Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits

By

SUNIL KUMAR
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CERTIFICATE-I

This is to certify that this thesis entitled **"Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits"** submitted in partial fulfilment of the requirement for the degree of **Master of Science (Agriculture)** in the subject of **Horticulture-Vegetable Science** to the **Chaudhary Charan Singh, Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Sunil Kumar,** Admission No., **2016A45M,** under my supervision and that no part of this thesis 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 **"Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits"** submitted by **Sunil Kumar,** Admission No., **2016A45M,** to **Chaudhary Charan Singh Haryana Agricultural University, Hisar** in partial fulfillment of the requirement for the degree of **Master of Science (Agriculture)** 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 **External Examiner**.

MAJOR ADVISOR **EXTERNAL EXAMINER**

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DEAN, POSTGRADUATE STUDIES

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Place**: Hisar* ***Sunil Kumar
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LIST OF ABBREVIATIONS

ANOVA	Analysis of variance
A.O.A.C	Association of Official Analyst Chemist
C.D	Critical difference
C.V	Coefficient of variation
cm	Centimeter
cm^2	Centimeter square
cm^3	Centimeter cube
et al.,	*et alia* (and others)
etc.	*et ceteta*
GCV	Genotypic coefficient of variance
g	Gram
ha	Hectare
IU	International Unit
kg	Kilogram
Max.	Maximum
Min.	Minimum
mg	Milligram
mt.	Million tons
mm	Millimeter
MSS	Mean sum of square
NS	Non-significant
PCV	Phenotypic coefficient of variation
q	Quintal
q/ha	Quintal per hectare
RBD	Randomized block design
TSS	Total soluble solids
viz.,	Videlicet, Namely
%	Per cent

CHAPTER–I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), is an important member of Solanaceae family having chromosome number 2n=24 (X=12), is one of the most popular warm season fruit vegetable crops grown throughout the world (Kumar *et al.*, 2013), because of its wider adaptability, high yielding potential and suitability for variety of cuisines in fresh as well as in preserved form. It is typical day neutral plant and is mainly self-pollinated, but a certain percentage of cross-pollination (upto 5%) also occurs (Depra *et al*., 2014). The Peru-Ecuador-Bolivia region of South America considered as primary center of origin of tomato while secondary centre is Eastern Andes (Rick and Holle, 1990). The Veracruz-Puebla region of Mexico is the centre of domestication.

Tomato tops the list of processed vegetables and occupies a distinct place in the realm of vegetables because of its large-scale utilization and high nutritive value, containing vitamin A (320 IU), vitamin C (31 mg), total solids (4-7%), ascorbic acid (15-30 mg/100g), titrable acidity (7.5-10 mg/100ml) and and highest concentration of lycopene (20-50 mg/100g) (Radzevicius *et al.*, 2009) and innumerable medicinal properties as its fruit has the anticancer, antiseptic and blood purifier properties for that it is also considered as a "Protective food". The nutritional value of tomato makes it useful for reducing cardiovascular risk associated with type-II diabetes, weight loss and controlling eye disorders, night blindness, urinary tract infection and liver disorders. It also helps in cleansing toxic compounds from the body, acts as intestinal antiseptic and blood purification, promotes gastric secretion and cures cancer of mouth and sour throat, apart from improving quality of the prepared food. Tomato is a very good appetizer and its soup is said to be a good remedy for patients suffering from constipation (Kalloo *et al*., 2001).

It is a highly remunerative crop so best for peri-urban cultivation. It is also a *forcing crop* being grown in greenhouse in off-season, thus, it has now become a good source of income to small and marginal farmers. The ripe tomato fruits are consumed fresh as salad or after cooking. A large proportion of tomato is utilized in the preparation of various value added durable products such as puree, paste, powder, ketchup and sauce. It also forms an ingredient for the cocktail *Blood marry*. The fully ripened whole fruits are canned, while the green unripe fruits are used for making pickles and chutney.

Tomato is one of the most widely grown vegetables in the world ranking third in priority after potato and onion in India but ranks second after potato in the world. India ranks second in area as well as in production of tomato, the major tomato producing countries are China, United States of America, India, Egypt and Turkey. India ranks third in the world

production (NHB, 2016-17) with the total area of 809 (000 Ha) producing 1970 (000 MT) with the productivity of 24 T/Ha (NHB, 2016-17). The major tomato producing states in the country are Karnataka following by Andhra Pradesh, Orissa and Bihar etc. In Haryana, its area and production during 2016-2017 was 30 (000 Ha) and 801.6 (000 Tonnes) respectively, representing eight major tomato growing districts of state *viz.*, Karnal, Kurukshetra, Yamuna Nagar, Mewat, Gurgaon, Ambala, Sonipat and Fridabad.

So far, efforts of many vegetable breeders have resulted in spectacular improvement in yield and quality characters. As a result of these efforts, hundreds of new cultivars have been developed in last 50 years to meet the diverse needs. Considering the potentiality of this crop, there is a need to develop varieties suitable for cultivation under specific agro-ecological conditions and also for specific end use. A thorough knowledge regarding the amount of genetic variability existing for various characters is essential for initiating the crop improvement programme. With limited variability, much improvement cannot be achieved, hence, the breeder will have to enrich the germplasm or to create greater variability through hybridization, mutation and polyploidy breeding.

The phenotypic expression of plant characters is mainly controlled by the intraction genetic makeup of a plant and the environment in which it is grown. Further, the genetic variance of any quantitative trait is composed of additive (heritable) and non-additive variance including dominance and epitasis (non-allelic interaction), hence, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as phenotypic and genotypic coefficient of variation, heritability and genetic advance. The genetic advance can also be used to predict the efficiency of selection. Yield is a complex character and selection for yield and yield components deserves considerable attention. A crop-breeding programme aimed at increasing the productivity requires consideration not only of yield but also of its components that have direct or indirect bearing on yield. For any effective selection programme, it would be desirable to consider the relative magnitude of various characters associated with yield.

Correlation and path coefficient analysis give an insight into the genetic variability present in population. Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which the selection can be based for improvement in yield. Path analysis splits the correlation coefficients into direct and indirect effects of a set of dependent variables on the independent variable thereby aids in selection of elite genotype. Based on these studies, the quantum importance of individual characters is marked to facilitate the selection programme for better gains. The commercial F_1 hybrids are common in tomato and selection of new parents for higher heterosis is a continuous process. Generally, the genetically diverse plants are expected to give high hybrid vigour. Hence, it necessitates the study of genetic divergence among the

existing varieties and germplasm for the identification of parents for hybridization programme. The information on genetic divergence of various traits particularly of those that contribute to yield and quality would be of most useful in planning the breeding programme. An improvement in yield and quality in self-pollinated crop like tomato is normally achieved by selecting the genotypes with desirable character combinations existing in nature or by hybridization. Information on the nature and extent of variability present in genetic stocks, heritability, genetic advance and interrelationship among various characters is prerequisite for framing any selection programme.

The breeding in vegetable crops is primarily concerned with the improvement of both quantitative and qualitative plant characters, thus, complete knowledge of genetics is very essential in vegetable breeding programme for obtaining desired results. The success of vegetable breeding depends on the extent and the magnitude of variability existing in the germplasm. Variability is the basic requirement for successful genetic improvement in a crop.

Germplasm evaluation studies would help in the identification of genetic material for quality and yield traits in crop plants, effectively to generate noble variants having adaptation and yielding potential far better than parental types (Sekhar *et al*., 2008). Knowledge about interrelationship among yield and its components and their relative contribution towards yield is important for a fruit selection. Little attention has been paid so far on the development of suitable early maturing high yielding varieties. Keeping in view the above shortcomings of the released varieties, the utmost need is to evolve or identify such variety for the tomato growers, which may give not only good yield but may also have the market acceptability. Hence the present study was conducted to study heritability and the genetic variability among different tomato genotypes Systematic study and evaluation of tomato germplasm is of great importance for current and future agronomic and genetic improvement of the tomato crop.

Considering the spectrum of aforesaid requirement in tomato, the present investigation entitled "Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits" was taken up with the following objectives:

1. To evaluate tomato genotypes for growth, yield and quality traits
2. To study genetic variability among tomato genotypes.
3. To study character association among traits by correlation and path analysis

CHAPTER – II

REVIEW OF LITERATURE

Tomato genotypes possess tremendous variability in respect of morphological, physiological, as well as yield and its contributing traits. The wide spectrum of genetic variability in segregating populations depends on the extent of genetic diversity among genotypes, which offers a better scope for selection. Such literature pertaining to the objectives of the present investigation entitled **"Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits"** have been reviewed in this chapter under following sub-heads:

2.1 Evaluate tomato genotypes for growth, yield and quality traits

2.2 Genetic variability

2.3 Heritability and genetic advance

2.4 Correlation and path analysis

2.5 Genetic divergence

2.1 Evaluate tomato genotypes for growth, yield and quality traits

Regassa *et al.,* (2012) studied nine tomato genotypes for yield and yield attributing traits. They reported that the yield per plant was higher for H-1350, Eshet, Metadel, Marglobe and Moneymaker. Marketable and unmarketable fruit yield per hectare were significantly different among the varieties. Marketable yield was high for all varieties except the Jima local. The total yield was higher in all the varieties except the Fetan, Miya and Jimma local. H-1350 had better yield and yield components among all the varieties while Eshet, Marglobe and jimma local showed the poorest performance in almost all parameters.

Bhati *et al.,* (2017) evaluated nine tomato genotypes for growth, yield and quality under foothills condition of Nagaland state. They reported that the genotype TODVAR-8 was found superior among the genotype and recorded maximum plant height (64.75 cm), number of branches per plant (14.22), fruit length (4.24 cm), fruit diameter (5.28 cm), number of fruits per plant (34.01), fresh weight of fruit (37.00 g), yield ha (46.62 tones), ascorbic acid content (52.73 mg 100 per g) and total soluble solids (5.13° Brix).

Jatav *et al.,* (2017) carried an experiment to study performance of 23 tomato genotypes for yield and quality traits at research farm of the department of vegetable science, CCS Haryana Agricultural University, Hisar during 2014-15. The result revealed that the genotype, AVT-1-2 had highest plant height (140.33 cm) and the maximum number of branches per plant was observed in AVT-2-4 (7.60). The genotype Hisar Arun had the highest number of fruits per plant (38.33) and the maximum fruit yield per plant was recorded in genotype DVRT-3 (1540.00 g). The maximum polar and equatorial diameter of fruit was recorded in

genotype AVT-2-6 (5.10 cm) and Punjab Kesari (6.24 cm), respectively. The maximum number of locules was registered with genotype DVRT-3 (6.20) and fruit weight with H-86 (64.03 g). The genotype PKM-1 had highest TSS (8.43 °Brix) and highest acidity was recorded in H-86 (0.90). The minimum days was taken to ripening in genotypes Hisar Arun (79.00).

Spaldon and Hussain (2017) evaluated the performance of tomato genotypes for yield and quality at Chatha during spring summer of 2012-13 and 2013-14. They found that the highest numbers of fruits per plant were recorded in Pusa Ruby (30.82) and maximum marketable fruit yield per plot was recorded in hybrid Tokita (5.07 kg/plot). With respect to quality traits, maximum pericarp thickness (6.86 mm) was observed in genotype Anand. Arka Vikas recorded highest total soluble solids (5.02 °B). Genotype Aditya gave highest lycopene (5.22mg/100g) content and highest ascorbic acid content was recorded in Arka Meghali (27.96 mg/100g). They suggested that the genotypes Tokita, US-3383 and Pusa Ruby were high yielding and good for fresh marketing.

Dhyani *et al*., (2018) evaluated 22 F_1 of tomato (*Solanum lycopersicon* L.) including commercial 6 hybrids for fruit yield characters in hill region of Uttarakhand during 2014. The result revealed that hybrid *viz.* Utkal Urwasi × Gujrat Tomato-3 proved the best with respect to fruit yield (6935.08 g) whereas, Utkal Urwasi × Palam Pink was promising for number of fruit per plant (79.82), number of flower cluster per plant (14.13), number of flower per cluster (8.0) and fruit set percentage (85.71 %). The hybrid Marglobe × Pusa Sadabhar was the best for earlist picking (43.0 DAT) and highest fruit weight (106.74 g).

Kumar and Rana (2018) evaluated 27 tomato (*Solanum lycopersicum* L.) genotypes for yield and yield attributing characters in semi arid zone of Haryana (Hisar). They found that the maximum plant height (130.33 cm) was recorded in the genotype US 3140 and the maximum number of branches per plant was observed in BBWR-10-3-18. Number of fruits per plant was highest in BBWR-11-1. The maximum polar diameter of the fruit was recorded by the genotype Hisar Lalit and the maximum equatorial diameter is shown by Arka Meghali. The minimum fruit yield per plant was recorded with genotype EC 620536, while maximum with genotype DVRT 2. The highest TSS content of fruit was recorded with the genotype EC 620383.

2.2 Genetic variability

Success of genetic improvement in any crop plant is mainly dependent on the variability available in that species or related species which can be used for further improvement of that crop. Hence, the basic understanding of genetic variability and its component is a prerequisite for the planning of the breeding programme. Adequate variability facilitates the choice of genetically diverse parents feasible for hybridization programme for obtaining desirable transgressive segregants. Generally, genotypic coefficient of variance (GCV) and phenotypic

coefficient of variance (PCV) are measure to estimate the extent of variability present in material under investigation. Literature pertaining to estimate the magnitude of genetic variability and its components has been collected on tomato and reviewed below:

Khanom *et al*., (2008) investigated the genotypic variability, heritability and genetic advance amoung 55 tomato genotypes. They estimated very little differences between GCV and PCV for all the characters except dry matter content and yield per plant indicating that they were less influenced to environmental factors for their phenotypic expression.

Dar and Sharma (2011) studied 60 tomato genotypes and they revealed that the magnitude of PCV was higher than the GCV for all the characters under investigation. The higher values of PCV were reported for yield quintal per hectare, fruit weight, number of fruits per plant whereas highest GCV value was recorded with beta-carotene content in tomato.

Shankar *et al*., (2013) reported that high magnitude of GCV and PCV were observed for plant height, average fruit weight, yield per plant, ascorbic acid and lycopene content indicating a good deal of variability in those characters signifying the effectiveness of selection of desirable types for improvement.

Saini *et al*., (2013) studied 35 genotypes of tomato for yield, and quality attributes. They revealed that high heritability, with moderate to high GCV and genetic gain, was recorded for number of fruits per plant, yield per plant, fruit weight per plant and polar diameter. They concluded that maximum direct contribution to total yield per plant was made by number of fruits per plant followed by number of locules per fruit.

Kumar *et al*., (2016) conducted research using 18 tomato genotypes and recorded higher GCV and PCV values for fruits per plant, polar diameter, fruit weight, number of clusters per plant, number of seeds per fruit, test weight, plant height, number of primary branches per plant, number of fruits per cluster, locule number, flowers per cluster, equatorial diameter.

Kaur *et al.,* (2017) studied the variability among 51 elite tomato genotypes (*Solanum lycopersicum* L.) for growth and quality parameters. Higher magnitudes of GCV and PCV occurred for fruit weight followed by ascorbic acid, number of locules, marketable yield, plant height, total fruit yield, titrable acidity, TSS, and pericarp thickness. These results indicated that traits with higher magnitudes of coefficient of variation offer a better opportunity for improvement through selection.

Ligade *et al.*, (2017) conducted an experiment to evaluate the genetic variability present in the twenty genotypes. Under the study, high values of GCV and PCV were observed for characters *viz.*, number of fruits per plant (55.74, 56.21), number of locules per fruit (36.44, 37.15), fruit yield per plant (31.09,32.35) marketable fruit yield per plot (31.10, 32.36) and which indicated the presence of high genetic variation.

Meena *et al*., (2018) studied genetic variability for yield and quality attributes in tomato (*Solanum lycopersicum* L.) during the year 2014-2015 at Lucknow. The study included fifteen genotypes of tomato i.e. IIVR-Sel.-1, G-3, S. Naveen, DVRT-2, H-24, H-86, H-88, Pusa Sheetal, FLA 7171, Hisar Arun, Sel.-32, Flora Dode, Pusa Sadabhar, Kashi Vishesh and Kashi Amrit). They reported the maximum phenotypic and genotypic variance was observed for average fruit weight (g). The highest of PCV and GCV was estimated for fruit yield per plant (kg).

Yadav *et al.,* (2017) analyzed the morphological based genetic variability in 19 genotypes of tomato for two seasons. They reported that range of variability was highest for number of fruits per plant (28.3-317.6), followed by plant height (98.3-143.3), fruit weight (31.6-115), days to 50% flowering (50.1-62.9), number of primary branches (5.9-13.6), number of locules per fruit (3.3-7.1), fruit length (2.2-6.3) and fruit diameter (2.6-5.3). This study was concluded that there is a wide genetic variability in the genotypes and the genotypes could be utilized for genetic improvement of tomato.

2.3 Heritability and genetic advance

Heritability in broad sense can be defined as the proportion of the total genetic variability to the total phenotypic variance. It is a good index of characters transmission from parents to their off spring for a particular trait. Estimate of heritability assists breeders to allocate resources necessary for effectively select desired traits and to achieve maximum genetic gain with little time and resources. Improvement in the mean genotypic value of the selected families over that of the base population is genetic advance. High heritability coupled with high genetic advance helps to ascertain the possibility of selecting high yielding cultivars from the present collection. The literature pertaining to heritability and genetic advance in tomato is reviewed here:

Brar *et al.,* (2000) revealed that the heritability estimates were high for number of marketable fruits per plant (83.50%), and number of fruits per plant (77.34%) whereas total fruit yield (58.59%) and marketable fruit yield per plant (63.53%) showed moderate values of heritability in tomato. Singh (2001) noticed that if heritability of a character is very high say 80% or more, selection for such characters could be fairly easy because there would be a close correspondence between the genotype and the phenotype due to the relative small contribution of the environment to the phenotype.

Joshi and Kohli (2006) reported heritability in narrow sense was low for total soluble solids, ascorbic acid content, fruit shape index and stem end scar size suggested that direct selection for these traits may be ineffective as the trait was largely governed by dominant genes.

Hidayatullah *et al.,* (2008) reported high heritability for plant height, number of fruits per plant, fruit weight per plant, fruit length, fruit diameter, single fruit weight, number of locules, pericarp thickness, total soluble solids and seeds per fruit in tomato.

Mehta and Asati (2008) showed high heritability in board sense coupled with high genetic advance for plant height, fruit yield per hectare, weight of fruits per plant, number of locules per fruit, total soluble solids and number of branches per plant in tomato.

Kumar *et al.,* (2012) studied heritability among 13 genotypes (10 lines+3 testers) of tomato at Varanasi. They revealed a positive and significant association of yield per plant with all the traits both at genotypic and phenotypic levels. They also observed high values of heritability(broad sense) for plant height (99%) and fruit per cluster, total soluble solids and lycopene (97%) and high genetic advance for plant height and average fruit weight (26.59 and 14.88%), respectively.

Mohamed *et al.,* (2012) reported highest heritability for plant height (97%) while the lowest was for fruit yield per plant (43%). High heritability (broad senses) estimates were observed for all the tested characters indicating that these characters are controlled by additive genes action which is very useful in selection.

Saini *et al.,* (2013) studied 35 genotypes of tomato for yield, quality and fruit characters. They revealed that high heritability, with moderate to high GCV and genetic gain, was recorded for number of fruits per plant, yield per plant, fruit weight per plant and polar diameter. They concluded that maximum direct contribution to total yield per plant was made by number of fruits per plant followed by number of locules per fruit.

Shalaby (2013) reported heritability estimates in broad sense were high for early yield, total yield, average fruit weight, fruit firmness and total soluble solids content while heritability estimates in narrow sense were high for early yield and average fruit weight and moderate for TSS content.

Shankar *et al.,* (2013) found high heritability coupled with high genetic advance as per cent of mean was observed for plant height, number of primary branches per plant, fruit length', fruit width, and average fruit weight, number of locules per fruit, pericarp thickness and ascorbic acid.

Khapte and Jansirani (2014) reported high heritability for the plant height, number of flowers per truss, number of flower trusses per plant, fruit length, fruit diameter, fruit shape index, pericarp thickness, total soluble solids, average fruit weight, fruit firmness, number of fruits per plant and yield per plant. Hence, these characters could be improved by simple selection.

Sherpa *et al*., (2014) shown high heritability coupled with high genetic advance for plant height, number of flower clusters per plant, number of fruits per cluster, number of fruits per plant, fruit weight, polar diameter, fruit yield per plant, pericarp thickness, total soluble solids,

titratable acidity, ascorbic acid content and lycopene content, which were controlled by additive gene effects, indicating good response to selection for these characters.

Meitei *et al.,* (2014) reported that high heritability with moderate to low genetic advance was observed for days to 50% flowering and fruiting, first and last picking, plant height and fruit diameter in tomato.

Meena *et al*., (2015) estimated high heritability accompanied with high genetic advance for fruit yield per plant (1129.78), plant height (43.37), number of flowers per plant (40.35), number of leaves per plant (25.48) and ascorbic acid content (21.68).

Chadha and Walia (2016) studied 15 bacterial wilt resistant F_3 progenies of tomato and reported high heritability along with high genetic advance for total fruits per plant, marketable fruits per plant and marketable yield per plant.

Kumar *et al.*, (2017) evaluated the heritability and genetic advance over mean for fruit yield and component characters among 21 diverse tomato genotypes. They reported that high heritability in combination with high genetic advance as per cent over mean in yield per plant, fruit pericarp thickness and fruit equatorial diameter explaining that these characters are governed by additive gene action which is crucial in selection.

Meena *et al.,* (2018) studied the heritability for yield and quality attributes of fifteen genotypes of tomato (*Solanum lycopersicum* L.) during the year 2014- 2015 at Lucknow. The highest heritability was recorded for fruit yield per plant (0.89%) followed by plant height (0.81%), TSS (0.72%), flowers per cluster (0.71%), pericarp thickness (0.68%), fruits per plant (0.67%), fruits per cluster (0.66%), clusters per plant (0.63%) and branches per plant (0.62%).]

2.4 Correlation and path analysis

The correlation coefficient concept was elaborated by Fisher and Yates (1963). Correlation coefficient is used to measures the mutual relationship among various plant characters and determines the components on which selection can be based for genetic improvement between various plant traits and to determines the components characters on which selection can be based upon for genetic improvement in the yield. The literature pertaining to correlation among different traits is reviewed below:

Mohanty (2002) revealed significant and positive genotypic correlations of fruit yield with days to first harvest, number of branches and fruits per plant, and significant and negative with plant height and average fruit weight. Number of fruits per plant was inversely related with average fruit weight. Path analysis showed that the number of branches per plant and average fruit weight exerted high positive direct effect on yield and high positive indirect effect with each other.

Singh *et al.*, (2004) observed highly significant positive correlation between number of fruits per plant and yield. Similarly, there was a negative correlation between the number of

fruits per cluster and average weight per fruit. Plant height was positively correlated with days to 50% flowering, days to first set, number of fruits per plant and total soluble solids. The number of primary branches per plant was negatively and not significantly correlated with days taken to first fruit set, number of fruits per cluster, number of fruits per plant, average weight per fruit, fruit length and fruit diameter. Total soluble solids showed a highly significant and negative correlation with average fruit weight.

Jagdish *et al.,* (2007) reported that yield of tomato was positively correlated with number of fruits per plant, average fruit weight, fruit diameter and number of locules. Significant correlation was also observed between plant height and number of branches.

Golani *et al.,* (2007) reported that fruit yield had significantly positive genotypic and phenotypic association with fruit weight, fruit girth, total soluble solids (only at genotypic level) and number of locules per fruit but significantly negative with plant height. Fruit weight had significantly positive correlation with fruit length, fruit girth and number of locules per fruit at both the levels.

Anjum *et al.,* (2009) experimented on 35 genotypes of tomato where the correlation study revealed that economically important traits like fruit yield per plant exhibit high positive significant correlation with fruit size, plant height and number of fruits per plant.

Kumar and Dudi (2011) studied the correlation and path coefficient for yield and quality characters in 12 parents and their 66 F1 crosses of tomato (*Lycopersicon esculentum* Mill.). They investigated that the total fruit yield (kg) per plant was positively and significantly correlated with number of fruits per plant (0.507), fruit weight (0.439) and total sugar (0.279) while non-significant positive association was noticed with early fruit yield of first two pickings (0.196), number of locules per fruits (0.125), pericarp thickness (0.092) and number of branches per plant (0.068). Also positive direct effect was exerted by number of fruit per plant (1.056) followed by fruit weight (0.822), number of fruit per truss (0.384), number of branches per plant (0.218), total soluble solids (0.210 %), plant height (0.156 cm), total carotenoides (0.101), pericarp thickness (0.069) and titrable acidity (0.064).

Kumar *et al.,* (2012) investigated Genetic parameters and correlation of yield and quality traits in tomato at Vegetable Research Farm, Varanasi during Rabi 2008-09. The experimental material comprised of thirteen genotypes (10 lines+3 testers) and their thirty crosses along with two checks of tomato. Analysis of coefficient of variation revealed that magnitude of phenotypic co-efficient was higher than genotypic coefficient of variation for all the characters except primary branches per plant under study. They recorded maximum genotypic and phenotypic variation (168.30 and 169.95 cm) for plant height and minimum for fruit shape index (0.02 and0.02), respectively.

Ahirwar and Prakash (2013) elucidated that ascorbic acid and total soluble solids showed positive correlation with fruit yield per hectare, whereas, plant height and days to 50%

flowering showed negative correlation with fruit yield per hectare at both phenotypic and genotypic level.

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

Sharma *et al.*, (2013) reported that days to 50% flowering, days to first harvest, number of marketable fruits per plant, total number of fruits per plant, gross yield per plant, plant height, number of flower cluster per plant, number of locules per fruit and acidity will be effective for isolating plant with higher yield in tomato. A few characters, which were not significantly correlated with marketable yield per plant cannot be considered as indices of higher fruit yield.

Meitei *et al.*, (2014) revealed that fruit yield per plant was positively correlated with fruit diameter, single fruit weight and yield per hectare suggesting that selection based on these characters would result better genotypes with higher yield.

Rai *et al.*, (2017) studied the correlation and path coefficient between yield and quality traits at the experimental farm of Solan during, 2014. They found a significant direct effect towards yield by average fruit weight followed by number of fruits per plant and pericarp thickness whereas number of fruits per cluster, number of locules per fruit, days to first picking and total soluble solids showed negative direct effect.

Kaur *et al.*, (2017) studied the correlation coefficient among 51 elite tomato genotypes (*Solanum lycopersicum* L.) for growth and quality parameters. They observed that the total fruit yield per plant was positively, and significantly, correlated with lycopene content, plant height, fruit weight and marketable yield. They suggested that these characters can be considered as indicators of higher total fruit yield per plant and crop improvement may be best achieved by improvement in these four characters.

2.5 Genetic divergence

Genetic diversity is the basic criterion for the continued improvement of the crop either through natural selection or directed plant breeding. While formulating the tomato crop improvement program, understanding about the nature and degree of genetic divergence available in the germplasm plays a pivotal role. Selecting the parents for breeding program in such crops is critical because, the success of such program depends upon the segregants of hybrid derivatives between the parents, particularly when the aim is to improve the quantitative characters like yield. The literature pertaining to genetic diversity in tomato has been collected and reviewed below:

Joshi and Kohli (2003) studied on 73 genetically diverse group of tomato and grouped them into 15 clusters indicated the presence of wide range of genetic diversity among the genotypes. Genotypes belonging to cluster V and VI were highly diverse from each other. The mean fruit yield per plant (1034.64 g/plant) and average fruit weight (102.76 g) were highest in Cluster V and III, respectively. The plant height (135.91 cm) and harvest duration (37.77 days) were highest in Cluster XV.

Mahesh *et al.,* (2006) evaluated the genetic divergence among 30 genotypes of tomato and grouped them in to nine clusters irrespective of geographic divergence, indicating no parallelism between genetic diversity and geographical divergence. There were maximum numbers of genotypes in cluster II. The maximum genetic distance was observed between clusters VI and IX (8132.17), whereas it was minimum between clusters I and IV (405.05).

Reddy *et al.,* (2013) reported that genetic divergence analysis following Mahalanobis D^2 statistics revealed considerable genetic diversity among 19 genotypes of tomato (*Solanum lycopersicum* L.) for all the eighteen quantitative characters which was pertaining to the growth, earliness, yield and quality. Plant height, fruit weight and number of fruits per plant contributed 92.40% to the total divergence. Appreciable diversity within and between the clusters was observed.

Dar *et al.,* (2015) revealed that ascorbic acid contributed maximally towards the genetic divergence followed by total soluble solids, pericarp thickness, lycopene content and polygalacturonase activity through D^2 analysis. The 60 genotypes were grouped into 20 clusters. Out of 20 clusters, cluster VII is promising for minimum polygalacturonase activity and high average fruit weight, cluster VIII had highest number of locules per fruit, fruit yield per plant and yield per hectare and cluster XVII was superior for ascorbic acid. The highest inter cluster D^2 values were estimated between clusters XII and XX, followed by clusters XI and XX indicating that there is enough scope for the improvement of tomato crop by hybridization and selection.

Kaur *et al.,* (2017) evaluated the genetic divergence among 51 elite tomato genotypes (*Solanum lycopersicum* L.) for growth and quality parameters. They revealed that the D^2 statistics confirmed the highest inter-cluster distance between clusters VI and VIII (27638.44). Maximum similarity was observed in clusters IV and VI (191.02). This indicated existence of the possibility to improve genotypes through hybridization from any pair of clusters and subsequent selection can be made from segregant generations.

CHAPTER – III

MATERIALS AND METHODS

The present investigation entitled **"Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits"** was conducted at Regional Research Station, Karnal and Laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during *rabi* season of 2016-17. The material used for this study and statistical methods adopted in the investigation have been reviewed in this chapter under following sub-heads:

3.1 Location of experimental site and climate

The experimental field is located at latitude of 29º 43' in the North and longitude of 76º 58' in the East and at an altitude of 253 meter above mean sea level. It is located 5 KM towards North from District head quarters Karnal and 132 KM from state city capital Chandigarh at eastern side of Jammu-Delhi GT road.

3.2 Climate and Weather conditions

The climate of Uchani (Karnal) is semi-arid and sub-tropical with hot and dry winds during summer months, warm and humid in monsoon and cold and dry weather in winter. Both, winters and summers are usually harsh to bear upon. The mean minimum and maximum temperature exhibits a wide range, the maximum temperature zooming 44 to 48ºC during summer and temperature dipping as low as to the freezing point. Most of the rainfall is received during the months of July to September and few showers during December to late spring. The meteorological data on various parameters as observed during the experimental period of investigation collected are presented below in (Table 3.1).

3.3 Soil of the experimental field

In order to know the physico-chemical properties of soil, samples were taken randomly from 0-15 cm depth from five different spots of the experimental field and a representative composite sample was prepared by mixing all these samples together. This composite sample was analyzed to determine the physico-chemical properties (organic carbon and available N, P and K) of the soil. The results of the analysis along with methods used are depicted below in (Table 3.2). Result of soil analysis revealed that the soil of the experimental field was clay-loam and near neutral with average in organic carbon, low in available nitrogen, medium in available phosphorus and potassium.

Table 3.1: Weekly Meteorological data of Karnal for the crop span (December 2016 – May 2017)

Stan-dard Week	Duration	Temperature (°C)		Relative Humidity (%)		Pan Evaporation (mm/day)	Bright sunshine Hours	Rainfall (mm)
		Max.	Min.	RHM	RHE			
49	3 Dec-9 Dec	22.6	08.3	98.7	63.0	01.3	03.7	00.0
50	10 Dec-16 Dec	21.7	09.5	99.3	63.4	01.1	04.3	00.0
51	17 Dec-23 Dec	22.2	06.5	95.4	49.4	01.2	06.8	00.0
52	24 Dec-31 Dec	20.7	07.8	94.6	59.3	00.9	04.6	00.0
1	1 Jan- 7 Jan	22.2	08.3	99.1	62.7	01.0	05.8	08.0
2	8 Jan-14 Jan	16.2	03.4	99.6	61.3	00.8	06.7	19.0
3	15 Jan-21 Jan	17.5	05.0	98.7	63.3	00.7	04.4	03.6
4	22 Jan-28 Jan	20.5	09.7	98.0	70.3	01.1	04.1	07.9
5	29 Jan-4 Feb	20.5	08.0	98.6	62.1	01.2	05.0	00.0
6	5 Feb-11Feb	20.6	07.3	94.3	56.1	01.4	06.5	00.0
7	12 Feb-18 Feb	23.8	08.4	91.9	53.9	02.0	07.5	00.0
8	19 Feb- 25 Feb	25.0	09.9	87.0	47.9	02.7	08.1	00.0
9	26 Feb-4 Mar	26.3	09.3	85.6	39.0	02.7	08.8	00.0
10	5 Mar- 11Mar	24.8	10.1	78.4	49.4	02.6	08.4	01.1
11	12 Mar-18 Mar	23.4	7.6	86.9	42.3	2.4	9.2	0.0
12	19 Mar- 25 Mar	30.3	13.7	83.0	38.7	3.0	10.0	0.0
13	26 Mar-1 Apr	35.2	16.6	77.7	25.4	3.9	10.5	0.0
14	2 Apr- 8 Apr	35.8	18.2	60.4	29.9	4.5	9.5	2.0
15	9 Apr- 15 Apr	35.9	14.5	50.6	12.6	5.7	10.9	0.0
16	16 Apr- 22 Apr	40.4	21.9	65.1	23.4	6.0	10.9	0.0
17	23 Apr- 29 Apr	38.0	21.0	48.1	19.6	6.9	10.5	0.0
18	30 Apr- 6 May	37.8	20.2	53.0	19.0	5.0	10.5	1.4
19	7 May- 13 May	39.8	24.3	56.4	28.1	7.0	10.6	0.0
20	14 May- 20 May	40.6	24.6	49.6	23.9	6.4	9.3	0.0
21	21 May- 27 May	39.1	24.2	56.3	31.9	6.8	9.9	2.4

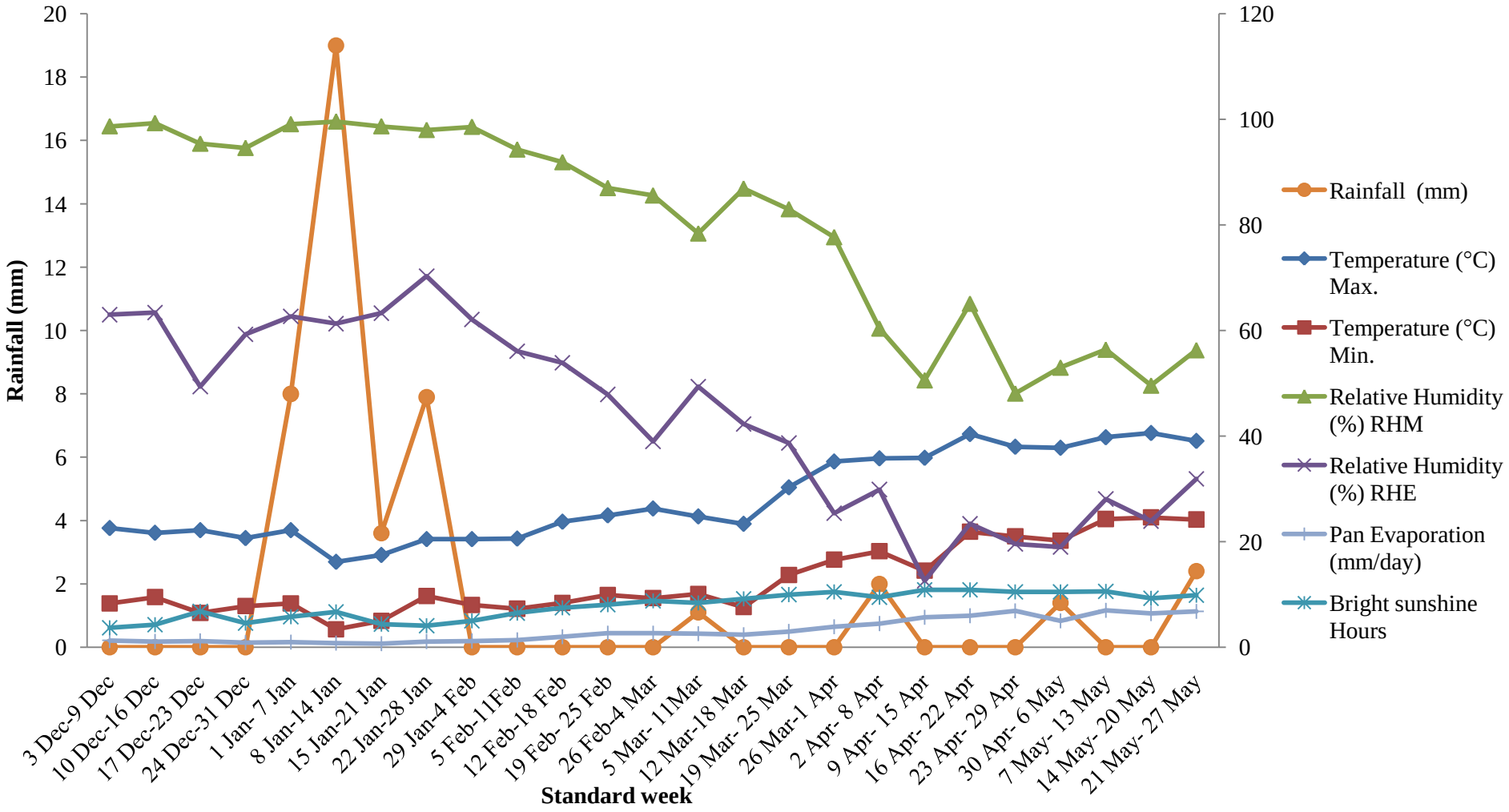

Figure 3.1 Mean weekly agro-meteorological data of Karnal for the crop span (December 2016 – May 2017)

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

Sr. No.	Parameter	Values	Method of analysis
1.	Texture	Clay loam	International Pipette Method (Piper, 1966)
2.	pH	7.86	Potentiometric Method (jackson, 1973)
3.	Electrical Conductivity (dS m^{-1})	0.12	Conductivity Bridge Method (Richard, 1954)
4.	Organic carbon (%)	0.40	Walkey & Black Wet Oxidation Method , 1965
5.	Available nitrogen (kg ha^{-1})	158	Alkaline Permanganate Method (Subbaih and Asija, 1956)
6.	Available phosphorus (kg ha^{-1})	11	Sodium Bi-carbonate Extractable Phosphorus Method (Olsen *et al.*, 1954)
7.	Available potassium (kg ha^{-1})	197	Flame Photometer (Jackson, 1973)
8.	CEC	14.92	Hesse's Method (1971)

3.4 Experimental details

The particulars of present experiment entitled "Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits" are given below:

Number of genotypes investigated : 22 along with one standard check
Experimental design : Randomized block design (RBD)
Plot size : 3 rows of 4.5 meter length
Spacing (row x plant) : 60 cm x 45 cm
Replications : Three
Crop season : *Rabi* 2016-17

3.5 Raising of crop nursery

The seeds of twenty-three germplasm lines including released varieties were procured from different sources (Table 3.3). The seedlings were raised in outdoor nursery beds in the field. The seeds of all twenty-three lines after treating with Captan @ 2 g/kg were sown in rows 10 cm apart in last week of November 2016. The beds after sowing seeds were covered with fine compost, and water was sprinkled regularly with a fine rose-can. The beds were kept moist until the seedlings emerged out in the beds. The nursery beds were covered with transparent polythene sheet to protect the seedlings from frost and cold waves. After germination, proper care was taken to ensure the proper growth of seedlings in the nursery. Seedlings became ready for transplanting in the last week of December 2016.

Table 3.3: List of germplasm lines and standard released varieties included in the research programme

Sr. No.	Genotype	Sr. No.	Genotype
1.	DVRT-1	13.	PNR-7
2.	DVRT-2	14.	Palam Pink
3.	DVRT-3	15.	Punjab Ratta
4.	DVRT-5	16.	Pusa Ruby
5.	DVRT-6	17.	Punjab Tropics
6.	DVRT-8	18.	Pusa Uphar
7.	Arka Vikas	19.	Punjab Upma
8.	Castle Rock	20.	Sel-7
9.	NT-8	21.	S-12
10.	Punjab Chhuhara	22.	H-86
11.	P.H.S	23.	Pusa Sadabahar (C)
12.	Punjab Kesari		

3.6 Field preparation

The experimental field after applying recommended dose of farmyard manure (FYM) was ploughed repeatedly and brought to a fine tilth. Full dose of phosphorus and potassium along with one-third dose of the nitrogen was applied at final harrowing followed by planking. The field was divided into small blocks where the ridges and furrows were made at a distance of 60 cm. The remaining two-third dose of nitrogen was top dressed in two splits, one 20 days after transplanting at the time of earthing up and second at 45 days after transplanting.

3.7 Transplanting of seedlings

The seedlings were transplanted in the main field on 31st December 2016 in a randomized block design (RBD) with three replications. Transplanting was done early in the morning on both sides at base of the ridges at 45 cm spacing followed by light irrigation. All other cultural operations were followed as per the package of practices for raising a healthy crop.

3.8 Recording of observations

Five randomly marked plants were observed for recording various plant characters and likewise the randomly picked five fruits were used for recording the fruit characters for each genotype in each replication. The mean of these five plants and fruits was used for statistical analysis. Observations recorded for twenty-one characters and the method followed for recording observations utilizing five competitive plants are described below:

3.8.1 Plant height (cm)

The height of five randomly selected individual plants was measured at final harvest stage from ground to tip of the plant and replication wise the average plant height of each genotype was worked out.

3.8.2 Number of branches per plant

The total number of fruiting branches of five plants was counted at the time of final picking and then averaged for number of branches per plant.

3.8.3 Days to 50% flowering

The number of days taken from transplanting to the anthesis of first flowers on 50% plants of each genotype per replication was recorded and the average was expressed as days to 50% flowering.

3.8.4 Days to first picking

The number of days taken from transplanting to picking of first ripened fruits of each genotype per replication was recorded and the average was expressed as days to first picking.

3.8.5 Days to last picking

The number of days taken from transplanting to the picking of last ripened of each genotype per replication was recorded and the average was expressed as days to last picking.

3.8.6 Polar Diameter (cm)

Fruits polar diameter was measured from stalk end to blossom end with the help of digital Vernier calliper.

3.8.7 Equatorial diameter (cm)

Fruits equatorial diameter was measured from fruit breadth at highest bulged portion of the fruit with the help of digital Vernier calliper.

3.8.8 Pericarp thickness (mm)

Fruit pericarp thickness was measured after cutting the fruits transversely with the help of digital Vernier callipper.

3.8.9 Number of marketable fruits per plant

Fruits of good quality were identified and counted from five marked plants and their average was calculated.

3.8.10 Weight of marketable fruits per plant

Fruits of good quality were identified and collected from five marked plants and their weight was calculated and their average was taken.

3.8.11 Number of unmarketable fruits per plant

Fruits of inferior quality and diseased one were identified and counted from five marked plants and their average was calculated.

3.8.12 Weight of unmarketable fruits per plant

Fruits of inferior quality and diseased one were identified and collected from five marked plants and their weight was calculated and their average was taken.

3.8.13 Total number of fruits per plant

The fruits harvested from five selected plants of each genotype from all the pickings were summed up separately and then averaged per plant.

3.8.14 Yield of fruits per plant (g)

The yield of fruits per plant of individual genotypes was counted by adding up the weight of marketable fruits per plant into the weight of unmarketable fruits per plant obtained from all pickings and averaged.

3.8.15 Yield of fruits per hectare (q)

The weight of fruits collected from each plot all plants in all replications was recorded and then converted into quintal per hectare.

3.8.16 Number of locules per fruit

The randomly five fruits of each genotype were selected and dissected transversely. The number of locules per fruit was counted and averaged.

3.8.17 Fruit firmness (kg/cm^2)

Fruit firmness was determined after the rate of penetration of a needle driven into the fruits with the help of digital penetrometer. Two reading were taken at two different positions on the flesh of each fruits.

3.8.18 Specific gravity (g/cm^3)

A weighed number of fruits were placed in a graduated cylinder, and their volume was determined by water displacement. Specific gravity of fruits was obtained by dividing the weight of fruits (g) to the volume of fruit (ml).

3.8.19 Quality Traits

To evaluate quality traits samples were drawn during peak period of harvest at full ripe stage of fruit maturity. A random sample of five fruits was taken from all replications of each genotype to determine number of locules per fruit. Thereafter, the juice extracted from composite sample of fruits of each genotype was filtered through double-layered muslin cloth and used for estimating the total soluble solids, acidity and ascorbic acid content. Three readings were recorded for each sample. The following standard methods were adopted for recording the quality traits:

3.8.19.1 Total soluble solid (%)

The total soluble solids (TSS) of the fruit juice samples was determined with the help of refractrometer and expressed in percent at room temperature. The refractrometer was washed with distilled water and dried with blotting paper after every use**.**

3.8.19.2 Ascorbic acid (mg/100g fruit juice)

The ascorbic acid content of fruit juice was estimated by 2, 6-dichlorophenol indophenols visual titration method of A.O.A.C (1975). The method is an under:

Reagents used

(i) 5% 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 final volume was made up to 500 ml.

(ii) Indophenols standard solution: 50 mg of 2,6 dichlorophenol indophenols and 42 mg of $NaHCO_3$ were dissolved in 100 ml of hot distilled water and filtered, and the final volume was made to 100 ml with distilled water. This dye solution were pour in amber coloured bottle and stored in the refrigerator and standardized every day.

(iii) Ascorbic acid standard solution (1 mg/ml): 50 mg of ascorbic acid was dissolved in metaphosphoric acid solution and final volume was made up to 50 ml by adding metaphosphoric acid. It was kept in desiccators away from sunlight.

Procedure for extraction

Tomato fruit juice: The juice of tomato was extracted by squeezing the pulp, and then, it is filtered rapidly. The extracted juice was added to equal volume of metaphosphoric acid (acetic acid) and total volume was made up to 100 ml.

Determination: Two ml of juice sample was added to an equal volume of 5% metaphosphoric acid in a conical flask and titrated with standard dye solution. The end-point was indicated by the appearance of pink color which persisted for about 15 seconds. The result was expressed as ascorbic acid milligram per 100 ml of tomato fruit juice and calculated as given below:

Calculations:

Ascorbic acid content of the sample was calculated by the following formula:

$$\text{Ascorbic acid (mg/100g)} = \frac{\text{Titre x Dye factor x Volume made up x 100}}{\text{Aliquot of extract x volume of sample taken for estimation}}$$

3.8.19.3 Acidity (%)

Acidity was determined by titrating 5 ml of juice against 0.1 N sodium hydroxide (NaOH) using 1-2 drops of phenolphthalein as an indicator. NaOH was added slowly to the sample until finally one drop gave a pink colour lasting for a minute or longer. Appearance of pink colour was taken as end-point of titration. The acidity expressed in percent citric acid was estimated using the following formula:

$$\text{Acidity (\%)} = \frac{\text{Titre x normality of alkali x Volume made x Eq. wt. of acid x100}}{\text{Vol. of sample taken for estimation x vol. of sample taken for titration x 1000}}$$

3.9 Statistical Analysis

The data was collected, compiled and analyzed statistically in order to find the magnitude of variability in terms of variances and coefficients of variation (Burton and Devane, 1953). Correlation coefficient analysis will be done as per the method of Al-Jibouri *et al.*(1958) and path coefficient analysis as per the method of Dewey and Lu (1959). Hierarchical cluster analysis will be done using the method suggested by Romesberg (1990).

3.9.1 Analysis of variance

The analysis of variance was carried out for individual characters to test the significance of differences among the genotypes following the method given by Fisher (1925) and described by Panse and Sukhatme (1967). The following model was used:

$$Y_{ij} = \mu + a_i + b_j + e_{ij}$$

Where,

Y_{ij} = Observation for the i^{th} treatment in j^{th} block

μ = General mean

a_i= Effect of i^{th} treatment

b_j= Effect of j^{th} block

e_{ij}= Random error (uncontrolled variation) associated with i^{th} treatment in j^{th} block

Table 3.4 Analysis of variance

Source of variation	**d. f.**	**Mean Squares**	**Expected mean squares**	**F value**
Replications	(r-1)	M_r	$\sigma_e^2 + g\sigma_r^2$	
Genotypes	(g-l)	M_g	$\sigma_e^2 + r\sigma_g^2$	M_g / M_e
Error	(r-l)(g-l)	M_e	σ_e^2	

Where,

r = Number of replications

g = Number of genotypes

Assumptions of the model:

The following assumptions were made during analysis of variance-

1. All the observations should be independent.
2. The different effects in the model should be additive.
3. Error involved in the population should be normally and independently distributed with mean zero and variance σ_e^2.

The significance of M_r and M_g was tested against M_e by 'F' test at 5 and 1 per cent level of significance.

3.9.2 Parameters of variability

3.9.2.1 Mean

The mean value of each character was calculated by summing up of all the observations and dividing the total by corresponding number of observations:

$$\bar{x} = \frac{\sum Xij}{N}$$

Where,

$\sum x_{ij}$: Summation of i^{th} treatment in j^{th} replication

N : Total number of observations

3.9.2.2 Range

The minimum and maximum value of observation means for each character was taken as range.

3.9.2.3 Standard error (SE)

$$S.E.(d) = \sqrt{\frac{2MSe}{r}}$$

Where,

SE (d) = Standard error of difference of two means

MSe = Error mean sum of squares

r = Number of replications

3.9.2.4 Critical Difference (CD)

Critical difference was calculated for all the traits to compare the treatment means using difference of two means and tabulated value of t (p=0.05) at error degree of freedom using the following formula :

CD =SE(d) X 't' value at error degree of freedom

Where,

SE (d) = Standard error (difference of two means)

3.9.2.5 Coefficient of variation (CV)

The coefficient of variation as percentage of mean was estimated as mentioned bellow:

$$CV\ (\%) = \frac{S.D}{Mean} \times 100$$

Where,

CV (%) = Coefficient of variation in per cent,

S.D. = Standard deviation

3.9.2.6 Variances

Genotypic and phenotypic variances were computed as follows:

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

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

Where,

r = Number of replications

M_g= Mean squares due to genotypes

M_e = Mean squares due to error

σ^2_g = Genotypic variance

σ^2_e = Environmental variance

σ^2_p = Phenotypic variance

3.9.2.7 Estimation of coefficient of variation

Genotypic and phenotypic coefficients of variation for different characters were calculated by the formula as suggested by Burton and Devane (1953).

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

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

Where,

GCV = Genotypic coefficient of variation

PCV= Phenotypic coefficient of variation

$\sigma^2 g$ = Genotypic variance

$\sigma^2 p$ = Phenotypic variance

GCV and PCV was classified as low (0-10%), moderate (10-20%) and high (>20%) as suggested by Shivasubramanian and Madhavamenonenon (1973).

3.9.2.8 Heritability (Broad sense)

Heritability (broad sense) in per cent was estimated as per the formula given by Burton and De Vane (1953), Johnson *et al.,* (1955) and Hanson *et al*., (1956).

$$h^2_{bs} = \frac{\sigma_g}{\sigma_p} \text{ x } 100$$

Heritability was classified in following categories as suggested by Robinson (1966)

Low	:	0-50%
Moderate	:	50-70%
High	:	>70%

3.9.2.9 Genetic advance

The expected genetic advance was calculated by the formula as suggested by Hanson *et al*., (1956).

$$\text{Genetic advance (G.A.)} = k\sigma_p h^2$$

Where,

GA= Genetic advance

σ_p = Phenotypic standard deviation

h^2 = heritability in broad sense

k = selection intensity

Genetic advance was classified as low (0-10%), moderate (10-30%) and high (>30%) (Johnson *et al*., 1955).

3.9.3 Estimation of correlation co-efficient

Genotypic and phenotypic coefficients of correlation were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.*, (1958).

$$r_{ij}(G) = \frac{\sigma^2 gij}{\sqrt{\sigma^2 gii \times \sigma^2 gjj}}$$

Where,

σ^2_{gij} = Genotypic co-variance of character x_i and x_j

σ^2_{gii} = Genotypic variance of character x_i

σ^2_{gjj} = Genotypic variance of character x_j

$$r_{ij}(P) = \frac{\sigma^2 pij}{\sqrt{\sigma^2 pii \times \sigma^2 pjj}}$$

Where,

σ^2_{pij}= Phenotypic co-variance of character x_i and x_j

σ^2_{pii}= Phenotypic variance of character x_i

σ^2_{pjj}= Phenotypic variance of character x_j

3.9.4 Path Coefficient analysis

Path analysis was originally developed by Wright (1921) and elaborated by Dewey and Lu (1959). Path coefficient analysis splits the genotypic correlation coefficient into the measure of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variable.

Setting up of simultaneous equations

For estimation of various direct and indirect effects, a set of simultaneous equations were formed.

$r_{1y} = P_{1y} + r_{12} P_{2y} + r_{13}P_{3y} + \ldots\ldots\ldots\ldots + P_{1k}P_{ky}$

$r_{2y} = r_{21} P_{1y} + P_{2y} + r_{23}P_{3y} + \ldots\ldots\ldots\ldots + r_{2k}P_{ky}$

$r_{iy} = r_{i1} P_{1y} + P_{i2} P_{2y} + r_{i3} P_{3y} + \ldots\ldots\ldots\ldots + r_{ik}P_{ky}$

$r_{ky} = r_{k1} P_{1y} + P_{k2} P_{2y} + r_{k3}P_{ky} + \ldots\ldots\ldots\ldots + . r_{kk}P_{ky}$

Solution of simultaneous equations

The above equations were written in a matrix form as under.

$$\begin{pmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ r_{iy} \end{pmatrix} \qquad \begin{pmatrix} r_{11} & r_{12} & r_{13} & \ldots\ldots r_{1j} \\ r_{21} & r_{22} & r_{23} & \ldots\ldots r_{2j} \\ r_{31} & r_{32} & r_{33} & \ldots\ldots r_{3j} \\ r_{i1} & r_{i2} & r_{i3} & \ldots\ldots r_{ij} \end{pmatrix}$$

The technique given by Goulden (1954) was followed for inversion (B-1) of B matrix. Path coefficients P_{jy} were obtained as follows:

P_{jy} = (B-1) x (A)

The indirect effect for a particular character through other character was obtained by multiplication of direct path and particular correlation coefficient between those two characters, respectively.

Indirect effect = r_{ij} x P_{jy}

Where,

i = 1, 2……..n

j = 1, 2……..n and

$P_{jy} = P_{1y}, P_{2y}.....P_{ny}$

The residual factor, *i.e.* the variation in yield unaccounted for (by such traits which could not be studied) was calculated as:

Residual factor (x) = $1-R^2$

Where,

$R^2 = P_{1y} r_{1y} + P_{2y} r_{2y} + \ldots\ldots\ldots P_{ny} r_{ny}$

R^2 = Squared multiple correlation coefficients and the amount of variation in yield that can be accounted for by the yield component characters.

3.9.5 Genetic divergence

Hierarchical cluster analysis

This analysis was carried out using the statistical software SPSS (version 20.0). In cluster analysis resemblance and divergence between pairs of genotypes of a set is determined. A commonly used method *i.e.* hierarchical cluster analysis for forming clusters was used with agglomerative method in the present study, in which clusters are formed by grouping genotypes into bigger and bigger clusters until all genotypes are members of a single cluster. Through this procedure relatively homogeneous groups of genotypes are identified using an algorithm that starts with each case in a separate cluster and combines clusters until only one is left. From the several alternatives like between-groups linkage, within-group linkage, nearest neighbour, furthest neighbour, centroid clustering, median clustering, Ward's method, etc., between-group linkage or UPGMA (Unweighted Pair Group

Method Using Arithmetic Averages) was used for the present investigation as suggested to be best by Romesburg (1990).

This method considers only the distances between pairs of cases between different clusters. As per this method the distance between two clusters is the average of the distances between all pairs of cases in which one member of the pair is from each of the clusters. Distances are generated by the Proximity procedure. From the many available options to measure similarity and dissimilarity (proximity) City Block (also known as Manhattan) distance was used in the present investigation. For two cases it is the sum of the absolute differences of the values for all the variables.

$$\textbf{City Block Distance (X,Y)} = \sum \left| X_i - Y_i \right|$$

After calculation of distance matrix, the actual formation of clustering was carried out. The first two cases combined were those that have the smallest absolute distance between them. The absolute distance between the two clusters was calculated as the average of the distances between all pairs of cases in which one member of pair is from each of the clusters. *e.g*. If cases 1 and 2 form cluster A and cases 3, 4 and 5 form cluster B, the distance between cluster A and B is taken as to be the average of the distances between the following pairs of cases: (1,3) (1,4) (1,5) (2,3) (2,4) (2,5). This process continued until all cases were merged into a single cluster. At every step, either an individual case was added to clusters or already existing clusters were combined. Once a cluster was formed, it could not be split; it could only be combined with other cluster. Thus, this method did not allow cases to separate from clusters to which they have been allocated.

Based on the process of cluster formation dendogram was produced using rescaled distances so that the ratio of distances between steps is preserved and problem of large distances was overcome and also makes it easier to see the similarities and dissimilarities between all pairs of objects. The dendogram showed the clusters being combined and the values of coefficient (distance) at each step. Determination of number of clusters we want is quite a subjective matter. However, Romesburg (1990) suggested a strategy to cut the tree at some point within a wide range of the resemblance coefficient for which the number of clusters remains constant, because a wide range indicates that the clusters are well separated and is least sensitive to error. This method of Romesburg was used to determine the number of clusters to be retained.

CHAPTER-IV

RESULTS

The present investigation entitled "Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits" was accomplished to ascertain the extent of genetic variation and divergence among promising tomato genotypes and to determine the association among yield and its component traits, fruit quality characters. Twenty-two tomato genotypes along with one standard check were assessed by using the randomized block design (RBD) and the data collected on different attributes were statistically analyzed for various parameters and the results obtained through analysis in the present investigation are described under following sub-heads:

4.1 Analysis of variance

4.2 Variability

4.3 Correlation coefficient

4.4 Path coefficient

4.5 Genetic divergence

4.1 Analysis of variance

The perusal of analysis of variance depicted in (Table 4.1). The mean squares for the genotypes was found highly significant results for all the morphological, yield and fruit quality characters investigated at 1% level of significance indicated the existence of considerable variability in the genotypes of tomato among the characters studied.

4.2 Variability

Performance of genotypes and genetic parameters of variation for yield and quality traits are shown in Tables 4.2(a), 4.2(b) and 4.3, respectively. The overall mean, range, phenotypic and genotypic coefficients of variation, heritability (broad sense) and genetic advance as percent of the mean for yield and quality traits revealed that there exists substantial genetic variability for all the characters among the genotypes under study. Genetic parameters of variation are discussed herewith.

4.2.1 Character mean and range

The result of mean performance studies of different genotypes for different characters and grand mean for different characters are depicted in Table 4.2a to 4.2b. The details of various characters recorded during the course of experimentation are furnished given below:

Table 4.1: Analysis of variance for yield and quality traits in tomato

Characters	Mean sum of squares		
	Replications	Genotypes	Error
df	**2**	**22**	**44**
Plant height (cm)	36.15	1937.34**	14.94
Number of branches per plant	0.07	2.41**	0.14
Days to 50% flowering	0.36	88.65**	4.85
Days to first picking	22.11	73.54**	8.07
Days to last picking	20.93	74.04**	7.99
Polar diameter (cm)	0.06	2.59**	0.05
Equatorial diameter (cm)	0.26	0.72**	0.07
Pericarp thickness (mm)	0.91	3.38**	0.05
Number of marketable fruit per plant	51.20	89.92**	11.36
Weight of marketable fruits per plant (g)	147.43	59268.66**	377.56
Number of unmarketable fruits per plant	1.88	9.11**	2.01
Weight of unmarketable fruits per plant (g)	39.49	29162.30**	74.17
Total number of fruits per plant	72.03	136.96**	17.67
Yield of fruit per plant (g)	1461.61	133387.40**	1601.55
Yield of fruit per hectare (q)	98.60	14478.07**	145.57
Number of locules per fruit	0.41	2.32**	0.26
Fruit firmness (kg/cm2)	0.12	0.19**	0.02
Specific gravity (g/cm3)	0.01	0.02**	0.00
Total Soluble Solids (%)	0.74	0.52**	0.10
Ascorbic acid (mg/100g)	7.38	8.22**	0.97
Acidity (%)	0.00	0.02**	0.00
Residual = -0.01322			

**Significant at 1% level of probability, * Significant at 5% level of significance

4.2.1.1 Plant height (cm)

The plant height was observed in a range from 60.78 cm to 145.22 cm, with average plant height 77.88 cm. The shortest plant height has been recorded in Punjab Upma (60.78 cm) which was closely followed by DVRT-3 (61.67 cm) and Castle Rock (62.33 cm) while the tallest plant height among genotypes was recorded in Pusa Ruby (145.22 cm) followed by PNR-7 (144.66 cm) and Pusa Uphar (131.00 cm).

4.2.1.2 Number of branches per plant

The number of branches per plant ranged from 3.89 to 7.00, with a mean value of 4.87. Among all genotypes, the highest number of branches per plant was produced by NT-8 (7.00) which was at par with S-12 (6.67) and Sel-7 (6.41) while least number of branches per plant was produced by genotypes Castle Rock and P.H.S (3.89).

4.2.1.3 Days to 50% flowering

The average days taken to flowering in 50% plants was 45.62 days, with a range from 36.67 to 56.33 days. The significant early in days to 50% flowering was taken by the genotype Pusa Ruby (36.67) closely followed by Palam Pink (37.67), Sel-7 (38.00), P.H.S (39.33) and Arka Vikas (40.00) which were at par with each other whereas, the maximum

days to 50% flowering by the genotype DVRT-2 (56.30) followed by PNR-7 (52.33) which were late in days to 50% flowering.

4.2.1.4 Days to first picking

The days to first picking showed a range from 85.33 days to 109.44 days, with a mean value of 101.25 days. The minimum days was taken for first picking by the genotypes Pusa Ruby (85.33) closely followed by Palam Pink (94.34), P.H.S (95.55), H-86 (95.89), Sel-7 (96.56), and Arka Vikas (97.11), Castle Rock (97.44) and S-12 (97.56) while, the maximum days was taken for first picking by the genotypes DVRT-2 (109.44) followed by DVRT-1 (107.22) and Punjab Upma (106.89).

4.2.1.5 Days to last picking

The days to last picking among tomato genotypes showed a range from 127.33 (Pusa Ruby) to 144.33 days (DVRT-2), respectively with an overall mean value of 136.62 days. The minimum days was taken for last picking by the genotypes Pusa Ruby (127.33) closely followed by Palam Pink (129.67) P.H.S (130.33), H-86 (131.00), Sel-7 (131.67) and Arka Vikas (132.00) which were at par with each other while, the maximum days was taken for first picking by the genotypes DVRT-2 (144.33) followed by Punjab Kesari (142.67), DVRT-1 (142.33) and PNR-7 (142.33).

4.2.1.6 Polar diameter (cm)

The variation for the polar diameter of fruit showed a range from 3.36 to 6.76 cm as comprising to the mean value of 4.34 cm. Maximum range of polar diameter among tomato genotypes were recorded in Punjab chhuhara (6.76 cm) which was followed by DVRT-6 (5.67 cm), Castle Rock (5.61 cm), Punjab Ratta (5.44 cm), Punjab Upma (5.40 cm) and DVRT-8 (5.37 cm) while, the minimum polar diameter was registered in Sel-7 (3.36 cm) which was closely followed by Pusa Ruby (3.41 cm) and Pusa Uphar (3.44 cm).

4.2.1.7 Equatorial diameter of fruit (cm)

As it is obvious from (Table 4.2a), the equatorial diameter of fruit showed a range from 3.47 cm to 5.35 cm, with a mean value of 4.34 cm. Highest range of equatorial diameter reported in the genotypes Castle Rock (5.35cm) which was at par with DVRT-2 (5.11 cm) and PNR-7 (5.05 cm) while, the lowest value was recorded in DVRT-8 (3.47 cm), which was closely followed by DVRT-5 (3.63 cm), Punjab Chhuhara (3.64 cm) and DVRT-3 (3.65 cm).

4.2.1.8 Pericarp thickness (mm)

The value for pericarp thickness varied a range from 3.24-7.44 mm, with an average means performance of 5.33 mm. Among genotypes highest value for pericarp thickness was noted in genotype DVRT-8 (7.44 mm) which was at par with Punjab Upma (7.26 mm) and Castle Rock (7.22 mm) while the lowest value was recorded in Pusa Ruby (3.24 mm) followed by Sel-7 (3.97 mm), Pusa Uphar (4.02 mm) and DVRT-5 (4.09 mm).

4.2.1.9 Number of marketable fruits per plant

A wide variation was found among the genotypes for the number of marketable fruits per plant, which significantly varied from 13.11 to 38.53, with an average means number of marketable fruits per plant lay 21.41. The genotype DVRT-5 (38.53) showed the highest number of marketable fruits per plant followed by DVRT-3 (30.73), Pusa Uphar (26.20), Pusa Ruby (25.76) and Punjab Kesari (25.29) while the genotype Castle Rock (13.11) had the lowest number of marketable fruits per plant.

4.2.1.10 Weight of marketable fruits per plant (g)

A wide variation was reported among the genotypes for the weight of marketable fruits per plant of tomato after the final picking with an overall mean of 1071 g. Among the genotypes, the maximum weight of marketable fruits per plant was recorded in genotype PNR-7 (1356.70 g) followed by H-86 (1169.79 g), NT-8 (1151.15 g), Castle Rock (1139.72 g), DVRT-6 (1126.87 g), DVRT-2 (1117.05 g), DVRT-5 (1100.78 g) and Punjab Ratta (1093.54 g) While, the minimum weight of marketable fruits per plant has been recorded in S-12 (745.59 g) followed by Palam Pink (801.79 g), Sel-7 (835.64 g) and DVRT-1 (849.89 g).

4.2.1.11 Number of unmarketable fruits per plant (g)

The average mean value for number of unmarketable fruits per plant ranged from 7.90 to 16.82. The genotype S-12 (7.90) and Castle Rock (8.98) had the lowest number of unmarketable fruits per plant and both were at par with each other.

4.2.1.12 Weight of unmarketable fruits per plant (g)

The weight of unmarketable fruits per plant ranged from 226.11 to 660.34 g with an overall mean of (371.74 g). The most promising superior genotypes namely DVRT-3 (226.11 g), S-12 (235.74g), Punjab Chhuhara (270.83 g), Pusa Uphar (294.94 g) and Punjab Kesari (308.39 g) had lowest weight of unmarketable fruits per plant among all the genotypes.

4.2.1.13 Total number of fruits per plant

A wide variation was reported among the genotypes for the total number of fruits per plant, which ranged from 22.09 to 55.36, with an overall mean of 32.92. A perusal of data indicated that the maximum number of fruits per plant was produced by the genotype DVRT-5 (55.36) followed by DVRT-3 (43.07), Punjab Kesari (38.26), Pusa Ruby (38.07), Punjab Tropics, Pusa Uphar (36.20), P.H.S (35.69) and Punjab Chhuhara (35.33) while the least number of fruits per plant was noticed for the genotype Castle Rock (22.09).

Table 4.2 (a): Mean performance of different genotypes for various traits in tomato

Observations / Treatments	Plant height (cm)	Number of branches per plant	Days to 50% flowering	Days to first picking	Days to last picking	Polar diameter (cm)	Equatorial diameter (cm)	Pericarp thickness (cm)	Number of marketable fruits per plant	Weight of marketable fruits per plant (g)	Number of un-marketable fruits per plant
DVRT-1	64.22	4.33	52.00	107.22	142.33	4.36	4.30	4.59	17.71	849.89	11.85
DVRT-2	73.67	4.44	56.33	109.44	144.33	4.49	5.11	5.80	20.76	1117.05	10.53
DVRT-3	61.67	6.33	50.67	105.45	140.67	3.76	3.65	4.22	30.73	931.68	12.33
DVRT-5	70.78	5.00	47.33	104.55	139.33	3.55	3.63	4.09	38.53	1100.78	16.82
DVRT-6	68.55	4.45	46.67	103.11	138.33	5.67	4.60	7.44	18.49	1126.87	11.24
DVRT-8	65.33	4.56	45.00	101.67	136.67	5.37	3.47	5.20	20.11	1047.69	11.98
Arka Vikas	81.11	5.23	40.00	97.11	132.00	4.10	4.67	5.22	20.18	958.93	11.36
Castle Rock	62.33	3.89	43.00	97.44	132.33	5.61	5.35	7.22	13.11	1139.72	8.98
NT-8	64.33	7.00	45.00	106.00	141.00	3.99	4.29	5.52	19.78	1151.15	11.07
Punjab Chhuhara	70.44	4.44	44.33	100.78	136.00	6.76	3.64	6.73	24.62	1066.01	10.71
P.H.S	66.22	3.89	39.33	95.55	130.33	3.50	4.15	5.20	22.47	911.14	13.22
Punjab Kesari	63.55	4.89	53.67	107.34	142.67	3.60	4.38	5.04	25.29	988.75	12.98
PNR-7	144.66	5.00	52.33	107.33	142.33	4.01	5.05	5.54	19.02	1356.70	10.45
Palam Pink	67.22	4.00	37.67	94.34	129.67	4.43	4.52	4.61	15.02	801.79	11.40
Punjab Ratta	80.22	4.33	49.00	104.78	140.00	5.44	4.56	6.85	17.44	1093.54	9.62
Pusa Ruby	145.22	5.00	36.67	85.33	127.33	3.41	4.20	3.24	25.76	932.14	12.31
Punjab Tropics	70.56	4.56	45.67	101.56	136.67	3.51	4.44	4.25	23.22	916.35	12.98
Pusa Uphar	131.00	4.78	43.00	99.22	134.33	3.44	3.93	4.02	26.20	1036.81	10.00
Punjab Upma	60.78	4.56	51.67	106.89	142.00	5.40	4.59	7.26	17.40	1067.39	12.13
Sel-7	66.29	6.41	38.00	96.56	131.67	3.36	4.08	3.97	19.46	835.64	11.53
S-12	66.89	6.67	44.00	97.56	132.67	3.66	3.99	5.00	18.51	745.59	7.90
H-86	76.89	4.11	41.67	95.89	131.00	4.20	4.68	5.67	16.98	1169.79	12.27
Pusa Sadabahar (C)	69.22	4.11	46.33	103.56	138.67	4.25	4.60	5.82	21.69	1045.71	10.98
General mean	77.88	4.87	45.62	101.25	136.62	4.34	4.34	5.33	21.41	1017.00	11.51
C.D. @ 5%	6.38	0.63	3.64	4.69	4.67	0.37	0.42	0.54	5.56	32.10	2.33
SE(m)	2.23	0.22	1.27	1.64	1.63	0.13	0.15	0.19	1.95	11.23	0.82
SE(d)	3.16	0.31	1.80	2.32	2.31	0.18	0.21	0.27	2.75	15.88	1.15
C.V.	4.96	7.78	4.83	2.80	2.07	5.10	5.91	6.11	15.74	1.91	12.27

4.2.1.14 Yield of fruits per plant (g)

The yield of fruits per plant of tomato after the final picking of a single plant ranged from (981.33 to 1800.06 g), with a mean value of 1388.74 g. Among genotypes, the highest yield of fruit per plant was recorded in genotype Castle Rock (1800.06 g) which was at par with PNR-7 (1756.57 g). While, the lowest yield of fruit per plant among the genotypes has been recorded in S-12 (981.33 g) followed by Palam Pink (1144.41 g), DVRT-3 (1157.78 g) and Sel-7 (1177.02 g).

4.2.1.15 Yield of fruits per hectare (q)

Significant differences were observed among the genotypes for the yield of fruits per hectare. It was ranged from (327.11 to 600.01 q), with an overall mean of 462.91 q. Among genotypes, the highest yield of fruit per hectare was recorded for Castle Rock (600.01 q) which was at par with PNR-7 (585.52 q) while, the lowest fruits yield per hectare among the genotypes has been observed in S-12 (327.11 q). Other promising superior genotypes are H-86, DVRT-6, DVRT-2, NT-8, DVRT-8, Punjab Upma and Punjab Ratta.

4.2.1.16 Number of locules per fruit

The number of locules per fruit showed a range from 2.44 to 5.52, respectively with overall mean value of 3.68. The maximum number of locules was registered with genotype DVRT-2 and Arka Vikas (5.22), while minimum registered with the genotype DVRT-8 (2.44) closely followed by Punjab upma (2.67), DVRT-6 (2.68), Punjab ratta (2.78), DVRT-3 (2.89), DVRT-5 (3.00) DVRT-1 (3.11) and P.H.S (3.11) which were at par with each other.

4.2.1.17 Fruit firmness (kg/cm^2)

The analyzed data in (Table 4.2b) for this traits revealed that fruit firmness showed a range from 0.62-1.75 kg/cm^2, with a mean value of 0.99 kg/cm^2. Among all the genotypes highest value for fruit firmness has been shown by Punjab Upma (1.75 kg/cm^2) which was at par with Castle Rock (1.51 kg/cm^2) while, lowest value has been recorded in S-12 (0.62 kg/cm^2) which was closely followed by Punjab Tropics (0.69 kg/cm^2).

4.2.1.18 Specific gravity (g/cm^3)

The value for specific gravity showed a range from 0.97-1.30 g/cm^3, with a mean value of 1.11 g/cm^3. Among all the genotypes highest value for specific gravity has been shown by DVRT-5 (1.30 g/cm^3) followed by check Pusa Sadabahar (1.16 g/cm^3) while, lowest value recorded in Punjab Upma (0.97 g/cm^3) which was closely followed by DVRT-1 (1.01 g/cm^3), DVRT-3 (1.02 g/cm^3), Castle Rock (1.02 g/cm^3), DVRT-2 (1.03 g/cm^3), S-12 (1.03 g/cm^3) and NT-8 (1.04 g/cm^3) which were at par with each other.

Table 4.2 (b): Mean performance of different genotypes for various traits in tomato

Observations / Treatments	Weight of un-marketable fruits per plant (g)	Total number of fruits per plant	Yield of fruit per plant (g)	Yield of fruit per hectare (q)	Number of locules per fruit	Fruit firmness (kg/cm^2)	Specific gravity (g/cm^3)	TSS (%)	Ascorbic acid (mg/100g)	Acidity (%)
DVRT-1	341.74	29.56	1191.63	397.21	3.11	0.96	1.01	4.83	22.19	0.54
DVRT-2	432.23	31.29	1549.28	516.42	5.22	0.91	1.03	4.03	21.09	0.56
DVRT-3	226.11	43.07	1157.78	385.93	2.89	0.96	1.02	4.23	26.39	0.77
DVRT-5	320.36	55.36	1421.14	473.71	3.00	0.77	1.30	4.70	22.35	0.80
DVRT-6	463.83	29.73	1590.71	530.23	2.68	0.99	1.10	4.43	22.58	0.84
DVRT-8	446.28	32.09	1493.97	497.98	2.44	1.02	1.21	4.17	22.70	0.78
Arka Vikas	352.50	31.53	1311.44	437.14	5.22	0.95	1.13	4.97	21.52	0.73
Castle Rock	660.34	22.09	1800.06	600.01	4.11	1.51	1.02	4.50	23.59	0.61
NT-8	361.23	30.84	1512.38	504.12	3.78	1.09	1.04	4.06	22.55	0.72
Punjab Chhuhara	270.83	35.33	1336.84	445.61	2.89	1.16	0.97	4.30	24.38	0.59
P.H.S	313.16	35.69	1224.29	408.10	3.11	0.77	1.17	5.03	26.38	0.76
Punjab Kesari	308.39	38.26	1297.13	432.37	3.55	0.87	1.14	4.83	25.42	0.69
PNR-7	399.87	29.47	1756.57	585.52	3.56	0.87	1.07	5.50	22.57	0.71
Palam Pink	342.62	26.42	1144.41	381.47	4.00	0.87	1.11	4.83	23.40	0.63
Punjab Ratta	371.72	27.07	1465.26	488.42	2.78	1.22	1.08	5.07	20.48	0.78
Pusa Ruby	351.25	38.07	1283.38	427.79	3.55	0.97	1.20	4.77	20.80	0.62
Punjab Tropics	417.17	36.20	1333.52	444.50	4.89	0.69	1.20	4.43	23.66	0.68
Pusa Uphar	294.94	36.20	1331.75	443.91	4.85	0.95	1.14	4.83	23.36	0.79
Punjab Upma	410.37	29.53	1477.76	492.58	2.67	1.75	1.07	3.77	24.95	0.69
Sel-7	341.38	31.00	1177.02	392.34	4.67	0.80	1.09	4.17	23.47	0.68
S-12	235.74	26.41	981.33	327.11	3.79	0.62	1.03	4.76	24.62	0.75
H-86	563.64	29.24	1733.43	577.80	4.72	0.94	1.16	4.17	23.44	0.81
Pusa Sadabahar (C)	324.25	32.67	1369.96	456.65	3.11	1.16	1.16	4.43	22.42	0.72
General Mean	371.74	32.92	1388.74	462.91	3.68	0.99	1.11	4.56	23.36	0.71
C.D. @ 5%	14.21	6.94	65.41	19.93	0.84	0.24	0.07	0.53	1.63	0.05
SE(m)	4.97	2.43	22.87	6.97	0.29	0.08	0.02	0.19	0.57	0.02
SE(d)	7.03	3.43	32.34	9.85	0.41	0.12	0.03	0.26	0.81	0.03
C.V.	2.32	12.77	2.85	2.61	13.78	14.70	3.57	7.03	4.22	4.55

4.2.1.19 Total Soluble Solids (%)

The total soluble solids content of fruit at marketable stage varied a range from 3.77-5.50%. The highest total soluble solids content of fruit was recorded in the genotype PNR-7 (5.50%) while the genotype Punjab Upma (3.77%) registered the lowest total soluble content in fruit followed by DVRT-2 (4.03%), NT-8 (4.06%), DVRT-8 (4.17%), SEL-7 (4.17%), H-86 (4.17%) DVRT-3 (4.23%) and Punjab Chhuhara (4.30%) which were at par with each other.

4.2.1.20 Ascorbic acid (mg/100g)

This character is much important from a nutrition point of view. The ascorbic acid content of fruit at marketable stage ranged from 20.48 to 26.39. The general mean of the population in relation to the ascorbic acid content of fruit was 23.36 mg/100g. Among the evaluated genotypes, the maximum ascorbic acid content was exhibited by the genotypes DVRT-3 (26.39 mg/100g) closely followed by P.H.S (26.38 mg/100g), Punjab kesari (25.42 mg/100g) and Punjab Upma (24.95 mg/100g) which were at par with each other.

4.2.1.21 Acidity (%)

The general mean of population in relation to acidity content of the fruit at marketable stage was 0.71%. The titrable acidity percentage of the fruits varied a ranged from 0.54% to 0.84%. The highest amount of acidity content was recorded in the genotype DVRT-6 (0.84%) which was at par with H-86 (0.81%), DVRT-5 (0.80%) and Pusa Uphar (0.79%) while the genotype DVRT-1 (0.54%) registered the lowest amount of acidity content in the fruit.

4.2.2 Coefficient of variation

The estimates of components of variance such as genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were evaluated to ascertain the heritable and non-heritable components of variation as depicted in (Table 4.3). In general, the magnitude of phenotypic coefficients of variation were marginally higher than their respective genotypic coefficient of variation for almost all the traits indicating the environmental influences on the expression of these characters. GCV and PCV are categorized as low (< 10%), moderate (10-20%) and high (> 20%) as proposed in (1973) by Sivasubramanian and Madhavamenon.

4.2.2.1 Genotypic coefficient of variation

The highest magnitude of genotypic coefficient of variation (GCV) was observed for traits plant height (32.50%) followed by number of marketable fruits per plant (23.90%), fruit firmness (23.90%), number of locules per fruit (22.95%) and polar diameter (21.20%). Moderate estimates of GCV was observed for traits pericarp thickness (19.76%), total number of fruits per plant (19.15%), number of branches per plant (17.86%), weight of unmarketable fruits per plant (15.49%), yield of fruits per plant (15.09%), yield of fruits per hectare

(14.93%), number of unmarketable fruits per plant (13.36%), weight of marketable fruits per plant (13.08%), days to 50% flowering (11.59%), titrable acidity (11.50%) and equatorial diameter (10.73%). while low estimate of GCV was recorded for traits days to last picking (3.43%), days to first picking (4.60%), ascorbic acid (6.65%), specific gravity (6.78%), total soluble solids (8.13%).

4.2.2.2 Phenotypic coefficient of variation

A perusal of (Table 4.3) revealed that phenotypic coefficient of variation was higher than the genotypic coefficient of variation for all the traits under investigation. The highest estimates of phenotypic coefficient of variation (PCV) was observed for traits plant height (32.88%) followed by number of marketable fruits per plant (28.62%), fruit firmness (28.03%), number of locules per fruit (26.42%) total number of fruits per plant (23.02%) and polar diameter (21.81%) whereas, the moderate PCV was observed for traits pericarp thickness (20.23%), number of branches per plant (19.48%), number of unmarketable fruits per plant (18.18%), weight of unmarketable fruits per plant (16.59%), yield of fruits per plant (15.36%), yield of fruits per hectare (15.16%), weight of marketable fruits per plant (13.21%), days to 50% flowering (12.55%), acidity content (12.33%) and equatorial diameter (12.26%). Low estimate of PCV was recorded for days to last picking (4.01%), days to first picking (5.38%), ascorbic acid content (7.88%), specific gravity (7.89%) and total soluble solids (10.75%).

4.2.3 Heritability and Genetic Advance:

The uniformity between parents and their progeny is governed by heritability. The magnitude of heritability in broad sense indicates the reliability with which a genotype can be recognized by its phenotypic expression. According to Burton and DeVane (1953), heritability is a measure of heritable variation and is helpful in predicting expected amount of improvement to be achieved through selection together with the genotypic coefficient of variation. Heritability acts as an index of transmissibility of a particular character to its offsprings. However, the knowledge of heritability alone does not help in formulating concrete breeding programme.

Genetic advance along with heritability helps to ascertain the possible genetic control for any particular trait and provide the knowledge about the expected gain for a particular trait after selection. The nature and extent of the inherent ability of a genotype for a character is an important parameter determining the extent of improvement of any crop species. The heritability in a broad sense and genetic advance as per cent of the mean was worked out for all the characters have been presented in (Table 4.3)

Category	Heritability (broad sense)	Genetic Advance as per cent of mean
High	> 60 %	> 20%
Moderate	30%-60%	10% - 20%
Low	< 30%	< 10%

Table 4.3: Range, mean, coefficient of variations, heritability and genetic advance as % of mean for 21 characters in tomato

Characters	Mean	Range		Variance		Coefficient of variation		Heritability% (broad sense)	Genetic advance
		Min	max	Genotypic	Phenotypic	Genotypic	Phenotypic		As *percent* of mean
Plant height (cm)	77.88	60.78	145.22	640.80	655.74	32.50	32.88	97.72	66.19
Number of branches per plant	4.87	3.89	7.00	0.76	0.90	17.86	19.48	84.06	33.74
Days to 50% flowering	45.62	36.67	56.33	27.94	32.78	11.59	12.55	85.22	22.03
Days to first picking	101.55	92.33	109.44	21.82	29.89	4.60	5.38	73.01	8.10
Days to last picking	136.62	127.33	144.33	22.02	30.01	3.43	4.01	73.38	6.06
Polar diameter (cm)	4.34	3.36	6.76	0.85	0.90	21.20	21.81	94.53	42.45
Equatorial diameter (cm)	4.34	3.47	5.35	0.22	0.28	10.73	12.26	76.71	19.36
Pericarp thickness (mm)	5.33	3.24	7.44	1.11	1.16	19.76	20.23	95.42	40.10
Number of marketable fruit per plant	21.41	13.11	38.53	26.19	37.54	23.90	28.62	69.75	41.12
Weight of marketable fruits per plant (g)	1071.00	745.59	1356.70	19630.37	20007.92	13.08	13.21	98.11	28.11
Number of unmarketable fruits per plant	11.51	7.90	16.82	2.37	4.38	13.36	18.18	54.03	20.20
Weight of unmarketable fruits per plant (g)	371.74	226.11	660.34	9696.05	9770.21	26.49	26.59	99.24	54.36
Total number of fruits per plant	32.92	22.09	55.36	39.76	57.43	19.15	23.02	69.24	32.84
Yield of fruit per plant (g)	1388.74	981.33	1800.06	43928.62	45530.16	15.09	15.36	96.48	31.28
Yield of fruit per hectare (q)	462.91	327.11	600.01	4777.50	4923.07	14.93	15.16	97.04	30.30
Number of locules per fruit	3.68	2.44	5.22	0.69	0.95	22.55	26.42	72.83	39.66
Fruit firmness (kg/cm2)	0.99	0.62	1.75	0.06	0.08	23.90	28.03	72.53	41.91
Specific gravity (g/cm3)	1.11	0.97	1.30	0.01	0.01	6.78	7.89	79.44	12.75
Total Soluble Solids (%)	4.56	3.77	5.50	0.14	0.24	8.13	10.75	57.24	12.67
Ascorbic acid (mg/100g)	23.36	20.48	26.39	2.41	3.39	6.65	7.88	71.27	11.57
Acidity (%)	0.71	0.54	0.84	0.01	0.01	11.50	12.33	86.41	21.98

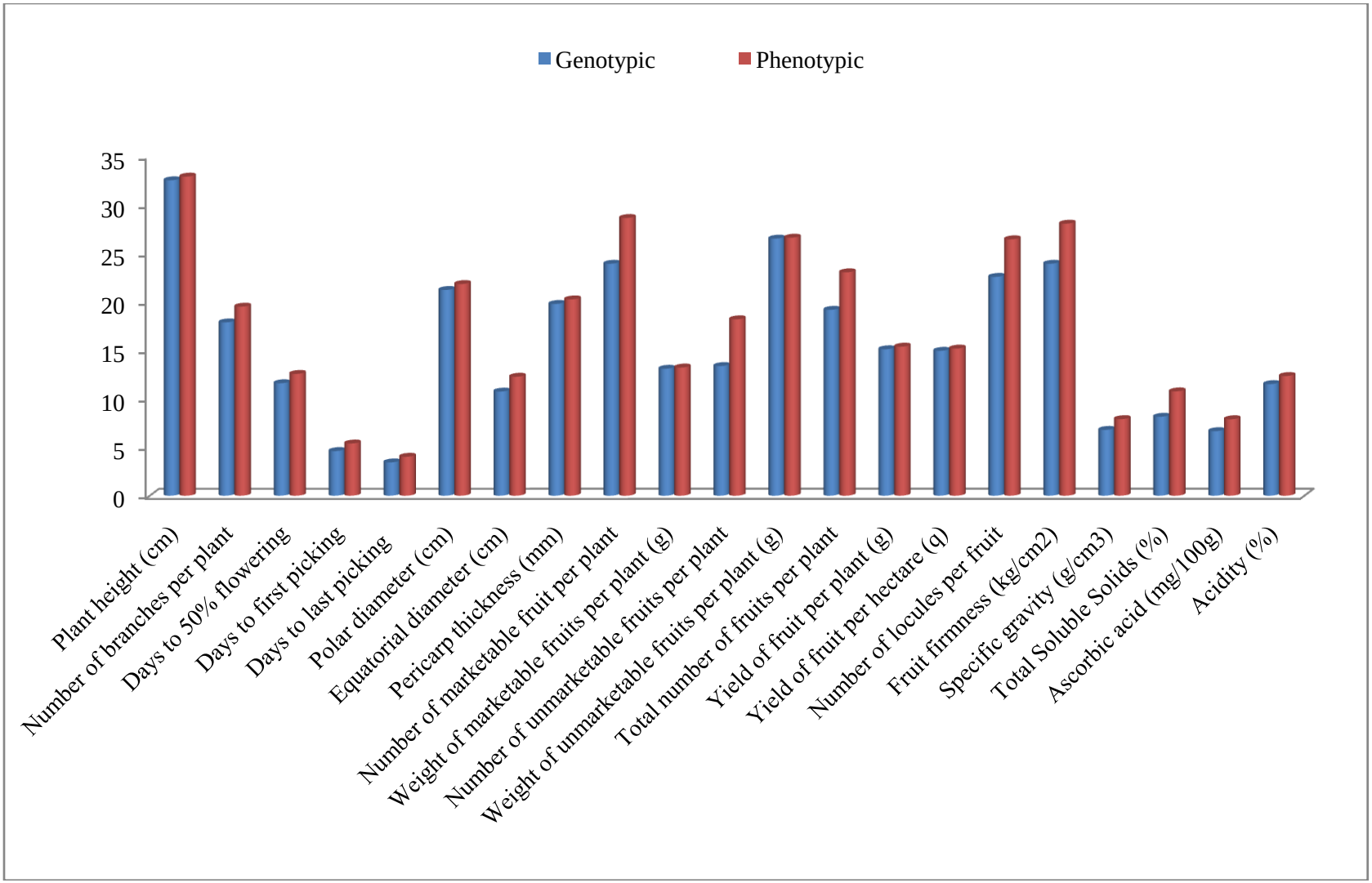

Figure 4.1: Genotypic and phenotypic variability in tomato

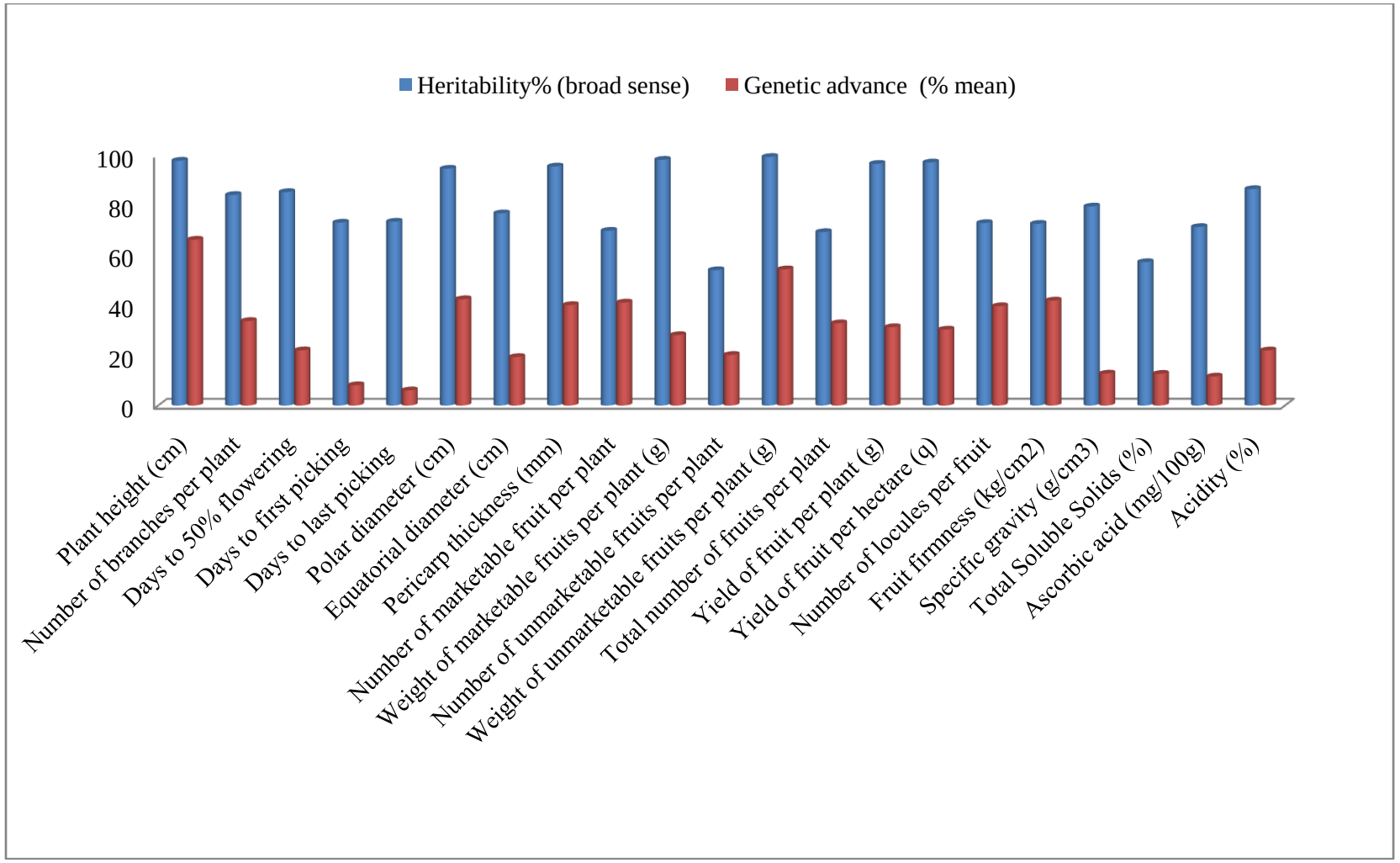

Figure 4.2: Heritability and genetic advance over different yield contributing characters in tomato

On the basis of above characterization, it was evaluated from Table 4.3 that the high magnitude of heritability (broad sense) was noticed in almost all characters like weight of marketable fruits per plant (98.11%) followed by plant height (97.72%), yield of fruits per hectare (97.04%), yield of fruits per plant (96.48%), pericarp thickness (95.42%), polar diameter (94.53%), acidity content (86.41%), days to 50% flowering (85.22%), number of branches per plant (84.06%), specific gravity (79.44%), equatorial diameter (76.71%), days to last picking (73.38%), days to first picking (73.01%), number of locules per fruit (72.83%), fruit firmness (72.53%), ascorbic acid content (71.27%), weight of unmarketable fruits per plant (71.24%), number of marketable fruits per plant (69.75% and total number of fruits per plant (69.24%) whereas, the moderate heritability was observed for total soluble solids (57.24%), number of unmarketable fruits per plant (54.03%).

In the present investigation, the magnitude of genetic advance as percentage of mean was observed high for plant height (66.19%) followed by polar diameter (42.45%), fruit firmness (41.91%), number of marketable fruits per plant (41.12%), pericarp thickness (40.10%), number of locules per fruit (39.66%), number of branches per plant (33.74%), total number of fruits per plant (32.84%), yield of fruits per plant (31.28%) and yield of fruits per hectare (30.30%). It was recorded moderate for weight of marketable fruits per plant (28.11%), days to 50% flowering (22.03%), titerable acidity content (21.98%), weight of unmarketable fruits per plant (29.36%), number of unmarketable fruits per plant (20.20%), equatorial diameter (19.36%), specific gravity (12.75%), total soluble solids (12.67%), ascorbic acid content (11.57%), and whereas, the low magnitude of heritability was observed for days to first picking (8.10%), days to last picking (6.06%).

4.3 Correlation coefficient analysis

The correlation coefficients were computed for all the characters studied with yield of fruits per hectare and among the characters themselves at both genotypic and phenotypic levels to find out the association among them. For the characters studied, the genotypic correlation coefficients (GCV) estimates were higher in magnitude than the corresponding phenotypic correlation coefficients (PCV) ones for most of the traits which indicating that though there is a strong inherent association among the various characters, the phenotypic expression of the correlation gets reduced under the influence of environment. The effective yield improvement would be achieved through the characters which have significant and positive/desirable correlation with each other. Correlation coefficients analysis provides the information on nature and magnitude of the association of different component characters with yield which is ultimately of the interest to the breeders. The results were analyzed and are presented in (Tables 4.4 and 4.5).

The yield of fruits per hectare had shown significant positive association with the weight of marketable fruits per plant, yield of fruits per plant, days to 50% flowering, days to first picking, days to last picking, polar diameter, equatorial diameter, fruit firmness, pericarp thickness, weight of unmarketable fruits per plant. Whereas, it was negatively correlated with number of branches per plant, number of marketable fruits per plant, total number of fruits per plant and ascorbic acid. Highest significant correlation was found between the, weight of marketable fruits per plant, followed by yield of fruits per plant. plant height revealed a positive association with the weight of marketable fruits per plant and total soluble solids while it had a negative association with ascorbic acid, number of locules per fruit, pericarp thickness and polar diameter at both the levels.

Days to 50% flowering had a significant and positive association with days to first picking, days to last picking, pericarp thickness, weight of marketable fruits per plant, yield of fruits per plant and yield of fruits per hectare but have a negative correlation with specific gravity at both the levels.

Days to first picking showed significant and positive association with days to last picking, weight of marketable fruits per plant, yield of fruits per plant and yield of fruits per hectare and pericarp thickness at both the levels and that with fruit firmness at genotypic level only. Further, it had negative association with specific gravity at both the levels.

Days to last picking showed significant and positive association with days to last picking, weight of marketable fruits per plant, yield of fruits per plant and pericarp thickness at both the levels and that with yield of fruits per hectare, fruit firmness at genotypic level only. Further, it had negative association with specific gravity at both the levels.

Polar diameter of fruit was noticed highly significant and positive correlation with fruit firmness, pericarp thickness, weight of marketable fruits per plant, yield of fruits per plant and yield of fruits per hectare and weight of unmarketable fruits per plant at both the levels. Further, it had negative association with specific gravity, total soluble solids, total number of fruits per plant, number of marketable fruits per plant, number of unmarketable fruits per plant at both the levels.

A positive association of pericarp thickness was observed with fruit firmness, yield of fruits per plant and yield of fruits per hectare, weight of marketable fruits per plant and weight of unmarketable fruits per plant at both phenotypic and genotypic levels. However, it indicated negative association with number of unmarketable fruits per plant, number of marketable fruits per plant, total number of fruits per plant and specific gravity at both the levels.

Total number of fruits per plant had revealed highly significant positive association with specific gravity, number of marketable fruits per plant and number of unmarketable fruits per plant at both the levels and that with number of locules per fruit and acidity at genotypic level

only. In contrary, it showed negative association with fruit firmness, pericarp thickness, polar diameter and equatorial diameter and at both the levels and that with yield of fruits per hectare at genotypic level only.

Yield of fruits per plant was found highly significant and positively correlated with yield of fruits per hectare, weight of marketable fruits per plant, fruit firmness, days to 50% flowering, days to first picking, days to last picking, pericarp thickness, polar diameter, equatorial diameter and weight of unmarketable fruits per plant at both genotypic and phenotypic level whereas, it was negatively correlated with number of locules per fruit and ascorbic acid at both the levels.

The number of locules per fruit was observed significant and positively association with total number of fruits per plant, number of marketable fruits per plant and ascorbic acid content at genotypic level only whereas, it was negatively correlated with plant height and yield of fruits per plant at both genotypic and phenotypic levels.

A highly significant positive association of specific gravity observed with acidity, total number of fruits per plant, number of marketable fruits per plant and number of unmarketable fruits per plant at both the levels. However, it indicated negative association with days to 50% flowering, days to first picking, days to last picking, polar diameter, fruit firmness and pericarp thickness at both genotypic and phenotypic levels and that with equatorial diameter at genotypic level only.

The total soluble solids were observed highly positively correlated with plant height at both phenotypic and genotypic level however, it indicated negative correlation with polar diameter and fruit firmness at both the levels. And that with weight of unmarketable fruits per plant at genotypic level only.

A positive association of acidity was observed with specific gravity at both genotypic and phenotypic levels. And that with total number of fruits per plant and number of marketable fruits per plant at genotypic level only. Further, it had negatively correlated with equatorial diameter at both genotypic and phenotypic levels.

Table 4.4: Estimates for phenotypic (above diagonal) and genotypic (below diagonal) correlation coefficients among different traits in tomato

Traits	PHT	NB	DFF	DFPi	DLPi	PD	ED	PT	NMF	WMF	NUMF	WUMF	TNFP	YFP	NLF	FF	SG	TSS	ASAD	ACDY	YFPH
PHT	**1.00**	-0.015^{NS}	-0.148^{NS}	-0.175^{NS}	-0.179^{NS}	-0.280*	0.098^{NS}	-0.327**	0.136^{NS}	0.296*	-0.099^{NS}	-0.056^{NS}	0.083^{NS}	0.179^{NS}	-0.306*	-0.121^{NS}	0.181^{NS}	0.443**	-0.351**	0.023^{NS}	0.167^{NS}
NB	-0.015^{NS}	**1.00**	-0.046^{NS}	0.047^{NS}	0.050^{NS}	-0.385**	-0.354**	-0.277*	0.220^{NS}	-0.215^{NS}	-0.078^{NS}	-0.436**	0.155^{NS}	-0.207^{NS}	0.003^{NS}	-0.247*	-0.200^{NS}	-0.168^{NS}	0.040^{NS}	0.141^{NS}	-0.342**
DFF	-0.138^{NS}	-0.025^{NS}	**1.00**	0.847**	0.847**	0.175^{NS}	0.183^{NS}	0.345**	0.077^{NS}	0.375**	0.003^{NS}	-0.017^{NS}	0.066^{NS}	0.326**	-0.034^{NS}	0.165^{NS}	-0.307*	-0.129^{NS}	0.001^{NS}	-0.118^{NS}	0.238*
DFPi	-0.187^{NS}	0.101^{NS}	1.014**	**1.00**	0.999**	0.172^{NS}	0.117^{NS}	0.336**	0.147^{NS}	0.402**	0.098^{NS}	-0.074^{NS}	0.148^{NS}	0.397**	-0.133^{NS}	0.121^{NS}	-0.260*	-0.102^{NS}	-0.049^{NS}	-0.058^{NS}	0.238*
DLPi	-0.190^{NS}	0.100^{NS}	1.015**	1.000**	**1.00**	0.178^{NS}	0.110^{NS}	0.341**	0.142^{NS}	0.394**	0.094^{NS}	-0.081^{NS}	0.143^{NS}	0.389**	-0.130^{NS}	0.118^{NS}	-0.271*	-0.105^{NS}	-0.042^{NS}	-0.055^{NS}	0.230^{NS}
PD	-0.286*	-0.430**	0.176^{NS}	0.175^{NS}	0.181^{NS}	**1.00**	0.144^{NS}	0.621**	-0.354**	0.346**	-0.271*	0.358**	-0.361**	0.412**	-0.001^{NS}	0.550**	-0.418**	-0.243*	-0.090^{NS}	-0.150^{NS}	0.398**
ED	0.109^{NS}	-0.371**	0.201^{NS}	0.104^{NS}	0.102^{NS}	0.122^{NS}	**1.00**	0.384**	-0.494**	0.362**	-0.275*	0.591**	-0.478**	0.387**	-0.010^{NS}	0.233^{NS}	-0.193^{NS}	0.093^{NS}	-0.212^{NS}	-0.244*	0.523**
PT	-0.338**	-0.313**	0.397**	0.411**	0.411**	0.653**	0.485**	**1.00**	-0.418**	0.451**	-0.238*	0.338**	-0.405**	0.405**	-0.120^{NS}	0.491**	-0.289*	-0.118^{NS}	0.031^{NS}	0.171^{NS}	0.465**
NMF	0.148^{NS}	0.236^{NS}	0.143^{NS}	0.172^{NS}	0.165^{NS}	-0.416**	-0.708**	-0.513**	**1.00**	-0.028^{NS}	0.604**	-0.478**	0.976**	-0.126^{NS}	0.135^{NS}	-0.260*	0.388**	0.035^{NS}	0.100^{NS}	0.192^{NS}	-0.233^{NS}
WMF	0.304*	-0.221^{NS}	0.403**	0.457**	0.448**	0.356**	0.410**	0.474**	-0.014^{NS}	**1.00**	-0.004^{NS}	0.500**	-0.022^{NS}	0.713**	-0.078^{NS}	0.346**	0.011^{NS}	-0.023^{NS}	-0.227^{NS}	0.196^{NS}	0.899**
NUMF	-0.145^{NS}	-0.124^{NS}	0.007^{NS}	0.066^{NS}	0.054^{NS}	-0.370**	-0.418**	-0.288*	0.706**	-0.021^{NS}	**1.00**	-0.102^{NS}	0.763**	-0.106^{NS}	0.139^{NS}	-0.188^{NS}	0.548**	-0.028^{NS}	0.048^{NS}	0.159^{NS}	-0.049^{NS}
WUMF	-0.058^{NS}	-0.476**	-0.026^{NS}	-0.088^{NS}	-0.096^{NS}	0.370**	0.672**	0.349**	-0.570**	0.505**	-0.144^{NS}	**1.00**	-0.414**	0.480**	0.080^{NS}	0.367**	0.046^{NS}	-0.200^{NS}	-0.268*	-0.055^{NS}	0.802**
TNFP	0.084^{NS}	0.159^{NS}	0.123^{NS}	0.161^{NS}	0.152^{NS}	-0.426**	-0.680**	-0.488**	0.985**	-0.015^{NS}	0.816**	-0.497**	**1.00**	-0.131^{NS}	0.146^{NS}	-0.260*	0.466**	0.019^{NS}	0.099^{NS}	0.198^{NS}	-0.201^{NS}
YFP	0.181^{NS}	-0.234^{NS}	0.393**	0.463**	0.450**	0.441**	0.486**	0.419**	-0.135^{NS}	0.733**	-0.159^{NS}	0.492**	-0.147^{NS}	**1.00**	-0.274*	0.418**	-0.072^{NS}	0.025^{NS}	-0.296*	-0.083^{NS}	0.710**
NLF	-0.338**	0.046^{NS}	-0.089^{NS}	-0.189^{NS}	-0.188^{NS}	-0.017^{NS}	-0.083^{NS}	-0.155^{NS}	0.256*	-0.083^{NS}	0.181^{NS}	0.083^{NS}	0.250*	-0.317**	**1.00**	-0.175^{NS}	0.036^{NS}	-0.101^{NS}	0.222^{NS}	-0.015^{NS}	-0.006^{NS}
FF	-0.158^{NS}	-0.315**	0.199^{NS}	0.270*	0.274*	0.720**	0.361**	0.569**	-0.406**	0.408**	-0.255*	0.436**	-0.392**	0.522**	-0.186^{NS}	**1.00**	-0.253*	-0.249*	0.023^{NS}	-0.186^{NS}	0.401**
SG	0.194^{NS}	-0.218^{NS}	-0.302*	-0.268*	-0.276*	-0.461**	-0.262*	-0.323**	0.507**	-0.005^{NS}	0.797**	0.048^{NS}	0.603**	-0.103^{NS}	0.068^{NS}	-0.383**	**1.00**	0.128^{NS}	-0.048^{NS}	0.433**	0.017^{NS}
TSS	0.563**	-0.166^{NS}	-0.076^{NS}	-0.200^{NS}	-0.200^{NS}	-0.312**	0.150^{NS}	-0.182^{NS}	0.049^{NS}	-0.037^{NS}	-0.090^{NS}	-0.255*	0.012^{NS}	0.024^{NS}	-0.149^{NS}	-0.497**	0.182^{NS}	**1.00**	-0.151^{NS}	0.079^{NS}	-0.117^{NS}
ASAD	-0.425**	0.063^{NS}	0.026^{NS}	-0.009^{NS}	-0.002^{NS}	-0.130^{NS}	-0.283*	0.037^{NS}	0.174^{NS}	-0.273*	0.110^{NS}	-0.316**	0.173^{NS}	-0.330**	0.252*	0.018^{NS}	-0.123^{NS}	-0.194^{NS}	**1.00**	0.156^{NS}	-0.281*
ACDY	0.027^{NS}	0.184^{NS}	-0.126^{NS}	-0.085^{NS}	-0.087^{NS}	-0.177^{NS}	-0.325**	0.196^{NS}	0.301*	0.208^{NS}	0.213^{NS}	-0.054^{NS}	0.295*	-0.104^{NS}	-0.021^{NS}	-0.186^{NS}	0.493**	0.090^{NS}	0.156^{NS}	**1.00**	0.103^{NS}
YFPH	0.180^{NS}	-0.380**	0.264*	0.266*	0.256*	0.418**	0.595**	0.485**	-0.287*	0.920**	-0.083^{NS}	0.818**	-0.251*	0.725**	-0.022^{NS}	0.485**	0.027^{NS}	-0.140^{NS}	-0.333**	0.116^{NS}	**1.00**

*significant at 5 % level of significance, **significant at 1 % level of significance;

PHT: Plant height (cm); **NB:** Number of branches per plant; **DFF:** Days to 50 % flowering; **DFPi:** Days to first picking; **DLPi:** Days to last picking; **PD:** Polar diameter (cm); **ED:** Equatorial diameter (cm); **PT:** Pericarp thickness (mm); **NMFP:** Number of marketable fruits per plant; **WMFP:** Weight of marketable fruits per plant (g); **NUMFP:** Number of unmarketable fruits per plant; **WUMFP:** Weight of unmarketable fruits per plant (g); **TNFP:** Total number of fruits per plant; **YFP:** Yield of fruits per plant (g); **YFPH:** Yield of fruits per hectare (q); **NLF:** Number of locules per fruits; **FF:** Fruit firmeess (kg/cm^2); **SG:** Specific gravity (g/cm^3); **TSS:** Total soluble solids (%); **ASAD:** Ascorbic acid (mg/100g); **ACDY:** Acidity (%)

Table 4.5: Types of correlations among different characters in tomato

Sr. No.	Characters	Positive correlation	Negative Correlation
1	**Plant height(cm)**	Weight of marketable fruits per plant, total soluble solids	Polar diameter, pericarp thickness, number of locules per fruit, ascorbic acid
2	**Number of branches per plant**	-	Polar diameter, equatorial diameter, pericarp thickness, weight of unmarketable fruits per plant, fruit firmness, yield of fruits per hectare
3	**Days to 50% flowering**	Days to first picking, days to last picking, pericarp thickness, weight of marketable fruits per plant, yield of fruits per plant, yield of fruits per hectare	Specific gravity
4	**Days to first picking**	Days to last picking, pericarp thickness, weight of marketable fruits per plant, yield of fruits per plant, fruit firmness, yield of fruits per hectare	Specific gravity
5	**Days to last picking**	Pericarp thickness, weight of marketable fruits per plant, yield of fruits per plant, fruit firmness, yield of fruits per hectare	Specific gravity
6	**Polar diameter (cm)**	Pericarp thickness, weight of marketable fruits per plant, weight of unmarketable fruits per plant, yield of fruits per plant, fruit firmness, yield of fruits per hectare	Number of marketable fruits per plant, number of unmarketable fruits per plant, total number of fruits per plant, specific gravity, total soluble solids
7	**Equatorial diameter (cm)**	Pericarp thickness, weight of marketable fruits per plant, weight of unmarketable fruits per plant, yield of fruits per plant, fruit firmness, yield of fruits per hectare	Number of marketable fruits per plant, number of unmarketable fruits per plant, total number of fruits per plant, specific gravity, ascorbic acid, acidity
8	**Pericarp thickness (mm)**	Weight of marketable fruits per plant, weight of unmarketable fruits per plant, yield of fruits per plant, fruit firmness, yield of fruits per hectare	Number of marketable fruits per plant, number of unmarketable fruits per plant, total number of fruits per plant, specific gravity
9	**Number of marketable fruits per plant**	Number of unmarketable fruits per plant, total number of fruits per plant, number of locules per fruit, specific gravity, acidity	Weight of unmarketable fruits per plant, fruit firmness, yield of fruits per hectare
10	**Weight of marketable fruits per plant (g)**	Weight of unmarketable fruits per plant, yield of fruits per plant, fruit firmness, yield of fruits per hectare	Ascorbic acid
11	**Number of unmarketable fruits per plant**	Total number of fruits per plant, specific gravity	Fruit firmness, polar diameter, equatorial diameter, pericarp thickness
12	**Weight of unmarketable fruits per plant (g)**	Yield of fruits per plant, fruit firmness, yield of fruits per hectare, polar diameter, equatorial diameter, pericarp thickness	Total number of fruits per plant, total soluble solids, ascorbic acid, number of branches per plant, number of marketable fruits per plant
13	**Total number of fruits per plant**	Number of locules per fruit, specific gravity, acidity, number of marketable	Fruit firmness, yield of fruits per hectare, polar diameter, equatorial

		fruits per plant, number of unmarketable fruits per plant	diameter, pericarp thickness, weight of unmarketable fruits per plant
14	**Yield of fruits per plant (g)**	Fruit firmness, yield of fruits per hectare, days to 50% flowering, days to first picking, days to last picking, polar diameter, equatorial diameter, pericarp thickness, weight of marketable fruits per plant, weight of unmarketable fruits per plant	Number of locules per fruit, ascorbic acid
15	**Yield of fruits per hectare (q)**	Days to 50% flowering, days to first picking, days to last picking, Polar diameter, equatorial diameter, pericarp thickness, weight of marketable fruits per plant, weight of unmarketable fruits per plant, yield of fruits per plant, fruit firmness	Number of branches per plant, number of marketable fruits per plant, total number of fruits per plant, ascorbic acid
16	**Number of locules per fruit**	Ascorbic acid, number of marketable fruits per plant, total number of fruits per plant	Plant height, yield of fruits per plant
17	**fruit firmness (kg/cm^2)**	Yield of fruits per hectare, days to first picking, days to last picking, polar diameter, equatorial diameter, pericarp thickness, weight of marketable fruits per plant, weight of unmarketable fruits per plant, yield of fruits per plant	Specific gravity, total soluble solids, number of branches per plant, number of marketable fruits per plant, number of unmarketable fruits per plant, total number of fruits per plant
18	**Specific gravity (g/cm^3)**	Acidity, number of marketable fruits per plant, number of unmarketable fruits per plant, total number of fruits per plant	Days to 50% flowering, days to first picking, days to last picking, polar diameter, equatorial diameter, pericarp thickness, fruit firmness
19	**Total Soluble Solids (%)**	Plant height	Polar diameter, weight of unmarketable fruits per plant, fruit firmness
20	**Ascorbic acid (mg/100g)**	Number of locules per fruit	Plant height, equatorial diameter, weight of marketable fruits per plant, weight of unmarketable fruits per plant, yield of fruits per plant
21	**Acidity (%)**	Number of marketable fruits per plant, total number of fruits per plant, specific gravity	Equatorial diameter

4.4 Path coefficient analysis

Path coefficient analysis is simply a standardized partial regression coefficient, which partitioning the genetic correlation coefficient into direct and indirect effects. Correlation coefficients along with path coefficients together provide more reliable information, which can be effectively utilized in crop improvement programme. The path coefficient analysis was carried out to know direct as well as indirect effects taking yield of fruits per hectare as a resulted variable and rest of the characters as causal variables were computed and the results have been presented in (Table 4.6).

4.4.1 Direct effects

A critical perusal of path coefficient analysis in which diagonal values are direct effects which revealed that total number of fruits per plant (1.376) had highest positive direct effects on yield of fruits per hectare followed by days to last picking (1.239), weight of marketable fruits per plant (0.651), weight of unmarketable fruits per plant (0.510), number of branches per plant (0.042) and plant height (0.032). The highest negative direct effect was reported for number of marketable fruits per plant (-1.147) followed by days to first picking (-1.203) and number of unmarketable fruits per plant (-0.254) as evaluated in (Table 4.6).

4.4.2 Indirect effects

Regarding indirect effects, it was observed that days to 50% flowering had positive indirect effect on yield of fruits per hectare mainly *via* days to last picking (1.257), weight of marketable fruits per plant (0.263) and total number of fruits per plant (0.169). It had high negative indirect effect *via* days to last picking (-1.219).

Days to first picking had positive indirect effect toward yield of fruits per hectare mainly *via* days to last picking (1.239), weight of marketable fruits per plant (0.298) and total number of fruits per plant (0.221). It had negative indirect effect *via* number of marketable fruits per plant (-0.197).

Similarly, equatorial diameter of fruit contributed to the yield of fruits per hectare mainly through its positive indirect effect via number of marketable fruits per plant (0.811) and weight of marketable fruits per plant (0.267). It had high negative indirect effect via total number of fruits per plant (-0.935)

Yield of fruit per plant had positive indirect effect on yield of fruits per hectare via days to last picking (0.557) and weight of marketable fruits per plant (0.477). It had negative indirect effect mainly via days to first picking (-0.557), total number of fruits per plant (-0.202).

Specific gravity, total soluble solids, acidity, ascorbic acid content of fruit had very less values for indirect effect in both positive and negative direction towards yield of fruits per hectare.

Based on path coefficients analysis concluded that total number of fruits per plant, days to last picking and weight of marketable fruits per plant are most promising traits which influences yield directly as well as indirectly.

4.5 Genetic divergence analysis

Un-weighted Pair Group Method using Arithmetic Averages (UPGMA) method of Hierarchical Cluster analysis was used with City Block distances to classify the 23 tomato genotypes for their genetic diversity on the basis of 17 yield and quality variables. Optimum number of clusters was determined using sum of squares index, Djk (Romesburg 1990). In agglomerative hierarchical clustering process, average linkage was kept the criterion for clustering. The 23 tomato genotypes were grouped into four clusters (Table 4.7 and Fig.1). Maximum numbers of genotypes were grouped in cluster II and III (seven genotypes each) followed by cluster I (six genotypes) and cluster IV (three genotypes) respectively. The intra and inter-cluster distances among four clusters are presented in (Table 4.8). The maximum inter cluster distance was observed between cluster I and IV (789.87) followed by cluster III and IV (558.70). The minimum inter cluster distance was observed in between II and III (228.84) followed by cluster I and III (240.66). The maximum intra cluster distance was observed in cluster IV (114.14) followed by cluster I (102.43).

The cluster mean in respect of 21 characters studied is presented in (Table 4.9). Genotype of cluster II showed highest mean for days to last picking (140.24), days to first picking (105.21), days to 50% flowering (48.71), fruit firmness (1.16 mg/100g), acidity (0.74 %) and polar diameter (4.84 cm) whereas lowest for number of locules per fruit (3.22), total soluble solids (4.32%) and ascorbic acid (24.10 mg/100g). Genotypes of cluster I showed highest mean for ascorbic acid (24.41 mg/100g) and number of branches per plant (5.27) whereas lowest for fruit firmness (0.83 kg/cm2), specific gravity (1.07 g/cm3), polar diameter (3.84 cm), equatorial diameter (4.12 cm), pericarp thickness (4.60 mm), days to 50% flowering (43.61), days to first picking (99.45), plant height (65.42 cm).

Table 4.6: Direct effects(Diagonal) and indirect effects (off diagonal) genotypic path coefficient of various traits with yield of tomato

Traits	PHT	NB	DFF	DFPi	DLPi	PD	ED	PT	NMFP	WMFP	NUMFP	WUMFP	TNFP	YFP	NLF	FF	SG	TSS	ASAD	ACDY	Genotypic correlation with yield
PHT	**0.032**	-0.001	0.005	0.225	-0.236	-0.009	0.001	0.000	-0.169	0.198	0.037	-0.030	0.115	0.001	-0.002	0.000	-0.004	0.022	-0.004	0.000	0.180^{NS}
NB	0.000	**0.042**	0.001	-0.121	0.123	-0.014	-0.003	0.000	-0.270	-0.144	0.031	-0.242	0.219	-0.001	0.000	0.000	0.005	-0.007	0.001	0.002	-0.380**
DFF	-0.004	-0.001	**-0.034**	-1.219	1.257	0.006	0.002	0.000	-0.164	0.263	-0.002	-0.013	0.169	0.002	-0.001	0.000	0.007	-0.003	0.000	-0.001	0.264*
DFPi	-0.006	0.004	-0.034	**-1.203**	1.239	0.006	0.001	0.000	-0.197	0.298	-0.017	-0.045	0.221	0.003	-0.001	0.000	0.006	-0.008	0.000	-0.001	0.266*
DLPi	-0.006	0.004	-0.034	-1.203	**1.239**	0.006	0.001	0.000	-0.189	0.292	-0.014	-0.049	0.209	0.003	-0.001	0.000	0.006	-0.008	0.000	-0.001	0.256*
PD	-0.009	-0.018	-0.006	-0.211	0.224	**0.033**	0.001	0.000	0.477	0.232	0.094	0.189	-0.586	0.003	0.000	0.001	0.010	-0.012	-0.001	-0.002	0.418**
ED	0.003	-0.016	-0.007	-0.125	0.126	0.004	**0.008**	0.000	0.811	0.267	0.106	0.342	-0.935	0.003	0.000	0.000	0.006	0.006	-0.003	-0.003	0.595**
PT	-0.011	-0.013	-0.013	-0.494	0.510	0.021	0.004	**0.001**	0.588	0.309	0.073	0.178	-0.671	0.002	-0.001	0.001	0.007	-0.007	0.000	0.002	0.485**
NMFP	0.005	0.010	-0.005	-0.207	0.204	-0.014	-0.005	0.000	**-1.147**	-0.009	-0.179	-0.291	1.355	-0.001	0.001	0.000	-0.011	0.002	0.002	0.003	-0.287*
WMFP	0.010	-0.009	-0.014	-0.550	0.555	0.012	0.003	0.000	0.016	**0.651**	0.005	0.258	-0.020	0.004	0.000	0.000	0.000	-0.001	-0.003	0.002	0.920**
NUMFP	-0.005	-0.005	0.000	-0.080	0.067	-0.012	-0.003	0.000	-0.809	-0.014	**-0.254**	-0.073	1.123	-0.001	0.001	0.000	-0.017	-0.004	0.001	0.002	-0.083^{NS}
WUMFP	-0.002	-0.020	0.001	0.106	-0.118	0.012	0.005	0.000	0.654	0.329	0.037	**0.510**	-0.684	0.003	0.000	0.000	-0.001	-0.010	-0.003	-0.001	0.818**
TNFP	0.003	0.007	-0.004	-0.193	0.188	-0.014	-0.005	0.000	-1.130	-0.010	-0.207	-0.253	**1.376**	-0.001	0.001	0.000	-0.013	0.000	0.002	0.003	-0.251*
YFP	0.006	-0.010	-0.013	-0.557	0.557	0.014	0.004	0.000	0.155	0.477	0.040	0.250	-0.202	**0.006**	-0.002	0.001	0.002	0.001	-0.003	-0.001	0.725**
NLF	-0.011	0.002	0.003	0.227	-0.233	-0.001	-0.001	0.000	-0.294	-0.054	-0.046	0.042	0.343	-0.002	**0.006**	0.000	-0.001	-0.006	0.002	0.000	-0.022^{NS}
FF	-0.005	-0.013	-0.007	-0.324	0.339	0.024	0.003	0.000	0.466	0.266	0.065	0.222	-0.540	0.003	-0.001	**0.001**	0.008	-0.019	0.000	-0.002	0.485**
SG	0.006	-0.009	0.010	0.322	-0.341	-0.015	-0.002	0.000	-0.581	-0.004	-0.202	0.025	0.830	-0.001	0.000	0.000	**-0.021**	0.007	-0.001	0.005	0.027^{NS}
TSS	0.018	-0.007	0.003	0.240	-0.247	-0.010	0.001	0.000	-0.057	-0.024	0.023	-0.130	0.017	0.000	-0.001	-0.001	-0.004	**0.039**	-0.002	0.001	-0.140^{NS}
ASAD	-0.014	0.003	-0.001	0.010	-0.002	-0.004	-0.002	0.000	-0.199	-0.178	-0.028	-0.161	0.238	-0.002	0.001	0.000	0.003	-0.008	**0.009**	0.001	-0.333**
ACDY	0.001	0.008	0.004	0.103	-0.108	-0.006	-0.003	0.000	-0.346	0.135	-0.054	-0.028	0.406	-0.001	0.000	0.000	-0.011	0.004	0.001	**0.009**	0.116^{NS}

*significant at 5 % level of significance, **significant at 1 % level of significance; Residual are (-0.01322)

PHT: Plant height (cm); **NB:** Number of branches per plant; **DFF:** Days to 50 % flowering; **DFPi:** Days to first picking; **DLPi:** Days to last picking; **PD:** Polar diameter (cm); **ED:** Equatorial diameter (cm); **PT:** Pericarp thickness (mm); **NMFP:** Number of marketable fruits per plant; **WMFP:** Weight of marketable fruits per plant (g); **NUMFP:** Number of unmarketable fruits per plant; **WUMFP:** Weight of unmarketable fruits per plant (g); **TNFP:** Total number of fruits per plant; **YFP:** Yield of fruits per plant (g); **YFPH:** Yield of fruits per hectare (q); **NLF:** Number of locules per fruits; **FF:** Fruit firmeess (kg/cm^2); **SG:** Specific gravity (g/cm^3); **TT:** Total soluble solids (%); **ASAD:** Ascorbic acid (mg/100g); **ACDY**: Acidity (%)

Table 4.7: Cluster membership and number of genotypes in each cluster of tomato

Cluster No.	Name of Genotypes	No. of Genotypes
1	DVRT-1, DVRT-3, P.H.S, Palam Pink, Sel-7, S-12	6
2	DVRT-2, DVRT-5, DVRT-6, DVRT-8, NT-8, Panjab Ratta, Panjab Upma	7
3	Arka Vikas, Panjab Chhuhara, Panjab Kesari, Pusa Ruby, Panjab Tropics, Pusa Uphar, Pusa Sadabhar (C)	7
4	Castle Rock, PNR-7, H-86	3
Total		**23**

Cluster III genotypes exhibited highest mean value for total number of fruits per plant (35.47), number of marketable fruits per plant (23.85 g) and specific gravity (1.13 g/cm3) whereas lowest for acidity (0.69 %). Genotypes belonging to cluster IV showed highest mean for yield of fruits per plant (1763.35 g), yield of fruits per hectare (587.78 g), plant height (94.63 cm), equatorial diameter (5.03 cm), pericarp thickness (6.14 mm) and total soluble solids (4.72 %) whereas lowest for number of branches per plant (4.33), number of marketable fruits per plant (16.37) and total number of fruits per plant (26.93).

Table: 4.8 Inter and intra – cluster distances in tomato

	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Cluster 1	**102.43**			
Cluster 2	464.207	**75.73**		
Cluster 3	240.664	228.842	**78.29**	
Cluster 4	789.866	333.825	558.704	**114.14**

Diagonal- Intra-cluster distances, Off-diagonal- Inter-cluster distances

Table 4.9: Cluster means for different characters in tomato

Characters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	General mean
PHT	65.419	69.095	90.158	94.629	79.83
NB	5.271	4.905	4.716	4.334	4.81
DFF	43.612	48.714	44.239	45.667	45.56
DFPi	99.446	105.207	100.271	100.222	101.29
DLPi	134.556	140.238	135.381	135.222	136.35
PD	3.844	4.844	4.153	4.604	4.36
ED	4.117	4.321	4.265	5.025	4.43
PT	4.598	6.022	4.902	6.141	5.42
NMF	20.651	21.788	23.851	16.370	20.67
WMF	845.955	1100.639	992.100	1222.069	1040.19
NUMF	11.372	11.914	11.615	10.564	11.37
WUMF	300.124	400.860	331.332	541.282	393.40
TNFP	32.024	33.701	35.467	26.933	32.03
YFP	1146.078	1501.499	1323.432	1763.351	1433.59
YFPH	382.024	500.494	441.139	587.776	477.86
NLF	3.596	3.224	4.009	4.128	3.74
FF	0.830	1.105	0.964	1.104	1.01
SG	1.073	1.118	1.134	1.086	1.10
TSS	4.643	4.319	4.652	4.722	4.58
ASAD	24.409	22.385	23.508	23.200	23.38
ACDY	0.689	0.738	0.690	0.712	0.71

PHT: Plant height (cm); **NB:** Number of branches per plant; **DF:** Days to 50 % flowering; **DFPi:** Days to first picking; **DLPi:** Days to last picking; **PD:** Polar diameter (cm); **ED:** Equatorial diameter (cm); **PT:** Pericarp thickness (mm); **NMFP:** Number of marketable fruits per plant: **WMFP:** Weight of marketable fruits per plant (g); **NUMFP:** Number of unmarketable fruits per plant; **WUMFP:** Weight of unmarketable fruits per plant (g); **TNFP:** Total number of fruits per plant; **YFP:** Yield of fruits per plant (g); **YFPH:** Yield of fruits per hectare (q); **NLF:** Number of locules per fruits; **FF:** Fruit firmeess (kg/cm^2); **SG:** Specific gravity (g/cm^3); **TT:** Total soluble solids (%); **ASAD:** Ascorbic acid (mg/100g); **ACDY:** Acidity (%)

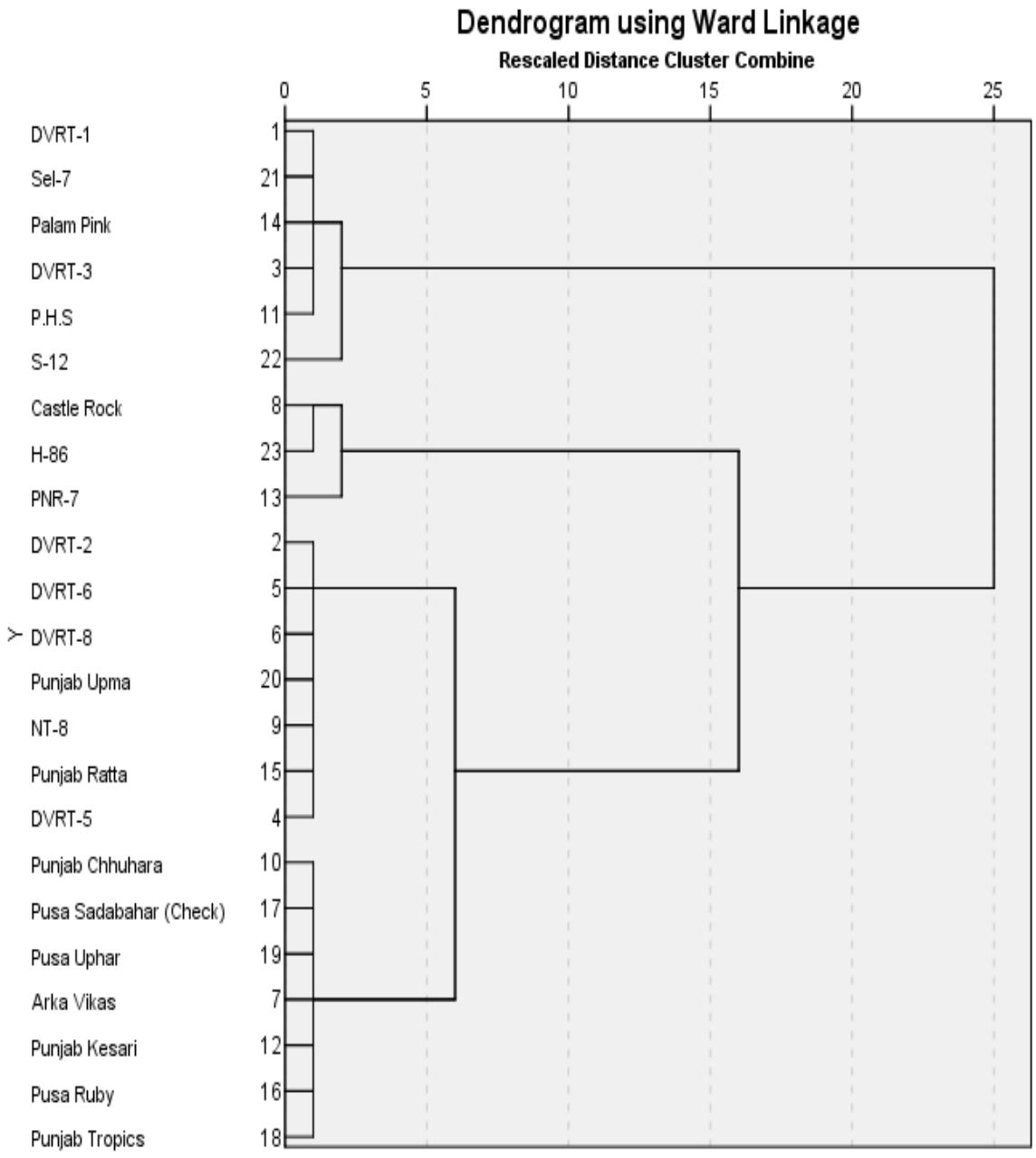

Figure 4.3: Dendrogram representing clustering pattern of 23 tomato genotype

CHAPTER - V

DISCUSSION

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

The silent facets of the results obtained from the present study are discussed in the light of the above consideration under the following heads:

5.1 Analysis of variance

5.2 Genetic parameters of variation

5.3 Correlation coefficient analysis

5.4 Path coefficient analysis

5.5 Hierarchical cluster analysis

5.1 Analysis of variance

The 23 tomato genotypes, evaluated during the present study, exhibited highly significant difference among the tested genotypes for all studied characters (Tabel 4.1). The significant variation among the genotypes indicates that presence of adequate variability which can be exploited through selection. In tomato, numerous studies were conducted in the past to judge the variability and our result are in agreement with Hidayatullah *et al*., (2008); Dar and Sharma (2011); Singh *et al.*, (2014); Meena *et al*., (2015); Chadha and Walia (2016) and Kumar *et al*., (2017).

5.2 Genetic parameters of variation

The estimates of genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability and genetic advance as percent of mean are very useful in determining the method of selection for the improvement of a particular trait in a population. From the results of present investigation (Table 4.3) it is clear that it is always not necessary for high heritability to be associated with high genetic advance. Phenotypic coefficient of variation (PCV) was always higher than the corresponding genotypic coefficient of variation (GCV) for all the traits denoting environmental factors influencing their expression to some degree or other on these traits. Denton and Nwangburuka (2011); Shankar *et al*., (2013) and Meitei *et al*., (2014) also observed higher PCV value than GCV value for all the traits. Wide difference between PCV and GCV for some of the traits implied that they are more susceptible to environment fluctuations than others. In present investigation high magnitude of GCV and PCV was observed for almost all traits. Similar results were also observed by Islam *et al.*, (2012); Rahaman *et al.*, (2012) and Vinod Kumar *et al.*, (2013).

The efficacy of selection for any character depends not only on the magnitude of variability present for the character but also on the extent to which it can be transferred from parents to the offspring *i.e*. heritability of the trait. Heritability estimates together with genetic advance is more important than heritability alone to predict the resulting effects of selection. In reality, heritability and genetic advance are two complementary aspects of crop improvement through selection. In the present investigation, high heritability coupled with high genetic advance as percent of mean and high GCV was observed for yield attributing traits. These results are in accordance with the findings of Kumari *et al.,* (2007); Saeed *et al.*, (2007); Sahanur *et* al., (2011); Madhurina and Paul (2012) and Tasisa *et al.*, (2012). It may be due to the presence of additive gene action for these characters and hence, simple selection would be the most appropriate breeding method for their improvement. Traits like plant height, number of marketable fruits per plant, fruit firmness, number of locules per fruit and polar diameter revealed high heritability associated with high genetic advance as percent of mean and moderate GCV indicated lesser variability but they can be improved through selection. Similar finding were also observed by Mehta and Asati (2008); Singh *et al.*, (2008); Dar and Sharma (2011); Mohamed *et al*., (2012) and Saleem *et al*., (2013). Low GCV coupled with low heritability and genetic advance were observed for days to first picking, days to last picking and ascorbic acid content indicated presence of non-additive gene action.

5.3 Correlation coefficient analysis

The yield is a complex trait that is controlled by a number of factors. Hence, the degree of association of these complex characters formed the basis for yield evaluations and correlation coefficient analysis measures the extent of closeness of the component traits. The phenotypic and genotypic correlation among the yield and yield components in tomato are depicted in (Table 4.4). Significant correlation of characters suggested that there is much scope for direct and indirect selection for further improvement. Genotypic correlation coefficient provides measures of genetic association between traits and thus helps to identify the more important as well as less important traits to be considered in breeding programs. Similar types of findings were also reported by Tiwari and Upadhyay (2011). In general, the estimate of genotypic correlation coefficient was higher than their corresponding phenotypic correlation coefficients. This can be interpreted as a strong inherent genotypic relationship between characters studied, through their phenotypic expression was impeded by environmental influence. The present findings are in conformity with Harer *et al.,* (2003); Golani *et al*., (2007); Islam *et al*., (2010) and Tasisa *et al*., (2012). The nature of genotypic correlation was similar to phenotypic correlation. However, in some cases correlation coefficients at genotypic level were significant, while at phenotypic level same were found to be non-significant (Kumari and Sharma, 2013).

Basically yield is the main character with which all other characters are positively or negatively correlated. In the present investigation, fruit yield per plant exhibited significant and positively correlated with fruit firmness, yield of fruits per hectare, days to 50% flowering, days to first picking, days to last picking, polar diameter, equatorial diameter, pericarp thickness, weight of marketable fruits per plant, weight of unmarketable fruits per plant at genotypic and phenotypic level, respectively, indicated that these traits are important for selection view point for getting high fruit yield in tomato. Similar results supported by the findings of Anjum *et al*., (2009); Kumari and Sharma (2013); Saleem *et al*., (2013) and Khapte and Jansirani (2014) for number of fruits per plant and fruit weight Dhankhar and Dhankar (2006); Hannan *et al*., (2007b) and Souza *et al*., (2012) for fruit number per plant Susic *et al*., (2002) for fruit weight.

Plant height showed significant and positive association with weight of marketable fruits per plant, total soluble solids at genotypic and phenotypic level, respectively. The results indicated that as the plant height increases all those characters would also increase. Similar kind of results were reported by Islam *et al*., (2010) for number of branches per plant and number of flowers per plant; Mahapatra *et al*., (2013) for number of branches per plant, number of flower clusters per plant and number of fruits per plant Ogwulumba and Ugwuoke (2013) for number of leaves per plant and number of fruits per plant. Plant height showed negative significant correlation with fruit weight and polar diameter of fruit, indicated that as the plant height increases, fruit weight and polar diameter of fruit would decrease. These results are in confirmation with the findings of Islam *et al*., (2010).

On the other hand total number of fruit per plant showed significant and positive association with number of locules per fruit, specific gravity, acidity, number of marketable fruits per plant, number of unmarketable fruits per plant. Similar types of findings were also reported by Islam *et al*., (2010) for number of fruits per plant and yield per plant. The result was also in full agreement with some earlier studies by Harer *et al*., (2003); Haydar *et al*., (2007) and Khapte and Jansirani (2014) for number of branches per plant Izge *et al*., (2012) for plant height.

Fruit weight showed significant and positive association both at genotypic and phenotypic level with yield of fruits per plant, fruit firmness, yield of fruits per hectare which indicated that as the fruit weight increases the fruit yield per plant would increase. The result was in line with findings of various investigators Prasad and Rai (1999) and Harer *et al*., (2003).

5.4 Path coefficient analysis

Path coefficient analysis provides an effective means of partitioning direct or indirect causes of association. As yield is influenced by many factors, selection based on correlation may be misleading because it measures only the mutual association between two variables, whereas path coefficient analysis specifically measures the relative importance of different

yield components. To find out the direct and indirect effects and to measure the relative importance of causal factors, path coefficient analysis is useful, which permits critical examination of the specific forces acting to produce a given correlation (Izge *et al*., 2012).

The results of the present investigation on path coefficient analysis as presented in (Table 4.6) revealed that total number of fruits per plant (1.376) had highest positive direct effects on yield of fruits per hectare followed by days to last picking (1.239), weight of marketable fruits per plant (0.651) and number of branches per plant (0.042). The results are in accordance with the finding of Ara *et al*., (2009); Ghosh *et al*., (2010) and Monamodi *et al*., (2013) and for fruit weight and number of fruits per plant; Indu Rani *et al*., (2010) for fruit weight; Mageswari *et al*., (1999) and Dhankar *et al*., (2001) for number of fruits per plant; Islam *et al*., (2010) for plant height, fruits per plant, fruit weight. On the other hand the traits, *viz.*, number of marketable fruits per plant (-1.147) and days to first picking (-1.203) had negative direct effect toward yield at the genotypic as well as phenotypic level. Anil Kumar *et al*., (2003) reported that based on the path coefficient analysis, selection should be based on more number of fruits with higher average fruit weight. Joshi *et al*., (2004) found that the number of fruits per plant is the most important yield contributing trait.

At both genotypic and phenotypic level days to 50% flowering had positive indirect effect on yield of fruits per hectare mainly *via* days to last picking (1.257), weight of marketable fruits per plant (0.263) and total number of fruits per plant (0.169). Similar findings have also been reported by Islam *et al*., (2010) for flowers per plant, branches per plant and fruits per plant; Saleem *et al*., (2013) for number of fruits per plant; Tiwari and Upadhyay (2011) for days to 50% flowering and number of branches per plant. Days to first picking had positive indirect effect toward yield of fruits per hectare mainly *via* days to last picking (1.239), weight of marketable fruits per plant (0.298) and total number of fruits per plant (0.221). Similar results were obtained by Tiwari and Upadhyay (2011) for fruit weight.

5.5 Hierarchical cluster analysis

To check the genetic divergence between these tomato genotypes, hierarchical cluster analysis was done using twenty-one traits which grouped these genotypes into four clusters (Table 4.7 and Fig.1). Maximum numbers of genotypes were grouped in cluster II and III (seven genotypes each). The intra and inter-cluster distances among four clusters are presented in (Table 4.8). The maximum inter cluster distance was observed between cluster I and IV (789.87) followed by cluster III and IV (558.70). The minimum inter cluster distance was observed in between II and III (228.84) followed by cluster I and III (240.66). The maximum intra cluster distance was observed in cluster IV (114.14) followed by cluster I (102.43). These results are in accordance with the findings of Mahesha *et al.*, (2006); Mehta and Asati (2008); Sekhar *et al.*, (2008); Rana and Singh (2010); Reddy *et al.*, (2013) and Nalla *et al*., (2014) in tomato.

CHAPTER-VI

SUMMARY AND CONCLUSION

The present investigation entitled "Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits" was conducted at Regional Research Station, Karnal and Laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during *rabi* season of 2016 and 2017. The objective of this study was to evaluate genetic variability among tomato genotypes for growth, yield and quality traits and to study character association among traits by correlation and path analysis.

Twenty-two genotypes of tomato along with one standard check was evaluated under Randomized Block Design in three replications. Observations were recorded for fourteen traits under field conditions and seven quality traits including pericarp thickness (mm), number of locules per fruit, fruit firmness (kg/cm^2), specific gravity (g/cm^3), total soluble solids (%), ascorbic acid (mg/100 g) and acidity (%) were estimated in laboratory. For all traits five plants were selected randomly from all three replications. Standard statistical programmes were used to analyze these data. The salient findings of the study and conclusions drawn from them are summarized below:

1. Significant genetic variability was present for all traits which were revealed by Analysis of variance. Maximum variability was recorded for yield of fruit per plant, weight of marketable fruit per plant and yield of fruits per hectare.
2. High GCV and PCV were recorded for all traits which showed variability both at genotypic and phenotypic level. Highest GCV was recorded for plant height (32.50%) followed by number of marketable fruits and fruit firmness (23.90%).
3. Highest PCV was recorded for plant height (32.88%) followed by number of marketable fruits per plant (28.62%).
4. Maximum heritability was recorded for weight of marketable fruits per plant (98.11%) followed by plant height (97.72%) and yield of fruit per hectare (97.04%). These traits can be utilized in selection programmes to improve yield.
5. Genetic advance was recorded for these traits. Maximum genetic advance was reported for plant height (66.19%) followed by polar diameter (42.45%) and fruit firmness (41.91%).
6. The yield of fruits per hectare had shown significant positive association with the weight of marketable fruits per plant, yield of fruits per plant, days to 50% flowering, days to first picking, days to last picking, polar diameter, equatorial diameter, fruit firmness and pericarp thickness.

7. Yield of fruit per hectare was negatively correlated with number of branches per plant, number of marketable fruits per plant, total number of fruits per plant and ascorbic acid. Highest significant correlation was found between the, weight of marketable fruits per plant followed by yield of fruits per plant.
8. The path coefficient analysis was carried out to know direct as well as indirect effects taking yield of fruits per hectare as a dependent variable.
9. Total number of fruits per plant (1.376) had highest positive direct effects on yield of fruits per hectare followed by days to last picking (1.239), weight of marketable fruits per plant (0.651), number of branches per plant (0.042) and plant height (0.032).
10. Days to 50% flowering had positive indirect effect on yield of fruits per hectare mainly *via* days to last picking (1.257), weight of marketable fruits per plant (0.263) and total number of fruits per plant (0.169).
11. Total number of fruits per plant, days to last picking and weight of marketable fruits per plant are most promising traits which influences yield directly as well as indirectly.
12. Unweighted Pair Group Method using Arithmetic Averages (UPGMA) method of Hierarchical Cluster analysis was used with City Block distances to classify these genotypes. Four clusters were formed based on their genetic diversity.
13. Maximum numbers of genotypes were grouped in cluster II and III (seven genotypes each) followed by cluster I (six genotypes) and cluster IV (three genotypes) respectively.
14. The maximum inter cluster distance was observed between cluster II and VIII (305.75) followed by cluster II and VI (254.64) and cluster II and IX (245.29) while, minimum inter cluster distance was observed in between IV and V (82.011) followed by cluster VI and IX (82.856).
15. The maximum intra cluster distance was observed in cluster I (59.73) followed by cluster IV (58.191) and cluster VI (57.269).

CONCLUSIONS

From the findings of the present investigation, it could be concluded that there is significant genetic variability among tomato genotypes which can be utilized in breeding programmes for further improvement. Traits like plant height, number of branches per plant, number of marketable fruits per plant, total number of fruits per plant *etc.* which are correlated with yield and showing high heritability can be used as selection criteria for genetic improvement. Similarly, for quality traits we can use fruit firmness, acidity (%) and specific gravity which are highly important quality parameters in tomato breeding.

BIBLIOGRAPHY

A.O.A.C. (1975). *Official Methods of Analysis*. Publication of the Association of Analytical Chemists, Washington DC, USA., 401-404 and 829-831.

Ahirwar, C.H., Bahadur, V. and Prakash, V. (2013). Genetic variability, heritability and correlation studies in tomato genotypes (*Lycopersicon esculentum* Mill.). *International Journal of Agricultural Sciences*, **9**(1): 172-176.

Akinfasoye, J., Dotun, A., Ogunniyan, J. and Ajayi, E.O. (2011). Phenotypic relationship among agronomic characters of commercial tomato (*Lycopersicum esculentum*) hybrids. *American-Eurasian Journal of Agronomy*, **4**(1): 17-22.

Al-Jibouri, H.A., Miller, P.A. and Robinson, H.F. (1958). Genotypic and environmental variances and co-variances in upland cotton crosses of inter specific origin. *Agronomy Journal*, **50**: 633-637.

Anjum, A., Narayan, R., Ahmed, N. and Khan, S.H. (2009). Genetic variability and selection parameters for yield and quality attributes in tomato. *Indian Journal of Horticulture*, 66: 73-78.

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

Bhati, V. (2017). Evaluation of tomato genotypes for growth, yield and quality traits under foothills condition of Nagaland, India. *International Journal of Current Microbiology and Applied Sciences*, **6**(3): 1645-1649.

Brar, G.S., Singh, S., Cheema, D.S. and Dhaliwal, M.S. (2000). Studies on variability heritability and genetic advance for yield and components characters in tomato. *Journal of Research, Punjab Agricultural University*, **37**(3/4): 190-193.

Burton, G.W. and Devane, E.H., 1953. Estimating heritability in tall fescue (*Festuca arundinancea*) from replicated clonal materials. *Agronomy Journal*, **45**: 478-481.

Chadha, S. and Walia, I. (2016). Genetic variability in bacterial wilt resistant F_3 progenies of tomato. *Journal of Hill Agriculture*, **7**: 187-190.

Dar, R.A. and Sharma, J.P. (2011). Genetic variability studies of yield and quality traits in tomato (*Solanum lycopersicum* L.). *International Journal of Plant Breeding and Genetics*, **5**: 168-174.

Dar, R.A., Sharma, J.P. and Ahmad, M. (2015). Genetic diversity among some productive genotypes of tomato (*Lycopersicon esculentum* Mill.). *African Journal of Biotechnology*, **14**(22): 1846-1853.

Depra, M.S., Delaqua, G.C., Freitas, L. and Cristina, M. (2014). Pollination deficit in open-field tomato crops (*Solanum lycopersicum L., solanaceae*) in rio de janeiro state, southeast Brazil. *Journal of Pollination Ecology*, **12**(1): 1-8.

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

Dhankar, S.K., Dhankhar, B.S. and Sharma, N.K. (2001). Correlation and path analysis in tomato under normal and high temperature conditions. *Haryana Journal of Horticultural Sciences*, **30**(1-2): 89-92.

Dhankhar, S.K. and Dhankar, S.S. (2006). Variability, heritability, correlation and path coefficient studies in tomato. *Haryana Journal of Horticultural Sciences*, **35**(1-2): 179-181.

Dhyani, S., Misra, A.C., Panday, V. and Sajwan, P. (2017). Evaluation of tomato (*Solanum lycopersicon* L.) hybrids for fruit yield characters in hill region of Uttarakhand, India. *International Journal of Current Microbiology and Applied Sciences,* **6**(9): 1622-1633.

Fischer, R.A. and Yates, F. (1963). Statistical Tables for Biological, Agricultural and Medical Research, Oliver and Boyd Edinburgh. pp. 55-57.

Ghosh, K.P., Islam, A.K.M.A., Mian, M.A.K. and Hossain, M.M. (2010). Variability and character association in F2 segregating population of different commercial hybrids of tomato (*Solanum lycopersicum* L.). *Journal of Applied Sciences and Environmental Management,* **14**(2): 91-95.

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

Goulden, C.H. (1954). Methods of statistical analysis. John Wiley and Sons. Inc., New York, 2nd Edition.

Hannan, M.M., Ahmed, M.B., Razvy, M.A., Karim, R., Khatun, M., Haydar, A., Hossain, M. and Roy, U.K. (2007). Heterosis and correlation of yield and yield components in tomato (*Lycopersicon esulentum* Mill.). *American-Eurasian Journal of Scientific Research*, ***2***(2): 146-150.

Hanson, C.H., Robinson, H.F. and Comstock, R.E. (1956). Biometrical studies of yield in segregating population of Korean Lespedeza. *Agronomy Journal,* **48**: 268-272.

Harer, P.N., Lad, D.B. and Bhor, T.J. (2003). Correlation and path analysis studies in tomato. *Journal of Maharashtra Agricultural Universities,* **27**(3): 302-303.

Haydar, A., Mandal, M.A., Ahmed, M.B., Hannan, M.M., Karim, R., Razvy, M.A., Roy, U.K. and Salahin, M. (2007). Studies on genetic variability and interrelationship among the different traits in tomato (*L. esculentum* Mill.). *Middle-East Journal of Scientific Research,* **2**(3-4): 139-142.

Hidayatullah, Shakeel, A.J., Abdul, G. and Tariq, M. (2008). Path coefficient analysis of yield component in tomato (*Lycopersicon esculentum*). *Pakistan Journal of Botany*, **40**(2): 627-635.

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

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

Islam, M.S., Mohanta, H.C., Rafii, M.Y. and Malek, M.A. (2012). Genetic variability and trait relationship in cherry tomato (*Solanum lycopersicum* L.). *Bangladesh Journal Botany*, **41**(2): 163-167.

Izge, A.U., Garba, Y.M. and Sodangi, I.A. (2012). Correlation and path coefficient analysis of tomato (*Lycopersicon lycopersicum* L. Karst) under fruit worm (*Heliothis Zea* Buddie) infestation in a line × tester. *Journal of Environmental Issues and Agriculture in Developing Countries,* **4**(1): 24-30.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd. New Delhi, pp. 183-192.

Jagdish, S., Mathura, R., Rajesh, K., Prasanna, H.C., Ajaya, V., Rai, G.K. and Singh, A.K. (2007). Genotypic variation and hirarchial clustering of tomato (*Lycopersicon esculentum* Mill.) based on morphological and biochemical traits. *Vegetable Science*, **34**(1): 44-45.

Jatav, P.K., Chikkeri, S.S., Kumar, N.M., Bharathkumar, M.V., Panghal, V.P.S. and Duhan, D. (2017). Performance of elite genotypes of tomato (*Solanum lycopersicum* Mill) for yield and quality traits under Hisar Condition, Haryana, India. *International Journal of Current Microbiology and Applied Sciences*, ***6***(8): 2698-2706.

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

Joshi, A. and Kohli, U.K. (2003). Genetic divergence for qualitative and quantitative traits in tomato (*Lycopersicon esculentum* Mill.). *Indian Journal of Agricultural Sciences*, **73**(2): 110-113.

Joshi, A., Vikram, A. and Thakur, M.C. (2004). Studies on genetic variability, correlation and path analysis of yieldand physic-chemical traits in tomato. *Progressive Horticulture*, **36**: 51-58.

Joshi, A. and Kohli, U.K. (2006). Combining ability and gene action studies for processing quality attributes in tomato (*Lycopersicon esculentum* Mill.). *Indian Journal of Horticulture*, **63**: 289-293.

Kalloo, G., Banerjee, M.K., Tewari, R.N. and Pachauri, D.C. (2001). Tomato. In: [Eds. S. Thamburaj, and N. Singh]. Textbook of vegetables, tuber crops and spices. Indian Council of Agricultural Research, New Delhi India, pp. 10-29.

Kaur, S., Jindal, S.K., Dhailwal, M.S., Chawla, N. and Meena, O.P. (2017). Genetic diversity analysis in elite lines of tomato (*Solanum lycopersicum* L.) for growth, yield and quality parameters. *Genetika*, **49**(1): 329-344.

Khanom, M.S.R., Khan, M.H.K. and Hassan, L. (2008). Variability, heritability and genetic advance for yield and yield contributing characters in tomato (*Lycopersicon esculentum* Mill.). *Progressive Agriculture*, **19**: 1-5.

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

Khapte, P.S. and Jansirani, P. (2014). Genetic variability and performance studies of tomato (*Solanum lycopersicum* L.) Genotypes for Fruit Quality and Yield. *Trends in Biosciences*, **7**: 1246-1248.

Kumar, A., V.R., Thakur, M.C. and Hedau, N.K. (2003). Correlation and path coefficient analysis in tomato. *Annals of Agricultural Research New Series*, **24**: 175-177.

Kumar, M. and Dudi, B.S. (2011). Research Note Study of correlation for yield and quality characters in tomato (Lycopersicon esculentum Mill.). *Electronic Journal of Plant Breeding*, **2**(3): 453-460.

Kumar, V., Nandan, R., Srivastava, K., Sharma, S.K., Kumar, R. and Kumar A. (2012). Genetic parameters and correlation study for yield and quality traits in tomato (*Lycopersicon esculentum* Mill.). *The Asian Journal of Horticulture*, **7**(2): 454-459.

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

Kumar, R., Srivastava, K., Singh, R.K. and Kumar, V. (2013). Heterosis for quality attributes in tomato (*Lycopersicon esculentum* Mill.). *Vegetos*, **26**(1): 101-106.

Kumar, M., Tanuja, B., Mohar, S.T. and Thakur, K.S. (2013). Genetic divergence and cluster analysis in tomato (*Solanum lycopersicum*). *Progressive Agriculture*, **13**(1): 114-117.

Kumar, P.P., Sathish, V., Ramesh, D., Bhutia, N.D., Koundinya, A.V.V., Hazra, P., Crops, V., Chandra, B., Viswavidyalaya, K., Bengal, W., Breeding, P., Chandra, B., Viswavidyalaya, K., Bengal, W., Statistics, A., Chandra, B., Viswavidyalaya, K. and Bengal, W. (2016). Assessment of genetic variability, correlation and path coefficients for yield components and quality traits in tomato. *International Journal of Agricultural Science*, **8**: 2870-2873.

Kumar, M., Yadav, R.K., K, Y.R., Behera, T.K. and Akshay, T. (2017). Estimates of genetic variability, heritability and genetic advance for yield and yield component traits in thermo tolerant tomato (*Solanum lycopersicum* L.) genotypes. *Inernational Journal of Agricultural Science*, **9**: 3640-3642.

Kumar, M. and Rana, M.K. (2018). Evaluation of tomato (Solanum lycopersicum L.) genotypes for yield and yield attributing characters in semi arid zone of Haryana (Hisar). *Journal of Pharmacognosy and Phytochemistry*, **7**(1): 1605-1608.

Kumari, N., Srivastava, J.P., Shekhavat, A.K.S., Yadav, J.R. and Singh, B. (2007). Genetic variability and heritability of various traits in tomato (*Lycopersicon esculentum* Mill.). *Progressive Agriculture*, **7** (½)**:** 80-83.

Kumari, S. and Sharma, M.K. (2013). Genetic variability studies in tomato (*Solanum lycopersicum* L.).*Vegetable Science*, **40**(1): 83-86.

Ligade, P.P., Bahadur, V. and Gudadinni, P. (2017). Study on genetic variability, heritability, genetic advance in tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences*, **6**(11): 1775-1783.

Madhurina, M. and Paul, A. (2012). Studies on genetic variability and characters association of fruit quality parameters in tomato. *Hort. Flora Research Spectrum*, **1**(2): 110-116.

Mageswari, K., Natarajan, S. and Thamburaj, S. (1999). Causal influence of component traits on yield in hybrids of tomato. *South Indian Horticulture*, **47**(1-6): 179-181.

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

Mahesha, D.K., Apte, U.B. and Jadhav, B.B. (2006). Studies on genetic divergence in tomato (*Lycopersicon esculentum* Mill.). *Crop Res*., **32**(3): 401-402.

Meena, O.P., Bahadur, V., Jagtap, A.B., Saini, P. and Meena, Y.K. (2015). Genetic variability studies of fruit yield and its traits among indeterminate tomato genotypes under open field condition. *African Journal of Agricultural Research*, **10**: 3170-3177.

Meena, R.K., Kumar, S., Meena, M.L. and Verma, S. (2018). Genetic variability, heritability and genetic advance for yield and quality attributes in tomato (Solanum lycopersicum L.). *Journal of Pharmacognosy and Phytochemistry*, **7**(1): 1937-1939.

Mehta, N. and Asati, B.S. (2008). Genetic relationship of growth and developeent traits with fruit yield in tomato (*Lycopersicon esculentum* Mill.). *Karnataka Journal of Agricultural Science*, **21**: 92-96.

Meitei, K.M., Bora, G.C., Senjam, J.S. and Anjan, K.S. (2014). Morphology based genetic variability analysis and identification of important characters for tomato (*Solanum lycopersicum* L.) crop

improvement. *American Eurasian Journal of Agricultural and Environmental Sciences*, **14(**10): 1105-1111.

Mohamed, S.M., Ali, E.E. and Mohamed, T.Y. (2012). Study of heritability and genetic variability among different plant and fruit characters of tomato (*Solanum lycopersicum* L.). *Int. J. of Sci. and Tech. Res*., **1**(2): 55-58.

Mohanty, B.K. (2002). Variability, heritability, correlation and path coefficient studies in tomato. *Haryana Journal of Horticultural Sciences,* **31**(3/4): 230-233.

Monamodi, E.L., Lungu, D.M. and Fite, G.L. (2013). Analysis of fruit yield and its components in determinate tomato (*Lycopersicon lycopersci*) using correlation and path coefficient. *Botswana Journal of Agriculture and Applied Sciences,* **9**(1): 29-40.

Nalla, M.K., Rana, M.K., Singh, S.J., Sinha, A.K., Reddy, P.K. and Mohapatra, P.P. (2014). Assessment of genetic diversity through D_2 analysis in tomato (*Solanum lycopersicum* L.*). International Journal of Innovation and Applied Studies*, **6**(3): 431-438.

NHB, 2nd advance estimate of area and production of horticultural crops, NHB Publication, Gurgaon, Haryana, 2016-17.

Olsen, S.R., Cole, C.V., Watanable, F.S. and Dean, C.A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. Circ. U.S.D.A., 939, Washington, D. C.

Ogwulumba, S.I. and Ugwuoke, K.I. (2013). Coefficient and path analyses of the impact of root galls caused byMeloidogyne javanica on some growth and yield parameters of tomato (*Solanum lycopersicum*).*International Journal of Plant and Soil Science*, **2**(2): 222-229.

Panse, V.G. and Sukhatme, P.V. (1967). Statistical methods for agricultural workers. ICAR, New Delhi.

Piper, C.S. (1966). Soil and water analysis. Published by Univ. Adelaide, Australia.

Prasad, V.S.R.K. and Rai, M. (1999). Genetic variation, component association and direct and indirect selections in some exotic tomato germplasm. *Indian Journal of Horticulture,* **56**(3): 262-266.

Radzevicius, A., Karkleliene, R., Viskelis, P., Bobinas, C., Bobinaite, R. and Sakalauskiene, S. (2009). Tomato (*Lycopersicon esculentum* Mill.) fruit quality and physiological parameters at different ripening stages of *Lithuanian* cultivars. *Agronomy Research*, **7**(2): 712-718.Rahaman, S., Lakshman, S. S. and Maitra, N. J. (2012). Genetic variability and heritability in tomato (*Lycopersicon esculentum* Mill.). *International J. Plant Sci.*, **7**(1): 58-62 .

Rai, A.K., Vikram A., Kumari S. and Gupta, M. (2017). Character association and path coefficient analysis for yield and quality traits in tomato (*Solanum lycopersicum* L.) under mid-hills of Himachal Pradesh. *Electronic Journal of Plant Breeding*, **8**(3): 922-926.

Rana, D.K. and Singh, R.V. (2010). Character linkage and genetic divergence in tomato genotypes. *Environment and Ecology*, **28**(1A): 476-479.

Reddy B.R., Begum, H., Sunil, N. and Reddy, M.P. (2013). Genetic divergence studies in exotic collections of tomato (*Solanum lycopersicum* L.). *International Journal of Agricultural Sciences*, **9**(2): 588-592.

Regassa, M.D., Mohammed, A. and Bantte, K. (2012). Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for yield and yield components. *African Journal of plant science and Biotechnology*, **6**: 45-49.

Richards, L.A. (1954). Diagnosis and improvement of saline and alkali soil. USDA Hand Book No. 60, Washington D.C.

Rick, C.M. and Holle, M. (1990). Andean *Lycopersicon esculentum* var. *cerasiformae*: genetic variation and evolutionary significance. *Economic Botany*, **43**: 69-78.

Robinson, H.F. (1966). Quantitative genetics in relation to breeding on centennial of Mendelism. *Indian Jounal of Genetics*. **26**: 171-187.

Romesburg, H.C. (1990). *Cluster Analysis for Researchers*. Krieger Publishing Co., Malabar, Florida.

Rukhsar, A.D., Sharma, J.P., Ambreen, N. and Chopra, S. (2012). Germplasm evaluation for yield and fruit quality traits in tomato (*Solanum Lycopersicon* L.). A*frican Journal of Agricultural Research,* **7**(46): 6143-6149.

Saeed, A., Kheizer, H., Khan, A.A., Iqbal, S. and Ghulam, A. (2007). Assessment of genetic variability and heritability in (*Lycopersicon esculentum* Mill.) *Int. J. Agri. Bio.*, **9**(2): 375-377.

Sahanur R., Lakshman, S.S. and Maitra, N.J. (2012). Genetic variability and heritability studies in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Plant Science.*, (Muzaffarnagar), **7**(1): 58-62.

Saini, R., Sidhu, A.S., Singh, D. and Kumar, A. (2013). Studies on genetic diversity in growth, yield and quality traits in tomato (*Lycopersicon esculentum* Mill.). *Journal of Horticultural Sciences,* **8**(1): 21-24.

Saleem, M.Y., Iqbal, Q. and Asghar, M. (2013). Genetic variability, heritability, character association and path analysis in F_1 Hybrids of tomato. *Pak. J. Agri. Sci.*, **50**(4): 649-653.

Sekhar, L., Prakash, B.G., Salimath, P.M., Sridevi, O. and Patil, A.A. (2008). Genetic diversity among some productive hybrids of tomato (*Lycopersicon esculentum* Mill.). *Karnataka Journal of Agricultural Science,* **21**(2): 264-265.

Shalaby, T.A. (2013). Mode of gene action, heterosis and inbreeding depression for yield and its components in tomato (*Solanum lycopersicum* L.). *Scientia Horticulturae*, **164**: 540-543.

Shankar, A., Reddy, R.V.S.K., Sujatha, M. and Pratap, M. (2013). Genetic variability studies in F1 generation of tomato (*Solanum lycopersicum* L.). *IOSR Journal of Agriculture and Veterinary Science*, **4**(5): 31-34.

Sharma, P., Sadhawi, Y.V. and Bhardwaj, N. (2013). Correlation and path-coefficient studies in tomato (*Solanum lycopersicum* L.) under protected environment. *Environment Ecology*, **31**(2B): 848-855.

Sherpa, P., Pandiarana, N., Shende, V.D., Tania, S., Subhra, M. and Arup, C. (2014). Estimation of genetic parameters and identification of selection indices in exotic tomato genotypes. *Electronic Journal of Plant Breeding*, ***5***(3): 552-562.

Singh, B.D. (2001). Plant breeding: Principles and methods. Kalyani Publishers, New Delhi, India, p. 896.

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

Singh, A.K., Sharma, J.P., Kumar, S. and Chopra, S. (2008). Genetic divergence in tomato (*Lycopersicon esculentum* Mill.). *Journal of Research*, **7**(1): 105-110.

Singh, V. and Rana, D.K. (2014). Naseeruddin, Kh. and Genetic variability of tomato genotypes for yield and other horticultural traits. *J. Hill. Agri.*, **5**: 186–189.

Sivasubramanium, J. and Madhavamenon, P. (1973). Genotypic and phenotypic variability in rice. *Madras Agric. J.*, **12**: 15-16.

Souza, L.M., Melo, P.C.T., Luders, R.R. and Melo, A.M.T. (2012). Correlations between yield and fruit quality characteristics of fresh market tomatoes. *Horticultura Brasileira*, **30:** 627-631.

Spaldon, S. and Hussain, S. (2017). Performance of Tomato (*Solanum Lycopersicum* L.) Genotypes for yield and quality traits under jammu subtropical condition. *International Journal of Agriculture Innovations and Research*, **6**(1): 2319-1473.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci.*, **25**: 259-260.

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

Tasisa, J., Belew, D. and Bantte, K. (2011). Variability, heritability and genetic advance in tomato (*Lycopersicon esculentum* Mill.). genotypes in West Shoa, Ethiopia, *American- Eurasian J. Agri. and Environ. Sci.*, **11**(1): 87- 94.

Tasisa, J., Belew, D. and Bantte, K. (2012). Genetic association analysis among some traits of tomato (*Lycopersicon esculentum* Mill.) genotypes in West Showa, Ethiopia. *International Journal of Plant Breeding and Genetics*, **6**(3): 129-139.

Tiwari, J.K. and Upadhyay, D. (2011). Correlation and path-coefficient studies in tomato (*Lycopersicon esculentum* Mill.). *Research Journal of Agricultural Sciences*, **2**(1): 63-68.

Walkley, A. and Black, I.A. (1934). An examination of method for determining organic carbon and nitrate in soils. *Soil Science*, **37**: 29-38.

Wright, S. (1921). Correlation of causation. *Journal of Agriculture Research*. **20:** 257-287.

Yadav A., Tandan N. and Singh R. (2017). Morphological based genetic variability analysis and clustering of tomato. *World Journal of Pharmaceutical and Medical Research*, **3**(6): 255-261.

ABSTRACT

Title of thesis	:	**"Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits"**
Full name of the degree holder	:	**Sunil Kumar**
Admission No.	:	2016A45M
Title of degree	:	M. Sc. (Ag.) in Horticulture (Vegetable Science)
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Degree awarding University/ Institute	:	CCS Haryana Agricultural University, Hisar, Haryana (India)
Year of award of degree	:	2018
Major subject	:	Vegetable Science
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Key words: Genetic variability, correlation, heritability, quality attributes

The present investigation entitled "Evaluation of tomato (*Lycopersicon esculentum* Mill.**)** genotypes for growth, yield and quality traits" with twenty-two genotypes along with one standard check was conducted at Regional Research Station, Karnal and Laboratory of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during *rabi* season of 2016-2017. The observations were recorded on 21 qualitative and quantitative traits. The objective of present investigation was to determine the genetic variability, estimation of character association between yield and its component traits by correlation and path analysis to determine the direct and indirect effect on dependent variable. The analysis of variance exhibited significant genotypic differences, showing considerable amount of genetic variability among different genotypes. The moderate PCV (15.16), GCV (14.93) and high genetic advance (30.30%) and high heritability (97.04%), observed for yield of fruits per hectare (q) was showing further scope of selection. Genotypes PNR-7, H-86, NT-8, Castle Rock, DVRT-2, DVRT-6, DVRT-8 and Punjab Upma were found promising for both yield and quality traits while genotypes P.H.S, Punjab Kesari, Punjab Upma and DVRT-3 were most promising for quality traits only. Yield of fruits per hectare (q) showed highly significantly and positive genotypic correlation with days to 50% flowering, days to first picking, days to last picking, polar diameter, equatorial diameter, pericarp thickness, weight of marketable fruits per plant, yield of fruits per plant and fruit firmness. The path coefficients analysis revealed that total number of fruits per plant, days to last picking and weight of marketable fruits per plant are most promising traits which influences yield directly as well as indirectly. Hierarchical cluster analysis indicated that crosses between the members of cluster separated by high inter cluster distances, are expected to produce desirable transgressive segregants.

MAJOR ADVISOR **SIGNATURE OF STUDENT**

HEAD OF THE DEPARTMENT

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i) Academic Qualification

Degree	Institution	Year of Passing	% age of marks	Subjects
M.Sc. (Vegetable Science)	CCS Haryana Agricultural University	2018	7.34/10	**Major**: Vegetable Science **Minor**: Genetics and Plant Breeding
B.Sc. (Hons.) Agriculture	CCS Haryana Agricultural University	2016	6.5/10	All Agricultural Subject

j) Achievements

- Awarded participation certificate of **NSS Pre-Republic Day Parade Camp** by Ministry of Skill Development, Entrepreneurship, Youth Affairs and Sports, New Delhi, Government of India.
- Participated in NSS **State Level Camp**-2014 held at CCS HAU (Hisar).
- Organized Inter College Youth Festival-2016 held at CCS HAU, Hisar as **Management Committee Member**.
- Participated in **North Zone Inter University Hockey** 2015 and 2017 held at JMI University New Delhi and GNDU Amritsar respectively.

k) Trainings attended at CCSHAU, Hisar:

- Basics Computer
- Industrial training at Center of Excellence for Vegetables, Gharaunda, Karnal
- Protected cultivation of horticultural crops.
- Post-harvest management of horticultural crops.
- Seed Production and Quality Assurance.

I hereby, declare that all the information provided in the resume is true to best of my knowledge

(Sunil Kumar)

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I, **Sunil Kumar**, Admission No., **2016A45M**, hereby undertake that I give the full copyrights of my thesis entitled **"Evaluation of tomato (*Lycopersicon esculentum* Mill.) genotypes for growth, yield and quality traits"** 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 with the competent authority of Chaudhary Charan Singh Haryana Agricultural University, Hisar.

SIGNATURE OF STUDENT