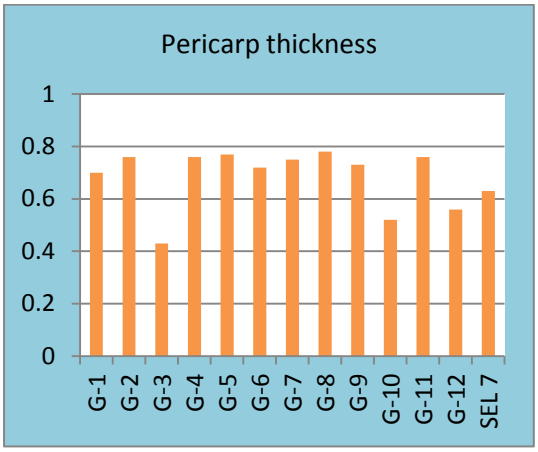


(Fig-11)

Mean performance of different tomato genotypes for number of locules per fruit and pericarp thickness

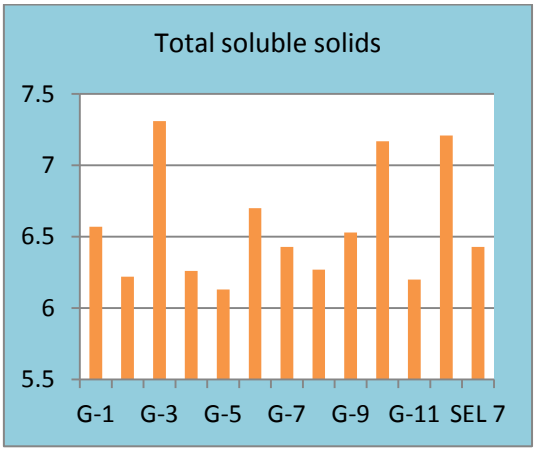


(Fig-12)

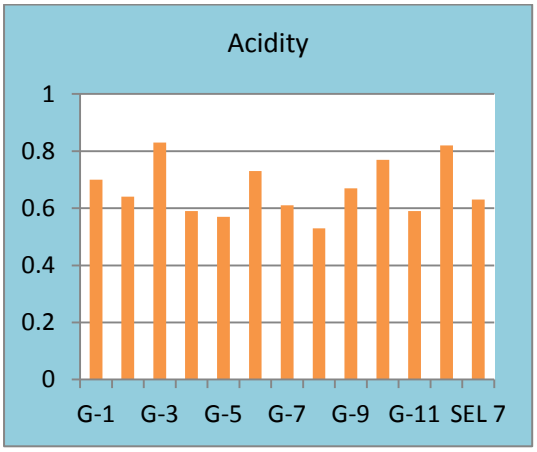


(Fig-13)

Mean performance of different tomato genotypes for total soluble solids and acidity

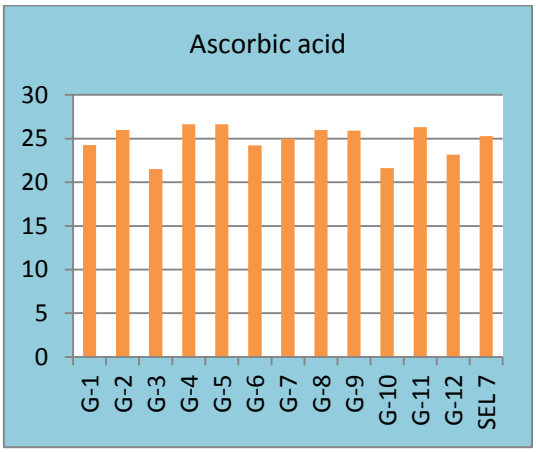


(Fig-14)

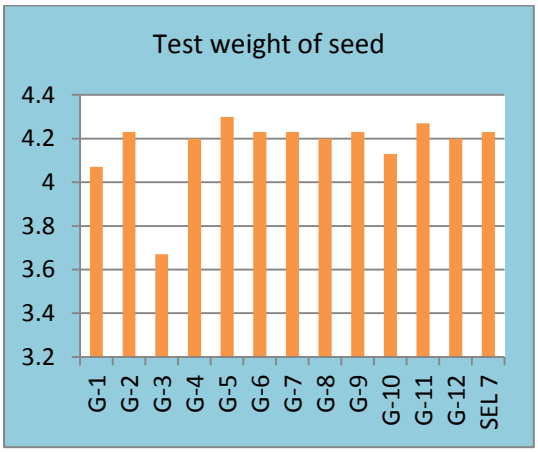


(Fig-15)

Mean performance of different tomato genotypes for ascorbic acid and test weight of seed

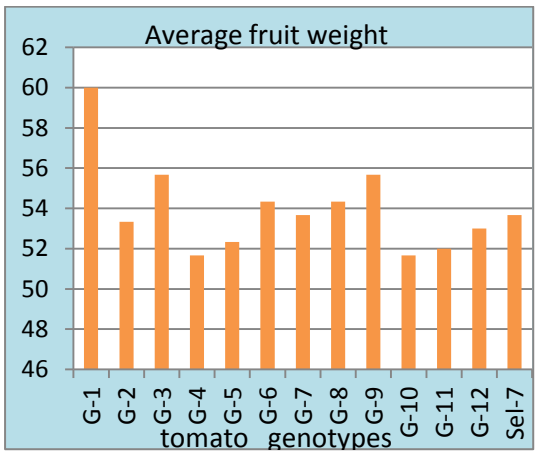


(Fig-16)

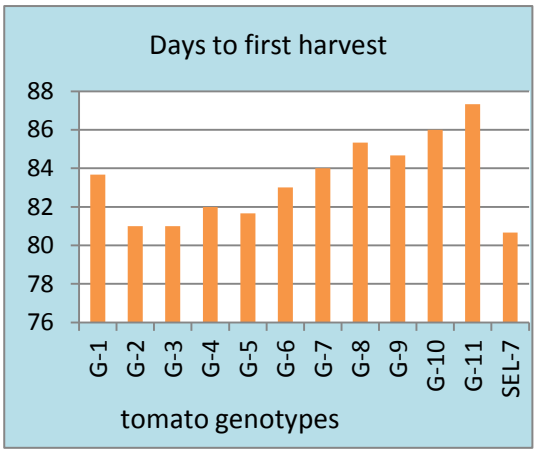


(Fig-17)

Mean performance of different tomato genotypes for average fruit weight and days to first harvest

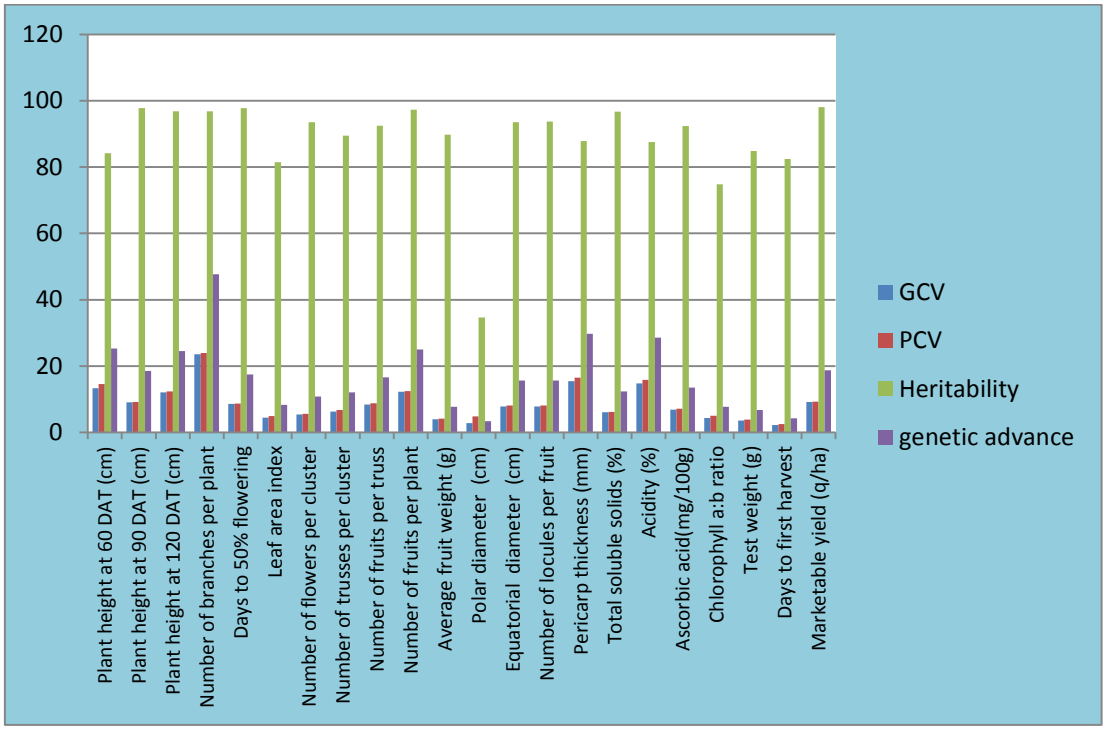


(Fig-18)



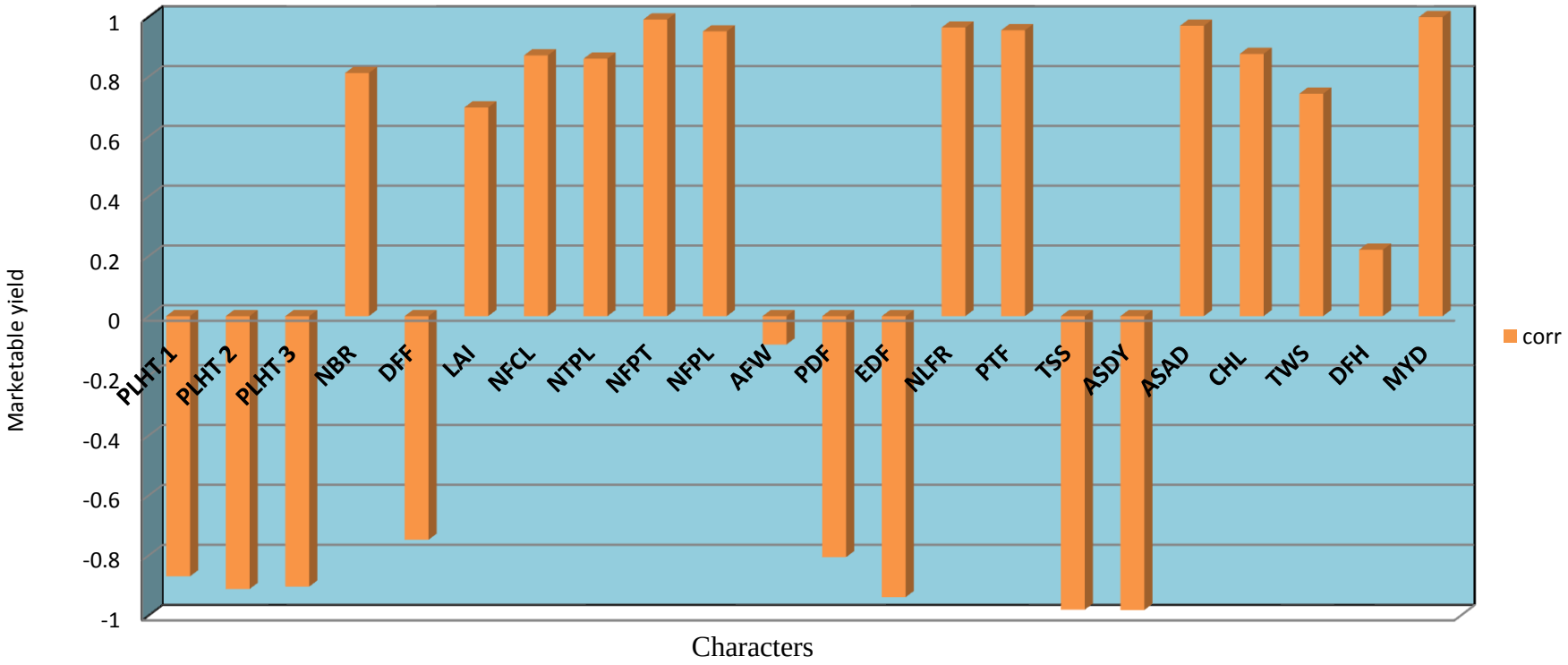
(Fig-19)

Graphical representation of GCV, PCV, Heritability and genetic advance



(Fig-20)

Graphical representation of correlation co-efficient among marketable yield and its characters in tomato



(Fig-21)

PLHT 1- Plant height at 60, 90 and 120 days after transplanting, NBR – The number of branches per plant, PDF- Polar diameter of fruit, CHL- Chlorophyll a : b ratio, LAI - Leaf area index, NTPL – The number of trusses per plant, EQD - Equatorial diameter of fruit, TW- Test weight, TSS - Total soluble solids, NFPT –The number of fruits per truss, PTF- Pericarp thickness of fruit DFH- Days to first harvest, ASDY- Acidity, DFF-Days to 50% flowering, NFPL – The number of fruits per plant, MYD- Marketable yield, AFW- Average fruit weight, ASDD- Ascorbic acid, NFCL –The number of flowers per cluster, NLFR- The number of locules per fruit

CHAPTER-VI

SUMMARY AND CONCLUSION

The present investigation was undertaken to estimate genetic variability with an objective to explore the possibilities of its utilization in the development of new recombinant genotypes with the goal to identify the most suitable genotype performing well in specific environmental condition.

The experiment entitled "Variability studies in growth, yield and quality parameters in tomato genotypes (*Lycopersicon esculentum* Mill.)" was conducted at Research Farm and Laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during a spring-summer season of the year 2018.Thirteen tomato genotypes were planted at a spacing of 60x45 cm, a plant to study the variability. The experimental data were subjected to statistical analysis to justify the information on genetic variation existing for different components of growth and yield.

The genetic variability was studied using parameters like genotypic variance (GV) and phenotypic variance (PV), heritability and genetic advance as per cent of mean (GAM). >>>> Inter-character correlation and path coefficient analysis were also carried out to know the relationship between various growth and yield components. The experimental results were discussed in the previous chapter are summarized below:

- The analysis of variance exhibited highly significant differences among the different tomato genotypes for all 22 traits in the material, indicating a wide range of variability in the genotypes.
- The PCV was slightly higher than the respective GCV for all the traits, indicating that environmental factors influencing their expression to some degree or other.
- Genotypic and phenotypic coefficients of variation were recorded high for all the characters studied *viz*., days to 50% flowering, plant height, number of branches per plant, leaf area index, number of flowers per cluster, number of trusses per plant, number of fruits per truss, number of fruits per plant, equatorial diameter of fruit, polar diameter of fruit, number of locules per fruit, pericarp thickness, total soluble solids, average fruit weight, marketable yield, ascorbic acid content, acidity, chlorophyll a:b ratio, days to first harvest and test weight of seed.
- The maximum value for genotypic and phenotypic variations in terms of a unit of their expression were observed highest for marketable yield, plant height and number of fruits per plant, moderate for number of flowers per cluster, total soluble solids and number of trusses per plant and lowest for acidity, pericarp thickness and leaf area index.
- High estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were recorded for number of branches per plant, pericarp thickness and

acidity, whereas, lowest estimates of PCV and GCV (<10%) were recorded for traits like days to first harvest, polar diameter and test weight of seed. Moderate estimates (10-20%) of PCV and GCV were observed for the number of fruits per truss, days to 50% flowering and number of locules per fruit.

- In general, the magnitude of phenotypic variances, as well as coefficients of variation, was higher than their respective genotypic variation estimates.
- In the present investigation, the traits showed high heritability and ranged from 98%-34.66% .The estimates of high heritability were noticed in most of the characters like marketable yield days to 50% flowering, plant height at 90 DAT, number of fruits per plant, plant height at 120 DAT, number of branches per plant, total soluble solids, number of locules per fruit, equatorial diameter of fruit, number of flowers per cluster, number of fruits per truss, ascorbic acid, average fruit weight, number of trusses per plant, pericarp thickness, acidity, test weight of seed, plant height at 60 DAT, days to first harvest, leaf area index, chlorophyll a:b ratio and lowest in polar diameter of fruit.
- The estimates of genetic advance as per cent of mean were recorded a wide range from (47.72%3.42%).It was found high for the number of branches per plant followed by pericarp thickness, acidity, plant height at 60 DAT, number of fruits per plant, plant height at 120 DAT.
- High heritability along with high genetic advance was recorded for the number of branches per plant, the number of fruits per plant and marketable yield indicated that the characters have additive gene action, and hence, simple selection based on phenotypic performance would be more effective.
- Fruit yield had a positive and highly significant correlation with the number of branches per plant, number of flowers per cluster, number of trusses per plant, number of fruits per truss, number of fruits per plant, average fruit weight, number of locules per fruit, ascorbic acid and days to first harvest.
- Number of fruits per plant had a highly significant positive association with the number of fruits per truss, number of fruits per plant, number of locules per fruit, pericarp thickness of fruit, ascorbic acid, chlorophyll a:b ratio, test weight of seed and marketable yield at both genotypic and phenotypic level. It was noted highly significant but negatively correlated with an equatorial diameter of fruit, total soluble solids and acidity at both genotypic and phenotypic level.
- Days to 50% flowering had highly significant but negative association with leaf area index, number of flowers per cluster, number of trusses per plant, number of fruits per truss, number of fruits per plant, number of locules per fruit, pericarp thickness of fruit, ascorbic acid, chlorophyll a:b ratio, test weight of seed, days to first harvest and marketable yield at both genotypic and phenotypic level. It was noted highly significant

but positively correlated with polar diameter of fruit, equatorial diameter of fruit, total soluble solids and acidity at both genotypic and phenotypic level. Non-significant but negatively correlated with average fruit weight at both genotypic and phenotypic level.

- Path coefficient analysis revealed that nine characters had a positive and direct effect on fruit yield per plant. The characters leaf area index, number of flowers per cluster, number of trusses per plant, number of fruits per truss, a polar diameter of fruit, pericarp thickness of fruit, total soluble solids, chlorophyll a:b ratio and days to first harvest had a positive direct effect on fruit yield
- The number of flowers per cluster had an indirect positive effect *via* plant height at 60 DAT, days to 50 % flowering, average fruit weight, pericarp thickness of fruit, acidity, days to first harvest and test weight of seed. It had an indirect negative effect *via* the number of branches per plant, number of trusses per plant, number of fruits per plant and total soluble solids.
- Number of fruits per plant had an indirect positive effect *via* plant height at 120 DAT, days to 50 % flowering, number of flowers per cluster, number of trusses per plant, average fruit weight, acidity and days to first harvest. It had a negative indirect effect *via* the number of branches per plant, number of locules per fruit, total soluble solids and test weight of seed.
- Ascorbic acid content had an indirect positive effect *via* days to 50% flowering, leaf area index, number of trusses per plant, average fruit weight, pericarp thickness of fruit and days to first harvest. It had an indirect negative effect *via the* number of branches per plant, number of fruits per plant, acidity and test weight of seed.

Conclusion

Based on the results of one year study it can be concluded that out of thirteen tomato genotypes studied, the tomato genotype 16/TODVAR-5 recorded th**e** maximum number of fruits per plant (63.00)and marketable yield per plant and per hectare (318.33 q/ha)

Whereas, for quality purpose the tomato genotype which are found most suitable for total soluble solids(16/TODVAR-12), acidity (16/TODVAR-3), for chlorophyll (16/TODVAR-4) and ascorbic acid (16/TODVAR-4 and 16/TODVAR-5) were found most promising. Which can be further utilized in future breeding programme.

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ABSTRACT

Title of Thesis : Variability studies for growth, yield and quality characters of tomato (*Lycopersicon esculentum* Mill.)"

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Title of degree	: Master of Science
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Degree awarding University	: CCS Haryana Agricultural University, Hisar
Year of award of degree	: 2019
Major Subject	: Vegetable Science
Minor Subject	: Genetics & Plant Breeding
Total No. of pages in the thesis	: 66 + vii
Number of Words in the abstract	: 453

Keywords: Tomato, Characterization, Variability, Heritability, Correlation analysis, Path analysis

The present investigation entitled **"**Variability studies for growth, yield and quality characters of tomato (*Lycopersicon esculentum* Mill.)" was carried out at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during a spring-summer season of 2018.The study material comprised of genetically diverse thirteen tomato genotypes which were evaluated in randomized block design and. The genotypes were taken from IIVR Varanasi in All India coordinated research project and traits were evaluated on the basis of plant height, number branches, days to 50% flowering, number of trusses per plant, number of flowers per cluster, number of fruits per truss, number of fruits per plant, leaf area index, marketable yield, average fruit weight, equatorial and polar diameter of fruit, number of locules per fruit, pericarp thickness of fruit, total soluble solids, acidity, ascorbic acid content ,chlorophyll a:b ratio, test weight of seed and days to first harvest, which differentiate the tomato genotypes. Analysis of variance studies indicated a significant difference among all the genotypes for all the characters under study. Genetic variability studies showed high PCV and GCV values for number of branches per plant (23.54 and 23.93), pericarp thickness (15.42 and 16.46) and acidity(14.79 and 15.8), indicating that a greater amount of genetic variability was present for these characters and thus, there is greater scope for further improvement by genetic manipulation. High heritability coupled with high genetic advance as per cent of mean was observed for marketable yield (98.08 %), days to 50% flowering (97.80), plant height at 90 days after transplanting (97.75%), number of fruits per plant, number of branches per plant, total soluble solids number of locules per fruit, which indicated that these traits were under the strong influence of additive gene action, and hence, simple selection based on phenotypic performance would be more effective. The total yield per plant had positive and highly significant correlation with the number of branches per plant (0.813 and 0.798), number of flowers per cluster (0.872 and 0.837), number of trusses per plant (0.861 and 0.716), number of fruits per truss , number of fruits per plant, average fruit weight, number of locules per fruit, ascorbic acid and days to first harvest at both genotypic and phenotypic levels. It indicated that the improvement in these traits leads to an increase in total yield. The highly positive direct effect on total yield was shown by The characters leaf area index, number of flowers per cluster, number of trusses per plant, number of fruits per truss, polar diameter of fruit, pericarp thickness of fruit, total soluble solids, chlorophyll a:b ratio and days to first harvest, suggested that direct selection based on these characters would result in higher breeding efficiency for improving the yield in tomato.

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Degree	Year of passing	Division	Aggregate Marks (%)	Institution	Major subjects
10th	2011	I st	96.32%	Nuthan Eng Med High School, Ajjampura (Karnataka)	Maths, Science, Social science, English, Hindi, Kannada
10+2	2013	I st	81.116%	Aurbindo Ind Pu College, Shimoga (Karnataka)	Physics, Chemistry, Maths, Biology, English, Kannada
B.Sc.(Hort.)	2016-17	I st	84.8%	University of Agricultural and Horticultural Sciences, Shivamogga (Karnataka)	All Horticulture subjects

Extra Curriculum Activities

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- Obtained Junior Research Fellowship (JRF) from Indian Council of Agricultural Research during M.Sc.
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- Statistical Data Analysis for Research Scholar
- Green House Management for High Value Horticultural Crops
- Training on Protected Cultivation of Horticultural Crops (CCS HAU Hisar, Haryana)
- Abstract : 5

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"I, **Vidya. R,** Admission No. **2017A67M,** hereby undertake that I give the full copyrights of my thesis entitled **"Variability studies for growth, yield and quality characters of tomato (*Lycopersiconesculentum* Mill.)"** to the Chaudhary Charan Singh Haryana Agricultural University, Hisar.

I also undertake that the patent, if any, arising out of the research work conducted during the programme shall be filed by me only with due permission of the competent authority of Chaudhary Charan Singh Haryana Agricultural University, Hisar.

Signature of Student