EVALUATION OF GENOTYPES AND DIVERGENCE STUDIES UNDER ECO-FRIENDLY MANAGEMENT IN TOMATO (*Solanum lycopersicum* L.)

By

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(J-16-M-450)

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Main Campus, Chatha, Jammu-180 009

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CERTIFICATE-I

This is to certify that the thesis entitled **"Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)".** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture Horticulture (Vegetable Science)** to the **Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu** is a record of bonafide research carried out by **Mr. Vijayakumar Chabbi,** Registration No. **J-16-M-450,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma. The help and assistance received during the course of investigation have been duly acknowledged.

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ABSTRACT

Title of the Thesis	:	**Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)**
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ABSTRACT

The present investigation entitled **"Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)"** was carried out at Experimental Farm, Division of Vegetable Science and Floriculture of SKUAST-J, Chatha, Jammu (India) during *rabi* 2017-18 using RCBD with 3 replications and 20 diverse genotypes under ecofriendly management as early transplanted crop. Pooled analysis of variance revealed highly significant differences among genotypes for all the characters *viz.,* days to 50 % flowering, plant height (cm), number of primary branches per plant, number of flowers per truss, number of fruits per cluster, number of fruits per plant, average fruit weight (g), fruit shape index, fruit yield per plant (kg) and per hectare (q), pericarp thickness (mm), number of locules per fruit, total soluble solids (°B), ascorbic acid (mg/100 g), leaf curl incidence (%), wilt incidence (%), nematode incidence (%) and fruit borer incidence (%) under ecofriendly protected structures.

The genotype, Arka Rakshak was found promising for yield, quality and yield contributing traits. High PCV and GCV were recorded for wilt incidence, fruit borer incidence, leaf curl incidence, plant height, number of fruits per truss, number of fruits per plant, yield per plant and yield per hectare. High heritability with high genetic gain was recorded for plant height, fruit yield per plant and number of fruits per plant. Hence, selection for these traits can prove effective for improvement in fruit yield. Fruit yield per plant had positive and highly significant correlation with number of fruits per plant, average fruit weight, fruit shape index and number of primary branches per plant, whereas negative and significant association was observed with ToLCV incidence, fruit borer incidence, ascorbic acid content, pericarp thickness and days to 50 % flowering. Maximum positive and direct effect towards fruit yield per plant was exerted by average fruit weight, number of fruits per plant, leaf curl incidence and plant height.

Mahalanobis D^2 clustering analysis grouped 20 genotypes in to 4 clusters namely, cluster I (Arka Abha, Arka Alok, DVRT-2, Palam Pride, Arka Sourabh, Arka Vikas, Palam Pink, KH-105, Selection-2, S-22, PKM-1), cluster II (Pusa Ruby, Hawaii-7998, Bhagya, CLN-2670-B1, CLN-2123-A1 Red), cluster III (Arka Rakshak, BSS-488, BWR-5) and cluster IV (Marglobe). The cluster II and cluster III had maximum inter cluster distances. The cluster II had maximum intra cluster distance. The genotypes falling in cluster III were superior for most of the yield, quality and yield attributing traits and can be used alone as the parents for crossing with genotypes of cluster II in hybrid development programme. The traits like fruit yield per plant, plant height, number of fruits per plant, average fruit weight, fruit borer incidence, leaf curl incidence and wilt incidence had major contribution (99.43%) towards genetic divergence. The genotypes namely Arka Rakshak, BSS-488, DVRT-2 and CLN-2123-A1 Red performed better for yield under both eco-friendly protected structures (EPS) and low cost protected structures (LPS). The genotypes Pusa Ruby, Arka Alok, CLN-2670-B1 and KH-105 performed relatively better for yield in LPS over EPS. It can be concluded that tomato can be raised under ecofriendly management as early crop using specific hybrid/ variety and affordable protected structures.

Key words: Tomato, genetic variability, heritability, divergence, D^2 clustering, eco-friendly and protected structures.

Signature of Major Advisor **Signature of the Student**

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INTRODUCTION

CHAPTER-1

INTRODUCTION

Tomato [*Solanum lycopersicum* L. (2n=2x= 24)] is widely grown vegetable crop in the world. It belongs to family Solanaceae and diversified first in Peru, Mexico where it domesticated from its ancestor, *S. lycopersicum* var, *cerasiforme*. Tomato has emerged as one of the most important vegetable crop in short history of over two centuries across the globe in climates ranging from tropics, subtropics to cold climatic regions of the world. Major tomato producing countries are China, India, USA, Turkey, Egypt, Iran and Italy. In India, tomato is grown over an area of 801 thousand hectares with an annual production of 22,337 thousand tonnes (Anonymous, 2017). Major tomato producing states include Andhra Pradesh, Madhya Pradesh, Karnataka, Telangana, Gujarat and Odisha. In Jammu & Kashmir, total area under this crop is reported to be 3.58 thousand hectares with annual production as 88.09 thousand tonnes (Anonymous, 2016).

Tomato can be distinguished into two types based on growth habit viz., determinate and indeterminate. The former has predetermined number of clusters, require relatively little care and are grown both for fresh consumption and processing while later are mainly grown for fresh consumption and rarely for processing. Tomato is normally grown for its edible fruit, which is consumed as fresh, cooked or in form of processed products like juice, ketchup, sauce, puree, chutney, pickles and soup *etc*. It is also considered as an important source of nutrients like vitamin A, C, E and minerals (Calcium, phosphorus and magnesium); and antioxidants (lycopene and β-carotene, phenols). Tomato also contains red colour pigment called lycopene (a carotenoid formed during ripening) and its presence in plasma has been related in reducing prostate cancer (Giovannucci *et al.,* 1999).

In J&K state, it is grown in plains, hills, mid hills and temperate (wet/dry) climates depending upon choice of variety. Growing period of crop coincides with harsh summer in plains during March-April and uneven rains during July-September in low/mid hill regions. During growing period biotic stress (diseases, insect- pests and

nematodes) and abiotic stress (temperature and drought) seriously reduces the yield. Productivity of tomato in the region is affected at times because of non-availability of high yield; diseases and insect-pest resistant varieties. There is a need to identify/develop tomato varieties and hybrids suitable for higher yield and quality both under open and protected conditions in various agro-ecological situations in different regions of the state.

Tomato represents model plant both for basic and applied research including ease of growth in wide range of environments, short life cycle and well developed genetic and genomic tools (Foolad, 2007). The variability is primary requirement for identification/ development of suitable varieties or hybrids for various horticultural traits. The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and environment. The genetic variance of quantitative traits is composed of additive variance (heritable); non-additive variance (non-heritable); dominance and epistasis (non-allelic interaction). Therefore, it becomes important to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as Phenotypic and Genotypic Coefficient of Variation (Burton and De Vane, 1953) besides heritability and genetic advance. Genetic advance can be used to predict the efficiency of selection (Allard, 1960).

Further, yield is a complex character controlled by a large number of contributing genes and their interactions. A study of correlation between different quantitative characters provides an idea of association that could be effectively exploited to formulate selection strategies for improving yield components (Dewey and Lu, 1959). For any effective selection programme, it would be desirable to consider the relative magnitude of association of various characters with yield. The path coefficient technique developed by Wright (1921) helps in estimating direct and indirect contribution of various components in building up the total correlation towards yield. On the basis of these studies the quantum importance of individual characters is marked to facilitate the selection programme for better gains.

Knowledge of genetic diversity and its nature and degree is useful for selecting desirable genotypes from germplasm for successful breeding programme. Diverse plants are also expected to give high hybrid vigour (Harrington, 1940).). Sustainable genetic

diversity management constitutes a basis for tomato crop improvement (Kulus, 2018). Heterosis for plant regeneration ability has also been reported in tomato (Bhushan and Gupta, 2017). D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude for divergence between two genotypes under comparison. It considers the variation produced by any character and their consequent effect that it bears on other characters. This technique has been applied in several crops to select genotypes for further breeding programmes. Grouping of genotypes based on D^2 analysis will be useful in choosing suitable parents for hybridisation. After development of varieties through selection, the hybrids have become common in tomato and new trend is towards transgenic varieties. Now tomato genome has been mapped and transgenic developed for facilitating tomato breeding.

It is common practice among the farmers to use inorganic fertilizers and heavy doses of chemicals for higher productivity in tomato. In past, these chemicals have caused much harm to human health and environment. Keeping in view these negative facts, the environmentally safe methods for organic production and plant protection are being developed. Organic amendments in soil (Neem /Brassica cake and biofertilizers), Pheromone traps and bioagents have often been used as safe measures. Biopesticides (*Trichoderma viridae*) also been used as both to seed and soil to develop eco-friendly strategy in tomato (Devi, 2013). Pests especially nematodes are serious problem both under open and protected conditions and are difficult to control with chemicals and safe measures.

There is little information on testing of genotypes or breeding varieties both for open and protected conditions especially under eco-friendly management in country. However, a very less work has been done for testing of genotypes or breeding varieties under normal or early planted tomato under eco-friendly management in J&K state. These developments necessitate germplasm collection and genetic divergence studies in planning the breeding program in tomato.

The selection of new genotypes for direct use as varieties or parents for hybrids/hybridization or transgenic program, is continuous process both for timely or early transplanted tomato under normal/ eco-friendly management conditions. Keeping in

view of the above facts and benefits of eco-friendly management, an experiment was conducted on evaluation of genotypes and divergence studies under eco-friendly management in tomato with the following objectives:

i. To screen early planted tomato genotypes for yield and quality traits; and reaction to major diseases/insect- pest under eco-friendly management

ii. To study genetic diversity in tomato under eco-friendly management

REVIEW OF LITERATURE

CHAPTER-2

REVIEW OF LITERATURE

In any vegetable breeding program there is need to select best plants within a variable population. Various biometrical procedures have been used for evaluation of varieties and hybrids. The literature available pertaining to the present investigation in respect of Genetic variability, Correlations, Path coefficient analysis, Divergence and Ecofriendly management has been reviewed and presented in this chapter under the following heads:

2.1 Genetic Variability Studies

2.2 Correlation Studies

2.3 Path Coefficient Analysis

2.4 Divergence Study

2.5 Eco-friendly Management

2.1 GENETIC VARIABILITY STUDIES

Tomato crop possess tremendous variability for morphological, physiological and yield contributing traits. The variability is basic requirement for success of the program.

Ghosh *et al.* (2010) observed very little differences between Phenotypic Coefficient of Variation (PCV) and Genotypic Coefficient of Variation (GCV) for days to first flowering, fruit length and fruit diameter in tomato. High heritability was observed for all the yield contributing characters except for flowers per cluster. High heritability associated with high genetic advance was found for fruit cluster per plant, fruits per plant, fruits per cluster, individual fruit weight and fruit yield per plant.

Sharma *et al.* (2010) observed high GCV and PCV in tomato for trait like average fruit weight followed by number of fruits per plant, fruit yield, number of locules per

plant, plant height, pericarp thickness and number of branches per plant, while it was moderate for days to 50% flowering. High heritability coupled with high genetic gain was observed for average fruit weight, number of fruits per plant, fruit yield, plant height, number of locules per fruit, pericarp thickness and number of branches per plant Days to 50% flowering had high heritability and moderate genetic gain.

Shashikant *et al.* (2010) reported high heritability coupled with high genetic advance in tomato for plant height, number of branches per plant, number of fruits per plant, average fruit weight, number of flowers per clusters, number of clusters per plant, fruit shape index, pericarp thickness and total soluble solids.

Dar and Sharma (2011) observed high PCV for yield per hectare, average fruit weight, number of fruits per plant whereas high GCV was recorded for β-carotene, ascorbic acid and lycopene content.

Kaushik *et al*. (2011) also reported GCV and GCV for number of leaves per plant, fruit length and fruit yield. High values of heritability coupled with high genetic advance were observed for number of leaves at 60 days after transplanting and fruit yield.

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

Ayush *et al.* (2012) reported significant differences among diverse tomato genotypes for yield and yield contributing traits. The PCV and GCV were highest for number of fruits per plant and lowest for harvest index. High heritability coupled with high genetic advance as percent over mean were observed for number of primary branches per plant, number of fruits per plant, number of fruits per cluster, average fruit weight and fruit yield per plant.

Khan and Samadia (2012) observed high GCV and PCV for fruit weight, number of fruits per plant, plant height and fruit yield per plant. High heritability with high

genetic advance as percentage of mean were observed for yield per plant, average fruit weight, number of fruits per plant and plant height indicating the role of additive gene effects and effectiveness of selection for these traits.

Rahaman *et al*. (2012) evaluated thirty four genotypes of tomato, and reported high PCV and GCV were high for fruit weight followed by fruit length and lowest for number of flowers per cluster. High heritability coupled with high genetic advance expressed was observed for primary branches, secondary branches, plant height, fruits per plant, fruit length, fruit diameter and fruit weight indicating that these traits were mainly governed by additive gene effect.

Ahirwar and Prashad (2013) evaluated nineteen tomato genotypes and reported PCV was higher than GCV for traits like plant height (120 DAT) , number of branches (120 DAT), days to flower anthesis, number of fruits per plant, average fruit weight, number of cluster per plant, fruit set, radial diameter, polar diameter, ascorbic acid and TSS.

Patel *et al*. (2013) observed high GCV and PCV for fruit yield per plant. Low GCV and PCV were noticed for days to first harvest and days to 50% flowering. High heritability and high genetic advance as percent of mean was observed for fruit yield per plant and average fruit weight.

Khapte and Jansirani (2014a) observed high heritability for 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 (TSS), average fruit weight, fruit firmness, number of fruits per plant and yield per plant.

Kumar (2014) reported high PCV and GCV for number of fruits per plant, fruit yield per plant, fruit yield per plot, fruit yield per hectare and plant height. High heritability coupled with high genetic gain were recorded for number of fruits per plant, plant height, average fruit weight and fruit yield per plant, fruit yield per plot and fruit yield per hectare. High heritability and moderate genetic gain were observed for number of fruits per cluster, harvest duration and ascorbic acid content.

Singh *et al.* (2014) revealed high GCV and PCV for number of cluster/plant, number of flower/plant, fruit weight/cluster and number of fruits/plant. Heritability in broad sense was high for plant height, number of leaves/plant, number of cluster/plant, number of flower/plant, number of locules and pericarp thickness. Genetic advance was maximum for number of cluster/plant followed by number of flower/plant, fruit weight/cluster and number of fruits/plant.

Rai (2015) reported high genetic variability for number of fruits per plant, average fruit weight, lycopene content and yield per plant and low genetic variability for days to first picking. High heritability and high genetic gain were recorded for number of fruits per plant, average fruit weight, lycopene content, locular wall thickness and yield per plant

Singh *et al.* (2015) reported high magnitude of GCV and PCV for fruit yield per plant, average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant and low for days to 50 percent flowering.

Singh *et al.* (2017a) revealed high magnitude of PCV and GCV for fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant. High heritability coupled with high genetic advance were estimated for fruit yield per plant followed by average fruit weight, number of locules per fruit, number of fruits per plant, plant height and number of primary branches per plant.

2.2 CORRELATION STUDIES

Correlation coefficient analysis is measure of mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Phenotypic correlation is observable correlation between variables and measures environment deviation together with non additive gene action. Genotypic correlation on other hand is inheriting association between two variables

Ara *et al.* (2009) in their correlation studies, revealed that the fruit yield per plant exhibited high positive significant correlation with fruit size, plant height, number of fruits per plant and number of primary branches per plant both at phenotypic as well as genotypic levels. Ghosh *et al* (2010) observed significantly positive Genotypic and Phenotypic correlation between fruit yield and morphological traits like plant height at first flowering, flowers per plant, fruits per cluster, fruit clusters per plant and fruits per plant.

Rani *et al.* (2010) observed positive and significant correlation of yield per plant with fruit weight, pericarp thickness, acidity, ascorbic acid and lycopene and significantly negative with number of fruits per plant. However, Kumar and Dudi (2011) reported only positive and significant correlation of total fruit yield/plant with number of fruits per plant, fruit weight and total sugar.

Buckseth *et al.* (2012) observed that fruit yield per plant had highly significant positive correlation with pericarp thickness, shelf life, TSS and fruit shape index. Number of fruits per plant had positive and significant correlation with yield per plant, and significantly negative with average fruit weight.

Khan and Samadia (2012) revealed that fruit yield had significant positive correlation with fruit weight, fruit length, fruit diameter and number of fruits per plant, both at the genotypic and phenotypic levels, indicating mutual association of these traits. Negative correlation of days to flowering and days to first harvest on yield per plant suggested indirect selection for earliness for yield improvement.

Shashikant *et al.* (2012) reported that fruit yield had a positive and highly significant association with number of fruits per plant and number of branches per plant. Strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield.

Ahirwar and Prashad (2013) studied genetic diversity among nineteen genotypes of tomato and observed that traits like plant height, number of branches, days to flower, number of fruits per plant, average fruit weight, number of cluster per plant, fruit set, radial and polar diameter, ascorbic acid and TSS showed positive correlation with fruit

yield per hectare. Plant height, days to 50% flowering, leaf curl incidence and intensity showed negative correlation at both Phenotypic and Genotypic levels.

Srivastava *et al.* (2013) observed highly significant and positive correlation of yield per plant with days to 50 percent flowering, days to 50 percent fruiting, plant height, number of primary branches per plant, number of fruits per cluster, number of fruits per plant and average fruit weight, indicating that yield could be increased by improving these traits.

Kumar (2014) reported significant positive Phenotypic and Genotypic correlation of fruit yield per plant was observed with plant height, number of fruits per plant, harvest duration, number of fruits per cluster, total soluble solids and average fruit weight.

Sherpa *et al.* (2014) revealed that genotypic correlations were higher in magnitude than phenotypic correlations in most of the characters. Three characters namely number of fruits per cluster, number of fruits per plant and fruit weight exhibited significant positive correlation with fruit yield per plant at genotypic and phenotypic levels.

Meena and Bahadur (2015) observed fruit yield was significantly and positively correlated with number of flowers per plant, number of fruits per plant and fruit weight at genotypic and phenotypic levels. Strong association of these traits revealed that the selection based on these traits would ultimately improve the fruit yield.

Prajapati *et al.* (2015) reported positive and significant correlation of fruit yield with average fruit weight, number of secondary branches per plant, days to fruit maturity, plant height, total soluble solids, days to 50 percent flowering and days to 50 percent fruit setting.

Rai (2015) observed that yield per plant was significantly and positively correlated with fruit weight, plant height, inter-nodal distance, pericarp thickness and locular wall thickness. Sharma and Singh (2012) reported that fruit yield was significantly and positively correlated with fruit weight per plant followed by days to 50 percent flowering.

2.3 PATH COEFFICIENT ANALYSIS

Ara *et al.* (2009) reported that days to first picking had the highest positive direct effect on fruit yield followed by harvest duration, number of fruits per plant, average fruit weight, plant height and number of flowers per cluster, maximum shelf life direct effect followed by average fruit weight and number of fruits per plant towards fruit yield was reported by Buckseth *et al.* (2012).

Kumar (2010) revealed that marketable fruits per plant had maximum direct effect on marketable yield per plant followed by average fruit weight and pericarp thickness. Kumar and Dudi (2011) also reported highest positive direct effect by number of fruits per plant, towards fruit yield in tomato.

Dar *et al.* (2011) reported highest positive direct effect of fruit yield per plant on yield per hectare, followed by average fruit weight, number of fruits per plant, lycopene content per fruit and ascorbic acid. Ghosh *et al.* (2010) also reported highest positive direct effect of number of fruits per plant on fruit yield per plant.

Tiwari and Uphadhyay (2011) reported fruit weight influenced the fruit yield per plant with high direct effect and therefore, may be included in selection criteria for improvement in fruit yield per plant.

Sharma and Singh (2012) reported that fruit weight per plant had maximum direct effect on fruit yield, followed by number of fruits per plant and flower clusters per plant. Seed vigour index had maximum direct effect on seed yield. Shashikanth *et al.* (2012) also reported highest positive direct effect of number flowers per cluster and number of branches per plant on fruit yield.

Kumar *et al.* (2013a) observed positive direct effect of fruit weight on yield per plant followed by number of fruits per plant, fruit diameter and number of fruits per cluster. Direct selection on the basis of these characters is reliable for yield improvement in tomato.

Reddy *et al.* (2013b) reported high positive direct effects of plant height, number of fruits per plant, fruit length, fruit width and ascorbic acid on fruit yield per plant. Rani

et al (2010) reported that fruit weight had the highest positive direct effect on yield per plant.

Srivastava *et al.* (2013) observed average fruit weight showed the highest positive direct effect on yield per plant followed by number of fruits per plant, day to 50% flowering, number of primary branches per plant and number of fruits per cluster. Direct selection for these traits might be effective and there is a possibility of improving yield per plant.

Kumar (2014) observed that maximum positive direct effect towards fruit yield per plant was contributed by number of fruits per plant followed by harvest duration and average fruit weight. The maximum negative direct effect towards yield was by days to marketable maturity. However, Sherpa *et al.* (2014) revealed that number of flower clusters per plant, number of fruits per cluster and fruit weight had high positive direct effect on fruit yield per plant.

Meena and Bahadur (2015) reported high positive direct effect of fruit weight on fruit yield per plant followed by number of flowers per plant, fruit set per cent, number of fruits per plant, total soluble solids, plant height, radial diameter of fruit, leaf curl incidence and days to 50 percent flowering.

Prajapati *et al.* (2015) revealed that fruit weight had high estimate of positive direct effect on fruit yield followed by number of fruits per plant, number of fruiting clusters per plant, days to first flowering, days to fruit maturity, pericarp thickness, number of primary branches, number of flowers per cluster and fruit diameter and suggested direct selection based on these traits will be effective for improvement in tomato.

Rahaman *et al.* (2015) revealed that number of fruits per cluster had the highest positive direct effect on fruit yield per plant in tomato. Rai (2015) reported that average fruit weight followed by number of fruits per plant have maximum positive direct effect towards fruit yield per plant.

2.4 DIVERGENCE STUDIES

For identifying better parents, several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives. The review of literature pertaining to genetic divergence is as follow:

Basavaraj *et al.* (2010) studied genetic diversity in 30 genotypes of tomato and grouped them into ten diverse clusters. Cluster I had 17 genotypes followed by cluster II (3), cluster IV (2) and remaining clusters (III, VI, VII, VIII, IX and X) were solitary ones. Cluster I recorded a maximum intra cluster distance (16.22). Maximum inter cluster distance (67.68) was between VIII and X indicating high diversity among the genotypes, whereas it was minimum (18.55) between cluster III and VI.

Kumar *et al.* (2010) grouped forty-nine genotypes of tomato into ten clusters by Toucher's method. Cluster I contained highest number of genotypes (13) followed by cluster VII (8), cluster III (7) and cluster IV (7). Cluster IX and X consisted of one genotype each. The intra cluster distance was highest in cluster IV having large, round, red fruits with good yield potential followed by Cluster VI and cluster VIII. Cluster mean analysis indicated cluster II, IV, V and IX accommodated tall genotypes while clusters II, V and X were characterized by higher number of fruits per plant.

Kumar *et al.* (2013b) studied genetic divergence in forty genotypes of tomato using Mahalanobis D^2 statistics. High level of genetic diversity was observed among the genotypes and was grouped into four clusters. Cluster III was the largest containing 17 genotypes followed by cluster I (11). Maximum inter-cluster distance was observed between cluster III and IV. Clustering pattern indicated that the geographic distribution need not necessarily be related to genetic diversity.

Khapte and Jansirani (2014b) grouped tomato genotypes into eight clusters based on yield contributing traits. Maximum intra cluster distance was recorded in cluster VIII followed by cluster VII, cluster V and Cluster VI which revealed the existence of considerable genetic divergence among the genotypes of the respective clusters. The highest inter cluster distance of was observed between cluster V and VIII, followed by

cluster V and VII and cluster III and V, revealing enormous diversity among genotypes belonging to respective pairs of the clusters.

Meena and Bahadur (2013) grouped various genotypes of tomato into six clusters based on D^2 values. Intra-cluster distance was maximum for cluster V (10192.68) and minimum for cluster III (0). Maximum inter-cluster distance was between cluster III and cluster VI (47922.37) followed by clusters I and VI (44098.14) which may serve as a potential genotypes for hybridization program. Genotypes of the cluster III had highest mean yield per plant along with minimum leaf curl incidence percent and can be utilized as donor parent for enhancing the yield and minimum leaf curl incidence percent.

Nalla *et al.* (2014) studied genetic diversity for quantitative and qualitative traits in 27 tomato genotypes which were grouped into nine clusters, indicating the presence of diversity for different traits. Cluster I had the highest number genotypes (16) followed by cluster III (3) and VII (2). However, cluster II, IV, V, VI, VIII and IX were solitary. The maximum intra-cluster distance was recorded in cluster III and maximum inter cluster distance was between cluster VI and VII, indicating the existence of wide genetic diversity among the genotypes of respective clusters.

Pedapati *et al.* (2014) grouped 50 genotypes of tomato into nine clusters based on Tocher's method. Mahalanobis D^2 statistics revealed considerable genetic diversity within and among nine clusters. Considering the mean performance, eleven genotypes for fruit yield from clusters I, II, III and IX, eight genotypes for earliness from II, III, IV, VI, VIII and IX clusters, nine genotypes for root length from I, II, III IV and VII clusters and seven genotypes for RDW/SDW from I, III and VIII clusters were superior and they can be used for future breeding programmes.

Srivatsava *et al*. (2014) observed differences in thirty tomato genotypes and grouped them into ten different clusters using Tocher's method. Cluster I had many genotypes (16), III (3) and X (2) were having genotypes, rest of the seven clusters having single genotype each. Highest inter-cluster distance was found between clusters IV and X whereas, lowest distance was observed between cluster VI and VIII. The maximum contribution towards divergence was accounted by plant height, seed index and yield per

plant followed by fruits per plant, juice-pulp ratio, pericarp thickness and flowers per cluster.

Rathod *et al.* (2015) observed considerable genetic diversity among 43 genotypes of tomato for all the twenty characters. Seven clusters were framed from the Mahalanobis D^2 analysis using Tocher's method. Cluster I topped with maximum number of genotypes, while maximum inter-cluster distance was observed between cluster III and VI followed by cluster V and VI.

Spaldon and Kumar (2017) reported significant genetic diversity in 25 tomato genotypes and grouped them into six clusters based on D^2 values. Cluster VI was the largest containing 9 genotypes followed by cluster I, II and IV containing four genotypes each. Cluster III and cluster V had minimum number of genotypes *ie.,* two in each cluster. The intra-cluster distance was maximum in cluster III (3.69) consisting of 2 genotypes namely Lehar & US-3383. The maximum distance at inter-cluster level was between cluster II and cluster VI (11.48) followed by clusters III and VI (9.83) indicating that the genotypes in these groups can be used for heterosis and recombinant breeding programme which may serve as potential genotypes for hybridization programme.

2.5 ECO-FRIENDLY MANAGEMENT

Baldin *et al.* (2007) studied interaction between resistant tomato genotypes and plant extracts against Whitefly (*Bemisia tabaci).* Extracts of *Azadirachta indica* seeds and *Trichilia pallida* leaves and branches reduced the pest attraction and oviposition in tomato. The "genotype × extract" interaction was significant, indicating an additive effect between resistant genotypes and plant extracts on whitefly control.

Cristophore *et al.* (2010) revealed that application of *Trichoderma harizanum*as seed treatment @ 4mg Kg^{-1} plus soil @ 10 kg ha^{-1} showed the minimum wilt incidence. It also recorded the maximum fruit yield and rhizosphere survival of *Trichoderma harzianum* which was significantly superior over other treatments.

Hassan *et al.* (2010) studied efficacy of three organic wastes, namely refuse dump, rice husk and sawdust, for the management of root knot nematodes (*Meloidogyne*

spp) in tomato. Refuse dump treatment gave significantly highest reduction in the nematode population compared to non amended treatment. It resulted in a significant increase in the yield of tomato (17–100%) for refuse dump, (13–84%) for saw dust and (21–63%) for rice husk.

Polat *et al*. (2010) reported that organic fertilization results in improved yield and fruit quality compared to conventional fertilization. Singh *et al.* (2010) reported application of vermicompost together with NPK fertilizer increased plant height, leaf area, leaf weight, fruit weight, fruit yield, fruit density, post harvest life and TSS of tomato. Application of vermicompost alone too increased shelf-life by 250% and TSS beyond 4.5%.

Hooda *et al.* (2011) reported that treatment of tomato seeds with extracts of *Lantana camara*, neem cake and cow urine can be effectively utilized as a cost effective and eco-friendly method for the management of damping-off of tomato in organic farming and remote areas of hills where pesticides availability is meager.

Chourasia *et al.* (2013) studied effect of botanicals against early blight of tomato. Neem leaf extract was the most effective where as garlic bulb extract and eucalyptus leaf extracts were also found to be significantly effective in comparison to control.

Jogani (2014) studied different application methods of *Trichoderma harzianum* (Rifai) against *Fusarium* wilt of tomato, and revealed that among all the treatment combinations, FYM + *T. harzianum* @ 50g/kg (SA) + carbendazim @ 2g/kg (ST) as best method to control the disease (up to 86.60%).

Dhal *et al.* (2017) revealed that removal of infected lower leaves, staking of tomato plants and seed priming with *Trichoderma viride* followed by foliar spraying with *Trichoderma viride* and *Pseudomonas fluoroscens* recorded reduced early blight incidence by 93.4% and 88.8% respectively over control and also gave maximum fruit yield of 328.4q/ha and 324.9q/ha respectively.

Gul *et al.* (2017) reported that *rhizobacteria* suppressed disease symptoms of *Fusarium oxysporum f. sp. radicis-lycopersici* and significant increase in growth of tomato seedlings, among *Pseudomonas fluorescens* and *P. putida* found more effective.

MATERIALS AND METHODS

CHAPTER-3

MATERIALS AND METHODS

The present investigation titled "Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)" was carried out at the Experimental farm of the Division of Vegetable Science and Floriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu, Chatha, during *rabi* 2017-18. The materials used and methods followed during the investigation have been discussed as under:

3.1 Experimental Site

3.1.1 Location

The Experimental Farm of the Division of Vegetable Science and Floriculture, is located at an altitude of about 332 m above mean sea level, lying between $32^0$40'N latitude and 74^0 58' E. It falls under the plains of Jammu & Kashmir.

3.1.2 Climate

Agro climatically the location represents Zone V of Jammu and Kashmir. It is characterized by subtropical climate. The Jammu plains and low hills including experimental location normally experience hot dry summer, hot and humid rainy season and cold winter months. The maximum temperature goes up to 45˚C during summers (May to June) and minimum temperature falls to 1˚C during winters. The mean annual rainfall is about 1000-1200 mm. The meteorological data pertaining to the period of crop season in 2017-18 is given in Appendix-I.

3.1.3 Soil

The soil structure of the experimental farm was loamy to clay loam with pH ranging from 6.85-7.04.

3.2 Experimental Material

Experimental material comprised of twenty genotypes of tomato representing diverse sources. The genotypes along with their source shave been presented in Table.1.

Table.1: List of tomato genotypes used for present study along with their source.

Sl.no.	Genotype	Source	Growth habit
1.	PKM-1	TNAU, Coimbatore	Determinate
2.	Arka Abha	IIHR, Bengaluru	Semi-determinate
3.	Arka Alok	IIHR, Bengaluru	Indeterminate
4.	Arka Sourabh	IIHR, Bengaluru	Semi-determinate
5.	Arka Vikas	IIHR, Bengaluru	Indeterminate
6.	Pusa Ruby	Durga seeds co.	Indeterminate
7.	Palam Pink	CSKHPKV	Indeterminate
8.	Hawaii-7998	CSKHPKV	Indeterminate
9.	BWR-5	CSKHPKV	Determinate
10.	CLN-2670- B1	CSKHPKV	Indeterminate
11.	Palam Pride	CSKHPKV	Indeterminate
12.	CLN-2123-A1 Red	CSKHPKV	Indeterminate
13.	DVRT-2	SKUAST-J, Chatha	Determinate
14.	KH-105	Khan hybrid seeds co.	Indeterminate
15.	Marglobe	IARI, New Delhi	Indeterminate
16.	BSS-48	AICRVIP	Indeterminate
17.	Bhagya	AICRVIP	Indeterminate
18.	Arka Rakshak	IIHR,Bengaluru	Indeterminate
19.	Selection-2	AICRVIP	Determinate
20.	S-22	Local selection	Determinate

3.3 Experimental Layout

3.3.1 Material used

The experimental material comprised of twenty diverse genotypes of tomato obtained from various sources and representing determinate, indeterminate and semi-determinate groups. For ecofriendly management, soil amendment was done FYM, vermicompost, mustard cake while bio-pesticides namely, *Trichoderma viridae* and *Psuedomonas* obtained locally were used for control of pests. Protected structures

comprised paddy straw obtained locally and polythene sheet. Neem oil and crude chrysanthemum leaf extract was used along with Pheromone traps.

3.3.2 Nursery sowing and transplanting

The seeds were sown on 7th September of 2017 in lines 3-4 cm apart and 1 cm deep on raised nursery beds of size 3m x 1m x 0.15 m at the experimental farm of the Division. Healthy seedlings were transplanted in first week of October 2017 in Randomized Block Design with three replications.

3.3.3 Eco-friendly management practices

The individual tomato plants in early stages (December to January), were covered with paddy straw as protected cover to protect crop against cold and frost otherwise grown on open field with preceding crop marigold while keeping SE side open. Ecofriendly measures were adopted as per previous work by group (Dar, 2011). A uniform dose of bio-pesticides namely, *T. viridae* and *Psuedomonas* @1kg/1t was mixed with well decomposed FYM at least a fortnight before transplanting. This mixture was applied in the field @ 10t/ha at the time of transplanting along with vermicompost @ 5tn/ ha and Mustard cake @ 2t/ ha. Other intercultural operations were carried out in accordance with the Package and practices of tomato crop.

3.3.4 After care

First irrigation was given immediately after transplanting and thereafter as per need to keep the field under proper moisture condition. The experimental plots were kept free of weeds by regular hand weeding. To control the pests and diseases, neem oil and crude chrysanthemum leaf extract was used both at concentration 3% along with Pheromone traps 10 no.s/ha.

3.4 Observations Recorded

Observations were recorded on various morphological/yield contributing, flowering, fruit set and biochemical traits on three randomly selected plants from each genotype in each replication and means were worked out for statistical analysis as per

method given by Panse and Sukhatme (1967). The procedures of recording observations on different traits are given in respective sub-heads:

3.4.1 Plant height (cm)

Plant height of randomly selected plants was measured from the ground level to the highest tip of the plant, the average was worked out and plant height was expressed in centimeters.

3.4.2 Days to 50 percent flowering

Number of days from the date of transplanting to the date when at least 50 % of plants flowered were counted and mean values worked out to estimate the earliness of the genotype.

3.4.3 Number of primary branches per plant

In the randomly selected and already tagged plants the number of primary branches per plant was counted after last picking and mean was taken.

3.4.4 Number of flowers per cluster

Numbers of flower per cluster in selected plants were counted and average worked out.

3.4.5 Number of fruits per cluster

Numbers of fruits per cluster in randomly selected and already tagged plants were counted and average worked out.

3.4.6 Number of fruits per plant

Total number of healthy fruits picked at each harvest from selected and tagged plants were added and averaged to work out mean number of fruits per plant.

3.4.7 Average fruit weight (g)

Twenty randomly selected fruits were weighed and averaged to obtain average fruit weight.

3.4.8 Fruit shape index

Polar and equatorial diameter often randomly picked fruits was measured with digital Vernier Caliper. Ratio of polar diameter to equatorial diameter was worked out to calculate fruit shape index. Fruit shape index was calculated by as per the scale given by Roy and Choudhary (1972).

$$\text{Fruit Shape Index} = \frac{\text{Polar diameter}}{\text{Equatorial diameter}}$$

Sl.No.	$\frac{\text{Polar diameter}}{\text{Equatorial diameter}}$	Shape
1.	≥ 1.00	Oval
2.	0.86-0.99	Spherical
3.	0.71-0.85	Intermediate
4.	≤ 0.70	Flat

3.4.9 Fruit yield per plant (Kg)

The picking of marketable fruits was made at half ripe stage. Yield was recorded at every picking in grams and added up for all the picking to arrive at the total yield per plant.

3.4.10 Fruit yield per hectare (q)

On the basis of fruit yield per plant, yield in quintals per hectare was calculated.

3.4.11 Pericarp thickness (mm)

Mean value of pericarp thickness of five randomly picked fruits was worked out after cutting the fruits transversely. Measurement was taken with digital Vernier Calliper in millimetres.

3.4.12 Number of locules per fruit

Locule numbers were counted by cutting a transverse section of the fruit. Average of ten fruits was calculated.

3.4.13 Total soluble solids (°B)

Ten ripe fruits were crushed and their juice passed through a double layer of fine mesh cheese cloth. A drop of juice was placed on the plate of Hand refractometer (0-32 ^{0}B, ERMA, JAPAN) and the reading noted. A mean of ten readings was taken in every plot.

3.4.14 Ascorbic acid (mg/100 g)

The ascorbic acid (also known as Vitamin C) estimation of ascorbic acid was done by volumetric method given by Sadashivam and Balasubramanyam (1987).

Oxalic acid (4%): Dissolve 4gm oxalic acid in distilled water and make the final volume of the solution 100ml.

Materials

Dye solution: Weigh 42mg sodium bicarbonate into small volume of distilled water. Dissolve 52 mg of 2, 6-Dichloro phenol indophenols in it and make final volume to 200 ml with distilled water.

Stock standard solution: dissolve 100mg ascorbic acid in 100 ml of 4% of oxalic acid solution in a volumetric flask (1mg/ml).

Procedure

Working solution: Dilute 10 ml of stock solution to 100 ml of 4% oxalic acid. The concentration for working solution is 100µg/ml.

Pipette out 5 ml of the working standard solution into 100ml conical flask.

↓

Add 10 ml of 4% of oxalic acid and titrate the dye (V_1 ml). End point is appearance of pink color which persists for few minutes. Amount of dye consumed is equal to amount of Ascorbic acid.

↓

Extract the sample (5g) in 4% oxalic acid and make to volume of 100ml and centrifuge.

↓

Pipette out 5 ml supernatant, add 10 ml of oxalic acid and titrate against dye (V_2 ml).

Calculation

$$\text{Amount of ascorbic acid mg/100g sample} = \frac{0.5\text{ mg} \times V_2 \times 100\text{ml}}{V_1 \times 5\text{ml} \times \text{Wt of the sample}} \times 100$$

3.4.15 Incidence of pests (%)

For study of individual genotype responses to below mentioned nematodes, insect-pests and diseases as galls per plant and percentage incidence was recorded with no use of chemicals.

1. Nematode galls per plant
2. Fruit borer incidence
3. Leaf curl incidence
4. Wilt incidence

1. Nematode galls per plant (%)

Three randomly selected plants were uprooted after last picking from each plot. Their roots were cut carefully and root systems were soaked in plastic bucket containing water to remove adhering soil. Then roots were washed over 60 mesh sieve under running tap water. The number of galls of each root system was counted and averaged to give galls per plant. For the categorization of plants to resistance to root knot nematodes the following scale given by Quesenberry *et al*. (1986) was followed.

0 = no gall

1 = 1 or 2 galls

2= 3 to 10 galls

3= 11 to 30 galls

4= 31 to 100 galls

5= >100 galls.

2. Fruit borer incidence (%)

Three plants per plot were selected randomly for measuring the incidence of fruit borer. At the time of each picking the number of infested as well as total fruits from these plants was counted. The incidence of tomato fruit borer is calculated by using the following formula

$$\text{Fruit borer incidence (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants examined}} \times 100$$

The scale adopted by Shivaramu (1999) for fruit borer was used for grouping the genotypes in the different categories are as under.

Reaction	**Percent fruit borer incidence**
1. Resistant	0-5 %
2. Less susceptible	5-20%
3. Susceptible	>20 %

3. Leaf curl incidence (%)

The leaf curl and wilt incidence was recorded using the following formula (Mayee and Datar, 1986).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants examined}} \times 100$$

The angular transformed values were used for screening was done based on the scale given by Joshi and Choudhary (1981).

Reaction	Percent leaf curl incidence
1. Resistant	5-9 %
2. Moderately resistant	10-19 %
3. Moderately susceptible	20-39%
4. Susceptible	40-69%
5. Highly susceptible	70-100 %

4. Wilt incidence (%)

The wilt incidence was recorded using the following formula (Mayee and Datar 1986).

$$\text{Disease incidence (\%)} = \frac{\text{Number of infected plants}}{\text{Total number of plants examined}} \times 100$$

The disease reaction was categorized as per the scale given by Mew and Ho (1976).

Reaction	Per cent wilt incidence
1. Resistant	<20%
2. Moderately resistant	20-40%
3. Moderately susceptible	40-60 %
4. Susceptible	>60%

3.5 Statistical Analysis

The statistical analysis of the data was carried out using MS-Excel, OPSTAT and R studio packages. The mean values of data were subjected to analysis of variance as described by Gomez and Gomez (1983) for Randomized Complete Block Design. For estimation of different statistical parameters, following procedure and formulae were adopted:

Analysis of variance (ANOVA) was as follows:

Source of Variation	**(d.f)**	**Sum of squares (SS)**	**Mean sum of squares(MSS)**	**Variance ratio (F)**
Replications (r)	(r-1)	Sr	$S_r/(r-1) = M_r$	Mr/Me
Genotypes (g)	(g-1)	Sg	$S_g/(g-1) = M_g$	Mg/Me
Error	(r-1) (g-1)	Se	$S_e/(r-1)(g-1) = M_e$	

Where,

r = Number of replications

g = Number of genotypes

S_r= Sum of squares due to replications

S_g = Sum of squares due to treatments/genotypes

S_e= Sum of squares due to errors

M_r = Mean sum of squares due to replications

M_g = Mean sum of squares due to treatments/genotypes

M_e = Mean sum of squares due to errors

The calculated F-values were compared with the tabulated F-values. When F-test was found significant, Critical Difference (CD) and Coefficient of Variation (CV) was calculated to find out the superiority of one entry over the others.

The standard error of mean (SE_m) and critical difference (CD) for comparing the mean of any two genotypes were computed as follows:

$$SE_{(m)} = \pm(M_e/r)^{1/2}$$

$$SE_{(d)} = \pm (2M_e/r)^{1/2}$$

$CD_{(0.05)}$= $SE_{(d)}$ × ‘t’ value at error degree of freedom

Where,

$SE_{(m)}$ = Standard error of mean

$SE_{(d)}$ = Standard error of difference

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

All the characters which differed significantly among the genotypes were further utilized for estimation of following genetic parameters:

3.5.1 Coefficients of variability (phenotypic and genotypic)

3.5.2 Heritability (broad sense)

3.5.3 Genetic advance (GA)

3.5.4 Genetic gain (GG)

3.5.5 Correlation coefficients

3.5.6 Path coefficient analysis

3.5.7 Genetic diversity

3.5.1 Coefficients of variability

The Genotypic Coefficients of Variability (GCV) and Phenotypic Coefficients of Variability (PCV) were calculated as per the method suggested by Burton and De Vane (1953).

a) Genotypic Coefficient of Variability (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{Genotypic\,Variance(Vg)}}{General\ mean\ of\ \ population(\overline{X})} \times 100$$

b) Phenotypic Coefficient of Variability (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{Phenotypic\,Variance(Vp)}}{General\ mean\ of\ \ population(\overline{X})} \times 100$$

3.5.2 Heritability:

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

$$H\ (\%) = \frac{Vg}{Vp} \times 100$$

Where,

H = Heritability (%)

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

Vp = Phenotypic variance (Vg + Ve)

3.5.3 Genetic advance:

The expected genetic advance (GA) resulting from selection of five percent superior individuals was calculated as per Allard (1960).

$$GA = H \times \sigma_p \times K$$

Where,

H = Heritability (%)

σ_p = Phenotypic standard deviation

K = Selection differential at 5% selection intensity K = 2.06

3.5.4 Genetic gain:

Genetic advance expressed as per cent of population mean was calculated by the formula suggested by Johnson *et al.* (1955).

$$\text{Genetic gain (\%)} = \frac{\text{Genetic advance (GA)}}{\text{General mean of the population } (\overline{X})} \times 100$$

For categorizing the magnitude of different parameters, Sharma (1994) suggested the following limits:

PCV and GCV	>30%	-	High
	15-30%	-	Moderate
	<15%	-	Low
Heritability (H)	>80%	-	High
	50-80%	-	Moderate
	<50%	-	Low
Genetic gain	>50%	-	High
	25-50%	-	Moderate
	<25%	-	Low

3.5.5 Correlation coefficient

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

3.5.5.1 Analysis of variance and covariance

Source of Variation	**D.f**	**MSS**		**Mean sum of products**	**Variance**
		X	**Y**		
Replications	(r-1)	Mgx	Mgy	Mg XY =MP1	
Genotypes	(t-1)	Mex	Mey	Me XY =MP2	MP1 / MP2
Error	(r-1) (t-1)				

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

Environmental covariance (V_e XY) = MP_2

Genotypic covariance (V_g XY) = (MP_1 –MP_2) / r

Phenotypic variance (V_p XY) = V_g XY + V_e XY

Where,

V_eXY = Environmental covariance between X and Y

V_g XY = Genetic covariance between X and Y

V_pXY = Phenotypic covariance between X and Y

3.5.5.2 Coefficients of correlation

a) Phenotypic correlation between characters X and Y:

$$r_p = VpXY / \sqrt{Vp\ X \times Vp\ Y}$$

Where,

VpXY = Phenotypic co-variance between X and Y

VpX = Phenotypic variance of character X

VpY = Phenotypic variance of character Y

b) Genotypic correlation between characters X and Y:

$$R_g = VgXY / \sqrt{Vg\ X \times Vg\ Y}$$

Where,

Vg XY = Genotypic co-variance between X and Y

Vg X= Genotypic variance of character X

Vg Y = Genotypic variance of character Y

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

3.5.6 Path Coefficient Analysis

The genotypic and phenotypic correlation coefficients were used in finding out their direct and indirect contribution towards yield per plot.

Path coefficient analysis was done to calculate direct and indirect contribution of different characters towards yield. The direct and indirect effects were obtained following Dewey and Lu (1959). The path coefficients were obtained by the simultaneous selection of following equations, which express the basic relationship between genotypic correlation (r) and path coefficient (P).

$$r_{14} = P_{14} + P_{24}r_{12} + P_{34}r_{13}$$

$$r_{24} = P_{14}r_{21} + P_{24} + P_{34}r_{23}$$

$$r_{34} = P_{14}r_{31} + P_{24}r_{32} + P_{34}$$

Where, r_{14}, r_{24} and r_{34} are genotypic correlations of component characters with yield (dependent variable) and r_{12}, r_{13}, r_{23} are genotypic correlations among the component characters (independent variables).

The direct effects were calculated by the following set of equations:

$$P_{14} = C_{11}r_{14} + C_{12}r_{24} + C_{13}r_{34}$$

$$P_{24} = C_{21}r_{14} + C_{22}r_{24} + C_{23}r_{34}$$

$$P_{34} = C_{31}r_{14} + C_{32}r_{24} + C_{33}r_{34}$$

Where, C_{11}, C_{12}, C_{23} and C_{33} are constants derived by using abbreviated Doulittle's technique as explained by Goulden (1959) and $r_{12}P_{34}$, $r_{13}P_{34}$, $r_{23}P_{34}$, $r_{31}P_{14}$and $r_{32}P_{24}$ are indirect effects.

Residual effect:

The variation in the independent variable remained undetermined by including all the variables was assumed to be due to variable (s) on dependent variable was calculated as follows:

$$I = P^2x_4 + P^2_{14} + P^2_{24} + P^2_{34} + 2P_{14}r_{12}P_{24} + 2P_{14}r_{13}P_{34} + 2P_{24}r_{23}P_{34}$$

3.5.7 Genetic Diversity

3.5.7.1 Mahalanobis D^2 analysis

Mahalanobis's (1936) D^2 – statistic analysis was used for assessing the genetic divergence among the test entries. The generalized distance between any two populations is given by formula,

$$D^2 = \sum\sum \lambda_{ij} s_i s_j$$

Where,

D^2 = Square of generalized distance

λ_{ij} = Reciprocal of common dispersal matrix

$s^{ai} = (\mu i\ 1 - \mu i2)$

$s^{aj} = (\mu i\ 1 - \mu j2)$

μ = General mean

Since the formula for computation requires inversion of higher order determinant, transformation of the original correlated unstandardized character means (Xs) to standardized uncorrelated variable (Ys) was done to simplify the computational procedure. The D^2 values were obtained as the corresponding uncorrelated (Ys) values of any two genotypes (Rao, 1952).

3.5.7.2 Clustering of D^2 Values

Tocher's method was used for assigning various varieties to different clusters. The two varieties having smallest distance from each other were considered first to which a third variety having smallest average D^2 value from the first two varieties was added. Next came the nearest fourth variety and the process continued till the average D^2 value was increased. The remaining varieties were then considered for the next cluster and the process was continued till all the varieties were included in various clusters.

The remaining varieties were then considered for the next cluster and the process was continued till all varieties were included in various clusters.

The spatial distances between clusters were arrived at by taking square root of average intra and inter cluster D^2 values.

3.5.7.3 Intra cluster distance

The intra cluster distance was calculated by the formula given by Singh and Chaudhary (1977).

Square of intra cluster distance = $\frac{\sum Di^2}{n}$

$\sum Di^2$ = the sum of distance between all possible combinations.

n = Number of all possible combinations.

3.5.7.4 Inter cluster distance

The inter cluster distances were calculated by the formulae described by Singh and Chaudhary (1977).

Square of inter cluster distance = $\frac{\sum Di^2}{n_i n_j}$

Where,

$\sum Di^2$ is the sum of distances between all possible combinations $(n_i n_j)$ of the entries included in the cluster study.

n_i = Number of entries in cluster i

n_j = Number of entries in cluster j

3.5.7.5 Relative contribution of individual characters towards total divergences

The ranking of differences in uncorrelated means between all the characters for all pair wise combinations of varieties was carried out, with first rank being assigned to the highest differences. Finally relative contribution of a character towards total divergence was estimated by calculating the percentage of first rank in that character.

Plate 1. Tomato trial in both field and protected structures

RESULTS

CHAPTER-4

RESULTS

The present investigation entitled "Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)" was conducted at the experimental farm of the Division of Vegetable Science and Floriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu, Chatha, during *rabi* season of 2017-18. Twenty diverse genotypes of tomato (17 open pollinated and 3 hybrids) were evaluated for yield and yield contributing traits. The experimental results are presented under the following sub-heads:

4.1 Variability Studies

4.2 Correlation Studies

4.3 Path Coefficient Analysis

4.4 Genetic Divergence (D^2 Statistic)

4.5 Reaction to Pest and Diseases

4.1 VARIABILITY STUDIES

4.1.1 Analysis of variance

Analysis of variance indicated highly significant differences among the genotypes for all the traits studied namely, days to 50% flowering (days), plant height (cm), number of primary branches per plant, number of flowers per cluster, number of fruits per truss, number of fruits per plant, average fruit weight (g), fruit shape index, number of locules per fruit, total soluble solids (ºB), ascorbic acid (mg/100 g), pericarp thickness (mm), nematode galls per plant, fruit borer incidence (%), leaf curl incidence (%), wilt incidence (%) and fruit yield per plant (kg) and per hectare (q) (Appendix-II).

4.1.2 General performance of genotypes

The mean performance of all the genotypes for various horticultural traits is discussed as follows:

4.1.2.1 Days to 50 per cent flowering

Days to 50 % flowering varied from 23.67 days (Arka Rakshak) to 31.67 days (Palam Pride) with overall general mean value of 28.65 days (Table.2). None of the genotype was found to be statistically at par with Arka Rakshak which was earliest to attain 50 % flowering. Four genotypes [Bhagya (29.00), Arka Sourabh (29.00), Arka Abha (29.67) and CLN-2670-B1 (29.67)] were found to be statistically at par with overall general mean value for this trait.

4.1.2.2 Plant height (cm)

Comparison of genotypes revealed that all the genotypes significantly differed for plant height. It ranged from 65.60 cm in PKM-1 to 178.77 cm in BSS-488 with overall mean of 111.76 cm (Table.2). Marglobe (176.66 cm) was found to be statistically at par with 2nd ranking BSS-488 (178.77 cm). Arka Vikas (99.87) was found to be statistically at par with overall general mean value of 111.76 cm for the trait.

4.1.2.3 Number of primary branches per plant

It ranged from 4.78 in DVRT-2 to 8.41 in Arka Rakshak (Table.2). All the genotypes were found to be significantly different for number of primary branches per plant. The overall mean for number of primary branches per plant was 6.17. Two genotypes namely Marglobe (7.66) and BWR-5 (7.44) were found to be statistically at par with Arka Rakshak (8.41). Nine genotypes viz., Palam Pink (5.44), Arka Alok (5.44), Arka Abha (5.77), Arka Sourabh (5.77), Arka Vikas (5.77), CLN-2670-B1 (5.78), CLN-2123-A1 Red (5.89), Palam Pride (5.90) and S-22 (6.00) were found to be statistically at par with overall general mean.

4.1.2.4 Number of flowers per cluster

All the genotypes varied significantly for number of flowers per cluster. It ranged from 3.66 (Pusa Ruby) to 8.66 (BSS-488) with an overall mean of 5.58 (Table.2). Arka

Rakshak (8.28) was found to be statistically at par with BSS-488 (8.66). Eight genotypes namely, PKM-1 (4.66), Arka Abha (4.77), Arka Sourabh (4.99), Selection-2 (5.00), DVRT-2 (5.22), BWR-5 (5.22), Arka Vikas (5.33), and CLN-2123-A1 Red (5.44) were found to be statistically at par with overall mean.

4.1.2.5 Number of fruits per truss

Data recorded for number of fruits per truss showed that all the genotypes were significantly different for this trait. Its value ranged from 1.66 in DVRT-2 to 4.08 in Arka Rakshak, with overall mean value of 2.69 (Table.2). Two genotypes namely BSS-488 (4.00) and Hawaii-7998 (3.89) were found to be statistically at par with Arka Rakshak (4.08). Eight genotypes namely Palam Pride (2.04), S-22 (2.11), BWR-5 (2.33), CLN-2670-B1 (2.33), PKM-1 (2.44), CLN-2123-A1 Red (2.44), KH-105 (2.50) and Arka Sourabh (2.55) were statistically at par with overall mean.

4.1.2.6 Number of fruits per plant

All the genotypes were found to be significantly different for number of fruits per plant. It ranged from 12.92 in PKM-1 to 42.25 in Hawaii-7998 (Table.2). None of the genotypes was found to be statistically at par with Hawaii-7998. Five genotypes namely Arka Vikas (22.19), DVRT-2 (22.27), Arka Alok (23.35), S-22 (23.38) and CLN-2670-B1 (24.07) were found to be statistically at par with overall mean value.

4.1.2.7 Average fruit weight (g)

All the genotypes differed significantly for average fruit weight. Average fruit weight ranged from 26.03 g in Hawaii-7998 to 85.52 g in DVRT-2, with overall mean value of 60.58 g for this trait (Table.2). Genotype Arka Rakshak (81.31 g) was found to be statistically at par with DVRT-2. Four genotypes namely Marglobe (54.20 g), PKM-1 (55.05 g), Selection-2 (57.59 g) and Arka Sourabh (57.77 g) were found to be statistically at par with overall mean.

4.1.2.8 Fruit shape index

Significant differences were observed for fruit shape index among all the genotypes. Three genotypes namely CLN-2123-A1 Red, Arka Rakshak and Palam Pride

had oval shape. Five genotypes namely, Arka Abha, Arka Alok, CLN-2670B-1, BSS-488 and BWR-5 were spherical in shape. Eleven genotypes namely, Arka Sourabh, Arka Vikas, Pusa Ruby, Palam Pink, Hawaii-7998, DVRT-2, KH-105, Marglobe, Bhagya, Selection-2 and S-22 were placed under intermediate group while one genotype (PKM-1) under flat group.

4.1.2.9 Number of locules per fruit

All the genotypes were found to be significantly different for number of locules per fruit. Number of locules per fruit varied from 3.11 in Hawaii-7998 and Arka Rakshak to 5.44 in DVRT-2 (Table.2). The overall mean value was 4.20. Four genotypes namely, BWR-5 (4.89), CLN-2670-B1 (4.94), Marglobe (5.00) and DVRT-2 (5.44) were found to be statistically at par with DVRT-2. Six genotypes, namely, Pusa Ruby (3.67), Palam Pink (3.78), Arka Sourabh (3.89), Bhagya (3.89), PKM-1 (4.00) and Arka Abha (4.00) were found to be statistically at par with general mean value.

4.1.2.10 Total Soluble Solids (ºBrix)

Significant differences were observed for total soluble solids among all the genotypes. Total soluble solids varied from 3.93 ºB in Selection-2 to 5.90 ºB in Marglobe. Overall mean value for this trait was 4.79 ºB. BSS-488 (5.53 ºB) was found to be statistically at par with Marglobe. Four genotypes *viz.*, PKM-1 (4.33 ºB), Arka Alok (4.37 ºB), Palam Pink (4.63 ºB) and Arka Vikas (4.77 ºB) were statistically at par with overall mean value (Table.2).

4.1.2.11 Ascorbic acid (mg/100 g)

All the genotypes were found to be significantly different for ascorbic acid content. It ranged from 23.32 mg in Marglobe to 33.91 mg in Arka Rakshak with overall mean value as 25.91 mg (Table.2). None of the genotypes were found to be statistically at par with Arka Rakshak (33.91 mg). Eleven genotypes, namely, Marglobe (23.32 mg), DVRT-2 (23.53 mg), Arka Abha (23.59 mg), PKM-1 (23.70 mg), Arka Alok (23.89 mg), Palam Pink (25.07 mg), Selection-2 (25.19 mg), CLN-2670-B1 (25.20 mg), Pusa Ruby (25.22 mg), Palam Pride (25.31 mg), S-22 (25.56 mg) and Arka Sourabh (25.87 mg) were found to be statistically at par with overall mean value.

4.1.2.12 Pericarp thickness (mm)

Significant variation for pericarp thickness was observed among all the genotypes studied. The data presented in revealed that pericarp thickness varied from 3.62 mm in Marglobe to 6.05 mm in BSS-488 with an overall mean value as 4.58 mm (Table.2). Two genotypes, namely, Palam Pride (5.78 mm) and Arka Rakshak (6.03 mm) were found to be statistically at par with BSS-488. Five genotypes *viz.*, Selection-2 (4.03 mm), Arka Sourabh (4.21 mm), Hawaii-7998 (4.25 mm), Arka Abha (4.38 mm) and BWR-5 (4.50 mm) were statistically at par with overall mean value.

4.1.2.13 Fruit yield per plant (kg)

All the genotypes were significantly different for fruit yield per plant (Table.2). Fruit yield per plant ranged from 0.59 kg in PKM-1 to 2.52 kg in Arka Rakshak, with an overall mean value as 1.25 kg. None of the genotype was found to be statistically at par with Arka Rakshak which was recorded maximum fruit yield per plant. Six genotypes *viz.*, Hawaii-7998 (1.04 kg), S-22 (1.08 kg), Pusa Ruby (1.08 kg), Arka Abha (1.13 kg), Bhagya (1.16 kg) and KH-105 (1.23 kg) were statistically at par with overall mean.

4.1.2.14 Fruit yield per hectare (q)

Significant differences were observed for fruit yield per hectare for all the genotypes. Fruit yield per hectare ranged from 103.59 q in PKM-1 to 443.91 in Arka Rakshak with an overall mean value of 220.58 q. Maximum fruit yield per hectare was recorded by Arka Rakshak (443.91 q) (Table.2). Six genotypes *viz.*, Hawaii-7998 (184.19 q), S-22 (190.30 q), Pusa Ruby (190.18 q), Arka Abha (199.88 q), Bhagya (204.70 q) and KH-105 (216.17 q) were statistically at par with overall mean.

4.1.2.15 Fruit borer incidence (%)

All the genotypes were found to be significantly different for fruit borer incidence under field conditions. Fruit borer incidence ranged from 6.83 % in Arka Rakshak to 18.68 % in Arka Abha with overall mean of 13.87 %. Genotype BSS-488 (7.84 %) was found to be statistically at par with Arka Rakshak. Four genotypes *viz.*, Arka Vikas (15.15 %), Palam Pink (15.69 %), CLN-2670-B1 (16.28 %) and Palam Pride (14.37 %)

were found to be statistically at par with overall mean value. All the genotypes relatively depicted less susceptible reaction.

4.1.2.16 Leaf curl incidence (%)

The data on leaf curl incidence under field conditions exhibited significant variation among different genotypes. Leaf curl incidence varied from 0.45 % (Arka Rakshak) to 43.08 % (PKM-1) with an overall mean value as 29.79 %. None of the genotype was found statistically at par with Arka Rakshak. Twelve genotypes *viz.,* Arka Abha (35.22 %), Arka Sourabh (35.22 %), Palam Pride (35.22 %), KH-105 (35.22 %), Selection-2 (35.22 %), CLN-2670-B1 (34.93 %), Arka Vikas (33.00 %), Pusa Ruby (33.00 %), Hawaii-7998 (33.00 %), Marglobe (37.14 %), Palam Pink (31.00 %) and S-22 (31.00 %) were found to be statistically at par with overall mean value (Table.2). One genotype Arka Rakshak (0.52%) was found resistant while BSS-488 (12.46 %) was found less susceptible and rest eighteen genotypes were susceptible.

4.1.2.17 Wilt incidence (%)

Significant differences were observed for wilt incidence under field conditions. Wilt incidence varied from 10.34 % in BWR-5 to 31.07 % in Arka Abha with overall mean value of 19.99 %. Two genotypes namely, BSS-488 (14.76 %) and Arka Rakshak (14.76 %) were found statistically at par with BWR-5 (Table.2) while five genotypes *viz.*, CLN-2123-A1 Red (23.74 %), Arka Alok (26.45 %), DVRT-2 (26.45 %), Bhagya (26.45 %) and Selection-2 (26.45 %) were found to be statistically at par with overall mean value. Seventeen genotypes were found to be resistant for wilt while five genotypes were moderately resistant.

Table 2: Mean performance of various genotypes for various traits in tomato (*Solanum lycopersicum* L.).

Genotypes	DFF	PHT	NPB	NFC	NFT	NFP	AFW	FSI	NLC
PKM-1	26.33	65.60	4.88	4.66	2.44	12.92	55.05	0.67	4.00
Arka Abha	28.33	89.50	5.77	4.77	2.88	18.91	67.50	0.86	4.00
Arka Alok	29.67	96.67	5.44	4.11	2.88	23.35	70.98	0.93	4.44
Arka Sourabh	29.00	87.27	5.77	4.99	2.55	14.87	57.77	0.82	3.89
Arka Vikas	27.67	99.87	5.77	5.33	2.89	22.19	50.33	0.81	4.55
Pusa Ruby	26.67	113.73	6.99	3.66	3.00	24.79	47.78	0.74	3.67
Palam Pink	31.00	79.83	5.44	4.55	2.11	14.06	74.80	0.85	3.78
Hawaii-7998	31.67	138.67	6.55	6.33	3.89	42.25	26.03	0.83	3.11
BWR-5	30.33	160.43	7.44	5.22	2.33	27.52	68.05	0.89	4.89
CLN-2670-B1	29.67	116.57	5.78	4.55	2.33	24.07	36.09	0.87	4.94
Palam Pride	31.67	95.57	5.90	6.77	2.04	13.95	67.07	1.03	4.13
CLN-2123-A1 Red	27.67	130.60	5.89	5.44	2.44	30.89	61.26	1.01	4.77
DVRT-2	30.33	68.77	4.78	5.22	1.66	22.27	85.52	0.74	5.44
KH-105	28.33	87.77	5.10	4.22	2.50	29.05	46.00	0.79	4.22
Marglobe	31.33	176.67	7.66	7.11	3.22	19.28	54.20	0.80	5.00
BSS-488	25.67	178.77	7.22	8.66	4.00	31.99	64.72	0.87	3.44
Bhagya	29.00	133.63	6.33	6.89	2.77	27.10	46.30	0.73	3.89
Arka Rakshak	23.67	159.43	8.41	8.28	4.08	33.04	81.31	1.07	3.11
Selection-2	26.67	69.90	6.22	5.00	1.77	26.10	57.59	0.81	4.55
S-22	28.33	85.87	6.00	5.77	2.11	23.38	50.74	0.78	4.22
Overall mean	**28.65**	**111.76**	**6.17**	**5.58**	**2.69**	**24.10**	**58.45**	**0.85**	**4.20**
$CD_{(0.05)}$	**1.53**	**14.68**	**0.96**	**0.94**	**0.57**	**2.33**	**7.64**	**0.05**	**0.61**
CV	**3.225**	**7.945**	**9.428**	**10.165**	**12.891**	**5.845**	**7.908**	**3.412**	**8.759**

DFF = Days to 50% flowering, PHT = Plant height (cm), NPB = Number of primary branches per plant, NFC = Number of flowers per cluster, NFT = Number of fruits per truss, NFP = Number of fruits per plant, AFW = Average fruit weight (g), FSI = Fruit shape index, NLC = Number of locules per fruit.

Table 2: Mean performance of various genotypes for various traits in tomato (*Solanum lycopersicum* L.). (Contd..)

Genotypes	TSS	ASC	PCT	YPH	YPP	FBI*	LCI*	WLI*
PKM-1	4.33	23.70	3.68	103.59	0.59	16.72 (8.33)	43.08 (46.67)	18.05 (10.00)
Arka Abha	5.23	23.59	4.38	199.88	1.13	18.68 (10.33)	35.22 (33.33)	31.07(26.67)
Arka Alok	4.37	23.89	3.91	266.90	1.51	13.60 (5.55)	28.78 (23.33)	26.45(20.00)
Arka Sourabh	3.93	25.87	4.21	130.39	0.74	17.77 (9.33)	35.22 (33.33)	18.05(10.00)
Arka Vikas	4.77	25.99	4.75	177.25	1.01	15.15 (6.88)	33.00 (30.00)	18.05(10.00)
Pusa Ruby	5.00	25.22	3.87	190.18	1.08	13.85 (5.77)	33.00 (30.00)	18.44(10.00)
Palam Pink	4.63	25.07	3.84	157.55	0.89	15.69 (7.33)	31.00 (26.67)	18.05(10.00)
Hawaii-7998	5.33	26.15	4.25	184.19	1.04	12.65 (4.88)	33.00 (30.00)	18.05(10.00)
BWR-5	5.03	27.88	4.50	304.11	1.72	10.79 (3.55)	26.07 (20.00)	10.34(3.33)
CLN-2670-B1	4.07	25.20	4.15	139.21	0.79	16.28 (7.88)	34.93 (33.33)	18.05(10.00)
Palam Pride	4.20	25.31	5.78	140.21	0.80	14.37 (6.22)	35.22 (33.33)	18.05(10.00)
CLN-2123-A1 Red	4.23	27.55	5.72	309.70	1.76	12.11 (4.44)	23.86 (16.67)	23.74(16.67)
DVRT-2	4.87	23.53	5.30	304.23	1.73	11.52 (4.11)	23.86 (16.67)	26.45(20.00)
KH-105	5.30	25.97	3.93	216.17	1.23	12.30 (4.55)	35.22 (33.33)	18.44(10.00)
Marglobe	5.90	23.32	3.62	164.08	0.93	17.67 (9.22)	37.14 (40.00)	18.05(10.00)
BSS-488	5.53	28.81	6.05	341.04	1.93	7.84 (1.89)	12.46 (6.67)	14.76(6.67)
Bhagya	4.87	26.52	4.88	204.70	1.16	13.36 (5.44)	26.07 (20.00)	26.45(20.00)
Arka Rakshak	4.90	33.91	6.03	443.91	2.52	6.83 (1.44)	0.52 (0.00)	14.76(6.67)
Selection-2	3.93	25.19	4.03	243.97	1.38	16.97 (8.55)	35.22 (33.33)	26.45(20.00)
S-22	5.33	25.56	4.77	190.30	1.08	13.29 (5.33)	31.00 (26.67)	18.05(10.00)
Overall mean	**4.79**	**25.91**	**4.58**	**220.58**	**1.25**	**13.87**	**29.79**	**19.99**
$CD_{(0.05)}$	**0.45**	**2.78**	**0.42**	**37.97**	**0.21**	**2.65**	**9.28**	**6.58**
CV	**5.661**	**6.485**	**5.606**	**10.417**	**10.417**	**11.544**	**18.847**	**19.935**

TSS = Total soluble solids (ºB), ASC = Ascorbic acid (mg/100gm), PCT = Pericarp thickness (mm), YPH = Yield per hectare (q), YPP = Yield per plant (kg), FBI = Fruit borer incidence (%), LCI = Leaf curl incidence (%), WLI = Wilt incidence (%).
(*) Arcsine transformed values, (original values).

4.1.3 Parameters of Variability

The parameters of variability *viz.*, mean, range, coefficients of variation (genotypic and phenotypic), heritability (broad sense), genetic advance and genetic gain were worked out for various characters and are presented in Table.3.

4.1.3.1 Coefficients of variation

Phenotypic coefficients of variation (PCV) were higher in magnitude than the corresponding genotypic coefficients of variation (GCV) for all the characters studied (Fig.1), but differences were less in majority of cases. It indicated that environmental factors had played less influence on the expression of these characters. Coefficients of variation varied in magnitude (low to moderate to high). It indicated that there was a great diversity in the experimental materials (genotypes) used.

For determining the magnitude of phenotypic and genotypic variation, PCV and GCV were calculated and marked extent of variation was observed for all the characters studied. The PCV and GCV were higher for wilt incidence (55.43 % and 42.64 %), leaf curl incidence (48.08 % and 37.22 %), fruit borer incidence (43.85 % and38.20%), fruit yield per plant (39.40 % and 38.00 %), plant height (32.88 % and 31.04 %) and number of fruits per plant (31.06 % and 30.51 %), respectively (Table.3).

Moderate PCV and GCV were observed for average fruit weight (25.94 % and 24.71 %), number of fruits per truss (27.64 % and 24.45%), number of flowers per cluster (25.76 % and 23.67 %) and pericarp thickness (17.99 % and 17.09 %), respectively. Moderate phenotypic coefficient of variation (PCV) and low genotypic coefficient of variation (GCV) were recorded for number of primary branches (17.34 % and 14.55 %) and number of locules per plant (16.61 % and 14.11 %), respectively.

Low values of PCV and GCV were observed for days to 50 % flowering (7.28 % and 7.96 %), ascorbic acid (10.65 % and 8.44 %), total soluble solids (12.63 % and 11.29 %) and fruit shape index (12.42 % and 11.94 %), respectively.

4.1.3.2 Heritability

Heritability (broad sense) estimates ranged from 59.19 % to 96.46 %. High heritability was recorded for number of fruits per plant (96.46 %), plant height (94.16 %), fruit yield per plant (93.01 %), fruit shape index (92.45 %), average fruit weight (90.71 %), pericarp thickness (90.28 %), number of flowers per cluster (84.43 %) and days to 50 % flowering (83.61 %).

Moderate heritability was recorded for total soluble solids (79.92%), number of fruits per truss (78.24 %), fruit borer incidence (75.88 %), number of locules per fruit (72.18 %), number of primary branches per plant (70.42 %), ascorbic acid (62.88%), leaf curl incidence (59.93) and wilt incidence (59.19 %).

4.1.3.3 Genetic advance and genetic gain

The genetic gain (genetic advance expressed as per cent of population mean) was low to high in nature but ranged from 13.72 % to 75.49 % (Table.3). High genetic gain was recorded for fruit yield per plant (75.49 %), fruit borer incidence (68.55 %), wilt incidence (67.58 %), plant height (63.77 %), number of fruits per plant (61.73 %) and leaf curl incidence (59.35 %).

Genetic gain was moderate for average fruit weight (48.48 %), number of flower per cluster (44.81 %), number of fruits per truss (44.55 %), pericarp thickness (33.45 %) and number of primary branches per plant (25.15 %). Low genetic gain was observed for number of locules per fruit (24.69 %), fruit shape index (23.65 %), total soluble solids (20.80 %), ascorbic acid (13.79 %) and days to 50% flowering (13.72 %).

High heritability and high genetic gain were observed for number of fruits per plant (96.46 % and 61.35 %), plant height (94.16 % and 63.77 %) and fruit yield per plant (93.01 % and 75.49 %). High heritability along with moderate genetic gain was observed for average fruit weight (90.71 % and 48.48 %), number of flower per cluster (84.43 % and 44.81 %) and pericarp thickness (90.28% and 33.45 %). High heritability along with low genetic gain was observed for fruit shape index (92.45 % and 23.65 %) and days to 50 % flowering (83.61 % and 13.72 %).

Moderate heritability along with high genetic gain was observed for pest incidence, like fruit borer incidence (75.88 % and 68.55 %), wilt incidence (59.19 % and 67.58 %) and leaf curl incidence (59.93 % and 59.35 %). Moderate heritability along with moderate genetic gain was observed for number of fruit per truss (78.24 % and 44.55 %) and number of primary branches per plant (70.42 % and 25.15 %). Moderate heritability along with low genetic gain was observed for number of locules per fruit (72.18 % and 24.69 %), total soluble solids (79.92 % and 20.80 %) and ascorbic acid (62.88 % and 13.79 %). The pattern of heritability and genetic advance over percent mean is presented in Fig.2.

Table 3: Estimation of phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic gain for various traits in tomato (*Solanum lycopersicum* L.).

Observations/Traits	Mean	Range	Coefficients of variation		Heritability (%)	Genetic advance	Genetic advance as %age of mean
			Phenotypic Coefficients of variation	Genotypic Coefficients of variation			
Days to 50% flowering	28.65 ± 0.75	23.67 - 31.67	7.96	7.28	83.61	3.93	13.72
Plant height (cm)	111.76 ± 7.25	65.60 - 178.77	32.88	31.90	94.16	71.27	63.77
Number of primary branches per plant	6.17 ± 0.47	4.78 - 8.41	17.34	14.55	70.42	1.55	25.15
Number of flowers per cluster	5.58 ± 0.46	3.66 - 8.66	25.76	23.67	84.43	2.50	44.81
Number of fruits per truss	2.70 ± 0.28	1.66 - 4.08	27.64	24.45	78.24	1.20	44.55
Number of fruits per plant	24.10 ± 1.15	12.92 -42.25	31.07	30.51	96.46	14.88	61.73
Average fruit weight (g)	58.46 ± 3.77	26.03 - 85.52	25.94	24.71	90.71	28.34	48.48
Fruit shape index	0.85 ± 0.02	0.67 - 1.07	12.42	11.94	92.45	0.20	23.65
Number of locules per fruit	4.20 ± 0.30	3.11 - 5.44	16.61	14.11	72.18	1.04	24.69
Total soluble solids (B^{o})	4.79 ± 0.22	3.93 - 5.90	12.63	11.29	79.92	1.00	20.80
Ascorbic acid(mg/100gm)	25.91 ± 1.37	23.32 - 33.91	10.65	8.44	62.88	3.57	13.79
Pericarp thickness (mm)	4.58 ± 0.21	3.62 - 6.05	17.99	17.09	90.28	1.53	33.45
Fruit borer incidence (%)	6.05 ± 1.06	1.44 - 10.33	43.85	38.20	75.88	4.15	68.55
Leaf curl incidence (%)	26.67 ± 6.63	0.00 - 46.67	48.08	37.22	59.93	15.83	59.35
Wilt incidence (%)	12.50 ± 3.61	3.33 - 26.67	55.43	42.64	59.19	8.45	67.58
Yield per plant (kg)	1.25 ± 0.11	0.59 - 2.52	39.40	38.00	93.01	0.94	75.49
Yield per hectare(q)	220.57± 18.76	103.59 - 443.91	39.40	38.00	93.01	166.51	75.49

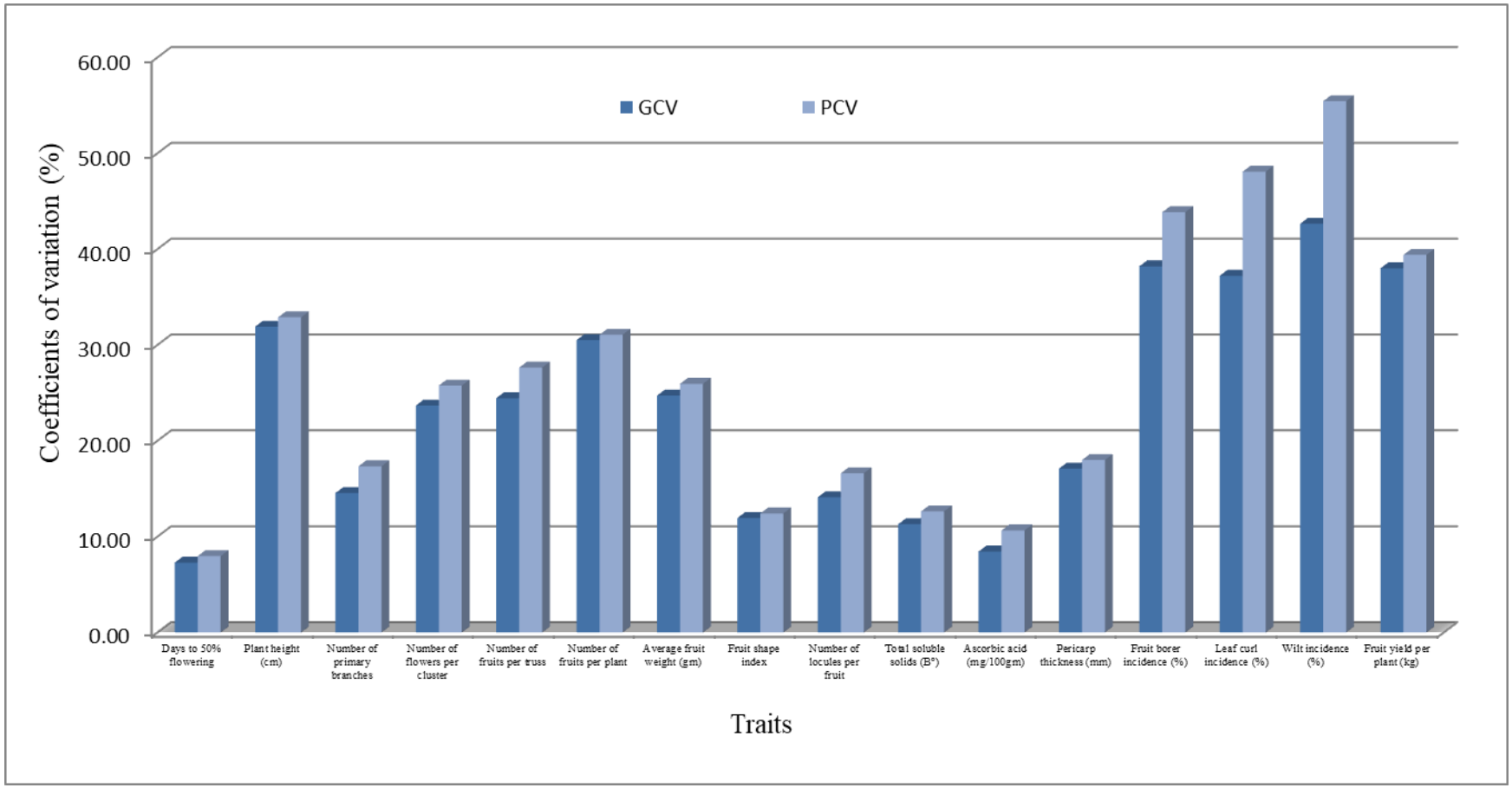

Fig.1: Genotypic and phenotypic variability for 16 traits in tomato

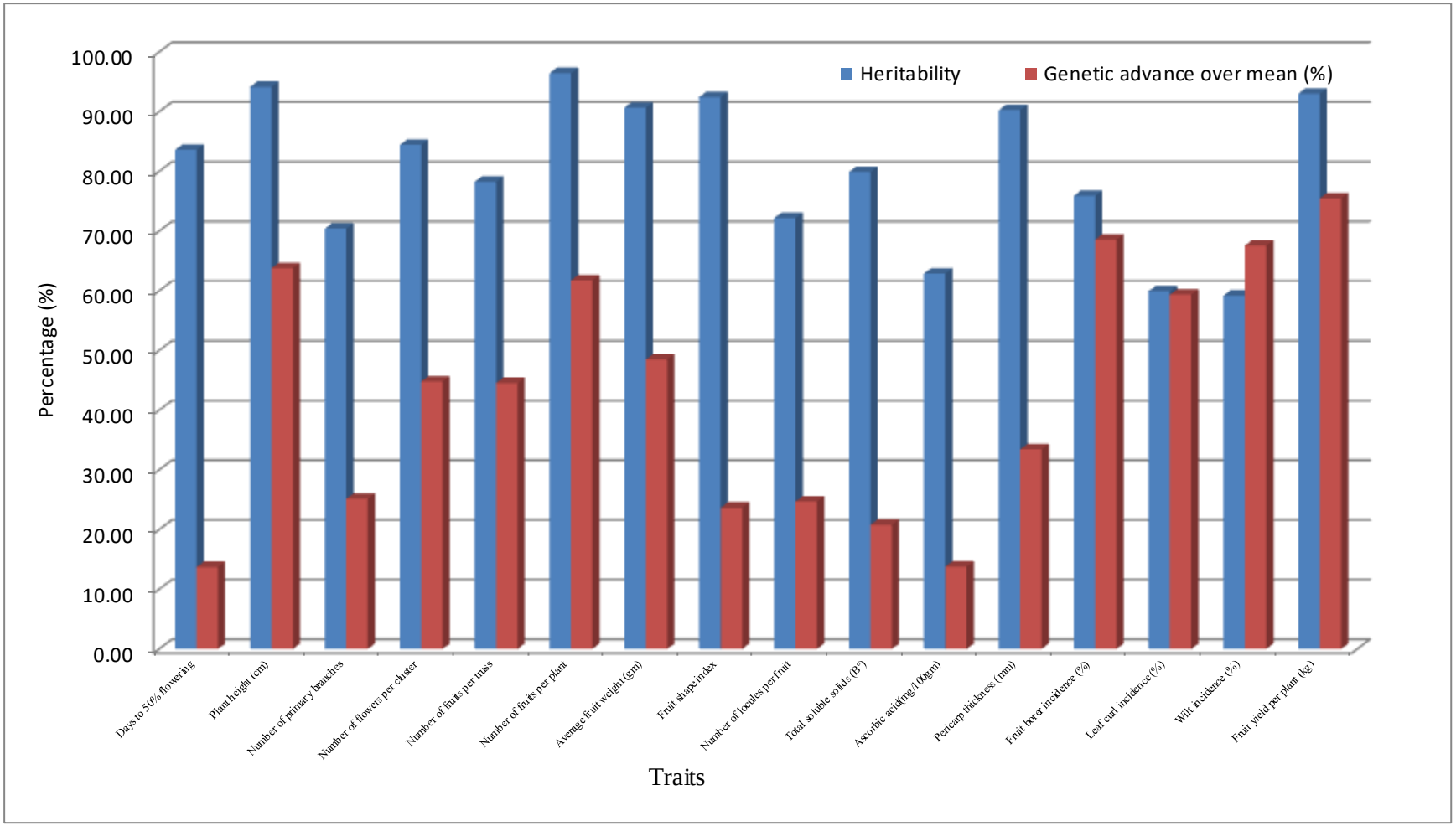

Fig.2: Heritability estimates and genetic advance over per cent mean for 16 traits in tomato

4.2 CORRELATION STUDIES

The correlation coefficients among different characters worked out at genotypic and phenotypic levels, is presented in Table 4. The genotypic correlation coefficients were high in magnitude than phenotypic correlation coefficients. Days to 50% flowering exhibited negative and significant association with fruit yield per plant (-0.494 and -0.449) both at genotypic and phenotypic levels, respectively while for number of fruits per truss (-0.369) at genotypic level only. Positive and significant association of days to 50% flowering was observed for ascorbic acid (0.646 and 0.436) both at genotypic and phenotypic levels respectively but with leaf curl incidence (0.420) and number of locules per fruit (0.395) only at genotypic level. Number of fruits per plant were positively and significantly correlated with fruit yield per plant (0.590 and 0.586) both at genotypic and phenotypic levels, respectively but with total soluble solids (0.367) at genotypic level only. Negative and significant correlation of number of fruits per plant with leaf curl incidence (-0.598 and -0.465), ascorbic acid (-0.602 and -0.492) and fruit borer incidence (-0.688and -0.603) was observed both at genotypic and phenotypic levels, respectively. Average fruit weight showed positive and significant association with fruit yield per plant (0.529 and 0.547) and fruit shape index (0.404 and 0.354) both at genotypic and phenotypic levels, respectively but negative and significant correlation of average fruit weight with leaf curl incidence (-0.513 and -0.444) and pericarp thickness (-0.391 and -0.426) both at genotypic and phenotypic levels, respectively. Number of locules per fruit showed positive and significant association with wilt incidence (0.423), ascorbic acid (0.587) at genotypic level. Ascorbic acid showed negative and significant association with fruit yield per plant (-0.801 and -0.594) both at genotypic and phenotypic levels, respectively. Positive and significant association of ascorbic acid with leaf curl incidence (0.954 and 0.539), fruit borer incidence (0.848 and 0.525), pericarp thickness (0.725 and 0.522) and wilt incidence (0.666 and 0.364) was observed both at genotypic and phenotypic levels, respectively. Pericarp thickness showed positive and significant association with leaf curl incidence (0.811 and 0.692) and fruit borer incidence (0.654 and 0.663) while negative and significant association with fruit yield per plant (-0.629 and -0.639). Fruit shape index showed positive and significant correlation with fruit yield per plant (0.526 and 0.478) both at genotypic and phenotypic levels respectively, while

negative and significant association with ascorbic acid (-0.638 and -0.485), pericarp thickness (-0.607and -0.548), leaf curl incidence (-0.594 and -0.394).

Fruit borer incidence showed positive and significant association with leaf curl incidence (0.898 and 0.740) and wilt incidence (0.351 and 0.457) both at genotypic and phenotypic levels respectively. While, fruit borer incidence and leaf curl incidence were had negative and significant correlation with fruit yield per plant at both genotypic and phenotypic levels (-0.785 and -0.755) and (-0.979 and -0.785) respectively.

4.3 PATH COEFFICIENT ANALYSIS

Path coefficient analysis helped in partitioning the correlation coefficient under direct and indirect effects that permitted a critical examination of the relative importance of each trait. In order to understand such effects of different independent characters or in combination with other characters on yield, the estimates of direct and indirect effects were computed through path coefficient analysis (Table .5). Perusal of data indicated that maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight (0.851), followed by number of fruits per plant (0.847), leaf curl incidence (0.390) and plant height (0.285). The other traits which showed positive direct effect with fruit yield per plant were fruit shape index (0.095), number of primary branches per plant (0.085), pericarp thickness (0.042), number of locules per fruit (0.0046) and flower per cluster (0.0042). Whereas, days to 50 % flowering (-0.379), fruit borer incidence (-0.237), number of fruits per truss (-0.207), ascorbic acid (-0.153) and total soluble solids (-0.023) had negative direct effect on fruit yield per plant.

High indirect effects on fruit yield per plant via fruits per plant for fruits per truss (0.4940) followed by leaf curl incidence for fruit borer incidence (0.3506) and average fruit weight for fruit shape index (0.3438) was recorded. Whereas maximum negative indirect effect on fruit yield per plant via number of fruits per plant for fruit borer incidence (-0.5828), followed by number of fruits per plant for leaf curl incidence (-0.5060) and average fruit weight for leaf curl incidence (-0.4365).

The residual effect was recorded very low i.e., 0.00634.

Table 4: Genotypic (G) and phenotypic (P) correlation coefficients for various quantitative and quality traits in tomato (*Solanum lycopersicum* L.)

Traits		Days to 50% flowering	Plant Height	Number of primary branches	Number of flowers Per cluster	Number of fruits per truss	Number of fruits per plant	Average fruit weight	Fruit shape index	Number of locules per fruit	Total soluble solids	Ascorbic acid	Pericarp thickness	Fruit boerer incidence	Leaf curl incidence	Wilt incide -nce	Fruit yield Per Plant
Days to 50% flowering	(G)	-	-0.078	-0.296*	-0.204	-0.369**	-0.228	-0.146	-0.056	0.395**	0.065	0.646**	0.316*	0.319*	0.420**	0.149	-0.494**
	(P)	-	-0.06	-0.234	-0.162	-0.300*	-0.189	-0.159	-0.055	0.312*	0.035	0.436**	0.281*	0.250	0.323*	0.153	-0.449**
Plant height	(G)		-	0.913**	0.705**	0.746**	0.549**	-0.095	0.375**	-0.217	0.558**	-0.605**	-0.345**	-0.490**	-0.523**	-0.473**	0.462**
	(P)		-	0.738**	0.642**	0.656**	0.539**	-0.086	0.352**	-0.143	0.462**	-0.486**	-0.337**	-0.427**	-0.427**	-0.366**	0.447**
Number of primary branches per plant	(G)			-	0.683**	0.700**	0.480**	0.013	0.409**	-0.380**	0.467**	-0.791**	-0.288*	-0.385**	-0.538**	-0.511**	0.512**
	(P)			-	0.559**	0.575**	0.403**	0.040	0.327*	-0.261*	0.370**	-0.462**	-0.273*	-0.355**	-0.345**	-0.409**	0.452**
Number of flowers per cluster	(G)				-	0.560**	0.365**	0.113	0.390**	-0.387**	0.411**	-0.687**	-0.684**	-0.436**	-0.582**	-0.318*	0.443**
	(P)				-	0.600**	0.330*	0.188	0.331**	-0.276*	0.351**	-0.465**	-0.685**	-0.512**	-0.489**	-0.381**	0.457**
Number of fruits per truss	(G)					-	0.583**	-0.222	0.266*	-0.736**	0.552**	-0.620**	0.193	-0.316*	-0.373**	-0.341**	0.351**
	(P)					-	0.515**	-0.089	0.211	-0.533**	0.441**	-0.415**	0.270*	-0.443**	-0.405**	-0.386**	0.376**
Number of fruits Per plant	(G)						-	-0.326*	0.224	-0.324*	0.367**	-0.602**	-0.317*	-0.688**	-0.598**	-0.144	0.590**
	(P)						-	-0.310*	0.215	-0.233	0.322*	-0.492**	-0.309*	-0.603**	-0.465**	-0.131	0.586**
Average fruit Weight	(G)							-	0.404**	0.168	-0.101	0.228	-0.391**	-0.201	-0.513**	0.222	0.529**
	(P)							-	0.354**	0.147	-0.099	0.121	-0.426**	-0.288*	-0.444**	0.02	0.547**
Fruit shape index	(G)								-	-0.158	-0.216	-0.638**	-0.607**	-0.402**	-0.594**	-0.206	0.526**
	(P)								-	-0.081	-0.155	-0.485**	-0.548**	-0.310*	-0.394**	-0.138	0.478**
Number of locules per fruit	(G)									-	-0.193	0.587**	0.177	0.263*	0.250	0.423**	-0.099
	(P)									-	-0.131	0.328*	0.093	0.183	0.177	0.203	-0.033
Total soluble solids	(G)										-	-0.108	0.028	-0.309*	-0.194	-0.231	0.215
	(P)										-	-0.027	0.007	-0.244	-0.127	-0.117	0.175
Ascorbic acid	(G)											-	0.725**	0.848**	0.954**	0.666**	-0.801**
	(P)											-	0.522**	0.525**	0.539**	0.364**	-0.594**
Pericarp thickness	(G)												-	0.654**	0.811**	0.094	-0.629**
	(P)												-	0.663**	0.692**	0.199	-0.639**
Fruit boerer incidence	(G)													-	0.898**	0.351**	-0.785**
	(P)													-	0.740**	0.457**	-0.755**
Leaf curl incidence	(G)														-	0.125	-0.979**
	(P)														-	0.167	-0.785**
Wilt incidence	(G)															-	-0.011
	(P)															-	-0.126
Fruit yield per plant	(G)																-
	(P)																-

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

Table 5: Estimates of direct and indirect effects of different traits on yield in tomato (Diagonal bold value is direct effect)

	Days to 50% flowering	Plant height	No. of primary branches	No. of flower per cluster	No. of fruits Per truss	No. of fruits per plant	Average Fruit weight	Fruit Shape index	No. of locules per fruit	Total Soluble solids	Ascorbic acid	Pericarp thickness	Fruit borer incidence	Leaf curl incidence	Wilt Incidence	Yield Per plant
Days to 50% flowering	**-0.3787**	-0.0222	-0.0252	-0.0009	0.0763	-0.1928	-0.1246	-0.0053	0.0018	-0.0015	0.0987	-0.0133	-0.0758	0.1641	0.0052	-0.4942
Plant height	0.0297	**0.2825**	0.0777	0.0030	-0.1542	0.4650	-0.0809	0.0358	-0.0010	-0.0131	-0.0925	0.0146	0.1163	-0.2043	-0.0163	0.4623
No. of primary branches per plant	0.1123	0.2581	**0.0851**	0.0029	-0.1447	0.4061	0.0110	0.0391	-0.0018	-0.0109	-0.1209	0.0122	0.0913	-0.2102	-0.0177	0.5119
No. of flowers per cluster	0.0774	0.1992	0.0582	**0.0042**	-0.1159	0.3090	0.0961	0.0373	-0.0018	-0.0096	-0.1050	0.0289	0.1035	-0.2274	-0.0110	0.4430
No. of fruits per truss	0.1398	0.2107	0.0595	0.0024	**-0.2068**	0.4940	-0.1888	0.0254	-0.0034	-0.0129	-0.0947	0.0082	0.0749	-0.1455	-0.0118	0.3510
No. of fruits per plant	0.0862	0.1552	0.0408	0.0016	-0.1206	**0.8467**	-0.2773	0.0214	-0.0015	-0.0086	-0.0920	0.0134	0.1634	-0.2334	-0.0050	0.5904
Average fruit weight	0.0555	-0.0269	0.0011	0.0005	0.0459	-0.2760	**0.8507**	0.0386	0.0008	0.0024	-0.0349	0.0165	0.0478	-0.2004	0.0077	0.5293
Fruit shape index	0.0211	0.1058	0.0348	0.0017	-0.0551	0.1896	0.3438	**0.0955**	-0.0007	0.0051	-0.0974	0.0256	0.0954	-0.2321	-0.0071	0.5259
No. of locules per fruit	-0.1497	-0.0614	-0.0324	-0.0016	0.1521	-0.2748	0.1432	-0.0151	**0.0046**	0.0045	0.0897	-0.0075	-0.0625	0.0976	0.0146	-0.0987
Total soluble solids	-0.0247	0.1578	0.0398	0.0017	-0.1141	0.3109	-0.0858	-0.0207	-0.0009	**-0.0234**	-0.0165	0.0012	0.0733	-0.0758	-0.0080	0.2149
Ascorbic acids	0.2446	0.1711	0.0673	0.0029	-0.1282	0.4098	0.1942	0.0609	-0.0027	-0.0025	**-0.1527**	0.0306	0.2013	-0.3725	-0.0230	-0.8010
Pericarp thickness	0.1196	0.0976	0.0245	0.0029	-0.0400	0.2688	0.3326	0.0579	-0.0008	-0.0007	-0.1107	**0.0422**	0.1553	-0.3167	-0.0032	-0.6291
Fruit borer incidence	-0.1209	-0.1383	-0.0327	-0.0019	0.0653	-0.5828	-0.1714	-0.0384	0.0012	0.0072	0.1295	-0.0276	**-0.2375**	0.3506	0.0121	-0.7855
Leaf curl incidence	-0.1592	-0.1478	-0.0458	-0.0025	0.0770	-0.5060	-0.4365	-0.0567	0.0012	0.0045	0.1457	-0.0343	-0.2132	**0.3905**	0.0043	-0.9786
Wilt incidence	-0.0566	-0.1337	-0.0435	-0.0014	0.0705	-0.1215	0.1890	-0.0197	0.0020	0.0054	0.1017	-0.0040	-0.0833	0.0489	**0.0346**	-0.0115

Residual value: 0.00634

4.4 GENETIC DIVERGENCE (D^2 STATISTIC)

The quantitative assessment of genetic divergence was made by adopting Mahalanobis D^2 statistic for yield and its contributing characters.

4.4.1 Grouping of genotypes into different clusters

The D^2 value between any two genotypes was calculated as the sum of squares of the differences between the mean values of all the sixteen characters and used for final grouping of genotypes. Procedure suggested by Tocher (Rao, 1952) was used to group genotypes into clusters by treating estimated D^2 value as the square of the generalized distance. Based on D^2 values, the 20 genotypes were grouped into four divergent clusters (Table.6). Cluster I was the largest and comprised 11 genotypes (Arka Abha , Arka Alok, DVRT-2, Palam Pride, Arka Sourabh, Arka Vikas, Palam Pink, KH-105, Selection-2, S-22, PKM-1). It was followed by Cluster II with 5 genotypes (Pusa Ruby, Hawaii-7998, CLN-2670-B1, CLN-2123-A1 Red, Bhagya); Cluster III with 3 genotypes (Arka Rakshak, BSS-488, BWR-5) and Cluster IV with single genotype (Marglobe).

Table 6: Clustering of twenty genotypes of tomato (*Solanum lycopersicum* L.) based on D^2 analysis.

Cluster	Number of genotypes	Cluster members
I	**11**	Arka Abha , Arka Alok, DVRT-2, Palam Pride, Arka Sourabh, Arka Vikas, Palam Pink, KH-105, Selection -2, S-22,PKM-1
II	**5**	Pusa Ruby, Hawaii-7998, CLN-2670-B1, CLN-2123-A1 Red, Bhagya
III	**3**	Arka Rakshak , BSS-488, BWR-5
IV	**1**	Marglobe

4.4.2 Inter and intra-cluster distance

The inter and intra cluster D^2 values are given in Table.7. The inter cluster D^2 value was found maximum between the cluster I and cluster III (160.30) thereby suggesting considerable diversity among the genotypes in these clusters. The minimum distance observed between cluster I and II (97.17) indicated close relationship among the genotypes included. The intra cluster distance was highest in cluster II (63.51) followed by Cluster III (60.61) and lowest in Cluster I (58.96) (Table.7), which indicated ample amount of genetic diversity within the clusters. The Cluster IV had only one genotype, hence no intra cluster relation was observed.

Table 7: Average intra (bold) and inter-cluster D^2 values for four clusters in 20 genotypes of tomato (*Solanum lycopersicum L.*) (Tocher's method).

Cluster	I	II	III	IV
I	**(58.96)**	97.17	160.30	137.65
II		**(63.51)**	118.13	107.46
III			**(60.61)**	102.68
IV				**-**

4.4.3 Cluster mean analysis

The cluster means of 16 different characters given in Table.8 were compared. It indicated considerable differences between clusters for all the characters studied. The maximum days to first flowering was observed in Cluster IV (31.33) whereas minimum in Cluster III (26.55). Genotypes in Cluster I showed the lowest plant height (84.23 cm) and those in Cluster IV highest mean (176.67 cm) for plant height. Maximum number of primary branches per plant was observed in cluster III (7.69) and minimum (5.55) in Cluster I. Maximum number of flowers per cluster was observed in cluster III (7.39), whereas minimum number of flower per cluster was observed in cluster I (5.03). Highest number of fruits per truss was observed in Cluster III (3.47), cluster I had the lowest number of fruits per truss (2.35).

Highest number of fruits per plant was recorded in Cluster III (30.85) while cluster IV (19.28) showed the least number of fruits per plant. Maximum average fruit weight was observed in the Cluster III (71.36 g) whereas minimum in the Cluster II (43.49 g). The maximum fruit shape index was observed in cluster III (0.94) whereas minimum in Cluster IV (0.80).

Highest number of locules per fruit was recorded in Cluster IV (5.00) while genotypes of cluster III showed the least number of locules (3.81) per fruit. Genotypes of cluster IV had highest TSS content (5.90 ºB) while that of Cluster I recorded the lowest TSS content of fruit (4.63 ºB).

Maximum ascorbic acid content in fruits was observed in cluster III (30.20 mg/100 g), whereas minimum ascorbic acid content was observed in cluster IV (23.32 mg/100 g), similarly Cluster III composed of genotypes showing highest pericarp thickness (5.53 mm) and lowest pericarp thickness by the cluster IV (3.62 mm). Highest mean for fruit borer incidence was observed in Cluster IV (9.22 %) whereas cluster III recorded lowest fruit borer incidence (2.29 %).

Leaf curl incidence was highest in Cluster IV (mean value 40 %) and minimum in Cluster III (8.89 %). Maximum and minimum wilt incidences were observed in cluster I (14.24 %) and III (5.56 %). The maximum mean for fruit yield per plant (22.06 kg) was observed in the Cluster III whereas minimum (0.72 kg) in the Cluster IV.

Table 8: Cluster mean for various quantitative and quality traits in tomato (*Solanum lycopersicum* L.)

Cluster	DFF	PHT	NPB	NFC	NFT	NFP	AFW	FSI	NLC	TSS	ASC	PCT	FBI	LCI	WLI	YPP
I	28.85	84.23	5.55	5.03	2.35	20.10	62.12	0.83	4.30	4.63	24.88	4.42	6.95	30.60	14.24	1.10
II	28.94	126.64	6.31	5.37	2.89	29.82	43.49	0.84	4.08	4.70	26.13	4.57	5.68	26.00	13.33	1.16
III	26.55	166.21	7.69	7.39	3.47	30.85	71.36	0.94	3.81	5.15	30.20	5.53	2.29	8.89	5.56	2.06
IV	31.33	176.67	7.66	7.11	3.22	19.28	54.20	0.80	5.00	5.90	23.32	3.62	9.22	40.00	10.00	0.93

DFF = Days to 50 % flowering, PHT = Plant height (cm), NPB = Number of primary branches per plant, NFC = Number of flowers per cluster, NFT = Number of fruits per truss, NFP = Number of fruits per plant, AFW = Average fruit weight (g), FSI = Fruit shape index, NLC = Number of locules per fruit, TSS = Total soluble solids (ºB), ASC = Ascorbic acid (mg/100gm), PCT = Pericarp thickness (mm), YPH = Yield per hectare (q), YPP = Yield per plant (kg), FBI = Fruit borer incidence (%), LCI = Leaf curl incidence (%) and WLI = Wilt incidence (%).

4.4.4 Per cent contribution towards total divergence

The percent contribution of each character towards divergence is presented in Table.9. It was observed that leaf curl incidence contributed maximum (38.5 %) towards total divergence followed by wilt incidence (18.60 %), fruit borer incidence (12.10 %), plant height (9.65 %), fruit yield per plant (8.78 %), number of fruits per plant (4.50 %), number of flowers per cluster (0.31 %) and total soluble solids(0.26 %).

Out of 16 characters studied seven traits *viz.*, fruit yield per plant, plant height, number of fruits per plant, average fruit weight, fruit borer incidence, leaf curl incidence and wilt incidence had major contribution (99.43 %) towards divergence **(**Table.9**)**. The Cluster pattern in 20 tomato genotypes is depicted in Fig.3.

Table 9: Per cent contribution of 16 characters towards diversity in tomato genotypes

Sl.no	Characters	Per cent of contribution	Order of contribution
1.	Leaf curl incidence	38.50	1
2.	Wilt incidence	18.60	2
3.	Fruit borer incidence	12.10	3
4.	Plant height	9.65	4
5.	Fruit yield per plant	8.78	5
6.	Average fruit weight	7.30	6
7.	Number of fruits per plant	4.50	7
8.	Number of flowers per cluster	0.31	8
9.	Total soluble solids	0.26	9

Clustering by Tocher method

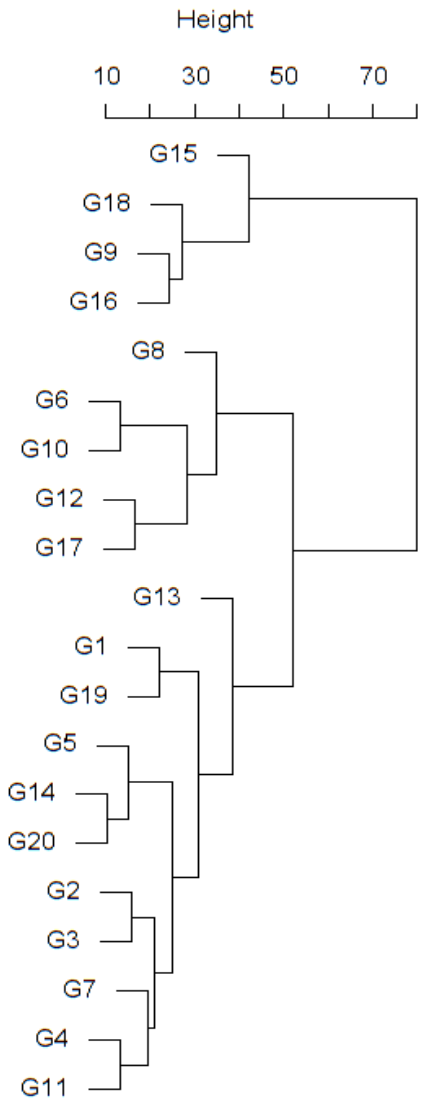

Fig. 3: Dendrogram of genotypes depicting cluster pattern

G1-PKM-1, **G2**-Arka Abha, **G3**- Arka Alok**, G4**- Arka Sourabh, **G5**- Arka Vikas, **G6**- Pusa Ruby, **G7**- Palam Pink, **G8**- Hawaii-7998, **G9**- BWR-5, **G10**- CLN-2670-B1, **G11**- Palam Pride, **G12**- CLN-2123-A1 Red, **G13**- DVRT-2, **G14**- KH-105, **G15**- Marglobe, **G16**- BSS-488, **G17**- Bhagya, **G18**- Arka Rakshak, **G19**-Selection-2 and **G20**-S-22.

4.5 REACTION OF TOMATO GENOTYPES TO PESTS

Twenty genotypes were screened against the incidence of pests (nematode, fruit borer, wilt and leaf curl virus) under natural conditions in crop grown under eco-friendly management with preceding crop as marigold. The 20 genotypes have shown different resistance level against incidence of fruit borer, wilt and leaf curl (Table.10, 11, 12 &13).

4.5.1 Fruit borer incidence

Data pertaining to reaction of genotypes to fruit borer incidence indicated that none of the genotype was resistant to the fruit borer. All the genotypes were graded as less susceptible to fruit borer incidence with infestation ranging from 5 to 20 %.

Table 10: Reaction of tomato genotypes to fruit borer incidence

Reaction	Number of genotypes	Genotypes
1. Resistant	-	-
2. Less susceptible	20	Arka Rakshak , BSS-488, CLN-2123-A1 Red, Arka Abha , Arka Alok, DVRT-2, BWR-5, Palam Pride, Arka Sourabh, Arka Vikas, Pusa Ruby, Palam Pink, Hawaii-7998, KH-105, Marglobe, Bhagya, Selection-2, S-22, PKM-1, CLN-2670-B1.
3. Susceptible	-	-

4.5.2 Leaf curl incidence

Among all genotypes evaluated, two hybrids namely Arka Rakshak (0.52 %) and BSS-488 (12.46 %) were found to be resistant and moderately resistant respectively. Seventeen genotypes showed moderately susceptible reaction (20-39 %) while one genotype PKM-1 susceptible (Table.11).

Table.11: Reaction of tomato genotypes to ToLCV incidence

Reaction	Number of genotypes	Genotypes
Resistant	1	Arka Rakshak
Moderately Resistant	1	BSS-488
Moderately Susceptible	17	CLN-2123-A1 Red, DVRT-2, BWR-5, Palam Pride, Arka Sourabh, Arka Vikas, Pusa Ruby, Palam Pink, Hawaii-7998, KH-105, Marglobe, Bhagya, Selection-2, S-22, CLN-2670-B1, Arka Abha and Arka Alok.
Susceptible	1	PKM-1
Highly Susceptible	-	-

4.5.3 Wilt incidence

Of 20 genotypes evaluated, 14 were graded as resistant to wilt (less than 20 per cent of wilt incidence) and 6 moderately resistant (20-40 per cent of wilt incidence) (Table.12).

Table.12: Reaction of tomato genotypes to wilt incidence

Reaction	Number of genotypes	Genotypes
Resistant	14	Arka Rakshak, BSS-488, BWR-5, Palam Pride, Arka Sourabh, Arka Vikas, Pusa Ruby, Palam Pink, Hawaii-7998, KH-105, Marglobe, S-22, PKM-1, CLN-2670-B1.
Moderately Resistant (MR)	6	Arka Abha, Arka Alok, CLN-2123-A1 Red, DVRT-2, Bhagya, Selection-2.
Moderately Susceptible (MS)	-	-
Susceptible (S)	-	-

4.5.4 Nematode incidence

The experimental plot with marigold as the preceding crop, showed no nematode incidence under both eco-friendly protected structure (EPS) and low cost protected structure (EPS).

4.5.5 Comparison of genotypes for yield and pests under EPS and LPS

Graphical representation of comparison of fruit yield per plant and pest incidence in crop grown under eco-friendly management with preceding crop as marigold in two types of protected structures depicted in Fig.4. Performance for yield of Arka Rakshak (2.52 kg and 2.72 kg) was best and followed by BSS-488 (1.93 kg and 1.92 kg), DVRT-2 (1.73 kg and 2.12 kg) and CLN-2123-A1 Red (1.76 kg and 1.93 kg) better in both EPS and LPS. The genotypes Pusa Ruby (1.08 kg and 2.40 kg), Arka Alok (1.51 kg and 2.30 kg), CLN-2670-B1 (0.79 kg and 1.77 kg) and KH-105 (1.23 kg and 1.84 kg) performed relatively better for yield in LPS over EPS (Table.13). Further, leaf curl and wilt incidence was relatively more higher in eco-friendly protected structure (EPS) over low cost protected structure (LPS) with mean of (29.79 % and 9.29 %) for leaf curl incidence and (19.99 % and 8.42 %) for wilt incidence respectively. Almost similar level of fruit borer incidence was observed in EPS (13.87 %) and LPS (10.23 %).

Table 13: Comparison of genotypes for yield, pest and diseases incidences under eco-friendly protected structures and low cost protected structures.

Genotypes	Yield/plant (kg)		Fruit borer incidence* (%)		Leaf curl incidence* (%)		Wilt incidence* (%)	
	EPS	**LPS**	**EPS**	**LPS**	**EPS**	**LPS**	**EPS**	**LPS**
PKM-1	0.59	0.89	16.72	9.48	43.08	9.27	18.05	7.28
Arka Abha	1.13	1.10	18.68	12.10	35.22	10.34	31.07	7.84
Arka Alok	1.51	2.30	13.60	11.19	28.78	9.27	26.45	7.77
Arka Sourabh	0.74	1.06	17.77	11.47	35.22	10.96	18.05	14.77
Arka Vikas	1.01	1.46	15.15	11.93	33.00	7.95	18.05	8.38
Pusa Ruby	1.08	2.40	13.85	7.85	33.00	7.33	18.44	8.38
Palam Pink	0.89	0.98	15.69	7.69	31.00	9.88	18.05	6.99
Hawaii-7998	1.04	1.12	12.65	11.54	33.00	9.27	18.05	6.97
BWR-5	1.72	1.49	10.79	12.55	26.07	10.50	10.34	8.74
CLN-2670-B1	0.79	1.77	16.28	11.82	34.93	11.48	18.05	7.33
Palam Pride	0.80	0.89	14.37	8.92	35.22	12.42	18.05	10.12
CLN-2123-A1 Red	1.76	1.93	12.11	7.14	23.86	11.48	23.74	10.24
DVRT-2	1.73	2.12	11.52	11.39	23.86	7.95	26.45	10.35
KH-105	1.23	1.84	12.30	7.73	35.22	7.95	18.43	9.27
Marglobe	0.93	0.76	17.67	11.61	37.14	15.32	18.05	9.88
BSS-488	1.93	1.92	7.84	8.67	12.46	6.72	14.76	5.00
Bhagya	1.16	1.42	13.36	10.71	26.07	7.48	26.45	4.75
Arka Rakshak	2.52	2.72	6.83	5.81	0.52	0.45	14.76	2.95
Selection-2	1.38	1.50	16.97	11.92	35.22	10.50	26.45	11.48
S-22	1.08	1.59	13.29	13.04	31.00	7.84	18.05	9.88
Mean	**1.25**	**1.56**	**13.87**	**10.23**	**29.79**	**9.22**	**19.99**	**8.42**
$CD_{(0.05)}$	**0.21**	**0.17**	**2.65**	**2.92**	**9.28**	**2.72**	**6.58**	**2.69**
CV	**10.42**	**6.58**	**11.54**	**17.28**	**18.85**	**17.85**	**19.93**	**19.19**

EPS-Eco-friendly protected structures
LPS- Low cost protected structures
(*) Arcsine transformed values

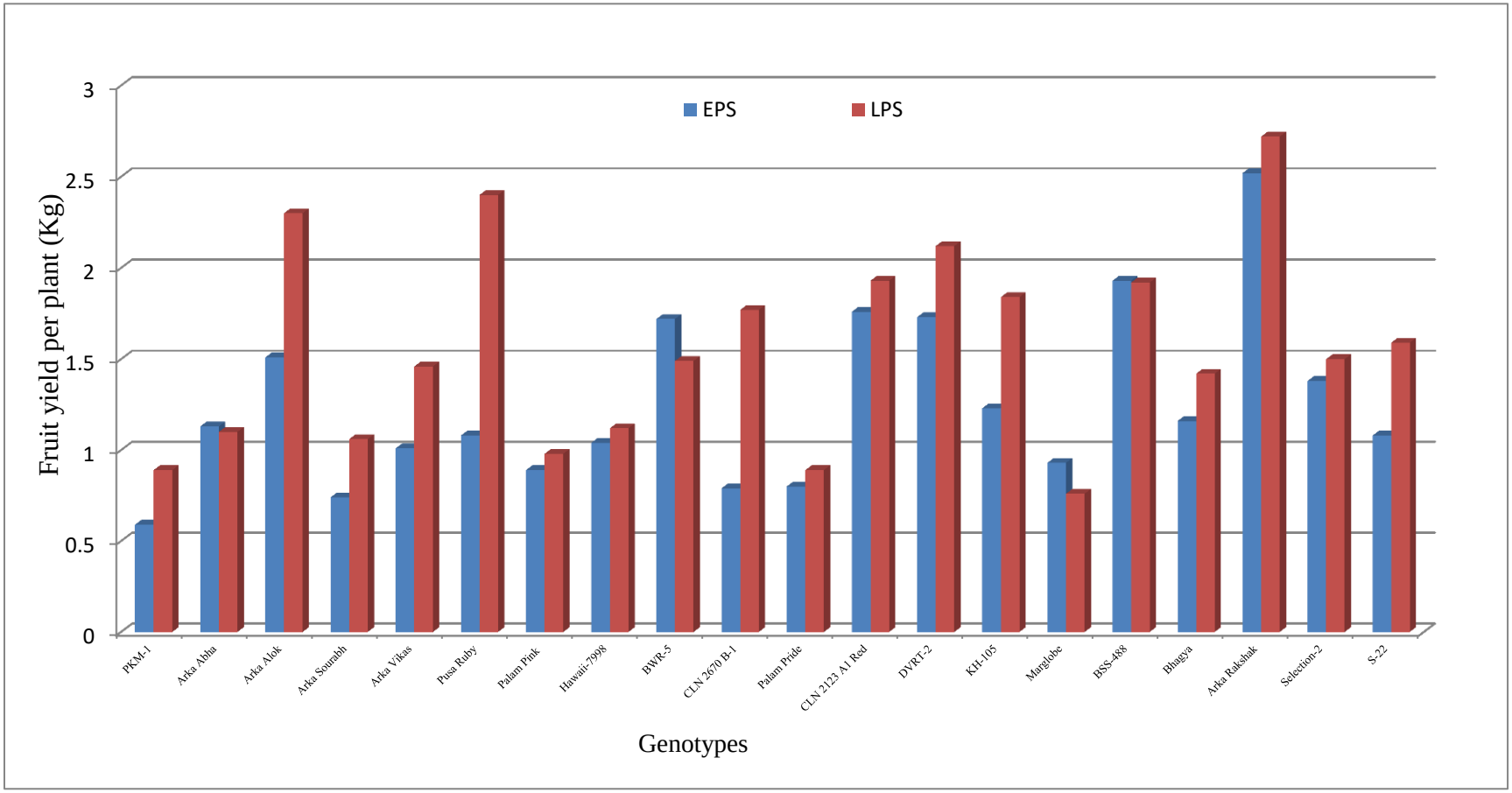

Fig.4 Comparison of genotypes for yield per plant under eco-friendly protected structure (EPS) & low cost protected structure (LPS).

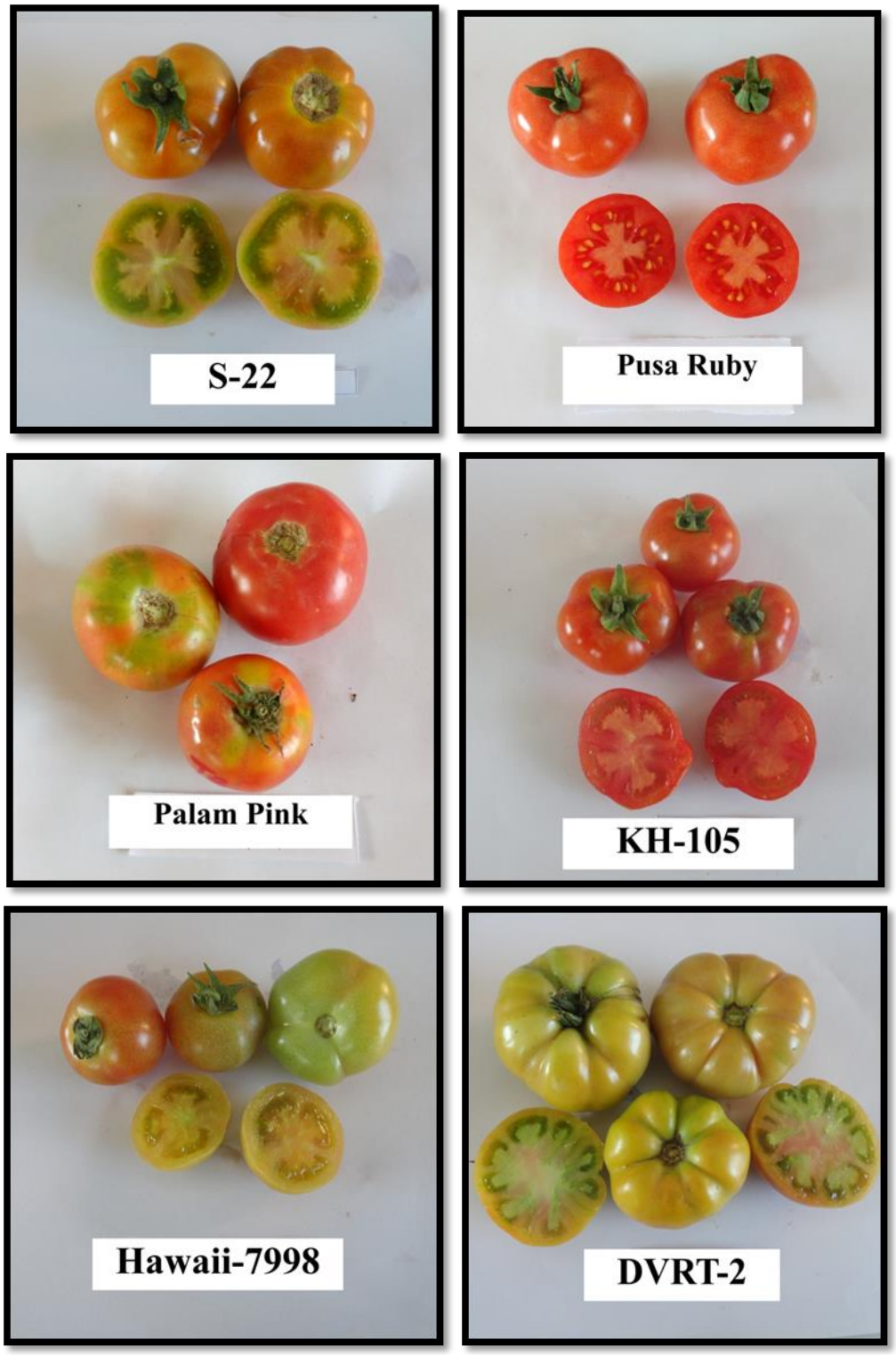

Plate 2 (a). Fruits of various tomato genotypes

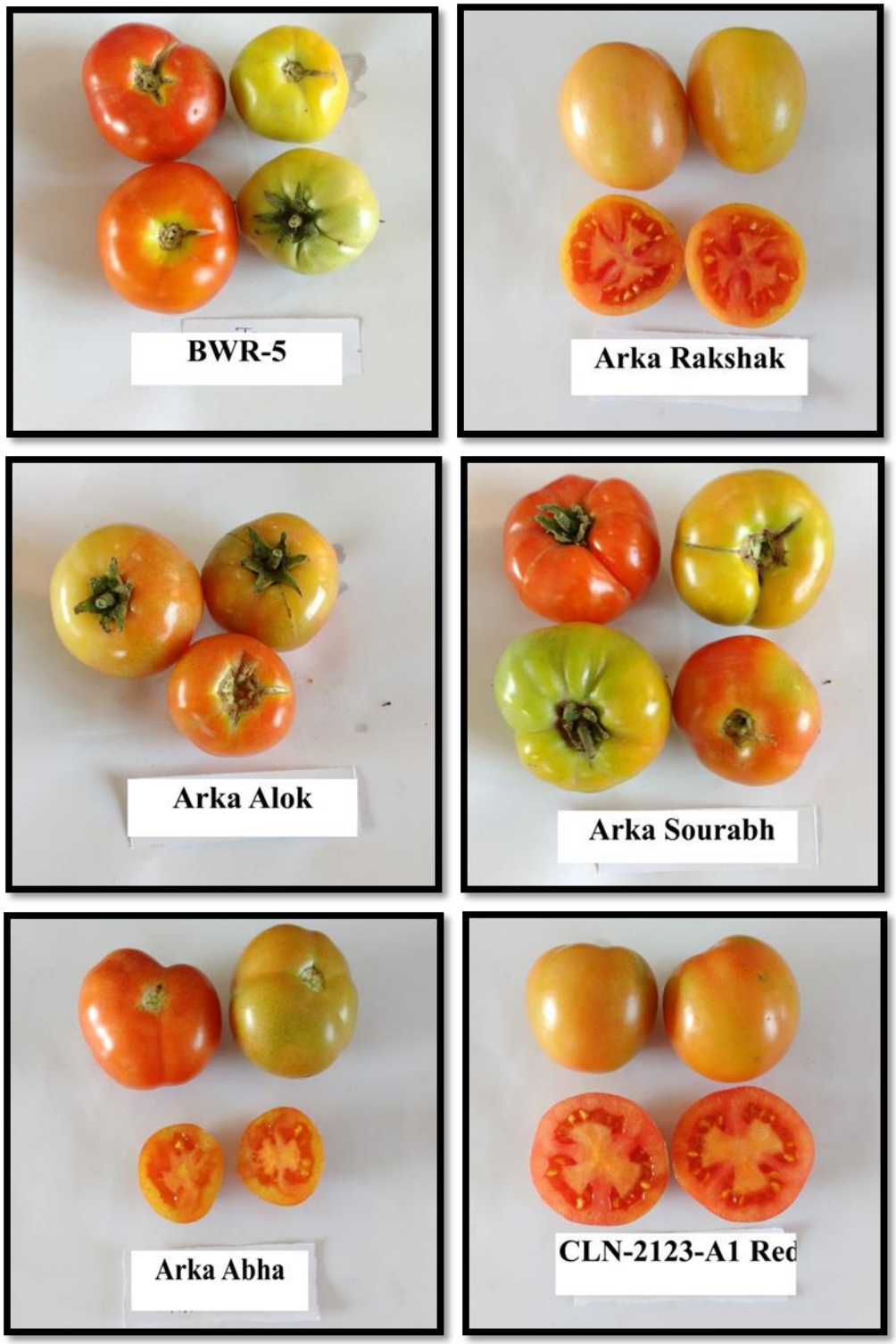

Plate 2 (b). Fruits of various tomato genotypes

DISCUSSION

CHAPTER-5

DISCUSSION

Tomato is gaining popularity at the global level for its amazing characteristics like wider adaptability, high yield potential, nutritive and medicinal values. There is need for continuous improvement in tomato by isolating superior genotypes having desirable horticultural traits and multiple disease resistance and better tolerance against other pests. The existence of sufficient variability for traits of interest, provide better chance of selecting desired genotypes. Hence, knowledge of the magnitude and kind of variability for yield and yield attributing traits is of primary importance. Heritability examines the extent of heritable portion of variability while genetic advance predicts the possible yield through selection. The fruit yield in tomato is a complex trait and dependent on number of yield components. For improvement in yield and quality traits, there is a need to know the inter-relationship of different traits. Knowledge of inter trait relationship also helps in the identification of important attributes that can be used to design suitable plant type with improved traits. Path coefficient analysis on the other hand partitions the correlation coefficients into direct and indirect effects. Information so generated can be utilized in restructuring desirable plant types. Grouping of genotypes based on D^2 analysis is useful in choosing suitable parental lines for heterosis breeding and hybridization. The results of present investigation carried out involving 20 diverse genotypes to study genetic variability, correlation, path analysis and genetic divergence for different horticultural traits under eco-friendly management in early planted crop, have been discussed here under in the light of available literature:

5.1 VARIABILITY STUDIES

5.1.1 Mean Performance of Genotypes

The analysis of variance depicted highly significant differences among the genotypes for all the traits studied and revealed the existence of good amount of variability in the germplasm. The results have been discussed under the following headings:

5.1.1.1 Days to 50 % flowering

Earliness is one of the most important factors which decide how fruits reach early in the market and appeal to the eyes of the customers. Significant variations were observed in all the genotypes for days to 50 % flowering which varied from 23.67 days in Arka Rakshak to 31.67 days in Palam Pride thereby suggesting considerable variability. These results are in accordance with earlier work of Singh *et al.* (2017a), Ligade *et al.* (2017), Bhandari *et al.* (2017), Kumar (2014), Singh *et al.* (2014) and Reddy *et al*. (2013b).

5.1.1.2 Plant height (cm)

Plant height is an important parameter in any crop plant determining the vigor of plant. All the genotypes indicated significant variations for this trait. Maximum plant height was recorded in BSS-488 (178.77 cm) followed by Marglobe (176.67 cm) and minimum in PKM-1 (65.60 cm). These findings are in agreement with the earlier work of Das *et al.* (2018), Bhandari *et al.* (2017), Patel *et al.* (2017), Singh *et al*. (2017a), Ligade *et al.* (2017), Kumar (2014), Buckseth *et al*. (2012) and Rahman *et al.* (2012).

5.1.1.3 Number of primary branches per plant

Number of primary branches per plant is an important trait which has direct effect on fruit yield of plant, and ultimately on total yield. Significant variations for number of primary branches per plant were obtained among all the genotypes studied. Maximum number of primary branches per plant were observed in Arka Rakshak (8.41) followed by Marglobe (7.66), BWR-5 (7.44), while DVRT-2 (4.78) had the minimum number of primary branches per plant. These results depicted a wide range of variation for the trait in the experimental material. These findings corroborate the work of earlier researchers like Das *et al.* (2018), Patel *et al.* (2017), Bhandari *et al.* (2017), Singh *et al.* (2017a), Singh *et al.* (2015) and Ayush *et al.* (2012).

5.1.1.4 Number of flowers per cluster

Number of flowers per cluster is also important trait determining the number of fruits per cluster and finally the number of fruits per plant. The significant differences were observed for this trait among all the genotypes. Maximum number of

flowers per cluster were observed in BSS-488 (8.66) followed by Arka Rakshak (8.28) and Marglobe (7.66) while Pusa Ruby (3.66) had the minimum number of flowers per cluster thereby suggesting ample variation. These results are in accordance with earlier work of Ligade *et al.* (2017), Bhandari *et al.* (2017), Singh *et al.* (2017a), Singh *et al.* (2015) and Ayush *et al.* (2012).

5.1.1.5 Number of fruits per truss

Number of fruits per truss directly contributes to the total number of fruits per plant and ultimately final yield. The significant variations among all the genotypes were observed for number of fruits per truss. Maximum numbers of fruits per truss were observed in Arka Rakshak (4.08) followed by BSS-488 (4.00) and Hawaii-7998 (3.89) while minimum in DVRT-2 (1.66). Similar results were reported by earlier researchers like Bhandari *et al.* (2017), Reddy *et al.* (2013b), Kumar *et al.* (2013a) and Mohamed *et al.* (2012) for this trait.

5.1.1.6 Number of fruits per plant

Number of fruits per plant is a major yield contributing trait. This trait showed significant differences among all the genotypes. Maximum number of fruits per plant were observed in the genotype Hawaii-7998 (42.25) and minimum in PKM-1(12.92). The wide variation for number of fruits per plant was also reported earlier by Das *et al.* (2018), Singh *et al.* (2017a), Bhandari *et al.* (2017), Patel *et al.* (2017), Ligade *et al.* (2017), Meena and Bahadur (2015), Agrawal *et al.* (2014) and Kumar *et al.* (2014b).

5.1.1.7 Average fruit weight (g)

Average fruit weight is another important trait and has direct effect on yield. The wide variation was observed among all the genotypes for this trait. Maximum average fruit weight was recorded in DVRT-2 (85.52 g) followed by Arka Rakshak (81.31 g) and Palam pride (74.80 g) while minimum in Hawaii-7998 (26.03). These results are in agreement with earlier work of Das *et al.* (2018), Patel *et al.* (2017), Ligade *et al.* (2017), Bhandari *et al.* (2017), Premalakshmi *et al.* (2014), Sharma and Jaipaul (2014), Agrawal

et al. (2014), Kumar *et al.* (2014b), Meena and Bahadur (2015) and Nwosu *et al.* (2014).

5.1.1.8 Fruit shape index

Fruit shape index is a measure of fruit shape and is the ratio of polar and equatorial diameter of fruit. Generally, round shape of fruit is preferred for fresh use and oval shape for processing. Arka Rakshak depicted maximum fruit shape index (1.07) under oval category. Minimum index value (0.67) was observed in PKM-1 under flat round category. Three genotypes had an oval shape (CLN-2123-A1 Red, Arka Rakshak, and Palam Pride) with a fruit shape index value of one and above. It indicated that these cultivars are suitable for processing. Five genotypes were in spherical shape while remaining eleven genotypes fell under intermediate and one under flat round group. These could be suitable for fresh/table purpose. On similarly, tomato fruits were also classified into oval, spherical, intermediate and flat round categories by Shweta *et al.* (2016), Kharshandi (2015), Kumar (2014) and Buckseth (2010).

5.1.1.9 Number of locules per fruit

Number of locules per fruit is an important quality trait and generally fruits with higher number of locules are preferred because it influences higher fruit size. Among the genotypes evaluated, maximum number of locules per fruit were recorded in DVRT-2 (5.44) and minimum in Hawaii-7998 and Arka Rakshak (3.11), suggesting a large variability in the material under study. Similarly wide variation with respect to this trait was reported by Bhandari *et al.* (2017), Kumar (2014), Manna and Paul (2012) and Buckseth *et al.* (2012).

5.1.1.10 Total soluble solids (ºBrix)

Total soluble solids content is one of the most important quality parameters in the processing industry. Significant variations were observed among all the genotypes for total soluble solid content. Significantly higher total soluble solids were observed in Marglobe (5.90 ºB) and low in Selection-2 (3.9 ºB). These results are in agreement with earlier work of Das *et al.* (2018), Ligade *et al.* (2017), Agrawal *et al.* (2014), Kumar *et al.*

(2014b) and Meena and Bahadur (2014), Kumar *et al.* (2013a), Patel *et al.* (2013) and Reddy *et al.* (2013b) .

5.1.1.11 Ascorbic acid (mg/100 g)

Ascorbic acid also known as vitamin C, ranged from 23.32 mg/100 g in Marglobe and 33.91 mg/100g in Arka Rakshak. Similar results were reported by Das *et al.* (2018), Ligade *et al.* (2017), Kumar (2014), Reddy *et al.* (2013b) and Dar and Sharma (2011).

5.1.1.12 Pericarp thickness (mm)

Pericarp thickness is an important trait as it is directly related with keeping quality and fruit firmness. All the genotypes studied revealed significant variations for this trait. Maximum pericarp thickness was observed in BSS-488 (6.05 mm) followed by Arka Rakshak (6.03 mm) and Palam Pride (5.78 mm), while minimum in Marglobe (3.62 mm). These findings are in line with the work of Agrawal *et al.* (2014), Kumar *et al.* (2014b), Khapte and Jansirani (2014a), Patel *et al.* (2013) and Buckseth *et al.* (2012).

5.1.1.13 Fruit yield per plant (kg)

High fruit yield is the ultimate goal of any breeding program. All the genotypes studied revealed significant variations for fruit yield per plant. Maximum fruit yield per plant was observed for Arka Rakshak (2.52 kg), followed by BSS-488 (1.93 kg), CLN-2123-A1 Red (1.76 kg) and DVRT-2 (1.73kg) while minimum in PKM-1 (0.59 kg). Similarly wide variations for fruit yield per plant have been reported earlier by earlier workers, Das *et al.* (2018), Patel *et al.* (2017), Bhandari *et al.* (2017), Ligade *et al.* (2017), Rai (2015), Kumar *et al.* (2014b), Meena and Bahadur (2014) and Nwosu *et al.* (2014).

5.1.1.14 Fruit yield per hectare (q)

The main focus of cultivating a crop is to have the maximum yield per unit area for better returns. All the genotypes under study revealed significant variations for fruit yield per hectare. Maximum fruit yield per hectare was recorded in the Arka Rakshak (443.91 q) followed by BSS-488 (341.04 q), CLN-2123-A1 Red (309.7 q) and DVRT-2 (304.23 q) while minimum in PKM-1 (103.59 q). Similar results were reported earlier by

Rai (2015), Kumar *et al.* (2014b), Meena and Bahadur (2014), Nwosu *et al.* (2014), Kumar *et al.* (2013a), Patel *et al.* (2013), Reddy *et al*. (2013b) and Buckseth *et al*. (2012).

5.1.1.15 Fruit borer incidence (%)

Tomato fruit borer is one of the serious pest infecting tomato and no variety having resistance to this pest has been reported. Fruit borer incidence among different tomato genotypes under study ranged from 6.83 % to 18.68 % in early transplanted crop Minimum fruit borer incidence was recorded in the genotype Arka Rakshak (6.83%) followed by BSS-488 (7.84%) and maximum in Arka Abha (18.68 %). These results of present investigation are in line with Badhani (2015), Iqbal *et al.* (2013) and Shashikant *et al.* (2010).

5.1.16 Leaf curl incidence

Tomato leaf curl disease caused by tomato leaf curl virus (ToLCV) is a major limiting factor in tomato cultivation in Jammu. In India, this virus caused 100% infection and yield loss up to 90% (Sastry and Singh, 1973). Minimum leaf curl incidence was observed in genotypes namely, Arka Rakshak (0.52 %) and BSS-488 (12.46 %), while maximum in PKM-1 (43.08 %). High variation to ToLCV was earlier reported by Nadkarni *et al.* (2017) and Meena *et al.* (2015), Singh (2014) and Shashikant *et al.* (2010).

5.1.1.17 Wilt incidence (%)

Wilt in tomato is mainly caused by two pathogens *viz.*, *Fusarium Spp.* and *Ralstonia Spp.*, the later one cause's bacterial wilt which cause sudden wilting and mortality. Field evaluation of genotypes for wilt indicated minimum disease incidence in BWR-5 (10.34 %) followed by, Arka Rakshak (14.76 %) and BSS-488(14.76 %) while maximum incidence in Arka Abha (31.07 %). These results are in line with that of Shashikant *et al.* (2010), Kumar *et al.* (2001).

5.1.2 PARAMETERS OF VARIABILITY

5.1.2.1 Coefficients of Variation

The analysis of variance indicated highly significant differences among genotypes for all the traits studied. The results indicated existence of high variability for all the yield and yield components among the genotypes studied. Thus suggesting a scope for selection of superior and desired genotypes for further improvement in tomato

An assessment of heritable and non-heritable components observed in the total variability is indispensable in adopting suitable breeding procedure. The heritable portion of the overall observed variation can be ascertained by studying the components of variation such as phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), heritability and predicted genetic advance. The presence of narrow gap between PCV and GCV for all the traits except for pest and disease incidences under study, suggested that these traits had low environmental influence.

Low GCV and PCV for days to 50 % flowering, total soluble solids, fruit shape index and ascorbic acid have been observed. These results are in accordance with the findings of Singh *et al.* (2017a), Rai *et al.* (2016) and Singh *et al.* (2014) for days to 50 % flowering, Kumar (2014) for total soluble solid; and Patel *et al.* (2013) and Rahman *et al.* (2012) for Fruit shape index; and Prashanth *et al.* (2015) for ascorbic acid. Low GCV and moderate PCV were observed for number of primary branches per plant and number of locules per fruit. These results are in conformity with earlier work of Bhandari *et al.* (2017) and Shashikant *et al.* (2010) for number of primary branches per plant; and that of Saini *et al.* (2013) and Manna and Paul (2012) for number of locules per fruit. Moderate GCV and PCV were observed for number of flowers per cluster, number of fruits per truss, average fruit weight and pericarip thickness. These results are in agreement with the earlier findings of Bhandari *et al.* (2017) and Kumar *et al.* (2016) for number of flower per cluster, Kumar *et al.* (2013a), Ara *et al.* (2009) and Singh *et al.* (2002) for number of fruits per truss, Meena *et al.* (2015) and Shashikant *et al.* (2008) for average fruit weight and that of Khapte and Jansirani (2014a) and Manna and Paul (2012) for pericarp thickness.

High genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were observed for plant height, number of fruits per plant, fruit yield per plant, fruit borer incidence, wilt incidence and leaf curl incidence. High PCV over respective GCV in fruit borer incidence, wilt incidence and leaf curl incidence suggested that these traits are more affected by environment. These results are in line with earlier work of Rai *et al.* (2016), Kumar *et al.* (2016) for plant height, Kumar *et al.* (2014b), and Sherpa *et al.* (2014) for number of fruits per plant; and Kumar *et al.* (2014b), Sherpa *et al.* (2014), Kumar *et al.* (2014b) and Patel *et al.* (2013) for fruit yield per plant; and that of Sharma *et al.* (2003), Rath and Math (2001), Rai *et al.* (2001), Vineet *et al.* (1997) and Sharma (1996) fruit borer incidence, bacterial wilt and tomato leaf curl virus.

5.1.2.2 Heritability

The ratio of genetic advance to the total variance called heritability which is a useful measure in predicting the progress to be achieved through selection. Estimates of heritability alone fail to indicate the response to selection (Johnson *et al.*, 1955). Therefore, the heritability estimates appear to be more meaningful when accompanied by genetic advance.

High heritability for the traits viz., days to 50 % flowering, plant height, number of flower per cluster, number of fruits per plant, average fruit weight, fruit shape index, pericarp thickness and fruit yield per plant was obtained. The above results are in accordance with the work of Bhandari *et al.* (2017) and Shweta *et al.* (2016) for days to 50 % flowering; and Singh *et al.* (2017a), Shweta *et al.* (2016) and Singh *et al.* (2014) for plant height; and Bhandari *et al.* (2017), Kumar *et al.* (2016) and Shweta *et al.* (2016) for number of flowers per cluster; and Kumar *et al.* (2014b), Agrawal *et al.* (2014) and Premalakshmi *et al.* (2014) for number of fruits per plant; and Singh *et al.* (2017a), Rai *et al.* (2016), Meena *et al.* (2015) and Singh *et al.* (2014) for average fruit weight; and Shweta *et al.* (2016) and Prashanth *et al.* (2015) for fruit shape index; and Singh *et al.* (2017a). Singh *et al.* (2014) for pericarp thickness; and Kumar *et al.* (2014b), Kumar *et al.* (2013a), Patel *et al.* (2013), Dar *et al.* (2011) and Khan and Samadia (2012) for fruit yield per plant.

Moderate heritability was observed for traits namely, primary branches per plant, number of fruits per truss, number of locules per fruit, total soluble solids, ascorbic acid, fruit borer incidence, wilt and tomato leaf curl virus. These results are in conformity with earlier work of Reddy *et al.* (2013b) and Khanom *et al.* (2008) for primary branches per plant; and Kumar *et al.* (2013a) and Ara *et al.* (2009) for number of fruits per truss; and Rai *et al.* (2016) and Shashikant (2008) for number of locules per fruit; and Rai *et al.* (2016), Kumar (2014) and Manna and Paul (2012) for total soluble solids, Singh *et al.* (2002a) and Singh *et al.* (2002b) for ascorbic acid; and Sharma *et al.* (2003) Rath and Math (2001), Rai *et al.* (2001), Vineet *et al.* (1997) and Sharma (1996) for fruit borer incidence, bacterial wilt and tomato leaf curl virus.

5.1.2.3 Heritability and Genetic Advance

The estimates of genetic advance along with the heritability values are more useful because they provide better response during selection than either of the parameters alone. Burton (1952) reported that the genetic coefficient of variation along with heritability give the best picture of the genetic advance to be expected from selection. In the present investigation genetic advance expressed as percentage of mean varied from 13.72 % to 75.49 %. High heritability coupled with high genetic advance as per cent of mean was observed for plant height, number of fruits per plant and fruit yield per plant. These traits could be controlled by additive gene action indicating usefulness in selection. Similarly, high heritability and high genetic advance was reported by Singh *et al.* (2017a) and Shweta *et al.* (2016) for plant height; and Rai *et al.* (2016) for number of fruits per plant; and Kumar *et al.* (2014b), Agarwal *et al.* (2014), Premalakshmi *et al.* (2014) and Sherpa *et al.* (2014) for fruit yield per plant; and Kumar *et al.* (2014b), Sherpa *et al.* (2014) and Buckseth *et al.* (2012) also reported. High heritability and low genetic advance recorded for days to 50 % flowering and fruit shaper index revealed the major role of non-additive gene action in the transmission of these traits from parents to off springs. Similar observation were made by Bhandari *et al.* (2017) and Shweta *et al.* (2016) Chadha and Bhusan (2013) for days to 50 per cent flowering, Prashanth *et al.* (2015) for fruit shape index. High heritability with moderate genetic advance was recorded for number of flowers per cluster, average fruit weight and pericarp thickness,

these results are in similarity with Bhandari *et al.* (2017) and Sahu *et al.* (2013) for number of flowers per cluster; and Meena *et al.* (2015) and Shashikant *et al.* (2008) for average fruit weight; and Dudi *et al.* (1983) for pericarp thickness.

Moderate heritability with high genetic advance was recorded for fruit borer incidence, wilt incidence and leaf curl virus incidence. These result are in line with the earlier work of Sharma *et al.* (2003), Rath and Math (2001), Rai *et al.* (2001), Vineet *et al.* (1997) and Sharma (1996) for fruit borer incidence, bacterial wilt and tomato leaf curl virus. Moderate heritability with moderate genetic gain was noted for primary branches per plant and number of fruits per truss and these results are in accordance with earlier work of Reddy *et al.* (2013b) and Khanom *et al.* (2008) for primary branches per plant; and Kumar *et al.* (2013a) and Ara *et al.* (2009) for number of fruits per truss. Similarly moderate heritability with low genetic gain was noted for number of locules per fruit, total soluble solids and ascorbic acid. These results are in conformity with earlier work of Shashikant *et al.* (2008) for number of locules per fruit; and Kumar (2014) Manna and Paul (2012) and Kumar *et al.* (2004) for total soluble solids; and Singh *et al.* (2002a) and Singh *et al.* (2002b) for ascorbic acid.

5.2 CORRELATION STUDIES

Knowledge of degree of association of yield with its components is of great importance. Yield is not an independent trait but resultant of the interactions of a number of component traits among themselves as well as with the environment in which the plant grow. Each trait is likely to be modified by action of genes present in the genotypes of plant and also by the environment so it becomes difficult to evaluate this complex trait directly. Therefore, correlation study of yield with its component traits has been executed, to find out the yield contributing traits.

In general, the genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients. The phenotypic and genotypic correlation among different traits showed that fruit yield per plant had positive and significant association with plant height, number of primary branches per plant, number of flowers per clusters, number of fruits per truss, number of fruits per plant, average fruit weight and fruit shape

index. Similar correlation results were earlier reported by Meena *et al.* (2018), Ambresh *et al.* (2017) and Rani *et al.* (2010) but significant and negative correlations was observed with days to 50 % flowering, ascorbic acid, pericarp thickness, fruit borer incidence and leaf curl incidence. Number of locules per fruit and total soluble solids have no correlation with fruit yield per plant. These results are in accordance with that of Ambresh *et al.* (2017) and Kumar *et al.* (2014a).

Average fruit weight had positive and significant association with fruit shape index and significantly negative correlation with pericarp thickness, leaf curl incidence. Significantly positive correlation of number of fruits per plant was found with total soluble solids while significant negative association with ascorbic acid content, fruit borer incidence and leaf curl incidence. Number of primary branches per plant showed significantly positive correlation with number of flower per cluster, number of fruits per truss, number of fruits per plant, fruit shape index and total soluble solids whereas number of locules per fruit, ascorbic acid pericarp thickness, fruit borer incidence, leaf curl incidence, wilt incidence had negative and significant correlation with it. Days to 50% flowering had positive and significant correlation with ascorbic acid content and leaf curl incidence while it was negatively and significantly correlated with number of fruits per truss. Similarly, correlation of yield with various horticultural and quality traits have also been reported by earlier workers *viz.*, Singh *et al.* (2018), Naveen *et al.* (2017), Rajolli *et al.* (2017), Singh *et al.* (2017b), Meena and Bahadur (2015), Prajapati *et al.* (2015), Khapte and Jansirani (2014a), Reddy *et al.* (2013b), Buckseth *et al.* (2012), Khan and Samadia (2012), Manna and Paul (2012), Sharma and Singh (2012), Dar *et al.* (2011) and Rani *et al.* (2010).

5.3 PATH COEFFICIENT ANALYSIS

Although correlation studies are helpful in determining the components of yield but it does not provide a clear picture of nature and extent of contributions made by number of independent traits. Path coefficient analysis devised by Dewey and Lu (1959) provides a realistic basis for allocation of appropriate weightage to various attributes for designing a pragmatic programme for the improvement of yield. Path coefficient analysis depicts the effects of different independent traits individually and in combination

with other traits on the expression of different traits on marketable fruit yield per plant.

The perusal of data for path coefficient analysis at genotypic level revealed that average fruit weight had maximum positive direct effect on fruit yield per plant followed by number of fruits per plant, fruit borer incidence, plant height, fruit shape index, number of primary branches per plant, pericarp thickness, wilt incidence and number of flowers per cluster. Negative direct effect of days to 50 % flowering, fruit borer incidence, fruits per truss, ascorbic acid and total soluble solids was observed on fruit yield per plant. These results are in agreement with earlier work of Singh *et al.* (2018), Naveen *et al.* (2017), Rajolli *et al.* (2017), Singh *et al.* (2017b), Meena and Bahadur (2015), Prajapati *et al.* (2015), Khapte and Jansirani (2014a), Mahapatra *et al.* (2013), Reddy *et al.* (2013b) and Sharma *et al.* (2013).

High indirect effects on fruit yield per plant via fruits per plant for fruits per truss followed by leaf curl incidence for fruit borer incidence and average fruit weight for fruit shape index was recorded. Maximum negative indirect effect on fruit yield per plant via number of fruits per plant for fruit borer incidence was observed, followed by number of fruits per plant for leaf curl incidence and average fruit weight for leaf curl incidence.

. At genotypic level residual effect was found to be 0.00634. Various workers like Singh *et al.* (2018), Naveen *et al.* (2017), Rajolli *et al.* (2017), Singh *et al.* (2017b), Meena and Bahadur (2015) and Prajapati *et al.* (2015), Khapte and Jansirani (2014a), Kumar *et al.* (2013a), Mahapatra *et al.* (2013), Reddy *et al.* (2013b), Sharma *et al.* (2013), Buckseth *et al.* (2012), Manna and Paul (2012), Rani *et al.* (2010) and Rani *et al.* (2010) had earlier reported similar direct and indirect effects of various horticultural and quality traits on yield in tomato.

5.4 GENETIC DIVERGENCE STUDIES

The analysis of variance revealed highly significant differences among the genotypes for all the traits studied, indicating the existence of wide genetic diversity in the germplasm. On the basis of performance of various traits, all the genotypes were grouped into 4 clusters. Maximum numbers of genotypes were accommodated in the

cluster-I (11) followed by cluster-II (5), cluster-III (3) and cluster-IV (1). The resultant four clusters showed genetic diversity. Similar results were earlier reported by Spaldon and Kumar (2017), Rathod *et al.* (2015), Iqbal *et al.* (2014), Nalla *et al.* (2014), Srivastava *et al.* (2014), Khapte and Jhansirani (2014b), Meena and Bahadur (2014), Reddy *et al.* (2013a) and Kumar *et al.* (2013b).

5.4.1 Inter and intra cluster distance

The intra cluster distance was found maximum in cluster II *i.e.,* 63.51 followed by cluster III i.e., 60.61 and cluster I i.e., 58.96. This suggests that crossing among the genotypes with maximum intra-cluster value (Cluster II) will result in maximum heterosis. Highest inter-cluster distance was recorded between cluster III and II, suggesting that crossing between the genotypes of these clusters will result in more heterosis. These results are in accordance with earlier work of Spaldon and Kumar (2017), Rathod *et al.* (2015), Iqbal *et al.* (2014), Nalla *et al.* (2014), Srivastava *et al.* (2014), Khapte and Jhansirani (2014b), Meena and Bahadur (2014), Reddy *et al.* (2013a) and Kumar *et al.* (2013b).

The existence of diversity among the genotypes was also assessed by the considerable amount of variation in cluster means for different traits. Cluster-III depicted highest cluster mean value for days to 50 % flowering, number of primary branches per plant, number of flowers per cluster, number of fruits per truss, number of fruits per plant, average fruit weight, number of locules per fruit, ascorbic acid, pericarp thickness, fruit borer incidence, leaf curl incidence, wilt incidence and fruit yield per plant whereas cluster-IV gave high cluster mean value for plant height and total soluble solids. Similar results were reported by earlier workers like Spaldon and Kumar (2017), Rathod *et al.* (2015), Iqbal *et al.* (2014), Nalla *et al.* (2014), Srivastava *et al.* (2014), Khapte and Jhansirani (2014b) and Meena and Bahadur (2014).

5.4.2 Per cent contribution of various traits

The selection and choice of parents mainly depends contribution of traits towards divergence (Ramya and Kumar, 2004). It was observed that among sixteen traits, leaf curl incidence (38.5 %) showed highest contribution for divergence. Seven traits contributed

for more than 99 % towards genetic divergence. These results are in similarity with Spaldon and Kumar (2017), Rathod *et al.* (2015) and Khapte and Jhansirani (2014b). It is important to note that while considering the genetic diversity among the parents to be included in hybridization programme, their field potential should not be ignored. It is necessary to carefully analyse the selection of a particular cluster from which genotypes are to chosen to make crossing programme as well as selection of a particular genotype from selected cluster. It has been reported that while selecting genotypes from distant cluster the mean values for different trait should be given importance to generate promising breeding material (Hazra *et al.*, 2002).

The results obtained from crop raised under eco-friendly management under protection for various traits as early transplanted crop have been discussed with the work of various workers for normal season crop. Broadly speaking there were no major and minor departures but varietal differences observed.

5.5 REACTION OF TOMATO GENOTYPES TO PEST AND DISEASES

Twenty tomato genotypes were screened against the incidence of nematodes, fruit borer, wilt and leaf curl virus under natural conditions in crop grown under eco-friendly management with preceding crop as marigold.

5.5.1 Fruit borer incidence

None of the genotypes were found completely resistant to the fruit borer. Normally fruit borer attack is serious in normal season. But low incidence was observed in early planted crop. Mean fruit borer incidence was comparable in both protected structures and may be due to seasonal effect or use of helicoverpa traps and neem oil spray, similar results have been earlier reported by Dass (2006).

5.5.2 Leaf curl incidence

ToLCV incidence was severe in early planted tomato as the vector population was high. Only one genotype (Arka Rakshak) was found to be resistant whereas BSS-488 moderately resistant. My personal observation is that leaf curl incidence could be minimum if crop transplanted in month November.

5.5.3 Wilt incidence

Among twenty genotypes 14 genotypes were graded as resistant to wilt and 6 as moderately resistant. Bio-fertilizers and *Trichoderma viridae* were also used to boost growth and supress soil borne diseases. Similar results were earlier reported by Cristophore *et al.* (2010).

5.5.4 Nematode incidence

The experimental plot with marigold as the preceding crop, showed no nematode incidence under both eco-friendly protected structure (EPS) and low cost polyhouse structure (EPS) thereby indicating that marigold crops residues performed the role of nematode repellent.

5.5.5 Comparison of genotypes for yield and pests incidences under EPS and LPS.

Comparison of data on mean fruit yield per plant and pest incidence in crops grown under eco-friendly management with preceding crop as marigold but under two types of protected structures (EPS & LPS) indicated that, Arka Rakshak and BSS-488, DVRT-2 and CLN-2123-A1 Red performed better for yield in both structures (EPS & LPS) and the values were comparable. However, genotypes Pusa Ruby, Arka Alok, CLN-2670-B1 and KH-105 performed relatively better for yield in low cost protected structure (LPS) over eco-friendly protected structures (EPS) whereas BWR-5 yield was comparatively higher in EPS over LPS. Fruit borer incidence was observed to similar in LPS and EPS. However, leaf curl and wilt incidence was relatively higher in EPS over LPS.

Comparative studies on yield in both type of protective structures under eco-friendly management indicated need of evaluating varieties/ hybrids/ segregating generations to develop better genotype for specific growing conditions. Present study also revealed usefulness of low cost and affordable protected structures for poor farmers who cannot afford costly polyhouse.

SUMMARY AND CONCLUSION

CHAPTER-6

SUMMARY & CONCLUSION

The present investigation entitled "Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)" involving twenty diverse genotypes (17 open pollinated and 3 hybrids) was carried out to assess the nature and extent of variability, correlation, path coefficient analysis, genetic diversity and screen genotypes against major pest and diseases in early planted tomato. The experiment was laid out in Randomized Complete Block Design with three replications at the Experimental farm of the Division of Vegetable Science and Floriculture, Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu, Chatha, during *rabi* 2017-18. The observations were recorded on various traits namely, days to 50 % flowering, plant height (cm), number of primary branches per plant, number of flowers per cluster, number of fruits per truss, number of fruits per plant, average fruit weight (g), fruit shape index, number of locules per fruit, total soluble solids (ºB), ascorbic acid(mg/100 g), pericarp thickness (mm), nematode galls per plant, fruit borer incidence (%), leaf curl incidence (%), wilt incidence (%), fruit yield per plant (kg) and fruit yield per hectare (q).

The analysis of variance showed highly significant variations among the genotypes for all the traits under study, indicating existence of good amount of variability in the germplasm. The mean performance of different traits indicated that genotypes namely Arka Rakshak, BSS-488, CLN-2123-A1 Red, DVRT-2 and BWR-5 were high yielders with regard to fruit yield per plant. Arka Rakshak was found to be the best performer for various traits like days to 50 % flowering, number of primary branches per plant, number of fruits per truss, ascorbic acid and yield, besides recording minimum fruit borer incidence and leaf curl incidence. Maximum plant height, number of flowers per cluster and pericarp thickness was recorded in another promising genotype BSS-488. DVRT-2 depicted highest fruit weight and maximum number of locules. Highest total soluble solids was observed in Marglobe while BWR-5 showed minimum wilt incidence.

High heritability estimates were observed for traits namely, days to 50% flowering, plant height, number of flower per cluster, number of fruits per plant, average fruit weight, fruit shape index, pericarp thickness and fruit yield per plant. High heritability estimates were accompanied with high genetic gain in case of plant height, number of fruits per plant and fruit yield per plant. It indicates that selection as breeding method can be successful for these characters having high heritability and high genetic gain.

Genotypic correlation coefficients were higher in magnitude than respective phenotypic coefficients, suggesting a strong inherent relationship between different traits. Fruit yield per plant had positive and significant association with plant height, number of primary branches per plant, number of flowers per clusters, number of fruits per truss, number of fruits per plant, average fruit weight and fruit shape index. Hence, there is ample scope of selection for these traits.

The path coefficient analysis revealed that maximum positive direct effect towards fruit yield per plant was contributed by average fruit weight followed by number of fruits per plant, plant height, fruit shape index, number of primary branches per plant, pericarp thickness, wilt incidence and number of flowers per cluster. It indicated that direct selection for these traits as criteria for improvement in tomato. Residual effect was observed to be low. It indicated negligible contribution of the characters not included in the study.

Based on genetic diversity assessed by using D^2statistics, twenty genotypes were grouped into 4 clusters. Cluster I comprised maximum numbers of genotypes (Arka Abha, Arka Alok, DVRT-2, Palam Pride, Arka Sourabh, Arka Vikas, Palam Pink, KH-105, Selection-2, S-22, PKM-1) followed by cluster-II (Pusa Ruby, Hawaii-7998, CLN-2670-B1, Bhagya, CLN-2123-A1 Red), cluster-III (Arka Rakshak, BSS-488 and BWR-5) and cluster-IV (Marglobe). The maximum intra-cluster distance was recorded in cluster II. The relative inter-cluster distance showed maximum divergence between cluster III and cluster I, revealing sufficient genetic divergence among the genotypes of the cluster. This showed that parents within cluster can be chosen for hybridization program. However trait like leaf curl incidence contributed maximum towards divergence.

Analysis of cluster mean indicated that cluster III registered the maximum cluster mean value for number of primary branches per plant, number of flower per cluster, number of fruits per truss, average fruit weight, ascorbic acid, pericarp thickness, fruit yield per plant and minimum mean value for days to 50 % flowering, leaf curl incidence, fruit borer incidence and wilt incidence. Cluster IV which comprised only one genotype Marglobe gave highest mean value for plant height, number of locules and total soluble solids.

It can be concluded that genetic diversity exist in tomato genotypes evaluated under eco-friendly management as early planted crop under eco-friendly management. High heritability and high genetic advance were observed for most of yield and yield attributing traits which indicated the usefulness of selection in breeding program. Fruit yield per plant had positive and significant correlation with most of traits (plant height, number of primary branches per plant, number of flowers per clusters, number of fruits per truss, number of fruits per plant, average fruit weight and fruit shape index) which can be utilized for future breeding program in tomato. Negative and significant association was observed for ascorbic acid content, pericarp thickness, fruit borer incidence and leaf curl incidence. The maximum direct and positive effect on fruit yield per plant was observed for average fruit weight followed by number of fruits per plant and plant height. Twenty genotypes were grouped into 4 clusters using D^2 analysis which indicated ample amount of inter and intra group genetic diversity, indicating possibility of their use as parents for tomato improvement. Further, genetic diversity observed among the genotypes under eco-friendly management suggested the existence of genetic differences among the genotypes and need of evaluating genotypes under specific growing conditions to develop varieties or hybrids for specific purpose. The results indicated that selected tomato genotypes identified (Arka Rakshak, BSS-488, CLN-2123-A1 Red, DVRT-2 and BWR-5) can be grown as early transplanted crop in Jammu region with protection against cold and frost under eco-friendly management using EPS and LPS.

REFERENCES

REFERENCES

Agarwal, A., Arya, D. N. and Ahmed, Z. 2014. Genetic variability studies in tomato (*Solanum lycopersicum* L.). *Progressive Horticulture*, **46**(2): 358-361.

Ahirwar, C. S. and Prashad, V. M. 2013. Variability pattern in agromorphological characters in tomato genotypes (*Lycopersicon esculentum* Mill.). *Trends in Biosciences*, **6**:758-61.

Al-Jibouri, H. A., Miller, P. A. and Robinson, H. F. 1958. Genotypic and environmental variances and co-variances in an upland cotton cross of interspecific origin. *Agronomy Journal*, **50**: 633-36.

Allard, R. W. 1960. *Principles of Plant Breeding*, John Wiley and Sons, Inc. New York, **pp** 485.

Ambresh., Lingaiah, H. B., Renuka, M. and Jyothi, K. 2017. Phenotypic and Genotypic Correlation Coefficient Studies in Tomato (*Solanum lycopersicum* L.) for Yield and Quality Traits. *International Journal of Current Microbiolilogy and Applied Sciences*, **6**(11): 2287-2292.

Anonymous (2016). Annual report of area and production of vegetables. NHB database, Gurgoan, India. NHB. http://www.nhb.gov.in.

Anonymous (2017). Annual report of area and production of vegetables. NHB database, Gurgoan, India. NHB. http://www.nhb.gov.in.

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.

Ayush, Al. F., Serhan, Al. M., Shareef, Al. A., Naseer, Al. and Kutma M. H. 2012. Study of genetic parameters and character interrelationship of yield and some yield components in tomato (*Solanum lycopersicum* L.). *International Journal of Genetics*, **2**: 29-33.

Badhani, C. H. 2015. Studies on genetic divergence in tomato (*Solanum lycopersicum* L.). M.Sc. thesis VCSG Uttarakhand University of Horticulture and Forestry, Bharsar, India.

Baldin, E. L., Vendramim, D. J. and Lourencao, L. A. 2007. Interaction between resistant tomato genotypes and plant extracts on *Bemisia tabaci* (Genn.) biotype B. *Scientia Agricola*, **64**(5).

Basavaraj, N., Shashikanth,. Patil, B. C., Salimath, P. M., Hosamani, R. M. and Krishnaraj, P. U. 2010. Genetic divergence in tomato (*Solanum lysopersicon* [Mill.] Wettsd.). *Karnataka Journal of Agricultural Sciences*. **23**(3): 538-539.

Bhandari, H. R., Srivatsava, K. and Reddy, E. G. 2017. Genetic Variability, Heritability and Genetic Advance for Yield Traits in Tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences*, **6**(7): 4131-4138.

Bhushan, A. and Gupta, R. K. 2017. Invitro shoot regenartaion and heterosis studies in tomato (*Solanum lycopersicum* L.). *Vegetos*, **30**: 359-364.

Buckseth, T. 2010. Studies on genetic divergence in tomato (*Solanum lycopersicum* L.), M.Sc. Thesis, Department of Vegetable Science. Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Buckseth, T., Sharma, M. K. and Thakur, K. S. 2012. Genetic variability and path analysis in tomato (*Solanum lycopersicum* L.). *Vegetable Science*, **39**: 221-23.

Burton, G. W. and De Vane, E. H. 1953. Estimating heritability in tall fescue (*Festuca arundinacea*) from replicated clonal material. *Agronomy Journal*, **45**: 478-81.

Burton, G.W. 1952. Quantitative interaction in grasses. *Proc. 6th Inter Grassland Congress*, **1**:277-283.

Chadha, S. and Bhushan, A. 2013. Genetic variability study in bacterial wilt resistant F6 progenies of tomato (*Solanum lycopersicum* L.). *Journal of Hill Agriculture*, **4**(1): 47-49.

Chourasiya, P. K., Lal, A. A. and Simon, S. 2013. Effect of certain fungicides and botanicals against early blight of tomato caused by *Alternaria solani* under Allahabad Uttar Pradesh, India conditions. *International Journal of Agricultural Science and Research,* **3** (3): 151-156.

Cristophore, D. J., Raj, T. S., Shanmugapackiam, S., Udayakumar, R. and Usharani, S. 2010. Ecofriendly management of fusarium wilt disease in tomato. *Annuals of Plant Protection Sciences*, **18**(2): 447-450.

Dar, A. N. 2011. Varietal responses in tomato (*Lycopersicum esculentum* Mill.) under eco-friendly management. M.Sc. thesis Sher-e-Kashmir University of Agricultural Sciences and Technology Jammu, Chatha.

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

Dar, R. A., Sharma, J. P., Gupta, R. K. and Chopra, S. 2011. Studies on correlation and path analysis for yield and physio-chemical traits in tomato (*Lycopersicon esculentum* Mill.). *Vegetos,* **24**: 136-41.

Das, B., Murmu, D. K., Ghimiray, T. S., Karforma, J., Kundu, S., and Yonzone, R. 2018. Estimation of Genetic Variability and Character Association of Fruit Yield and Quality Traits in Tomato. *International Journal Pure Applied Biosciences,* **6**(1): 1587-1595.

Dass, G. 2006. Eco-friendly Management of fruit borer and whitefly in tomato. PhD thesis, Department of Entomology, CSHPKV, Palampur.

Devi, T. N. 2013. Evaluation of Trichoderma species against *Fusarium oxysporum f. sp. lycopersici* for biological control of tomato wilt. *Indian Phytopathology*, **66**: 81-87.

Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of crested wheat grass seed production. *Agronomy Journal,* **51**: 515-18.

Dhal, A., Beura, K. S., Dash. K. S., Tripathy, L., Swain, K. S. and Sethi, D. (2017). Eco-friendly and integrated approaches for management of early blight disease in tomato. *International Journal of Current Microbiology and Applied Sciences,* **6** (10): 3052-3057.

Dudi, B. S., Dixit, J. and Pratap, P. S. 1983. Components of variability, heritability and genetic advance studies in tomato (*Lycopersicon esculentum* Mill.). *Haryana Agriculture University Journal Research,* **13**(1): 135-139.

Fisher, R. A. and Yates, F. 1963. *Statistical Tables for Biological, Agricultural and Medical Research,* 6thed., Oliver and Boyd Ltd, London. 146p.

Foolad, M. R. 2007. Genome mapping and molecular breeding of tomato. *International Journal of Plant Genomics,* pp-52.

Ghosh, K. P., Islam, A. K. M. A., Mian, M. A. K. and Hossain, M. M. 2010. Variability and character association in F_2 segregating population of different commercial hybrids of tomato (*Solanum lycopersicum* L.). *Journal of Applied Sciences, Environment and Management,* **14**: 91 – 95.

Giovanucci, E., Ascherio, A., Rimm, E., Stampfer, M., Colditz, G. and Willet, W. 1999. Tomatoes, tomato-based products, lycopene, and cancer: review of the epidemiologic literature, *Journal of National Cancer Institute*. **91** (4): 1767-76.

Gomez, K. A. and Gomez, A. A. 1983. *Statistical Procedures for Agricultural Research,* John wiley and Sons Inc., New York. pp. 357-427.

Goulden, C.H. 1959. *Method of Statistical Analysis,* John Wiley and Sons Inc, New York. 134p.

Gul, A., Ozaktan, H., Yolageldi, L. and Cakir, B. (2017). Rhizobacteria promoted growth and yield of tomato plants and control of *Fusarium oxysporum f. sp. radicis-lycopersici. Acta Horticulture,* 345-352.

Harrington, J. B. 1940. Yielding capacity of wheat crosses as indicated by balk hybrid tests. *Canadian Journal of Research*, **18**: 581–584.

Hassan, M. A., Chindo, P. S. Marley, P. S. and Alegbejo, M. D. 2010. Management of root knot nematodes (*Meloidogyne* spp) on tomato (*Lycopersicum esculentum*) using waste in Zaria, Nigeria. *Plant Protection Science*, **46**: 34-39.

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 (*Lycopersicon esculentum* Mill.). *Middle-East Journal of Scientific Research.* **2** (3-4): 139-142.

Hazra, P., Basu, D. and Sahu, F. K. 2002. Genetic divergence in okra. *Indian Journal of Horticulture,* **59**(4): 406-410.

Hooda, K. S., Joshi, D., Dhar, S, and Bhatt, J. C. 2011. Management of damping-off of tomato with botanicals and bio-products in North Western Himalayas. *Indian Journal of Horticulture*, **68**(2): 219-223.

Iqbal, M., Ahmed, W., Shafi, J., Ayub, C. M., Atiq, M., Shahid, M. and Saleem, M. 2013. Comaparative genetic variability and heritability in some tomato varieties against fruit borer, shape disorders and their correlations. *Bioengineering and Bioscience*, **1**(2): 17-23.

Iqbal, Q., Saleem, M. Y., Hameed, A. and Asghar, M. 2014. Assessment of genetic divergence in tomato through agglomerative hierarchical clustering and principal component analysis. *Pakistan Journal of Botany*, **46**(5): 1865-1870.

Jogani, V. (2014). Evaluation of different application methods of *Trichoderma harzianum* (Rifai) against Fusarium wilt of tomato. M.sc thesis, department of plant pathology, Navsari agricultural university, Navsari.

Johnson, H. W., Robinson, H. F. and Comstock, R. E. 1955. Estimates of genetic and environmental variability in soyabean. *Agronomy Journal*, **47**: 314-18.

Joshi. and Choudhury, B. 1981. Screening of *lycopersicon* and *solanum* species for resistance to leaf curl virus. *Vegetable Science,* **8**: 45-50.

Kaushik, S. K., Tomar, D. S. and Dixit, A. K. 2011. Genetics of fruit yield and its contributing characters in tomato (*Solanum lycopersicum* L.). *Journal of Agricultural Biotechnology and Sustainable Development,* **3**: 209-13.

Khan, H. and Samadia, D. K. 2012. Variability and association studies in tomato germplasm under high-temperature arid region. *Journal of Horticultural Sciences,* **7**: 194-98.

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

Khapte, P. S. and Jansirani, P. 2014b. Genetic diversity studies in tomato (*Solanum lycopersicum* L.) genotypes. *Trends in Biosciences,* **7**(15): 1958-1961.

Khapte, P. S. and Jansirani, P. 2014a. Genetic variability and performance studies of tomato (*Solanum lycopersicum* L.) genotypes for fruit quality and yield. *Trends in Biosciences,* **7**: 1246-1248.

Kharshandi, G. 2015. Studies on genetic evaluation of some tomato (*Solanum lycopersicum* L.) genotypes for yield and contributing traits, M.Sc. Thesis, Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Kulus, D. 2018. Genetic resources and selected conservation methods of tomato. *Journal of Applied Botany and Food Quality,* 91: 135 -44.

Kumar, M. S., Pal, A. K., Singh, A. K., Sati, K. and Kumar, D. 2013a. Studies on genetic parameters to improve the genetic architecture of tomato (*Solanum lycopersicum* L.). *International Journal of Applied Biology and Pharmaceutical Technology,* **4**: 234-237.

Kumar, M., and Dudi, B. S. 2011. Study of correlation for yield and quality characters in tomato (*Solanum lycopersicum* L.). *Electronic Journal of Plant Breeding,* **2**: 453-

60.

Kumar, M., Buckseth, T., Thakur, S. M. and Thakur, S.K. 2013b. Genetic divergence and cluster analysis in Tomato (*Solanum lycopersicum*), *Progressive Agriculture*, **13**(1): 114–117.

Kumar, N. 2014. Studies on genetic variability in tomato (*Solanum lycopersicum* L.) genotypes for different horticultural traits, M.Sc. Thesis, Department of Vegetable Science, Dr. Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan.

Kumar, P. P., Sathish, V., Ramesh, D., Bhutia, N. D., Koundinya, A. V. V. and Hazra, P. 2016. Assessment of genetic variability, correlation and path coefficients for yield components and quality traits in tomato. *International Journal of Agricultural Sciences*, **8**(54): 2870-2873.

Kumar, P. T., Joy, M. B. D., Radhakrishnan, N. V. and Aipe, K. C. 2001. Genetic variation in tomato for yield and resistance to bacterial wilt. *Journal of Tropical Agriculture*, **39**: 157-158.

Kumar, P., Singh, K., Jindal, S. K. and Khurana, D. S. 2014a. Association studies for processing traits in tomato (*Solanum lycopersicum* L.). *Journal of Research Punjab Agricultural University*, **51**(3&4): 250-254.

Kumar, R., Ram, C. N., Yadav, G. C., Deo, C., Vimal, S. C. and Bhartiya, H. D. 2014b. Appraisal studies on variability, heritability and genetic advance in tomato (*Solanum lycopersicum*). *Plant Archives*, **14**(1): 367-371.

Kumar, S. 2010. Genetic variability and interrelationship of traits in F_3 progenies of tomato (*Lycopersicon esculentum* Mill.) under cold desert of Leh-Ladakh. *Crop Improvement*, **37**: 66-72.

Kumar, S., Rattan, P., Sharma, J. P. and Gupta, R. K. 2010. D^2 analysis for fruit yield and quality components in tomato (*Lycopersicon esculentum*. Mill.). *Indian Journal of Plant Genetic Resource*, **23**(3): 318-320.

Kumar, S., Singh, T., Singh, B. and Singh, J. P. 2004. Studies on heritability and genetic advance in tomato (*Lycopersicon esculentum* Mill.). *Progressive Horticulture,* **4**(1): 76-77.

Kumar, V., Singh, B. M. and Sugha, S. K. 1997. Reaction of tomato genotypes to bacterial wilt. *Plant Disease Reserch,* **12**(1): 90-94.

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.

Mahalanobis, P. C. 1936. On the generalised distance in statistics. *Proceedings of National Institute Science,* **2**: 49-55.

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

Manna, M. and Paul, A. 2012. Studies on genetic variability and characters association of fruit quality parameters in tomato. *Horticulture Flora, Research Spectrum,* **1**: 110-16.

Mayee, C. D. and Datar, V. V. 1986. *Phytopathometry*. Department of Plant Pathology, Marathwada agricultural University, Parbhani, **6**: 146.

Meena, O. P. and Bahadur, V. 2013. Assessment of breeding potential of tomato (L*ycopersicon esculentum* Mill.) germplasm using D^2 analysis. *The Bioscan,* **8**(4): 1145-1148

Meena, O. P. and Bahadur, V. 2015. Genetic associations analysis for fruit yield and its contributing traits of indeterminate tomato (*Solanum lycopersicum* L.) germplasm under open field condition. *Journal of Agricultural Sciences,* **7**: 148-163.

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 Reasearch*, **10**(32): 3170-3177.

Meena, R. K., Kumar, S., Meena, M. L. and Kumar A. 2018. Correlation and Characters Association Studies in Tomato (*Solanum lycopersicum* L.). *International Journal of Pure and Appllied Biosci*ence, **6** (1): 1291-1295.

Mew, T. W. and Ho. W. C. 1976. Varietal resistance to bacterial wilt in tomato. *Plant Disease Report*, **60**: 264-268.

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.). *International Journal of Scientific and Technology Research*, **1**: 55-58.

Nadkarni, R. S., Jayalekshmy, V. G., Umamaheshwaran, K. and Harikrishnan, P. J. 2017. Evaluation of Tomato and Allied Species for Tomato Leaf Curl Virus (Tolcv) Resistance (*Solanum lycopersicum* L.). *International Journal of Pure & Applied Bioscience*, **5** (3): 271-277.

Nalla, M. K., Rana, M. K., Singh, S. J., Sinha, A. K., Reddy, P. K., Priyadarshani, P. and Mohapatra. 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.

Naveen, B. L., Saidaiah, P., Ravinderreddy, K. and Geetha, A. 2017. Correlation and path coefficient analysis of yield and yield attributes in tomato (*Solanum lycopersicum* L.). *Journal of Pharmacognosy and Phytochemistry*, **6**(6): 665-669.

Nwosu, D. J., Onakoya, O. A., Okere, A. U., Babatunde A. O. and Popoola, A. F. 2014. Genetic variability and correlations in rainfed tomato (*Solanum* spps.) accessions in Ibadan, Nigeria. *Greener Journal of Agricultural Sciences*, **4**(5): 211-219.

Panse, V. G. and Sukhatme, P. V. 1967. *Statistical Methods for Agricultural Workers*, pp.361. ICAR, New Delhi, India.

Patel, P., Kumar, U., Maurya, K. P., Thakur, G., and Pramila. 2017. Genetic variability studies in tomato (*Solanum lycopersicum* L.). *Bulletin of Environment, Pharmacology and Life Sciences,* **6**(1): 216-218.

Patel, S. A., Kshirsagar D. B., Attar, A. V. and Bhalekar, M. N. 2013. Study on genetic variability, heritability and genetic advance in tomato. *International Journal of Plant Sciences,* **8**:45-47.

Pedapati, A., Reddy, R. V. S. K., Babu, J. D., Kumar, S,.S. and Sunil, N. 2014. Genetic diversity analysis in Tomato (*Solanum lycopersicum* L.). *Electronic Journal of Plant Breeding,* **5**(3): 517-525.

Polat, E., Demir, H. and Erler, F. 2010. Yield and Quality criteria in organically and conventionally grown tomatoes in Turkey. *Scientific Agriculture,* **67**(4): 424-429.

Prajapati, S., Tiwari, A., Kadwey, S., Sharma, S. K. and Raghuwanshi, O. 2015. Correlation and path coefficient analysis of fruits yield and its attributing traits in tomato (*Lycopersicon esculentum* Mill.). *Indian Research Journal of Genetics & Biotechnology,* **7**:138-147.

Prashanth, S. J., Mulge, R., Madalageri, B. M., Mukhesh, L., Chavan, L. M. and Gasti, V. D. 2015. Studies on genetic variability for quality character in tomato (*Lycopersicum ecsulentum* Mill.). *Journal of Asian Horticulture,* **3**(2): 72-74.

Premalakshmi, V., Kumar, S. R. and Arumugam, T. 2014. Evaluation and genetic studies in tomato genotypes. *Trends in Biosciences,* **7**: 1407-10.

Quesenberry, K. H., Baltensperger, D. D. and Dunn, R. A. 1986. Screening *Trifolium* spp for response to *Meloidogyne* spp. *Crop Science,* **26**: 61-64.

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

Rahman, M. S., Parveen, S., Rashid, M. H. U., Akter, R., Hossin, A. Y. and Robbani, M. G. 2015. Correlation and path coefficient analysis of tomato germplasm.

International Journal of Applied Science and Biotechnology, **3**(2): 223-26.

Rai, A. K. 2015. Genetic divergence studies in tomato (*Solanum lycopersicum* L.), M.Sc. thesis, Department of Vegetable Science, Dr. Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan, HP, India. pp 50-72.

Rai, A. K., Vikram. A. and Pandav, A. 2016. Genetic Variability Studies in Tomato (*Solanum lycopersicum* L.) for Yield and Quality Traits. *International Journal of Agriculture, Environment and Biotechnology*, **9**(5): 739-744.

Rai, N., Path, R. and Tirkey, T. 2001. Screening of tomato genotypes and their stability against tomato leaf curl virus. *Progressive Horticulture*, **33**(2): 184-189.

Rajolli, G. M., Lingaiah, B. H., Malashetti, I. R., Bhat, A. S. and Aravindkumar, J. S. 2017. Correlation and Path Co-Efficient Studies in Tomato (*Solanum lycopersicum* L.). *International Journal of Pure & Applied Bioscience*, **5** (6): 913-917.

Ramya, K. and Kumar, N. S. 2004. Genetic divergence, correlation and path analysis in okra [*Abelmoschus esculentus* (L.) Moench]. *Madras Agricultural Journal*, **96**(7-12): 296-299.

Rani, C. I., 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**: 11-14.

Rani, K. R. and Anita, V. 2011. Studies on variability, heritability and genetic advance in tomato (*Lycopersicon esculentum* Mill.). *International Journal of Bio-resource and Stress Management*, **2**: 382-385.

Rao, C. R. 1952. *Advanced Statistical Methods in Biometrical Research*, John Willey and Sons Inc., New York, pp. 357-369.

Rath, P. C. and Math, P. 2001. Screening of some tomato genotypes for susceptibility to the fruit borer. *Vegetable Science*, **24** (2): 153-156.

Rathod, H., Saravaiya, S. N., Patel, A. I., Tank, R. V. and Patel, K. 2015. Genetic Divergence in Tomato (*Solanum lycopersicum*). *Trends in Biosciences,* **8**(2):301-304.

Reddy, B. R., Reddy, D. S., Reddaiah, K. and Sunil, N. (2013b). Studies on genetic variability, heritability and genetic advance for yield and quality traits in tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences,* **2**(9): 238-244.

Reddy, B.R., Begum, H., Sunil, N. and Reddy, T. M. 2013a. Genetic divergence studies in exotic collections of tomato (*Solanum lycopersicum* L.). *International Journal of Agricultural Sciences,* **9**(2): 588-92.

Roy, S. K. and Choudhary, B. 1972. Studies on physio-chemical characteristics of few varieties in relation to processing. *Journal of Food Science and Technology,* **9**: 151-53.

Sadashivam, S. and Balasubramanium, T. 1987. *Practical Manual in Biochemistry*, pp.14. Tamilnadu Agricultural University, Coimbatore, India.

Sahu, M., Sahu, K. K., Ambade, L. R. and Mehta, N. (2013). Genetic variability, heritability and scope of improvement for yield components in tomato (*Lycopersicum ecsulentum* Mill.). *Asian Journal of Bio Science,* **8**(2): 214-217.

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 Horticulture Sciences,* **8**(1): 21-24.

Sastry, K. M. S. and Singh S. J. 1973. Assessment of losses in tomato caused by tomato leaf curl virus. *Indian Journal of Mycology, Plant Pathology*, **3**: 50-54.

Sharma, A. K. and Jaipaul. 2014. Variability and correlation studies in diallel cross of tomato (*Solanum lycopersicum* L.). *Journal of Hill Agriculture,* **5**:168-70.

Sharma, B. and Singh, J. P. 2012. Correlation and path coefficient analysis for quantitative and qualitative traits for fruit yield and seed yield in tomato

genotypes. *Indian Journal of Horticulture*, **69**:540-44.

Sharma, D. K., Dhaliwal, M. S., Cheema, D. S. and Singh, S. 2003. Screening of tomato germplasm against tomato fruit borer *Helicoverpa armigera* (Hub.). *Journal of Research, Punjab Agricultural University*, **40**(1): 24-26.

Sharma, J., Singh K. A. and Tiwari, S. P. 2010. Selection parameters for productive plant type in tomato (*Lycopersicon esculentum* Mill.). *Journal of Hill Agriculture*, **1**: 52-55.

Sharma, P. 1994. Genetic variability and path coefficient analysis in cabbage (*Brassica oleracea* var. *capitata*), M.Sc. Thesis, H P K V, Palampur.

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

Sharma, S. 1996. Screening of international set of tomato genotypes to bacterial wilt disease. *Regional Agricultural Research Centre*, **96**: 17.

Shashikant, S. 2008. Genetic variability studies in tomato (*Solanum lycopersicon* (Mill.) wettsd.). Thesis submitted to the University of Agricultural Sciences, Dharwad.

Shashikanth, S., Basavaraj, N., Hosamani, R. M. and Patil, B. C. 2010. Genetic variability in tomato (*Solanum lycopersicon* [Mill]. Wettsd.). *Karnataka journal of agricultural sciences*, **23**(3): 536-537.

Shashikanth., Basavaraj, N. and Dhotre, M. 2012. Correlation and path co-efficient studies in tomato. *The Asian Journal of Horticulture*, **7**:379-84.

Sherpa, P., Pandiarana, N., Shende, V. D., Seth, T., Mukherjee, S. and Chattopadhyay, A. 2014. Estimation of genetic parameters and identification of selection indices in exotic tomato genotypes. *Electronic Journal of Plant Breeding*, **5**:552-562.

Shivaramu, K. 1999. Investigations on fruit borer, Helicoverpa armigera (Hubner) in chilli. Ph.D. thesis, University of Agricultural Sciences, Dharwad, p.141.

Shweta., Kumar, D. B. M., Ellur, V. and Patil, S. 2016. Assessment of genetic variability

and diversity in tomato (*Lycopersicon esculentum* Mill.) germplasm. *Green Farming,* **4**: 819-823.

Singh A. K., Solankey, S. S., Akhtar, S., Kumari, P. and Chaurasiya, J. 2018. Correlation and Path Coefficient Analysis in Tomato (*Solanum lycopersicum* L.). *International Journal of Current Microbiology and Applied Sciences,* **7**: 4278-4285.

Singh, A. K., Ram, C. N., Yadav, G. C., Srivastava, R. K., Deo, C., Gautam, D. K., Kumar, P. and Kumar, P. 2017a. Studies on genetic variability, heritability and genetic advance in tomato [*Solanum lycopersicum* (Mill.) Wettsd.]. *International Journal of Pure and Applied Biosciences,* **5**: 908-12.

Singh, A. K., Ram, C. N., Yadav, G. C., Srivastava, R. K., Deo, C., Gautam, D. K., Rao, J. K. and Kumar, P. 2017b. Studies on Correlation and Path Coefficient Analysis in tomato [*Solanum lycopersicon* (Mill.) Wettsd.]. *International Journal of Pure and Applied Biosciences,* **5** (2): 931-936.

Singh, B. K., Pathak, K. A., Bhoopathi, T. and Deka, B. C. 2010. Vermicompost and NPK fertilizer effects on morpho-physiological traits of plants, yield and quality of tomato fruits (*Solanum lycopersicum* L.). *Vegetable crops Research Bulletin,* **73**: 77-86

Singh, J. K., Singh, J. P., Jain, S. K and Josh, A. 2002. Studies on genetic variability and its importance in tomato (*Lycopersicon esculentum* Mill.). *Progressive Horticulture,* **34**(1): 77-79.

Singh, K. 2014. Evaluation of tomato genotypes and its reaction against ToLCV causing leaf curl disease in tomato (*Solanum lycopersicon* L.). *Journal of Experimental Biology and Agricultural Sciences,* **2**(1S): 121-125.

Singh, N., Ram, C. N., Deo, C., Yadav, G. C. and Singh, D. P. 2015. Genetic variability, heritability and genetic advance in tomato (*Solanum lycopersicum* L.). *Plant Archives,* **15**: 705-09.

Singh, P. K. and Choudhary, R. D. 1977. *Biometrical methods in quantitative genetic analysis*, Kalyani Publishers, New Delhi. pp. 178-185.

Singh, V., Naseeruddin, K. H. and Rana, D. K. 2014. Genetic variability of tomato genotypes for yield and other horticultural traits. *Journal of Hill Agriculture*, **5**: 186-89.

Spaldon, S. and Kumar, S. 2017. Genetic Divergence Studies for Quantative and Quality Traits in Tomato (*Solanum lycopersicum* L.). *International Journal of Environment, Agriculture and Biotechnology*, **2**(3): 1227-1231.

Srivastava, K., Kumari, K., Singh, P. and Kumar, R. 2013. Association studies for yield and its component traits in tomato (*Solanum lycopersicum* L.). *Plant Archives*, **13**: 105-112.

Srivatsava, K. M., Agarwal, K. V. and Agarwal, K. R. 2014. Estimation of genetic divergence among indigenous and exotic accessions of tomato (*Solanum lycopersicum* L.). *Asian Journal of Biological Sciences*, **9**(1):30-32.

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

Vineet, K., Singh, B.M. and Sugha, S.K. 1997. Reaction of tomato genotypes to bacterial wilt. *Plant Disease Resistance*, **12**(1): 90-94.

Wright, S. 1921. Correlation and causation. *Journal of Agricultural Research*, **20**: 557-585.

APPENDICES

APPENDIX-I

Agro-meteorological data during growing period (2017-18)

Month	Temperature (°C)			Relative humidity (%)		Rainfall
	2017-18		Mean	2017-18		2017-18
	Max	Min		max	min	
September	33.9	22.7	28.3	85	55	49.50
October	32.8	16.3	24.5	84	41	0.00
November	25.1	8.9	17.0	93	46	0.00
December	21.0	6.2	13.6	92	54	51.00
January-2018	19.1	3.9	11.5	93	83	9.60
February	22.6	7.4	15.0	90	48	50.08
March	28.5	11.9	20.2	84	42	12.60
April	33.6	16.5	25.0	75	34	45.20
May	36.4	20.4	28.4	59	27	15.12

Source: Meteorological section, Division of Agronomy. Sher-e-Kashmir University of Agricultural Sciences & Technology Jammu, Chatha. 180009

APPENDIX-II (A)

Analysis of variance for various horticultural characters in tomato

Character / Source	D.f	Mean Sum of Squares								
		Plant height (cm)	Days to 50% flowering	Number of primary branches	Number of flowers per cluster	Number of fruits per truss	Number of fruits per plant	Average fruit weight (g)	Fruit shape index	Number of locules per fruit
Replication	2	32.106	0.45	0.237	0.521	0.045	1.19	27.964	0.002	0.074
Treatment	19	3892.54*	13.911*	2.752*	5.55*	1.422*	164.17*	647.265*	0.031*	1.189*
Error	38	78.841	0.854	0.338	0.321	0.121	1.984	21.368	0.001	0.135

* Significant at 5% level of significance

APPENDIX-II (B)

Analysis of variance for various horticultural characters in tomato

Character / Source	D.f	Mean Sum of Squares							
		Total soluble solids (^{0}B)	Ascorbic acid (mg/100 g)	Pericarp thickness (mm)	Fruit borer incidence (%)	Leaf curl incidence (%)	Wilt incidence (%)	Fruit yield per plant (kg)	Fruit yield per hectare (qt/ha)
Replication	2	0.204	4.947	0.042	1.281	81.667	38.45	0.007	226.579
Treatment	19	0.951*	17.176*	1.907*	17.732*	361.404*	104.825*	0.694*	21600.912*
Error	38	0.073	2.824	0.066	1.699	65.877	19.59	0.017	527.967

* Significant at 5% level of significance

VITA

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CERTIFICATE-IV

Certified that all the necessary corrections as suggested by the external examiner and the advisory committee have been duly incorporated in the thesis entitled **"Evaluation of genotypes and divergence studies under eco-friendly management in tomato (*Solanum lycopersicum* L.)"** submitted by **Mr. Vijayakumar Chabbi,** Registration No. **J-16-M-450.**

17/09/18

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