GENETIC VARIABILITY AND DIVERGENCE STUDIES IN TOMATO (*Lycopersicon esculentum* Mill.)

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By

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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC VARIABILITY AND DIVERGENCE STUDIES IN TOMATO (*Lycopersicon esculentum* Mill.)"** submitted by **PRASHANTH S.J.** for the degree of **MASTER OF SCIENCE (HORTICULTURE)** in **OLERICULTURE** of the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this university under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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INTRODUCTION

I. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and widely grown vegetables in the world. It is a very versatile vegetable for culinary purposes. Ripe tomato fruit is consumed fresh as salads and consumed after cooking and utilised in the preparation of range of processed products such as puree, paste, powder, ketchup, sauce, soup and canned whole fruits. Unripe green fruits are used for preparation of pickles and chutney. Tomatoes are important source of lycopene (an antioxidant), ascorbic acid and β-carotene and valued for their colour and flavour.

In India, tomato ranks second among vegetables next only to potato in area and production. It occupies an area of 3.5 lakh hectares with an annual production of 53 lakh metric tonnes accounting to an average productivity of 15.4 tonnes per hectare (Anon., 1999). In Karnataka, tomato occupies an area of 39,617 hectare with an annual production of about 8,28,725 tonnes and an average productivity of 20.91 tonnes per hectare (Anon., 2001)

Tomato belongs to the family Solanaceae and is native of Peru - Equador region (Rick, 1969). The genus *Lecopersicon* consists of annual or short lived perennial herbaceous plants. Tomato is a typical day neutral plant and it is mainly self pollinated, but a certain percentage of cross-pollination also occurs. It is a warm season crop reasonably resistant to heat and draught and grows under wide range of soil and climatic conditions.

Considering the potentiality of this crop, there is a prime need for improvement and to develop varieties suited to specific agro-ecological conditions and also for specific end use. A thorough knowledge regarding the amount of genetic variability existing for various characters of the crop is essential for initiating the crop improvement programme. With limited variability nothing can be achieved and the breeder will have to enrich the germplasm or he can resort to create greater variability by hybridisation, mutation and polyploidy breeding.

The phenotypic expression of the plant characters is mainly controlled by the genetic makeup of the plant and the environment, in which it is growing and the interaction between the genotype and environment. Further, the genetic variance of any quantitative trait is composed of additive variance (heritable) and non-additive variance (non-heritable), which include dominance and epistasis (non-allelic interaction). Therefore, it becomes necessary to partition the observed phenotypic variability into its heritable and non-heritable components with suitable parameters such as phenotypic and genotypic coefficient of variation, heritability and genetic advance. Further, genetic advance can be used to predict the efficiency of selection.

Yield is a complex character controlled by a large number of contributing characters 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 and quality of a crop. In order to have more clear picture of yield components for 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.

Commercial F_1 hybrids are very common in tomato and selection of newer parents for higher heterosis is a continuous process. Generally diverse plants are expected to give high hybrid vigour (Harrington, 1940) and hence, it necessitates study of genetic divergence among the existing varieties and germplasm collection for identification of more heterotic parents for hybridisation programme. The information on genetic divergence of various traits particularly of those that contribute to yield and quality would be most useful in planning the breeding programme. D^2 statistics developed by Mahalanobis (1936) provides a measure of magnitude of divergence between two groups under comparison. It considers the variation produced by any character and their consequent effect that it bears on other characters. The technique was first used by Mahalanobis in an anthropometric survey of the united province in India. 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 parental lines for heterosis breeding. Such studies are also useful in selection of parents for hybridisation to recover superior transgressive segregants and it can further result in to release of improved open pollinated varieties for commercial cultivation.

Therefore, the present investigation on "genetic variability and divergence studies in tomato" was under taken involving popular varieties and freshly developed lines with the following objectives.

1. To study the nature and extent of genetic variability and divergence in tomato germplasm for yield and yield parameters
2. To study the nature and extent of genetic variability and divergence in tomato germplasm for growth, earliness, flowering and quality parameters, and
3. To study the association of growth, earliness, yield and quality parameters in tomato germplasm.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Literature on genetic variability, correlation, path coefficient analysis and genetic divergence in tomato is reviewed in this chapter and presented under different headings. As the relevant literature on some of these aspects is inadequate in tomato, efforts were made to include work done in other related crops on these aspects.

2.1 GENETIC VARIABILITY

The success of a breeding programme depends upon the extent and magnitude of variability existing in the germplasm. Variability may be defined as the amount of variation present among the members of a population or species for one or more characters at genotypic or phenotypic levels. A comprehensive summary of methods for estimating genetic variance is presented by Cockerham (1963). Phenotypic variability is observable and includes both genotypic and environmental variation and therefore, also called as total variation. Genotypic variation refers to genetic or inherent variability, which remains unaltered by environmental conditions. It is measured in terms of genotypic variance and consists of additive, dominance and epistatic components. Environmental variance is measured in terms of error mean variance. Genotypic coefficient of variability (GCV) and phenotypic coefficient of variability (PCV) are derived from standard deviation divided by mean and are used to assess the extent of variation.

Heritability is the transmissibility of characters from parents to offspring. Heritability in broad sense is the ratio of genotypic variance to total phenotypic variance generally expressed in percentage. Effectiveness of selection of genotypes depends on heritability. Genetic advance (GA) is the improvement over the base population that can potentially achieved from selection. It is a function of the heritability of the trait, the amount of phenotypic variation and the selection differential that, the breeder uses. When high heritability is accompanied with high genetic advance, it indicates additive gene effects and selection may be effective, when low heritability is accompanied with low genetic advance, it indicates predominance of environmental effects and selection would be ineffective. High heritability with low genetic advance indicates the importance of non-additive gene action, while low heritability with high genetic advance indicates the importance of additive gene effects.

Variability for growth, earliness, yield and yield components in tomato has been reported by several workers. The review of literature on variance and its components, heritability, genetic advance and genetic advance over mean for various characters are presented in tabular form as under (Table-1).

Table 1. Review of literature on mean, range, components of variance, heritability and genetic advance in tomato and related vegetable crops

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2(%)	GA	GAM	References
Plant height (cm)	Tomato	113.34	48.50-180.20	-	-	53.54	51.65	93.08	105.73	102.66	Nandpuri *et al.* (1977)
	Tomato	81.60	44.00-141.00	461.66	359.40	-	23.20	78.00	34.46	43.22	Paranjothi and Muthukrishnan (1979)
	Tomato	96.70	57.10-178.50	-	-	22.06	21.55	95.40	41.92	-	Reddy and Gulshanlal (1987)
	Tomato	-	-	20.476	8.389	11.65	7.46	40.97	3.819	9.84	Singh *et al.* (1988)
	Tomato	-	-	-	-	-	-	-	30.81	-	Gadekar *et al.* (1992)
	Tomato	67.95	49.87-99.65	297.31	286.30	25.50	24.90	96.30	-	50.33	Bora *et al.* (1993)
	Tomato	57.14	43.80-88.40	147.96	57.75	258.91	101.06	39.03	9.78	17.12	Narendrakumar and Arya (1995)
	Tomato	96.17	26.00-213.34	1292.11	1253.12	1343.57	1303.03	96.98	71.81	74.67	Pujari *et al.* (1995)
	Tomato	73.19	44.0-100.8	165.07	144.93	17.55	16.45	87.80	15.79	21.57	Sahu and Mishra (1995)
	Tomato	117.37	-	2088.69	1035.55	38.94	27.42	50.00	6.37	-	Krishnaprasad and Mathurarai (1999)
	Tomato	-	-	31.21	29.33	14.10	13.54	93.94	-	27.28	Mala and Vadivel (1999)
	Tomato	53.92	38.67-93.67	-	-	28.07	26.81	91.20	28.43	52.73	Mohanty (2003)
Number of primary branches	Tomato	12.80	5.50-29.00	6.640	5.350	-	18.04	83.00	4.34	33.91	Paranjothi and Muthukrishnan (1979)
	Tomato	12.09	8.8-15.0	-	-	13.37	9.33	48.70	1.62	-	Reddy and Gulshanlal (1987)
	Tomato	-	-	579.582	563.722	23.27	22.95	97.26	48.235	46.63	Singh *et al.* (1988)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	-	-	-	-	-	41.31	-	-	-	Gadekar *et al.* (1992)
	Tomato	5.76	3.90-7.80	0.83	0.29	15.90	9.49	35.67	0.45	8.02	Sahu and Mishra (1995)
	Tomato	6.86	5.06-8.46	1.51	0.27	22.60	4.06	17.99	1.79	26.09	Narendrakumar and Arya (1995)
	Tomato	-	-	1.80	1.709	20.37	19.79	94.42	-	22.96	Mala and Vadivel (1999)
	Tomato	6.87	4.97-13.73	-	-	32.35	30.62	89.60	4.11	59.83	Mohanty (2003)
Stem girth (cm)	Tomato	1.39	1.17-1.80	0.045	0.031	-	12.61	68.00	0.30	21.58	Paranjothi and Muthikrishnan (1979)
	Chilli	1.35	0.80-1.75	-	-	-	301.85	97.76	8.34	-	Arya and Saini (1976)
	Chilli	1.19	0.85-1.58	-	-	14.74	8.08	30.04	0.10	9.12	Basavaraja (1997)
Number of flowers per cluster	Tomato	19.70	14.50-33.20	-	-	19.61	19.20	95.90	7.63	-	Reddy and Gulshanlal (1987)
	Brinjal	3.87	1.30-5.80	-	-	33.22	29.24	79.08	2.10	54.26	Prakash *et al.* (1994)
	Brinjal	1.40	1.00-2.31	0.20	0.20	17.50	15.40	76.60	0.70	27.70	Pramanick *et al.* (1994)
	Brinjal	3.96	2.00-6.00	1.20	0.88	27.66	23.82	74.20	1.67	69.01	Sharma and Kishanswaroop (2000)
Breadth of the flower (mm)	Brinjal	14.40	9.00-23.00	16.58	7.32	28.22	18.76	44.16	3.70	12.46	Vivekanandan and Subramanian (1991)
Days to first flowering	Tomato	25.08	18.00-33.00	-	-	-	17.55	83.38	6.49	2.58	Singh *et al.* (1974)
	Tomato	25.09	18.80-33.50	18.44	11.56	17.09	13.55	62.68	-	22.12	Prasad and Prasad (1976)
	Tomato	59.54	51.00-72.00	26.28	19.50	8.61	7.42	74.19	5.32	8.94	Sahu and Mishra (1995)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	79.63	74.57-86.60	-	-	5.07	4.58	81.43	12.65	8.50	Parvindarsingh *et al.* (2002)
	Brinjal	41.00	32.80-48.20	-	-	9.91	7.83	0.62	12.65	-	Singh and Gopalakrishnan (1999)
Days to 50% flowering	Tomato	84.93	75.00-100.00	29.75	22.72	35.03	26.75	76.37	8.58	10.10	Pujari *et al.* (1995)
	Brinjal	69.20	65.31-75.33	12.14	9.27	5.03	4.39	76.35	548.02	-	Devi and Sankar (1990)
	Brinjal	40.09	33.00-48.33	13.40	9.57	9.08	7.68	71.40	5.36	13.36	Sharma and Kishanswaroop (2000)
	Chilli	45.96	37.33-54.66	-	-	9.82	9.27	88.91	8.26	17.99	Basavaraja (1997)
	Chilli	33.70	28.33-41.00	18.04	15.64	12.60	11.73	86.70	7.59	22.52	Nandadevi (1999)
Days to first fruit set	Tomato	-	-	0.018	0.016	13.78	13.11	90.50	0.249	25.69	Singh *et al.* (1988)
	Brinjal	46.40	37.90-55.20	-	-	8.89	6.32	0.51	9.29	-	Singh and Gopalakrishnan (1999)
Days to first fruit maturity	Tomato	58.78	49.25-68.25	-	-	-	5.90	85.31	8.34	1.41	Singh *et al.* (1974)
	Tomato	164.38	150.00-183.00	-	-	8.64	8.04	86.67	25.36	15.42	Nandpuri *et al.* (1977)
	Tomato	101.56	100.50-109.10	-	-	1.96	1.62	68.00	2.87	-	Reddy and Gulshanlal (1987)
	Tomato	166.79	157.50-174.30	-	-	2.47	2.38	93.56	7.93	4.76	Das *et al.* (1998)
Per cent fruit set	Tomato	45.65	20.90-80.60	-	-	20.10	19.71	94.30	2.68	-	Reddy and Gulshanlal (1987)
Number of fruits/cluster	Tomato	-	-	-	-	163.15	126.31	62.48	44.08	232.04	Srivastava and Sachan (1973)
	Tomato	2.38	1.86-3.00	0.20	0.15	18.79	16.27	75.00	-	29.21	Bora *et al.* (1993)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	2.55	2.00-3.43	0.13	0.07	5.18	2.82	54.57	0.39	15.29	Narendrakumar and Arya (1995)
	Brinjal	2.25	1.00-4.50	-	-	49.12	38.88	62.65	1.43	63.55	Prakash *et al.* (1994)
	Brinjal	2.60	1.80-3.70	0.10	0.10	25.40	22.50	78.60	0.60	41.30	Pramanick *et al.* (1994)
	Brinjal	2.41	1.00-4.00	2.50	2.19	42.12	35.35	0.70	1.48	11.47	Sharma and Kishanswaroop (2000)
Number of fruits per plant	Tomato	-	-	-	-	42.79	19.06	22.11	4.28	190.91	Srivastava and Sachan (1973)
	Tomato	21.39	10.44-63.32	-	-	-	50.69	98.61	22.18	10.36	Singh *et al.* (1974)
	Tomato	25.19	10.70-58.90	141.90	136.49	47.28	46.36	96.18	-	93.68	Prasad and Prasad (1976)
	Tomato	78.46	19.60-138.60	-	-	78.74	68.69	76.09	96.85	123.43	Nandpuri *et al.* (1977)
	Tomato	48.90	6.20-138.40	357.15	331.02	-	37.20	93.00	36.07	73.76	Paranjothi and Muthukrishnan (1979)
	Tomato	27.321	12.92-53.93	79.805	75.610	32.70	31.83	94.74	0.64	2.34	Bhutani *et al.* (1983)
	Tomato	-	-	-	-	34.24	16.83	24.17	192.76	17.07	Rattan *et al.* (1983)
	Tomato	17.99	4.20-142.50	-	-	134.80	124.10	84.70	42.30	-	Reddy and Gulshanlal (1987)
	Tomato	-	-	7.953	1.046	24.46	8.87	13.15	0.764	6.62	Singh *et al.* (1988)
	Tomato	39.26	18.02-70.80	475.67	457.25	55.55	54.47	96.13	-	110.01	Bora *et al.* (1993)
	Tomato	31.54	21.00-42.67	24.15	22.08	76.53	70.01	91.48	9.26	29.35	Narendrakumar and Arya (1995)
	Tomato	41.95	8.00-855.00	7036.14	6972.43	16772.6	16620.8	99.09	171.23	408.18	Pujari *et al.* (1995)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	29.28	18.66-53.80	82.07	74.07	30.94	29.39	90.25	11.44	39.09	Sahu and Mishra (1995)
	Tomato	42.82	29.40-64.85	-	-	22.30	21.38	91.23	18.01	42.06	Das *et al.* (1998)
	Tomato	-	-	57.14	54.89	29.85	28.57	96.05	-	59.05	Mala and Vadivel (1999)
	Tomato	45.91	22.83-75.00	-	-	31.79	30.29	90.80	27.30	59.46	Mohanty (2003)
Total yield per plant (kg)	Tomato	-	-	-	-	33.51	29.39	67.19	285.53	46.64	Srivastava and Sachan (1973)
	Tomato	1.68	1.44-2.34	-	-	-	13.09	84.14	0.42	25.00	Singh *et al.* (1974)
	Tomato	1.81	1.30-2.50	0.166	0.141	22.09	20.44	84.93	-	39.77	Prasad and Prasad (1976)
	Tomato	1.243	0.554-2.134	0.157	1.131	-	29.04	83.00	0.68	54.71	Paranjothi and Muthukrishnan (1979)
	Tomato	0.867	0.547-1.653	0.038	0.034	22.50	21.36	90.11	0.42	48.44	Bhutani *et al.* (1983)
	Tomato	-	-	-	-	34.24	16.83	24.17	192.76	17.07	Rattan *et al.* (1983)
	Tomato	441.00	198.00-931.00	-	-	41.24	33.19	64.80	24.38	-	Reddy and Gulshanlal (1987)
	Tomato	-	-	108.075	98.785	18.76	17.94	91.40	19.574	35.32	Singh *et al.* (1988)
	Tomato	1.62	0.95-2.18	0.18	0.15	26.19	23.90	83.33	-	44.44	Bora *et al.* (1993)
	Tomato	1.45	0.88-2.08	0.40	0.05	52.52	18.57	12.50	0.16	11.03	Narendrakumar and Arya (1995)
	Tomato	1.15	0.160-2.240	0.20	0.18	17.39	16.65	90.00	0.83	72.10	Pujari *et al.* (1995)
	Tomato	1097.25	698.40-1708.60	63719.1	56894.9	23.01	21.74	89.29	315.54	28.75	Sahu and Mishra (1995)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	2.87	1.69-4.23	-	-	27.23	24.15	78.69	1.27	44.28	Das *et al.* (1998)
	Tomato	-	-	1.20	1.12	52.95	50.36	93.57	-	100.43	Mala and Vadivel (1999)
	Tomato	0.99	0.70-1.22	-	-	17.65	16.85	91.13	-	37.13	Parvindarsingh *et al.* (2002)
Yield per hectare (q/ha)	Tomato	-	257.99-474.58	4074.64	3904.37	18.38	17.64	92.10	-	34.87	Pradeepkumar and Tewari (1999)
	Tomato	337.04	241.33-392.00	-	-	13.00	9.30	51.20	46.22	13.71	Mohanty (2003)
Average fruit weight (g)	Tomato	-	-	-	-	28.33	24.29	74.19	15.34	43.35	Srivastava and Sachan (1973)
	Tomato	49.59	26.60-107.60	-	-	67.45	65.70	94.88	63.88	131.84	Nandpuri *et al.* (1977)
	Tomato	37.70	7.00-102.00	257.00	235.60	-	40.70	92.00	30.27	80.29	Paranjothi and Muthukrishnan (1979)
	Tomato	-	-	-	-	39.38	35.95	83.37	40.51	67.65	Rattan *et al.* (1983)
	Tomato	32.19	5.20-49.80	-	-	35.28	35.04	98.70	23.03	-	Reddy and Gulshanlal (1987)
	Tomato	-	-	0.354	0.183	14.75	10.60	51.65	0.633	15.69	Singh *et al.* (1988)
	Tomato	-	-	381.74	323.14	-	42.18	-	34.52	-	Gadekar *et al.* (1992)
	Tomato	54.83	32.87-87.53	1780.93	1742.65	76.96	76.93	97.85	-	155.14	Bora *et al.* (1993)
	Tomato	41.88	1.00-122.50	384.16	366.17	917.29	874.33	95.32	38.49	91.81	Pujari *et al.* (1995)
	Tomato	38.43	20.53-52.20	67.59	61.37	21.00	20.38	95.25	10.45	27.19	Sahu and Mishra (1995)
	Tomato	64.13	35.45-106.00	-	-	24.96	23.39	87.85	30.75	45.17	Das *et al.* (1998)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	47.81	-	795.96	712.17	59.00	55.81	89.00	14.16	-	Krishnaprasad and Mathurarai (1999)
	Tomato	-	-	260.47	259.02	47.94	47.90	99.82	-	98.59	Mala and Vadivel (1999)
	Tomato	58.53	27.97-77.27	-	-	24.79	24.49	97.53	49.81	-	Parvindarsingh *et al.* (2002)
	Tomato	51.25	29.83-92.67	-	-	38.96	37.91	94.70	38.94	75.98	Mohanty (2003)
Polar diameter of the fruit (cm)	Tomato	5.35	4.40-6.78	-	-	-	9.15	87.57	0.93	1.73	Singh *et al.* (1974)
	Tomato	-	-	-	-	20.53	19.64	91.53	2.05	38.70	Rattan *et al.* (1983)
	Tomato	-	-	14.545	10.07	21.25	17.68	69.23	5.439	30.31	Singh *et al.* (1988)
	Tomato	4.21	3.10-5.80	0.37	0.20	14.38	10.58	54.15	0.46	10.50	Sahu and Mishra (1995)
	Tomato	5.27	3.87-7.22	-	-	18.64	18.24	95.79	1.92	36.71	Das *et al.* (1998)
	Tomato	3.59	-	0.55	0.48	20.58	19.19	87.00	8.12	-	Krishnaprasad and Mathurarai (1999)
	Tomato	-	-	5.33	5.18	22.91	22.59	97.24	-	45.88	Mala and Vadivel (1999)
Equatorial diameter of the fruit (cm)	Tomato	-	-	-	-	13.51	10.81	62.95	0.07	21.54	Srivastava and Sachan (1973)
	Tomato	6.09	4.49-8.14	-	-	-	13.44	96.87	1.68	27.58	Singh *et al.* (1974)
	Tomato	-	-	-	-	20.29	17.61	75.35	1.50	31.47	Rattan *et al.* (1983)
	Tomato	-	-	0.581	0.458	19.99	17.75	78.84	1.238	32.47	Singh *et al.* (1988)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	5.76	4.54-7.76	1.16	1.12	18.70	18.36	96.55	-	37.33	Bora *et al.* (1993)
	Tomato	5.34	3.10-6.68	0.66	0.57	15.25	14.07	85.15	0.97	18.17	Sahu and Mishra (1995)
	Tomato	5.18	5.51-7.02	-	-	18.04	16.99	88.76	1.72	32.89	Das *et al.* (1998)
	Tomato	4.47	-	1.23	1.04	24.72	22.81	85.00	8.72	-	Krishnaprasad and Mathurarai (1999)
	Tomato	-	-	3.45	3.23	18.20	17.61	93.62	-	35.10	Mala and Vadivel (1999)
Fruit shape index	Tomato	1.15	0.65-1.77	0.045	0.036	3.91	3.13	80.00	0.35	30.40	Pujari *et al.* (1995)
	Water melon	-	0.64-1.05	-	-	22.84	4.95	5.00	0.02	2.21	Rajendran and Thamburaj (1994)
	Musk-melon	1.03	0.72-1.48	0.04	0.02	20.39	13.59	48.62	0.210	20.39	Deol *et al.* (1981)
	Musk-melon	1.20	0.81-4.90	0.43	0.38	53-87	50-64	88.40	1.19	97.50	Swamy *et al.* (1985)
	Musk-melon	1.00	0.89-1.39	-	-	10.07	9.19	84.00	-	17.23	Tarsemlal and Sanjaysingh (1997)
	Brinjal	2.22	1.1-5.0	-	-	47.54	45.71	92.42	2.01	90.54	Prakash *et al.* (1994)
Pericarp thickness (cm)	Tomato	4.64	2.90-6.66	0.89	0.71	-	18.1	79.70	1.54	33.40	Padda *et al.* (1971)
	Tomato	0.407	2.56-7.08	0.010	0.008	24.56	21.97	82.01	0.41	100.74	Bhutani *et al.* (1983)
	Tomato	0.47	0.20-0.75	0.019	0.012	4.04	2.55	63.16	0.18	38.16	Pujari *et al.* (1995)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	-	3.00-6.79	0.881	0.880	20.71	20.69	99.90	-	42.56	Pradeepkumar and Tewari(1999)
Number of locules per fruit	Tomato	4.05	2.00-5.50	0.43	0.28	-	13.10	65.10	0.87	21.70	Padda *et al.* (1971)
	Tomato	6.40	2.20-14.20	-	-	-	42.56	95.25	5.46	85.15	Singh *et al.* (1974)
	Tomato	6.04	2.00-12.20	10.03	8.51	52.31	48.17	84.84	-	91.72	Prasad and Prasad (1976)
	Tomato	3.80	2.00-10.00	2.20	1.88	-	36.00	85.00	2.60	68.48	Paranjothi and Muthukrishnan (1979)
	Tomato	3.90	2.40-6.30	0.95	0.77	24.95	22.45	80.99	1.62	41.63	Arora *et al.* (1982)
	Tomato	3.66	2.07-5.42	0.571	0.534	20.63	19.95	93.46	0.40	10.18	Bhutani *et al.* (1983)
	Tomato	3.66	2.00-5.40	-	-	24.15	21.26	77.50	1.41	-	Reddy and Gulshanlal (1987)
	Tomato	3.62	2.00-5.72	-	-	31.15	30.79	97.69	2.29	62.57	Das *et al.* (1998)
	Tomato	-	2.36-6.25	0.992	0.934	25.56	25.40	98.80	-	52.05	Pradeepkumar and Tewari (1999)
	Tomato	3.80	-	2.22	1.45	39.13	31.57	65.00	8.39	-	Krishnaprasad and Mathurarai (1999)
TSS (°Brix)	Tomato	5.43	3.60-6.80	0.45	0.36	-	11.50	80.00	1.10	20.30	Padda *et al.* (1971)
	Tomato	-	-	-	-	15.38	14.28	88.25	2.65	29.19	Srivastava and Sachan (1973)
	Tomato	7.11	6.10-7.90	0.42	0.39	9.00	8.72	92.85	-	17.58	Prasad and Prasad (1976)
	Tomato	5.50	3.20-7.40	0.260	0.193	-	7.90	75.00	0.79	14.36	Paranjothi and Muthukrishnan (1979)
	Tomato	5.40	4.30-7.20	0.41	0.24	11.86	9.67	58.84	0.77	14.29	Arora *et al.* (1982)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	4.43	3.40-5.99	-	0.053	-	-	26.20	0.242	5.46	Kasrawi and Amr (1990)
	Tomato	4.24	3.00-6.20	0.55	0.42	12.97	9.91	76.36	1.17	27.51	Pujari *et al.* (1995)
	Tomato	-	3.65-5.50	0.1413	0.141	7.96	7.94	99.50	-	16.27	Pradeepkumar and Tewari (1999)
	Tomato	3.50	-	0.42	0.21	18.61	13.21	50.00	4.48	-	Krishnaprasad and Mathurarai (1999)
	Tomato	-	-	0.37	0.37	20.55	20.49	99.45	-	42.09	Mala and Vadivel (1999)
Acidity (%)	Tomato	0.62	0.32-1.04	0.012	0.010	-	16.10	85.60	0.197	31.90	Padda *et al.* (1971)
	Tomato	0.596	0.300-1.088	0.020	0.009	-	15.70	41.00	0.13	21.81	Paranjothi and Muthukrishnan (1979)
	Tomato	1.76	0.80-2.80	0.20	0.17	25.54	23.65	85.64	0.79	45.01	Arora *et al.* (1982)
	Tomato	-	-	-	-	16.78	12.77	57.84	0.93	19.98	Rattan *et al.* (1983)
	Tomato	0.402	0.316-0.569	-	0.002	-	-	61.30	0.076	18.90	Kasrawi and Amr (1990)
	Tomato	-	0.21-0.67	0.011	0.011	22.78	22.77	99.90	-	47.04	Pradeepkumar and Tewari (1999)
	Tomato	-	-	0.70	0.66	65.22	63.24	93.98	-	126.26	Mala and Vadivel (1999)
TSS : acid ratio	Tomato	8.89	5.76-12.09	1.55	0.73	-	9.50	47.00	1.20	13.60	Padda *et al.* (1971)
Fruit pH	Tomato	4.64	4.11-7.20	-	0.116	-	-	78.10	0.624	13.50	Kasrawi and Amr (1990)
	Tomato	-	-	0.64	0.60	21.67	21.10	94.68	-	42.27	Mala and Vadivel (1999)
Ascorbic acid (mg/100 g)	Tomato	33.57	24.70-43.00	26.63	26.02	15.37	15.19	97.70	-	30.92	Prasad and Prasad (1976)
	Tomato	13.03	4.29-28.60	78.79	71.39	-	64.70	91.00	16.57	127.17	Paranjothi and Muthukrishnan (1979)

Table 1. Continued...

Character	Crop	Mean	Range	PV	GC	PCV (%)	GCV (%)	h^2 (%)	GA	GAM	References
	Tomato	20.72	14.60-27.80	6.99	3.99	12.76	9.65	57.21	3.12	15.03	Arora *et al.* (1982)
	Tomato	-	-	-	-	26.48	25.72	94.35	7.28	51.49	Rattan *et al.* (1983)
	Tomato	-	11.52-26.08	10.78	10.78	19.39	19.39	100.00	-	39.91	Pradeepkumar and Tewari (1999)
	Tomato	-	-	11.27	10.86	13.73	13.48	96.36	-	44.23	Mala and Vadivel (1999)
Lycopene (mg/100 g)	Tomato	-	0.89-2.16	0.097	0.096	22.59	22.45	98.80	-	46.27	Pradeepkumar and Tewari (1999)
	Tomato	-	-	0.09	0.09	29.47	29.14	97.80	-	59.37	Mala and Vadivel (1999)
Fruit density	Tomato	0.99	0.82-1.04	-	0.001	-	-	46.30	0.044	4.40	Kasrawi and Amr (1990)
	Tomato	-	0.95-1.08	0.0008	0.0007	2.91	2.79	92.20	-	5.97	Pradeepkumar and Tewari (1999)
Number of seeds per fruit	Tomato	85.936	30.00-174.33	1044.47	991.37	37.61	36.64	94.92	0.74	0.86	Bhutani *et al.* (1983)
	Tomato	-	-	2432.32	2379.69	-	-	-	-	99.13	Gadekar *et al.* (1992)
	Water-melon	-	20.50-539.83	-	-	58.76	44.64	58.00	166.23	69.87	Rajendran and Thamburaj (1994)
Thousand seed weight (g)	Tomato	5.20	2.00-8.10	1.52	1.47	23.72	23.29	96.20	2.44	46.99	Arora *et al.* (1982)
	Tomato	3.13	1.40-8.60	-	-	42.73	42.32	98.07	2.70	-	Reddy and Gulshanlal (1987)
	Musk-melon	3.40	2.10-6.40	0.83	0.66	26.65	23.71	79.20	1.48	43.50	Swamy *et al.* (1985)
	Water-melon	-	2.88-11.37	-	-	43.09	40.65	89.00	4.78	79.00	Rajendran and Thamburaj (1994)

2.2 GENETIC DIVERGENCE

For getting high heterosis or for recovering transgressive segregants, parents choosen for hybridisation need to be genetically diverse or distant. The cultivars from widely separated localities have been usually included in the hybridisation programme, presuming the presence of genetic divergence and maximum likelihood of recovering promising segregants. As per expectations, this has not yielded very satisfactory and consistent results. Eco-geographical diversity has been regarded as a reasonable index of genetic diversity (Vavilov, 1926; Moll *et al.*, 1962 and Ram and Panwar, 1970). However, it was reported later that, there does not exist any parallelism between geographic distribution and genetic diversity (Sachan and Sharma, 1971 and Peter, 1975 in tomato).

Multivariate analysis have been put to good use enabling quantification of degree of divergence between populations (Michener and Sokal, 1957; Morishina and Oka, 1960 and Murty and Qadri, 1966). Several methods of divergence analysis based on quantitative traits have been proposed to suit various objectives, of which, Mahalanobis's generalised distance (Mahalanobis, 1936) occupy a unique place in plant breeding. It is a very sensitive and potent biometrical tool in quantifying the degree of divergence between biological populations and also to assess the relative contribution of different components to the total divergence both at inter- and intra-cluster levels (Nair and Mukherjee, 1960; Khanna and Misra, 1977; Suyambhulingam and Jobarani, 1978 and Singh and Singh, 1980). The concept of Mahalanobis's D^2 statistic is based on the technique of utilising the measurements in respect of aggregate of characters. The D^2 statistic as a measure of genetic divergence was used for the first time in the field of plant breeding by Nair and Mukherjee (1960) in the classification of natural and plantation teak. The relative studies on the analysis of genetic divergence in tomato are just countable and those which have been published are reported here along with similar studies on other related vegetable crops.

Sachan and Sharma (1971) while studying genetic divergence in 20 varieties of tomato from diverse geographical sources reported substantial divergence of an indigenous material 'Jaipuri' from both exotics and other indigenous stocks and established its utility for hybridisation programmes. Tomato genotypes were grouped into four clusters and it was also concluded that, genetic divergence was not found to be related with geographic diversity in this crop. In the relative ranking of different components of D^2, the authors found that, the maximum contribution to the total divergence was by stem length, followed by number of branches, number of inflorescence and number of fruits per plant, in that order.

Khanna and Misra (1977) studied 50 varieties with respect to the taxonomic distance between them using the Mahalanobis's D^2 technique and grouped them into 10 clusters on the basis of intra- and inter-cluster similarity with respect to plant height, fruit number per plant, number of branches, number of locules, number of days to flowering, total soluble solids and plant height. The authorsfound that, total soluble solids, locule number and fruit number per plant were the major contributors to the divergence.

Bhattacharya *et al.* (1979) attempted to know the species differentiation in tomato based on the results of genetic divergence by D^2 analysis using 50 tomato genotypes comprising of 4 wild collections and rest of them were common cultivars belonging to different geographical areas and were evaluated for 17 characters. Genotypes were grouped into 16 clusters on the basis of relative magnitude of D^2 values. The four wild collections of which three belonging to *Lycopersicon peruvianum* and one to *Lycopersicon pimpinellifolium* were grouped into three distant clusters, which were highly diverse from all the other clusters comprising only the cultivars of *Lycopersicon esculentum* Mill. The major contribution to the divergence was by the fruit number per plant which helped in species differentiation. Shape index was useful for varietal differentiation in the *Lycopersicon esculentum* Mill.

Singh and Singh (1980) studied 21 Indian and 9 foreign varieties of tomato using Mahalanobis's D^2 statistic. Maximum divergence resulted from number of fruits per plant followed by fruit size and number of primary branches per plant. The varieties were grouped into 8 clusters. There was no parallelism between genetic divergence and geographic distribution of the lines.

Chaurasia and Majorsingh (1998) evaluated 71 genotypes during 1993-94 and 1994-95. Based on Mahalanobis's D^2 values, genotypes were grouped into 9 clusters in 1993-94 and 10 clusters in 1994-95. Fruit weight showed maximum contribution to the genetic diversity in both years followed by plant height, considering the cluster distances and cluster means the genotypes KS-7, DVRT-2, Antey and PS-1 were recommended as potential parents for hybridisation.

Dharmatti *et al.* (2001) studied genetic divergence for 402 summer tomato lines using multivariate analysis method. The 402 lines were grouped into 4 clusters based on similarities of D^2 values. Considerable diversity within and between the clusters were observed and the characters like tomato leaf curl virus resistance, fruit yield per plant and number of white flies per plant contributed maximum to the divergence.

Parthasarathy and Aswath (2002) studied genetic divergence among 23 tomato genotypes. These genotypes were grouped into 5 clusters based on the characters like average yield, medium fruits with average yield, medium fruits with average fruit number (cluster 1), more fruit number of cherry type with tall plants (cluster 2), plants which were high yielders with medium fruit weight (cluster 3), vigorous plants with very small fruits of *Lycopersicon pimpinellifolium* (cluster 4) and high yielders with good fruit size (cluster 5). Cluster 4 showed high inter-cluster distance with all the groups. For high yield with good fruit size and maximum number of fruits, crosses involving cluster 3 and 5 were recommended. Peter and Rai (1976) reported that, plant height and locule number greatly contributed to diversity. Sachan and Sharma (1971) found that, plant height, number of branches and number of fruits contributed for divergence.

Pramanick *et al.* (1992) studied genetic divergence in 38 lines/ varieties of eggplant collected from different sources for 18 characters. On the basis of D^2 values, 38 genotypes were grouped into 9 clusters which were homogenous within and heterogenous between. Minimum intra-cluster divergence was observed between genotypes falling in cluster VI and maximum divergence was observed in cluster III. The maximum inter-cluster divergence was observed between cluster I and IX. The clustering pattern showed different behaviour irrespective of their geographical locations. On the basis of the mean performance of different clusters, varieties having acceptable yield were placed in clusters I and II.

Thambe *et al.* (1993) studied divergence on the basis of D^2 analysis for 25 brinjal varieties and were grouped into 5 clusters with substantial genetic divergence between them. Cluster E had ten entries, cluster A had seven entries, cluster B had four entries and cluster C and D had two entries each. The maximum inter-cluster distance was observed between clusters D and E (57.58), while minimum distance was recorded between cluster A and B (16.35). The cluster mean for the character yield per plot was the highest in the cluster D (37.13 kg) and the lowest in cluster E (28.427 kg). The geographical distribution did not follow clustering pattern of these entries. A suitable hybridisation programme has been suggested on the basis of clustering pattern and cluster means.

Behera *et al.* (1999) studied genetic diversity in *Solanum* spp. for resistance to shoot and fruit borer using D^2 analysis by Tocher's method. Altogether, 4 clusters were formed. The genotype *Solanum indicum* appearing in cluster III was highly resistant and the genotypes *Solanum gilo, Solanum incanum* and *Solanum anomolum* appearing in cluster I were resistant. The cultivars of *Solanum melongena,* Pusa Purple Cluster, Bhagyamathi, Annamalai, APAU-4, Nurki and Singhnath forming cluster IV were moderately resistant and Pusa Kranti and Aushey of cluster II were susceptible to *Leucinodes orbonalis*.

Rameshbabu and Patil (2002) studied genetic divergence for 20 characters in a collection of 90 brinjal genotypes using Mahalanobis's D^2

statistics. These 90 genotypes were grouped into 7 clusters on the basis of relative magnitude of D^2 values. The maximum contribution towards the total genetic divergence was from yield per plant. It has been observed that, no close correspondence is evident between geographical distribution and genetic divergence as estimated by D^2 statistics. The maximum intercluster distance was observed between cluster IV and VII, while minimum was recorded between III and IV.

2.3 CORRELATION STUDIES

Correlation study measures the natural relationship between various characters and helps in determining the component characters on which selection can be based for yield improvement. Correlation coefficient measures the degree of association either in positive or negative direction. Phenotypic correlation is the observable correlation between two variables, which includes both genotypic and environmental effects. Genotypic correlation on the other hand, is the inherent association between two variables and it may be either due to pleotropic action of genes or linkage or both. Environmental correlation arises entirely due to environmental effects. Review of literature on correlation studies are presented in Table-2.

Table 2. Review of literature on correlations among the different characters of tomato and other related vegetable crops

	Character	Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
1.	Plant height (cm)	Tomato													$P^{-}G^{--}$	$P^{--}G^{--}$	Nandpuri *et al.* (1976)
		Tomato		$P^{-}G^{-}$													Reddy and Gulshanlal (1987)
		Tomato		G^{+}			G^{++}										Supe and Kale (1992)
		Tomato		$P^{++}G^{++}$	$P^{++}G^{++}$						$P^{--}G^{--}$		$P^{--}G^{--}$		$P^{++}G^{++}$		Rajjadhav *et al.* (1996)
		Tomato						$P^{--}G^{--}$			$P^{--}G^{--}$			$P^{++}G^{++}$		$P^{--}G^{--}$	Fageria and Kohli (1996)
		Tomato				$P^{--}G^{--}$	$P^{-}G^{--}$				$P^{--}G^{--}$						Krishnaprasad and Mathurarai (1999)
		Tomato		G^{--}		G^{+}	G^{++}				G^{++}				G^{++}	G^{++}	Mala and Vadivel (1999)
		Tomato		$P^{++}G^{++}$							$P^{--}G^{--}$				$P^{--}G^{--}$	$P^{--}G^{--}$	Mohanty (2003)
2.	Number of Primary branches	Tomato														G^{+}	Pranjothi and Muthukrishnan (1979)
		Tomato									$P^{++}G^{++}$					$P^{+}G^{+}$	Reddy and Gulshanlal (1987)
		Tomato					G^{+}								G^{+}	G^{++}	Supe and Kale (1992)
		Tomato			$P^{++}G^{++}$						$P^{--}G^{--}$		$P^{--}G^{--}$		$P^{++}G^{++}$	$P^{+}G^{+}$	Rajjadhav *et al.* (1996)
		Tomato				G^{-}	G^{-}				G^{--}				G^{-}	G^{--}	Mala and Vadivel (1999)
		Tomato									$P^{++}G^{++}$					$P^{--}G^{--}$	Mohanty (2003)
3.	Stem girth (cm)	Chilli	$P^{+}G^{++}$			G^{++}	G^{++}									G^{++}	Basavaraja (1997)
4.	Number of Flowers per cluster	Tomato									$P^{--}G^{--}$		$P^{++}G^{++}$		$P^{++}G^{++}$		Reddy and Gulshanlal (1987)
		Tomato									$P^{--}G^{--}$		$P^{-}G^{-}$		$P^{++}G^{++}$		Rajjadhav *et al.* (1996)
		Tomato									P^{++}				P^{++}	P^{--}	Dhankar *et al.* (2001)
		Brinjal												$P^{++}G^{++}$	$P^{+}G^{++}$	$P^{++}G^{++}$	Sharma and Kishanswaroop (2000)
5.	Polar diameter of the fruit (cm)	Tomato					G^{-}									G^{--}	Supe and Kale (1992)
		Tomato					G^{++}									G^{+}	Mala and Vadivel (1999)

Table 2. Continued...

	Character	Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
		Tomato					$P^{++}G^{++}$										Krishnaprasad and Mathurarai (1999)
		Brinjal					$P^{--}G^{--}$									$P^{++}G^{++}$	Ushakumari and Subramanian (1993)
		Brinjal									$P^{++}G^{++}$				$P^{++}G^{++}$	$P^{++}G^{++}$	Ingale and Patil (1995)
		Brinjal					$P^{--}G^{--}$								$P^{++}G^{++}$	$P^{++}G^{++}$	Yadav *et al.* (1997)
6.	Equatorial diameter of the fruit (cm)	Tomato														$P^{++}G^{++}$	Srivastava and Sachan (1973)
		Tomato				P^{++}											Singh *et al.* (1974)
		Tomato							$P^{+}G^{++}$								Das *et al.* (1998)
		Tomato							$P^{++}G^{++}$								Krishnaprasad and Mathurarai (1999)
		Tomato														G^{++}	Mala and Vadivel (1999)
		Brinjal								$P^{+}G^{++}$							Ushakumari and Subramanian (1993)
		Brinjal	G^{-}								$P^{++}G^{++}$				$P^{-}G^{--}$		Ingale and Patil (1995)
		Brinjal									$P^{++}G^{++}$				P^{-}	P^{+}	Yadav *et al.* (1997)
7.	Pericarp thickness (cm)	Tomato								P^{++}							Padda *et al.* (1971)
		Tomato	G^{--}											G^{--}		G^{++}	Fageria and Kohli (1996)
8.	Number of locules per fruit	Tomato				$P^{++}G^{++}$	$P^{++}G^{++}$										Singh *et al.* (1974)
		Tomato													P^{--}		Verma *et al.* (1976)
		Tomato									P^{++}						Reddy and Gulshanlal (1987)
		Tomato						$P^{--}G^{-}$									Pradeepkumar and Tewari (1999)
9.	Fruit volume (cc)	Brinjal									$P^{++}G^{++}$						Ushakumari and Subramanian (1993)
		Chilli									$P^{++}G^{++}$	$P^{++}G^{++}$			G^{++}		Basavaraja (1997)

Table 2. Continued...

	Character	Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
10.	Average fruit weight (g)	Tomato					P^{--}									P^{-}	Srivastava and Sachan (1973)
		Tomato													$P^{++}G^{++}$		Nandpuri *et al.* (1976)
		Tomato													$P^{--}G^{--}$		Nandpuri *et al.* (1977)
		Tomato						P^{+}	P^{+}								Dudi and Kalloo (1982)
		Tomato							P^{++}								Reddy and Gulshanlal (1987)
		Tomato												$P^{--}G^{--}$		$P^{++}G^{++}$	Fageria and Kohli (1996)
		Tomato				G^{+}	$P^{++}G^{++}$		$P^{++}G^{++}$								Das *et al.* (1998)
		Tomato				$P^{++}G^{++}$	$P^{++}G^{++}$		$P^{++}G^{++}$								Krishnaprasad and Mathurarai (1999)
		Tomato				G^{++}	G^{++}									G^{++}	Mala and Vadivel (1999)
		Tomato													P^{-}		Dhankar *et al.* (2001)
		Tomato														P^{-}	Parvindarsingh *et al.* (2002)
		Tomato														$P^{--}G^{--}$	Mohanty (2003)
11.	Number of seeds per fruit	Chilli								$P^{++}G^{++}$	$P^{++}G^{++}$						Basavaraja (1997)
12.	Per cent fruit set	Tomato									$P^{--}G^{--}$				$P^{++}G^{++}$	$P^{++}G^{++}$	Reddy and Gulshanlal (1987)
		Tomato									$P^{++}G^{+}$					$P^{++}G^{++}$	Raijadhav *et al.* (1996)
		Tomato												P^{+}			Dhankar *et al.* (2001)
13.	Number of fruits per cluster	Tomato					G^{-}										Srivastava and Sachan (1973)
		Tomato													G^{++}	G^{++}	Narendrakumar and Arya (1995)
		Tomato						$P^{-}G^{--}$								$P^{--}G^{--}$	Fageria and Kohli (1996)
		Tomato													P^{++}		Dhankar *et al.* (2001)
		Brinjal													$P^{++}G^{++}$	$P^{++}G^{++}$	Sharma and Kishanswaroop (2000)
14.	Number of fruits per plant	Tomato					P^{-}				$P^{--}G^{--}$					$P^{++}G^{++}$	Srivastava and Sachan (1973)
		Tomato				$P^{-}G^{+}$	$P^{--}G^{--}$		$P^{-}G^{--}$								Singh *et al.* (1974)

Table 2. Continued...

	Character	Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
		Tomato	P^{+}														Verma *et al.* (1976)
		Tomato	$P^{-}G^{--}$														Nandpuri *et al.* (1976)
		Tomato	$P^{-}G^{--}$														Nandpuri *et al.* (1977)
		Tomato						P^{-}			P^{-}						Dudi and Kalloo (1982)
		Tomato														G^{+}	Supe and Kale (1992)
		Tomato														$P^{++}G^{++}$	Narendrakumar and Arya (1995)
		Tomato	$P^{++}G^{++}$	$P^{++}G^{++}$	$P^{++}G^{++}$						$P^{--}G^{--}$						Rajjadhav *et al.* (1996)
		Tomato					P^{--}				P^{-}					$P^{++}G^{++}$	Das *et al.* (1998)
		Tomato					G^{+}									G^{++}	Mala and Vadivel (1999)
		Tomato			P^{--}						P^{-}			P^{++}		P^{++}	Dhankar *et al.* (2001)
		Tomato									$P^{--}G^{--}$					$P^{++}G^{++}$	Mohanty (2003)
15.	Early yield per plant (kg)	Tomato													P^{++}	P^{++}	Dudi and Kalloo (1982)
16.	Total yield per plant (kg)	Tomato					P^{--}		G^{--}						$P^{++}G^{++}$		Singh *et al.* (1974)
		Tomato	P^{--}														Verma *et al.* (1976)
		Tomato									P^{+}				P^{+}		Dudi and Kalloo (1982)
		Tomato		$P^{+}G^{+}$									$P^{+}G^{+}$				Reddy and Gulshanlal (1987)
		Tomato									P^{-}				$P^{++}G^{++}$		Rajjadhav *et al.* (1996)
		Tomato						$P^{++}G^{++}$			$P^{++}G^{++}$			$P^{--}G^{--}$			Fageria and Kohli (1996)

Table 2. Continued...

	Character	Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
		Tomato				$P^{+}G^{++}$					$P^{++}G^{++}$				$P^{++}G^{++}$		Das *et al.* (1998)
		Tomato			P^{--}										P^{++}		Dhankar *et al.* (2001)
		Tomato									P^{+}						Parvindarsingh *et al.* (2002)

Characters

1. Plant height (cm)
2. Number of primary branches
3. Number of flowers per cluster
4. Polar diameter of the fruit (cm)
5. Equatorial diameter of the fruit (cm)
6. Pericarp thickness (cm)
7. Number of locules per fruit
8. Fruit volume (cc)
9. Average fruit weight (g)
10. Number of seeds per fruit
11. Per cent fruit set
12. Number of fruits per cluster
13. Number of fruits per plant
14. Total yield per plant (kg)

NOTE:

P^{+} and P^{++} denote phenotypic positive association at 5% and 1% significant level

P^{-} and P^{--} denote phenotypic negative association at 5% and 1% significant level

G^{+} and G^{++} denote genotypic positive association at 5% and 1% significant level

G^{-} and G^{--} denote genotypic negative association at 5% and 1% significant level

2.4 PATH ANALYSIS

The implication of correlation studies becomes more evident when correlations are partitioned in to it's components in path analysis to determine the relative magnitude of various attributes contributing to correlation. Path analysis is simply standardised partial regression coefficient, which splits the correlation coefficients into the measures of direct and indirect effects of a set of independent variables on the dependent variable. Partitioning of the total correlation in to direct and indirect effects would be worthwhile for an effective selection programme. If the correlation coefficient between a causal factor and the effect is almost equal to its direct effect then, correlation explains the true relationship and a direct selection through this trait will be effective. If the correlation coefficient is positive, but the direct effect is negative or negligible, the indirect effects seem to be cause of correlation. In such situations, the indirect causal factors need to be considered simultaneously for selection. Correlation coefficient may be negative but the direct effect can be positive and high, under these circumstances, a restricted simultaneous selection model is to be followed, i.e., restrictions are to be imposed to nullify the undesirable indirect effects in order to make use of the direct effects (Singh and Kakar, 1977). Review of literature on path analysis in tomato and other related crops is presented in tabular form as under (Table-3).

Table 3. Review of literature on direct and indirect effects of different characters with yield per plant (kg) in tomato and other related crops

	Character		Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
1.	Plant height (cm)	P	Tomato	DN												IN		Nandpuri *et al.* (1976)
		G	Tomato	DN								IN				IN		Nandpuri *et al.* (1977)
		G	Tomato	DN												IN	IN	Dudi and Kalloo (1982)
		G	Tomato	DP														Krishnaprasad and Mathurarai (1999)
		G	Brinjal	HDN														Ingale and Patil (1995)
		P	Brinjal	HDP														Sharma and Kishanswaroop (2000)
		G	Brinjal	LDP												IP		Sharma and Kishanswaroop (2000)
2.	Number of primary branches	P	Tomato		DP							IP				IP		Reddy and Gulshanlal (1987)
		G	Brinjal		LDP											HIP		Ushakumari and Subramanian (1993)
		G	Brinjal		HDP													Ingale and Patil (1995)
		P	Brinjal	IP	HDN										IP			Sharma and Kishanswaroop (2000)
		G	Brinjal		LDP											IP		Sharma and Kishanswaroop (2000)
3.	Number of. flowers per cluster	P	Tomato			HDP						IN						Reddy and Gulshanlal (1987)
		P	Tomato			LDN										HIP		Dhankar *et al.* (2001)
		P	Brinjal			HDN									IP			Sharma and Kishanswaroop (2000)
		G	Brinjal	IP		LDP										IP		Sharma and Kishanswaroop (2000)
4.	Polar diameter of the fruit (cm)	G	Tomato				DP											Krishnaprasad and Mathurarai (1999)
		G	Brinjal				HDP	IN										Ushakumari and Subramanian (1993)
		G	Brinjal				HDN					IP						Ingale and Patil (1995)
		G	Brinjal													IP		Sharma and Kishanswaroop (2000)
5.	Equatorial diameter of the fruit (cm)	G	Tomato					DP										Krishnaprasad and Mathurarai (1999)
		G	Brinjal					HDP										Ushakumari and Subramanian (1993)
		G	Brinjal					HDN				IP						Ingale and Patil (1995)
		P	Brinjal					HDP										Sharma and Kishanswaroop (2000)

Table 3. Continued...

	Character		Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
		G	Brinjal					HDP										Sharma and Kishanswaroop (2000)
6.	Pericarp thickness (cm)	G	Tomato						HDP									Patil and Bojappa (1987)
7.	Number of locules per fruit	G	Tomato							DP								Krishnaprased and Mathurarai (1999)
8.	Fruit volume (cc)	G	Brinjal					IN										Ushakumari and Subramanian (1993)
		P & G	Brinjal								HDP					IN		Rajyalakshmi *et al.* (2000)
9.	Average fruit weight (g)	G	Tomato	IP								DN						Krishnaprased and Mathurarai (1999)
		P	Tomato									DP				IN		Nandpuri *et al.* (1976)
		G	Tomato									LDN				HIN		Nandpuri *et al.* (1977)
		G	Tomato						IP	IP		LDP						Dudi and Kalloo (1982)
		P	Tomato	IN		IN				IN		HDP		IP		IN		Reddy and Gulshanlal (1987), Singh and Mittal (1976)
		P	Tomato									DP						Dhankar *et al.* (2001)
		P & G	Tomato									DP				IN		Mohanty (2003)
		G	Brinjal									DN						Ushakumari and Subramanian (1993)
		G	Brinjal									HDN						Ingale and Patil (1995)
		P	Brinjal									HDP						Sharma and Kishanswaroop (2000)
		G	Brinjal									HDP						Sharma and Kishanswaroop (2000)
		P & G	Brinjal									HDP						Rajyalakshmi *et al.* (2000)
10.	Number of seeds per fruit	G	Chilli	IP									DP			IN		Basavaraja (1997)
		P	Chilli	IP								IP	DP					Basavaraja (1997)
11.	Per cent fruit set	P	Tomato			IP								HDN		IP		Reddy and Gulshanlal (1987)
		P	Tomato											LDN		HIP		Dhankar *et al.* (2001)

Table 3. Continued...

	Character		Crop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Reference
		P & G	Brinjal											HDN		IP		Rajyalakshmi *et al.* (2000)
12.	Number of fruits per cluster	P	Tomato												DP			Dhankar *et al.* (2001)
		P & G	Brinjal												HDP			Sharma and Kishanswaroop (2000)
13.	Number of fruits per plant	P	Tomato	IP												HDP		Nandpuri *et al.* (1976)
		G	Tomato	IP								IP				HDP		Nandpuri *et al.* (1976)
		G	Tomato	IP												DP	IP	Dudi and Kalloo (1982)
		P	Tomato													DP		Rattan *et al.* (1983)
		P	Tomato			IP						IP		IN		HDP		Reddy and Gulshanlal (1987)
		P	Tomato													DP		Dhankar *et al.* (2001)
		P & G	Tomato	IP								IN			HDP			Mohanty *et al.* (2003)
		G	Brinjal	IN				IN								HDP		Ushakumari and Subramanian (1993)
		G	Brinjal				IP											Ingale and Patil (1995)
		P	Brinjal	IP											HIP	HDP		Sharma and Kishanswaroop (2000)
		G	Brinjal													HDP		Sharma and Kishanswaroop (2000)
		P & G	Brinjal													HDP		Rajyalakshmi *et al.* (2000)
14.	Early yield per plant (kg)	G	Tomato	IP				IN	IN			IN				IP	DP	Dudi and kalloo (1982)

HDP = High direct positive effect
DP = Direct positive effect
P = At phenotypic level

HIP = High indirect positive effect
DN = Direct negative effect
G = At genotypic level

LDP = Low direct positive effect
IP = Indirect positive effect
P & G = At phenotypic and genotypic level

LIN = Low indirect negative effect
IN = Indirect negative effect

Characters

1. Plant height (cm)
2. Number of primary branches
3. Number of flowers per cluster
4. Polar diameter of the fruit (cm)
5. Equatorial diameter of the fruit (cm)
6. Pericarp thickness (cm)
7. Number of locules per fruit
8. Fruit volume (cc)
9. Average fruit weight (g)
10. Number of seeds per fruit
11. Per cent fruit set
12. Number of fruits per cluster
13. Number of fruits per plant
14. Early yield per plant (kg)

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Field experiment on "Genetic variability and divergence studies in tomato" was undertaken during the year 2002-2003. The details of the materials used and techniques adopted are presented in this chapter.

3.1 EXPERIMENTAL SITE

The experiment was conducted in the Olericulture Unit (Plate-1) of Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district, Karnataka. The soils of the experimental site comprised of medium deep black. The chemical properties of the soils are presented in the Appendix-I.

3.2 LOCATION AND CLIMATE

Arabhavi is situated in northern dry zone of Karnataka state at 16°15' north latitude, 75°45' east longitude and at an altitude of 612.03 metres above the mean sea level. Arabhavi, which comes under zone-3 of region-2 of agro-climatic zones of Karnataka, has the benefits of both south-west and north-east monsoons. The average rainfall of this area is about 530 mm distributed over a period of five to six months (May to October) with peak (85.60 mm) during August.

The command area receives water from Ghataprabha Left Bank Canal from mid-July to mid-March. During the experimental period, the

Plate 1. General view of the experimental site

meteorological data recorded at meteorological observatory of the Agricultural Research Station, Arabhavi is presented in Appendix-II.

3.3 DETAILS OF EXPERIMENT

3.3.1 Entries

Present study was carried out with sixty-seven entries comprising of seven open-pollinated varieties developed by Public Sector Organisations and nine entries collected from different institutes and fifty-one entries developed at Kittur Rani Channamma College of Horticulture, Arabhavi.

List of the entries with their salient features are presented in the Table-4.

3.4 LAYOUT OF THE EXPERIMENT

The experiments were laid out during Rabi 2002-2003 with sixty-seven genotypes in randomised complete block design with three replications. The experimental field was brought to fine tilth by repeated ploughing. Farmyard manure was incorporated into soil at the rate of 20 tonnes per hectare. Ridges were opened with a distance of 75 cm. Healthy and uniform seedlings were transplanted on one side of the ridges with a spacing of 60 cm between the plants. Regular irrigation and hand weeding operations were carried out. Three weeks after

Table 4. List of tomato genotypes with their source pedigree and fruit traits

Sl. No.	Geno-type	Source	Pedigree	Fruit size*	Fruit shape**	Fruit blossom end shape	Fruit colour	Fruit firmness	Pulpiness
1.	KT01	KRCCH, Arabhavi	1-2/7	Medium large	Flat/squash	Flat	Red	Medium firm	Medium pulpy
2.	KT02	KRCCH, Arabhavi	2-2/7	Large	Flat/squash	Flat	Red	Firm	Pulpy
3.	KT03	KRCCH, Arabhavi	3-2/5	Medium large	Oblong	Flat	Red	Firm	Pulpy
4.	KT04	KRCCH, Arabhavi	T-3-2/5	Medium large	Round	Pointed	Red	Firm	Pulpy
5.	KT05	KRCCH, Arabhavi	T-4-2/8	Medium	Flat/squash	Flat	Light red	Soft	Juicy
6.	KT06	KRCCH, Arabhavi	T-5-1/5	Medium	Round	Flat	Red	Soft	Juicy
7.	KT07	KRCCH, Arabhavi	6-1/6	Large	Flat/squash	Flat	Red	Soft	Juicy
8.	KT08	KRCCH, Arabhavi	T-7-b	Very small	Flat/squash	Flat	Red	Soft	Juicy
9.	KT09	KRCCH, Arabhavi	8-b	Medium	Oblong	Flat	Red	Firm	Pulpy
10.	KT10	KRCCH, Arabhavi	T-11-b	Medium large	Flat/squash	Flat	Red	Soft	Juicy
11.	KT11	KRCCH, Arabhavi	11-b(b)	Large	Flat/squash	Flat	Red	Medium soft	Medium pulpy
12.	KT12	KRCCH, Arabhavi	13-1/1	Large	Oblong	Pointed	Light orange	Firm	Medium pulpy
13.	KT13	KRCCH, Arabhavi	13-3/10	Medium large	Round	Flat	Orange	Firm	Pulpy
14.	KT14	KRCCH, Arabhavi	14-2/5	Large	Round	Flat	Red	Firm	Medium pulpy
15.	KT15	KRCCH, Arabhavi	15-1/2	Large	Flat/squash	Flat	Red	Medium firm	Medium pulpy
16.	KT16	KRCCH, Arabhavi	16-3/6	Large	Round	Pointed	Red	Firm	Pulpy
17.	KT17	KRCCH, Arabhavi	16-1/7	Large	Round	Flat	Red	Firm	Pulpy
18.	KT18	KRCCH, Arabhavi	16-1/9	Medium	Oblong	Flat	Red	Firm	Pulpy
19.	KT19	KRCCH, Arabhavi	17-b(b)	Large	Round	Flat	Red	Firm	Pulpy

Table 4. Continued...

Sl. No.	Geno-type	Source	Pedigree	Fruit size*	Fruit shape**	Fruit blossom end shape	Fruit colour	Fruit firmness	Pulpiness
20.	KT20	KRCCH, Arabhavi	17-b(a)	Medium large	Round	Pointed	Red	Medium firm	Pulpy
21.	KT21	KRCCH, Arabhavi	17-2/2	Medium	Oblong	Flat	Red	Firm	Medium pulpy
22.	KT22	KRCCH, Arabhavi	18-b	Medium large	Round	Flat	Red	Firm	Medium pulpy
23.	KT23	KRCCH, Arabhavi	19-b	Medium large	Round	Pointed	Red	Firm	Pulpy
24.	KT24	KRCCH, Arabhavi	20-b	Medium	Oblong	Pointed	Red	Firm	Medium pulpy
25.	KT25	KRCCH, Arabhavi	21-b	Medium large	Round	Flat	Red	Medium firm	Juicy
26.	KT26	KRCCH, Arabhavi	23-1/1	Medium	Round	Pointed	Light red	Firm	Pulpy
27.	KT27	KRCCH, Arabhavi	23-b	Medium	Round	Pointed	Red	Firm	Pulpy
28.	KT28	KRCCH, Arabhavi	24-1/10	Medium large	Oblong	Flat	Red	Medium firm	Pulpy
29.	KT29	KRCCH, Arabhavi	24-b	Medium	Round	Flat	Red	Firm	Pulpy
30.	KT30	KRCCH, Arabhavi	25-b	Medium large	Round	Flat	Red	Firm	Pulpy
31.	KT31	KRCCH, Arabhavi	25-b(b)	Medium	Round	Flat	Red	Firm	Pulpy
32.	KT32	KRCCH, Arabhavi	26-b	Medium	Flat/squash	Flat	Red	Firm	Pulpy
33.	KT33	KRCCH, Arabhavi	27-1/10	Medium large	Flat/squash	Flat	Red	Medium firm	Medium pulpy
34.	KT34	KRCCH, Arabhavi	27-b	Medium large	Flat/squash	Flat	Red	Firm	Pulpy
35.	KT35	KRCCH, Arabhavi	28-R	Medium	Round	Flat	Red	Firm	Pulpy
36.	KT36	KRCCH, Arabhavi	28-E	Large	Round	Flat	Red	Medium firm	Medium pulpy
37.	KT37	KRCCH, Arabhavi	28-b	Large	Round	Flat	Red	Firm	Pulpy

Table 4. Continued...

Sl. No.	Geno-type	Source	Pedigree	Fruit size*	Fruit shape**	Fruit blossom end shape	Fruit colour	Fruit firmness	Pulpiness
38.	KT38	KRCCH, Arabhavi	29-b	Medium large	Round	Flat	Red	Medium firm	Medium pulpy
39.	KT39	KRCCH, Arabhavi	30-R	Large	Flat/squash	Flat	Red	Firm	Pulpy
40.	KT40	KRCCH, Arabhavi	30-F	Medium	Round	Flat	Red	Firm	Pulpy
41.	KT41	KRCCH, Arabhavi	30-F-1	Large	Flat/squash	Pointed	Red	Firm	Medium pulpy
42.	KT42	KRCCH, Arabhavi	T-30-E	Medium	Oblong	Flat	Red	Firm	Pulpy
43.	KT43	KRCCH, Arabhavi	30-E	Medium	Oblong	Flat	Red	Firm	Pulpy
44.	KT44	KRCCH, Arabhavi	31-1/1	Large	Round	Flat	Red	Firm	Pulpy
45.	KT45	KRCCH, Arabhavi	33-b	Very large	Round	Flat	Red	Firm	Highly pulpy
46.	KT46	KRCCH, Arabhavi	34-b	Medium	Round	Flat	Red	Firm	Pulpy
47.	KT47	KRCCH, Arabhavi	9-b	Large	Flat/squash	Flat	Red	Firm	Pulpy
48.	KT48	NBPGR, New Delhi	EC-1703	Medium	Flat/squash	Flat	Red	Soft	Juicy
49.	KT49	NBPGR, New Delhi	EC-5888	Medium	Flat/squash	Flat	Red	Soft	Juicy
50.	KT50	NBPGR, New Delhi	EC-8822	Medium	Flat/squash	Flat	Pinkish red	Soft	Juicy
51.	KT51	NBPGR, New Delhi	EC-14181	Small	Round	Flat	Red	Soft	Juicy
52.	Punjab Kesari	PAU, Ludhiana	Punjab Kesari	Medium	Round	Flat	Red	Medium film	Medium pulpy
53.	KT52	IIHR, Bangalore	IIHR-2274	Medium	Flat/squash	Flat	Light red	Medium firm	Juicy
54.	KT53	IIHR, Bangalore	IIHR-2300	Medium large	Round	Flat	Red	Medium soft	Medium pulpy

Table 4. Continued...

Sl. No.	Geno-type	Source	Pedigree	Fruit size*	Fruit shape**	Fruit blossom end shape	Fruit colour	Fruit firmness	Pulpiness
55.	KT54	IIHR, Bangalore	IIHR-2302	Medium	Round	Flat	Red	Medium firm	Medium pulpy
56.	KT55	IIHR, Bangalore	IIHR-2306	Medium	Round	Flat	Red	Medium firm	Medium pulpy
57.	KT56	IIHR, Bangalore	BL-333-1	Medium	Flat/squash	Flat	Pink	Soft	Juicy
58.	Arka Vikas	IIHR, Bangalore	Arka Vikas	Large	Flat/squash	Flat	Red	Firm	Juicy
59.	Arka Saurabh	IIHR, Bangalore	Arka Saurabh	Medium	Flat/squash	Flat	Red	Medium firm	Medium juicy
60.	Arka Meghali	IIHR, Bangalore	Arka Meghali	Large	Round	Pointed	Red	Firm	Pulpy
61.	Arka Alok	IIHR, Bangalore	Arka Alok	Medium large	Round	Flat	Red	Firm	Pulpy
62.	Arka Abha	IIHR, Bangalore	Arka Abha	Large	Round	Pointed	Red	Medium firm	Medium pulpy
63.	KT57	KRCCH, Arabhavi	Thally-18	Medium	Round	Flat	Red	Medium soft	Medium juicy
64.	KT58	KRCCH, Arabhavi	KT-58	Small	Round	Flat	Pink	Soft	Juicy
65.	KT59	KRCCH, Arabhavi	Hazaribagh Local	Medium large	Round	Flat	Red	Medium firm	Medium pulpy
66.	KT60	KRCCH, Arabhavi	RJL-1	Large	Round	Flat	Red	Medium firm	Medium pulpy
67.	Arka Ashish	IIHR, Bangalore	Arka Ashish	Large	Flat/squash	Flat	Red	Medium firm	Medium pulpy

***Fruit size:**
1) Very small ($\leq$20 g) 2) Small (20-30 g) 3) Medium (30-80 g) 4) Medium large (80-100 g)
5) Large (100-175 g) 6) Very large (>175 g)
****Fruit shape index:** 1) <0.90 – Flat/squash 2) 0.90-1.10 – Round 3) >1.10 – Oblong

transplanting, plants were supported with bamboo poles tied with galvanised wire and tying of vines to wire was regularly carried out. Other operations including plant protection measures, which are not specified, were carried out as per recommended package of practices of University of Agricultural Sciences, Dharwad (Anon., 2002). General view of experimental plot is presented in Plate-1.

3.4.2 Fertiliser application

Fertilisers (115 kg N, 100 kg P_2O_5 and 60 kg K_2O/ha) were applied uniformly to all genotypes. Half dose of the nitrogen and full dose of phosphorous and potassium were applied before transplanting of seedlings and remaining 50 per cent of nitrogen was applied four weeks after transplanting.

3.4.3 Experimental plot size

In each plot, there were eleven plants (in a row). The total area of experimental site was 1100 m^2.

3.5 OBSERVATIONS RECORDED

Five randomly chosen plants in each replication of each entry were labelled and used for recording the observations. The mean of five plants was taken for analysis. The characters studied and techniques adopted to record the observations are given below.

3.5.1 Growth parameters

3.5.1.1 Plant height (cm)

The height of the plant was measured from ground level to the tip of the plant at 30, 60 and 90 days after transplanting (DAT).

3.5.1.2 Plant spread in East to west (cm)

The spread of the plant was measured from east to west direction of the plant at 30, 60 and 90 DAT.

3.5.1.3 Plant spread in north to south (cm)

The spread of the plant was measured from north to south direction of the plant at 30, 60 and 90 DAT.

3.5.1.4 Plant canopy (cm^2)

The canopy of the plant was calculated by multiplying the plant spread in east to west with north to south direction at 30, 60 and 90 DAT.

3.5.1.5 Number of primary branches per plant

Number of primary branches on main stem was counted at 30, 60 and 90 DAT.

3.5.1.6 Stem girth (cm)

The girth of the main stem at ground level was measured using vernier calliperse at 30, 60 and 90 DAT.

3.5.2 Flower parameters

3.5.2.1 Number of flowers per cluster

Number of flowers per cluster was recorded by counting five flower clusters in each of five tagged plants at peak flowering stage and average was worked out.

3.5.2.2 Length of the flower (cm)

Length of the flower was measured in five randomly selected flowers in each of five tagged plants at peak flowering stage and average was worked out.

3.5.2.3 Breadth of the flower (cm)

Breadth of the flower was measured in five randomly selected flowers in each of five tagged plants at peak flowering stage and average was worked out.

3.5.3 Earliness

3.5.3.1 Days to first flowering

Number of days taken from the date of transplanting to date of first flower opening was counted.

3.5.3.2 Days to 50 per cent flowering

Number of days were counted from the date of transplanting to 50 per cent of plants flowered.

3.5.3.3 Days to first fruit set

Number of days were counted from the date of transplanting to first fruit set (pea grain size).

3.5.3.4 Days to first fruit maturity

Number of days were counted from the date of transplanting to first fruit attaining physiological maturity (turning stage).

3.5.4 Yield parameters

3.5.4.1 Per cent fruit set

Ten flowers from each of five plants tagged were tied with thread. After seven days, set fruits with threads were counted and per cent fruit set was worked out using following formula.

$$\text{Per cent fruit set} = \frac{\text{Number of fruits carrying thread}}{\text{Total number of flowers tagged}} \times 100$$

3.5.4.2 Number of fruits per cluster

Number of fruits per cluster was noted from randomly selected five clusters in each of five tagged plants and average was worked out.

3.5.4.3 Number of fruits per plant

Number of fruits harvested from five tagged plants at each picking (harvest) was counted and total number of fruits per plant was computed by adding number of fruits of all harvests and dividing it by five (number of plants).

3.5.4.4 Early yield per plant (kg)

The total weight of fruits harvested from first three pickings was recorded from each of five tagged plants and average was worked out as early yield and expressed in kilograms per plant.

3.5.4.5 Total yield per plant (kg)

The total weight of fruits harvested form five tagged plants of all six harvests were added and average yield per plant was worked out and expressed in kilogram per plant.

3.5.4.6 Yield per hectare (tonnes)

The yield per hectare was calculated by multiplying the yield per plant (kg) with the number of plants per hectare (22,222) and expressed in tonnes per hectare.

3.5.4.7 Average fruit weight (g)

Average fruit weight was calculated by adding the weight of five fruits from each of five tagged plants at second harvest and divided it by total number of fruits and expressed in grams per fruit.

3.5.5 Fruit parameters

At second picking, five randomly selected fruits from each of five tagged plats were used for taking observations on fruit parameters.

3.5.5.1 Polar diameter of the fruit (cm)

Polar diameter was measured from stalk end to blossom end of fruit by using vernier callipers and average of 25 fruits was worked and expressed in centimetre.

3.5.5.2 Equatorial diameter of the fruit (cm)

The fruit breadth at highest bulged portion was measured by using vernier callipers and average of 25 fruits was worked out and expressed in centimetres.

3.5.5.3 Fruit shape index

Fruit shape index was calculated by dividing polar diameter of fruit with its equatorial diameter.

3.5.5.4 Pericarp thickness (cm)

Fruits were cut in middle at horizontal axis and thickness of pericarp was measured by using vernier calliperse and expressed in centimetres.

3.5.5.5 Number of locules per fruit

Fruits were cut in horizontal axis and number of locules were counted.

3.5.5.6 Total soluble solids (°Brix)

Few drops of juice extracted from cut fruit was used to determine total soluble solids (TSS) with the help of 'Erma' (0 to 32°Brix) hand refractometer at room temperature and the value was noted in °Brix (degree brix)

3.5.5.7 Titrable acidity (%)

Titrable acidity of juice was determined by taking a known volume of juice (2 ml) and diluted to known volume (25 ml). An aliquat of 5 ml was taken and titrated against standard 0.1N NaOH using phenolphthalein (1%) indicator. The appearance of light pink colour was marked as the end point. The value was expressed in terms of citric acid as per cent titrable acidity of juice (Anon.,1984)

$$\text{Per cent acidity} = \frac{\text{Titre value x volume made up x equivalent weight of acid}}{\text{Aliquat taken x weight or volume of sample x 1000}} \times 100$$

3.5.5.8 TSS : Acid ratio

It was calculated by dividing total soluble solids by titrable acidity.

3.5.5.9 pH

The pH of tomato juice was determined using digital pH meter of Digisun electronics systems of model 2001E.

3.5.5.10 Ascorbic acid (mg / 100g)

Samples of the red ripe fruits were analysed for the ascorbic acid content, using 2,6-Dichlorophenol Indophenol dye titrimetrically as per the modified procedure of AOAC (Anon., 1984). Two grams of sample was blended with 0.4 per cent oxalic acid and filtered through muslin cloth. To an aliquat of extract (2ml) of the sample, 3 ml acid mixture was added and titrated against 2,6-Dichlorophenol indophenol dye till the pink end point which persisted for at least 15 seconds (TV_2). Similar procedure was followed against acid mixture to get blank titre value and against standard solution made in 0.4 per cent oxalic acid to get standard titre value (TV_1)

$$\underset{(mg/100g)}{\text{Ascorbic acid}} = \frac{\begin{array}{c}\text{Ascorbic acid (mg)}\\ \text{content in standard}\end{array}}{\text{ml of aliquat}} \times \frac{TV_2}{TV_1} \times \frac{\text{Total sample volume}}{\text{Weight of sample}} \times 100$$

3.5.5.11 Lycopene (mg/100g)

Five grams of fruit sample was crushed and extracted repeatedly with acetone until residue becomes colourless. This acetone extract was transferred to separating funnel containing 15 ml of petroleum ether and mixed gently. To this, 5 ml of 5 per cent sodium sulphate solution in water was added and mixed thoroughly by shaking. This aided in separating out any water present in the separating funnel and helped to form a clear extract. The lower phase (petroleum ether extract containing carotenoid) was transferred to another separating funnel to remove any residual acetone and finally the extract was transferred to amber coloured bottle. The extraction procedure with petroleum ether was repeated till the acetone phase becomes colourless. Acetone phase was discarded and small quantity of anhydrous sodium sulphate was added to the petroleum ether extract. Then petroleum ether extract was transferred to 25 ml volumetric flask and diluted to 25 ml with petroleum ether and from this, 5 ml was again diluted to 25 ml with petroleum ether for colour measurement. Optical density (OD) of the extract was measured at 503 nm in a UV-VIS-spectrophotometer using petroleum ether as a blank (Ranganna, 1986).

Lycopene content of the sample was calculated by using the following formula.

$$\text{Lycopene (mg/100 g)} = \frac{3.1206 \text{ x OD of sample x volume made up x dilution}}{\text{Weight of sample x 1000}} \text{ x } 100$$

3.5.5.12 Fruit volume (cc)

The fruit volume was estimated by water displacement method. Individual fruits were immersed in thousand millilitres of water and the amount of water displaced was measured and volume was worked out per fruit and expressed in cubic centimetre.

3.5.5.13 Fruit Density (g/cc)

The fruit density was estimated by dividing weight of the fruit by volume of the fruit.

$$\text{Fruit density (g/cc)} = \frac{\text{Weight of the fruit (g)}}{\text{Fruit volume (cc)}}$$

3.5.5.14 Number of seeds per fruit

The seeds from five fruits were extracted by fermentation method and number of seeds was counted and the mean number of seeds per fruit was calculated.

3.5.5.15 Thousand seed weight (g)

Weight of thousand seeds were estimated and expressed in grams.

3.6 STATISTICAL AND BIOMETRICAL ANALYSIS

3.6.1 Analysis of variance

Analysis of variance was carried out as per the procedure given by Panse and Sukhatme (1967) using the mean values of random plants in each replication from all treatments to find out the significance of treatment effects.

3.6.2 Estimation of genetic parameters

3.6.2.1 Genotypic, phenotypic and environmental variances

The variance due to genotype, phenotype and environment were computed as follows.

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

$$\text{Environmental variance } (\sigma_e^2) = \text{Error mean sum of squares}$$

$$\text{Phenotypic variance } (\sigma_p^2) = \sigma_g^2 + \sigma_e^2$$

where, 'r' is number of replications.

3.6.2.2 Genotypic and phenotypic coefficient of variation

Genotypic and phenotypic coefficient of variations was estimated according to Burton and Devane (1953) based on estimate of genotypic and phenotypic variance.

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\sqrt{\sigma_g^2}}{\overline{X}} x100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\sqrt{\sigma_p^2}}{\overline{X}} x100$$

where $\overline{X}$ = General mean of the character

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

3.6.2.3 Heritability

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

$$\text{Heritability } (h^2) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

where σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

3.6.2.4 Expected genetic advance

Expected genetic advance (GA) was calculated using the formula given by Robinson *et al.* (1949).

Expected genetic advance (GA) = i x h^2 x σp

Where i = selection differential (2.06) at 5 per cent selection intensity

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

3.6.2.5 Genetic advance over mean (GAM)

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

$$\text{Genetic advance over mean (GAM)} = \frac{GA}{\overline{X}} \times 100$$

where GA = Genetic advance

$\overline{X}$ = General mean of the character

3.6.3 Genotypic and phenotypic correlation coefficients

Genotypic (rG) and phenotypic (rP) correlation coefficients were estimated as suggested by Al-Jibourie *et al.* (1958).

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

Phenotypic correlation = $r_{xy}(P) = \dfrac{Cov_{xy}(P)}{\sqrt{V_x(P) \times V_y(P)}}$

where,

$Cov_{xy}(G)$ = Genotypic covariance between x and y

$Cov_{xy}(P)$ = Phenotypic covariance between x and y

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

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

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

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

3.6.4 Path coefficient analysis

Path coefficient analysis suggested by Wright (1921) and illustrated by Dewey and Lu (1957) was carried out separately to know the direct and indirect effects of the important component traits on fruit yield per plant. Standard path coefficients, which are the standardised partial regression coefficients were obtained by solving the following set of 'P' simultaneous equations through 'Doolittle technique' as given by Goulden (1959).

$$P_{01} + P_{02}\, r_{12} + \dots \dots \dots + P_{op}\, r_{1p} = r_{01}$$
$$P_{01}\, r_{12} + P_{02} + \dots \dots \dots + P_{op}\, r_{2p} = r_{02}$$
$$P_{op}\, r_{1p} + P_{02}\, r_{2p} + \dots \dots \dots + P_{op} = r_{op}$$

where, P_{01}, P_{02} ... P_{op} are the direct path effects of 1, 2, ..., P variable on zero variables and r_{12}, r_{13}, ..., r_{1p} r_p (P-1) are the possible coefficients between dependent variable and independent variables and r_{01}, r_{02}, ..., r_{op} are the correlation coefficients between dependent variables and independent variables. The indirect effect of i^{th} variable through j^{th} variable was worked out ($P_{oj} \times r_{ij}$).

The contribution of the remaining unknown was measured as the residual factor and calculated as given below:

$$P^2_{ox} = 1 - (P^2_{01} + 2P_{01} P_{02} r_{12} + 2P_{01} P_{03} r13 + \ldots + P^2_{02} + 2P_{02} P_{03} r_{23} + \ldots + P^2_{OP})$$

$$\text{Residual factor (R)} = \sqrt{P^2 ox}$$

3.6.6 Genetic divergence

3.6.6.1 Mahalanobis D^2 analysis

Mahalanobis (1936) D^2 statistics was used for assessing the genetic divergence between population comprising 67 genotypes.

The original correlated unstandardised character mean values were transformed into standardised uncorrelated values to simplify the computational procedure. The D^2 values were obtained as the sum of squares of the differences between the pairs of corresponding uncorrelated (Ys) values of any two genotypes (Rao, 1952). A total of $\frac{n(n-1)}{2}$ D^2 values were calculated.

where n = number of genotypes.

3.6.6.2 Clustering of genotypes

Using all D^2 values, the genotypes were grouped into clusters using Tocher's method as described by Rao (1952).

3.6.6.3 Intra- and Inter-cluster distances

The intra- and inter-cluster distances were calculated by the formula given by Singh and Chaudhary (1977).

$$\text{Intra-cluster distance} = \sqrt{\frac{D_i^2}{n}}$$

where D_i^2 is the sum of D^2 values between all possible combinations of the genotypes included in cluster 'i'.

$$\text{Inter-cluster distance} = \sqrt{\frac{D_{ij}^2}{n_i n_j}}$$

where D_{ij}^2 is the sum of distances between all possible combinations ($n_i n_j$) of the genotypes included in the clusters 'i' and 'j'.

n_i = number of genotypes in cluster 'i'

n_j = number of genotypes in cluster 'j'.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

Investigations on genetic variability, correlation, path analysis and genetic divergence were carried out using tomato genotypes collected from different sources. The results obtained from experiments are presented in this chapter.

4.1 GENETIC VARIABILITY, CORRELATION AND PATH ANALYSIS

4.1.1 Analysis of variance (Tables 5 and 6)

The results of analysis of variance for forty-seven characters under study are summarised in Tables 5 and 6. The variance due to treatments (genotypes) was highly significant (at P=0.01) for thirty-six characters, viz., plant height at 30, 60 and 90 days after transplanting (DAT), number of primary branches at 60 and 90 DAT, stem girth at 60 and 90 DAT, number of flowers per cluster, length of the flower, breadth of the flower, days to first flowering, days to 50 per cent flowering, days to first fruit set, days to first fruit maturity, per cent fruit set, number of fruits per cluster, number of fruits per plant, early yield per plant, total yield per plant, yield per hectare, average fruit weight, polar and equatorial diameter of the fruit, fruit shape index, pericarp thickness, number of locules per fruit, total soluble solids (TSS), acidity, TSS : acid ratio, pH, ascorbic acid, lycopene, fruit volume, fruit density, number of seeds per fruit and thousand seed weight. Number of primary branches at 30 DAT

Table 5. Analysis of variance (mean sum of squares) for growth, flower and earliness parameters

Sl. No.	Source of variation / characters	Replications	Genotypes	Error
	Degrees of freedom	2	66	132
a.	**Growth parameters**			
1.	Plant height at 30 DAT (cm)	29.734	44.647**	14.404
2.	Plant height at 60 DAT (cm)	72.593	193.113**	90.591
3.	Plant height at 90 DAT (cm)	66.875	178.539**	73.611
4.	Plant spread (East-West) at 30 DAT (cm)	616.917	27.648NS	19.555
5.	Plant spread (North-South) at 30 DAT (cm)	551.562	26.458NS	28.803
6.	Plant spread (East-West x North-South) at 30 DAT (cm^2)	1003474.00	44710.830NS	41531.795
7.	Plant spread (East-West) at 60 DAT (cm)	802.812	188.377NS	148.359
8.	Plant spread (North-South) at 60 DAT (cm)	1022.312	157.396NS	125.551
9.	Plant spread (East-West x North-South) at 60 DAT (cm^2)	12815872.00	1932439.30NS	1835465.70
10.	Plant spread (East-West) at 90 DAT (cm)	1780.125	181.762NS	135.159
11.	Plant spread (North-South) at 90 DAT (cm)	1973.625	169.603NS	129.766
12.	Plant spread (East-West x North-South) at 90 DAT (cm^2)	48413696.00	3770293.10NS	3267803.60
13.	Number of primary branches at 30 DAT	2.431	0.689*	0.440
14.	Number of primary branches at 60 DAT	17.214	5.187**	2.295
15.	Number of primary branches at 90 DAT	17.725	4.383**	1.921
16.	Stem girth at 30 DAT (cm)	0.0773	0.0131NS	0.0106
17.	Stem girth at 60 DAT (cm)	0.0449	0.0329**	0.0076
18.	Stem girth at 90 DAT (cm)	0.1589	0.0217**	0.0056
b.	**Flower parameters**			
1.	Number of flowers per cluster	0.1823	1.6328**	0.1655
2.	Length of the flower (cm)	0.0061	0.3988**	0.0029
3.	Breadth of the flower (cm)	0.0097	0.2955**	0.0082
c.	**Earliness parameters**			
1.	Days to first flowering	8.750	33.447**	2.247
2.	Days to 50 per cent flowering	9.937	36.870**	2.293
3.	Days to first fruit set	13.679	32.692**	1.994
4.	Days to first fruit maturity	81.50	64.20**	14.81

* indicates significant at P=0.05 ** indicates significant at P=0.01

DAT = Days after transplanting NS = Non-significant.

Table 6. Analysis of variance (mean sum of squares) for yield and quality parameters in tomato

Sl. No.	Source of variation / characters	Replications	Genotypes	Error
	Degrees of freedom	2	66	132
a.	**Yield parameters**			
1.	Per cent fruit set	12.4375	78.3674**	38.2054
2.	Number of fruits per cluster	0.1027	0.9077**	0.1081
3.	Number of fruits per plant	386.4687	1147.7925**	87.1896
4.	Early yield per plant (kg)	0.1394	0.4145**	0.0823
5.	Total yield per plant (kg)	0.4021	1.7074**	0.2514
6.	Yield (t/ha)	197.1562	843.6735**	123.9979
7.	Average fruit weight (g)	14.50	3392.4261**	27.8778
8.	Polar diameter of the fruit (cm)	0.4980	3.3609**	0.0508
9.	Equatorial diameter of the fruit (cm)	0.0053	2.1480**	0.0233
b.	**Quality parameters**			
1.	Fruit shape index	0.0215	0.0862**	0.0022
2.	Pericarp thickness (cm)	0.0042	0.0320**	0.0015
3.	Number of locules per fruit	0.6246	2.2106**	0.0923
4.	TSS (°Brix)	0.0173	0.6445**	0.0208
5.	Acidity (%)	0.0309	0.0232**	0.0044
6.	TSS : acid ratio	22.4892	24.3304**	4.5395
7.	pH	0.0031	0.1436**	0.0008
8.	Ascorbic acid (mg/100 g)	13.7968	22.3867**	3.8549
9.	Lycopene (mg/100 g)	1.3496	36.3986**	0.3181
10.	Fruit volume (cc)	162.4062	1952.1326**	46.1302
11.	Fruit density (g/cc)	0.0005	0.0228**	0.0006
12.	Number of seeds per fruit	86.3750	7035.3878**	4.1053
13.	Thousand seed weight (g)	0.0013	0.7026**	0.00019

* indicates significant at P=0.05   ** indicates significant at P=0.01

varied significantly among genotypes at P = 0.05. There was no significant difference among genotypes for stem girth at 30 DAT and plant spread (Table-5).

4.1.2 Genetic variability (Tables 7 and 10)

Mean, range, phenotypic variance (PV), genotypic variance (GV), phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability (h^2), genetic advance (GA) and genetic advance as per cent over mean (GAM) for 37 plant traits (significant treatment variance) are presented in Tables 7 and 10 and in Figures 1 and 2.

4.1.2.1 Plant height (Tables 7 and 8)

Plant height at 30 DAT (Tables 7 and 8) ranged from 18.80 cm (KT 18) to 34.13 cm (KT 56) with an average mean of 25.604 cm. Moderate GV (10.081), PV (24.485), GCV (12.40%) and PCV (19.33%), with low heritability (41.20%) and GA (4.20) and moderate GAM (16.403%) was observed for plant height at 30 DAT.

Maximum plant height at 60 DAT (Tables 7 and 8) was observed in KT 49 (81.67 cm) followed by KT 55 (79.53 cm), KT 51 (77.47 cm), KT 56 (73.40 cm), KT 48 (71.93 cm) and KT 50 (71.40 cm) and minimum was observed in KT 05 (35.93 cm). Plant height at 60 DAT ranged from 39.93 cm to 81.67 cm with an average mean of 61.374 cm. Moderage GV (34.174), high PV (124.765), low GCV (9.52%) and moderate PCV

Table 7. Estimates of mean, range, components of variance, heritability and genetic advance for growth, flower and earliness parameters in tomato

Sl. No.	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM
a.	**Growth parameters**									
1.	Plant height at 30 DAT (cm)	25.604 ± 2.190	18.80-34.13	10.081	24.485	12.40	19.33	41.20	4.20	16.403
2.	Plant height at 60 DAT (cm)	61.374 ± 5.473	35.93-81.67	34.174	124.765	9.52	18.20	27.40	6.30	10.264
3.	Plant height at 90 DAT (cm)	85.677 ± 4.953	61.20-106.27	34.976	108.587	6.90	12.16	32.20	6.91	8.065
4.	Number of primary branches at 30 DAT	0.592 ± 0.382	0.27-2.80	0.083	0.523	48.64	122.18	15.80	0.24	40.540
5.	Number of primary branches at 60 DAT	7.726 ± 0.873	4.73-10.33	0.964	3.259	12.71	23.37	29.60	1.10	14.237
6.	Number of primary branches at 90 DAT	10.838 ± 0.799	8.27-13.67	0.820	2.741	8.36	15.28	29.90	1.02	9.411
7.	Stem girth at 60 DAT (cm)	1.185 ± 0.050	0.87-1.55	0.0084	0.0160	7.75	10.70	52.50	0.14	11.814
8.	Stem girth at 90 DAT (cm)	1.834 ± 0.043	1.65-2.09	0.0053	0.0109	3.99	5.73	48.50	0.11	5.997
b.	**Flower parameters**									
1.	Number of flowers per cluster	5.764 ± 0.234	4.13-7.53	0.489	0.654	12.13	14.04	74.70	1.25	21.686
2.	Length of the flower (cm)	1.938 ± 0.031	1.04-2.96	0.1319	0.1348	18.74	18.94	97.80	0.74	38.183
3.	Breadth of the flower (cm)	1.877 ± 0.052	1.04-2.84	0.0957	0.1039	16.48	17.18	92.00	0.61	32.498
c.	**Earliness**									
1.	Days to first flowering	28.024 ± 0.864	18.33-33.67	10.402	12.643	11.51	12.69	82.30	6.03	21.517
2.	Days to 50 per cent flowering	30.472 ± 0.873	20.00-35.67	11.525	13.818	11.14	12.20	83.40	6.39	20.970
3.	Days to first fruit set	34.781 ± 0.815	25.00-41.00	10.232	12.226	9.20	10.05	83.70	6.03	17.337
4.	Days to first fruit maturity	69.029 ± 2.221	56.33-75.33	16.466	31.276	5.88	8.10	52.60	6.07	8.793

GV = Genotypic variance PV = Phenotypic variance GCV = Genotypic coefficient of variance
PCV = Phenotypic coefficient of variance h^2 = Heritability GA = Genetic advance
GAM = Genetic advance (per cent mean)

DAT = Days after transplanting

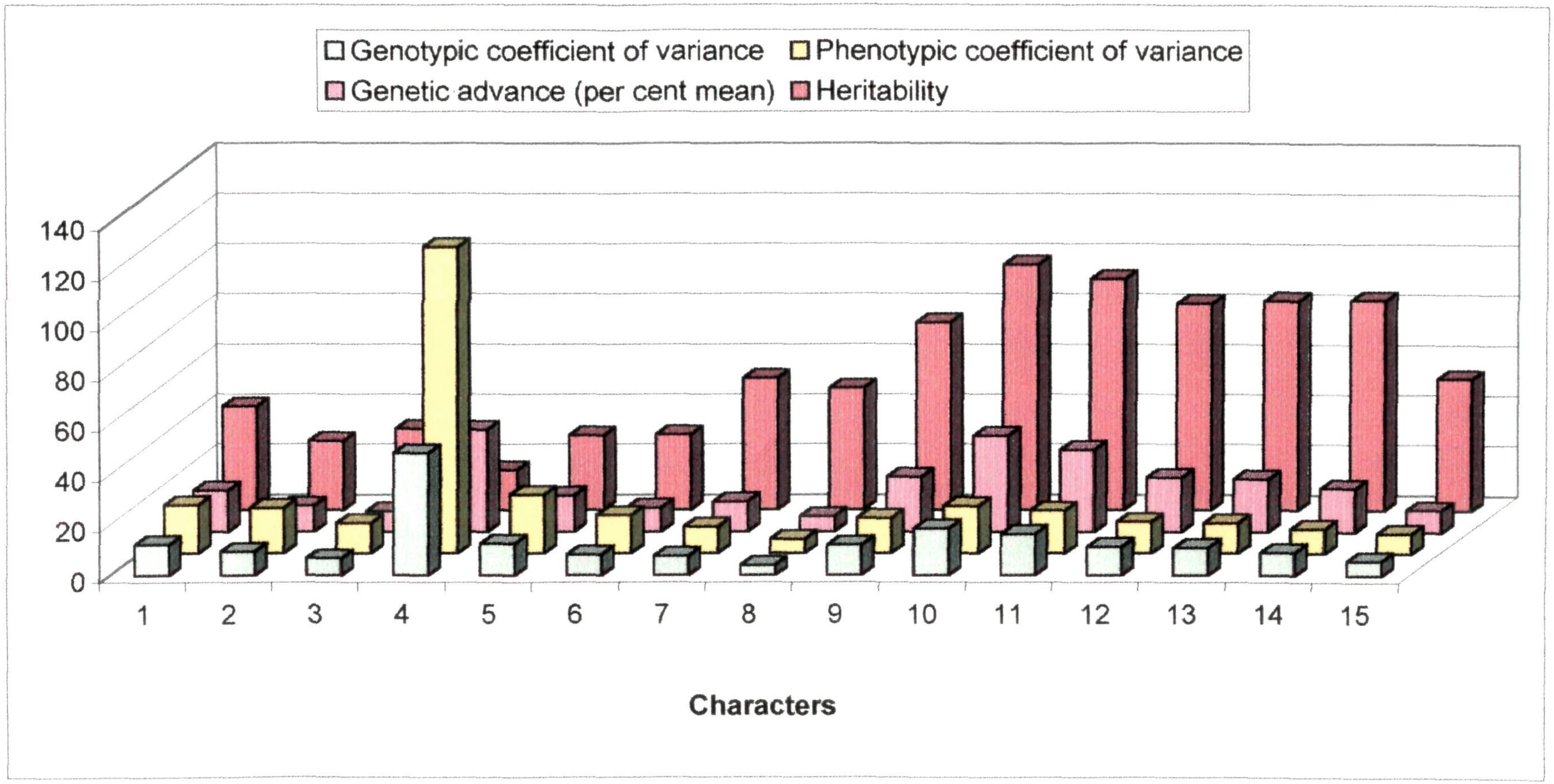

Fig. 1. GCV, PCV, GAM and heritability for growth, flower and earliness parameters in tomato

1. Plant height at 30 DAT (cm)
2. Plant height at 60 DAT (cm)
3. Plant height at 90 DAT (cm)
4. Number of primary branches at 30 DAT
5. Number of primary branches at 60 DAT
6. Number of primary branches at 90 DAT
7. Stem girth at 60 DAT (cm)
8. Stem girth at 90 DAT (cm)
9. Number of flowers per cluster
10. Length of the flower (cm)
11. Breadth of the flower (cm)
12. Days to first flowering
13. Days to 50 per cent flowering
14. Days to first fruit set
15. Days to first fruit maturity

Table 8. *Per se* performance of tomato genotypes for growth and flower parameters

Sl. No.	Geno-type	Plant height (cm)			Number of primary branches			Stem girth (cm)		No. of flowers per cluster	Length of the flower (cm)	Breadth of the flower (cm)
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	60 DAT	90 DAT			
1.	KT01	23.93	64.20	88.47	0.67	7.07	10.27	1.21	1.91	5.20	2.05	2.05
2.	KT02	32.67	54.00	78.60	2.07	8.27	11.27	1.35	2.02	4.53	2.48	2.37
3.	KT03	21.07	51.47	76.47	0.33	6.40	9.60	1.21	2.00	5.07	1.71	1.72
4.	KT04	23.07	62.77	81.47	0.87	7.13	10.20	1.34	1.97	5.47	2.00	1.90
5.	KT05	19.33	35.93	61.20	0.27	4.73	8.27	0.87	1.69	6.53	2.10	1.64
6.	KT06	20.00	56.73	80.47	0.53	7.73	10.93	1.17	1.86	5.20	1.59	1.58
7.	KT07	24.40	56.87	81.27	0.27	7.00	10.07	1.10	1.78	6.20	2.30	2.14
8.	KT08	29.80	65.07	89.20	0.73	8.80	11.67	1.11	1.78	5.40	1.04	1.04
9.	KT09	21.00	51.27	77.00	1.73	7.27	11.13	1.13	1.79	5.60	2.08	1.99
10.	KT10	23.67	63.40	88.13	1.33	8.33	11.13	1.28	1.88	6.40	2.53	1.90
11.	KT11	25.67	66.07	89.80	2.80	8.13	11.20	1.20	1.88	6.27	1.59	1.55
12.	KT12	21.53	49.40	73.87	1.20	6.13	9.33	1.06	1.76	6.07	2.11	2.15
13.	KT13	23.00	65.80	90.27	0.27	6.47	9.47	1.17	1.80	6.20	1.85	1.85
14.	KT14	21.27	63.53	83.33	0.33	8.20	10.40	1.15	1.82	6.07	1.65	1.66
15.	KT15	24.60	69.27	93.40	1.33	7.47	10.67	1.29	1.90	5.60	2.14	2.00
16.	KT16	22.13	49.60	74.20	0.87	6.40	9.40	1.30	1.94	5.80	2.01	1.98
17.	KT17	21.87	61.00	78.13	1.27	8.73	11.93	1.07	1.78	4.87	2.43	2.39
18.	KT18	18.80	65.33	89.60	0.73	9.00	12.73	1.15	1.71	6.33	2.08	2.08
19.	KT19	21.90	62.47	86.60	0.67	7.93	11.07	1.21	1.83	5.73	1.99	1.93
20.	KT10	24.27	58.07	82.40	0.60	6.60	9.80	1.23	1.76	5.27	1.72	1.75
21.	KT21	20.87	54.73	79.00	0.60	8.40	11.53	1.09	1.79	5.53	1.77	1.72
22.	KT22	25.13	69.07	91.93	0.80	6.93	10.00	1.14	1.77	4.93	1.82	1.82
23.	KT23	20.07	54.80	79.07	0.93	6.73	9.93	1.23	1.85	5.47	2.13	2.04
24.	KT24	21.00	59.07	83.07	0.47	6.87	10.13	1.21	1.79	5.47	1.75	1.75
25.	KT25	22.13	58.40	82.13	0.73	6.13	9.27	1.17	1.81	6.00	1.82	1.82
26.	KT26	21.60	64.67	90.00	0.73	5.80	9.00	1.15	1.83	6.47	2.41	2.42
27.	KT27	27.00	45.31	91.40	0.53	8.07	11.27	1.13	1.80	6.60	2.02	1.94
28.	KT28	31.13	56.87	80.47	0.33	7.60	10.73	1.15	1.79	7.47	1.81	1.85
29.	KT29	29.87	56.80	81.00	0.40	6.47	11.40	1.22	1.77	5.47	1.92	1.92
30.	KT30	30.93	56.80	80.80	0.33	6.33	9.40	1.18	1.83	6.07	2.14	2.03
31.	KT31	30.33	64.60	89.20	0.33	7.80	10.73	1.30	1.87	6.07	2.01	1.93
32.	KT32	29.47	62.67	86.53	0.40	10.27	13.00	1.07	1.69	5.53	2.51	2.43
33.	KT33	27.60	65.00	89.33	0.40	6.80	10.07	1.27	1.97	5.93	2.53	2.51
34.	KT34	32.47	64.60	88.13	0.27	10.27	13.47	1.25	1.91	5.27	1.85	1.81
35.	KT35	27.87	66.07	89.67	0.27	10.20	12.80	1.20	1.87	4.13	1.91	1.82
36.	KT36	23.80	58.07	82.33	0.33	7.60	11.00	1.21	1.87	5.87	1.84	1.74
37.	KT37	28.93	61.67	85.80	0.27	7.93	11.07	1.22	1.85	4.40	2.02	1.87
38.	KT38	24.33	46.20	71.00	0.40	8.27	11.40	1.08	1.79	6.40	2.81	2.04

Table 8. Continued...

Sl. No.	Genotype	Plant height (cm)			Number of primary branches			Stem girth (cm)		No. of flowers per cluster	Length of the flower (cm)	Breadth of the flower (cm)
		30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	60 DAT	90 DAT			
39.	KT39	31.13	65.53	89.40	0.40	9.13	12.13	1.23	1.83	6.20	1.82	1.82
40.	KT40	29.47	64.53	88.13	0.60	7.47	10.40	1.20	1.86	5.13	2.11	2.25
41.	KT41	23.67	60.13	84.20	0.27	5.93	9.47	1.01	1.74	6.40	2.50	2.20
42.	KT42	24.33	50.00	73.60	0.47	7.80	10.87	1.25	1.83	7.07	1.82	1.76
43.	KT43	28.60	56.27	80.53	0.40	8.00	11.07	1.29	1.95	5.33	2.11	2.02
44.	KT44	25.07	63.00	87.33	0.27	6.67	9.53	1.15	1.79	6.40	1.81	1.71
45.	KT45	31.53	61.80	86.40	0.27	6.93	10.20	1.27	1.79	4.93	2.05	1.84
46.	KT46	26.27	53.93	78.00	0.60	7.73	11.07	1.19	1.81	5.47	1.42	1.52
47.	KT47	26.60	66.27	90.60	0.27	9.20	12.27	1.17	1.85	5.27	1.81	1.77
48.	KT48	25.20	71.93	95.67	0.53	10.20	11.53	1.09	1.74	5.33	1.91	1.97
49.	KT49	25.13	81.67	106.27	1.13	10.33	13.67	1.47	2.01	6.13	1.56	1.52
50.	KT50	24.80	71.40	94.93	0.53	9.40	11.93	1.33	1.90	6.13	1.76	1.76
51.	KT51	29.53	77.47	100.47	0.60	9.07	11.87	1.55	2.09	7.53	1.41	1.38
52.	Punjab Kesari	25.53	51.60	76.20	0.27	5.13	8.33	1.02	1.65	7.27	2.54	2.48
53.	KT52	24.47	58.13	82.80	0.27	10.07	13.13	1.19	1.88	7.33	2.08	1.60
54.	KT53	24.40	66.07	91.40	0.27	7.67	10.20	1.10	1.88	4.73	2.39	2.42
55.	KT54	26.13	66.73	95.40	0.27	8.13	11.33	1.35	1.91	4.73	1.60	1.60
56.	KT55	27.87	79.53	102.60	0.53	10.00	12.93	1.15	1.80	5.73	1.33	1.26
57.	KT56	34.13	73.40	98.73	1.60	8.47	12.20	1.29	1.90	5.73	1.29	1.75
58.	Arka Vikas	31.27	67.67	92.20	0.27	6.53	9.87	1.15	1.87	5.40	1.64	1.71
59.	Arka Saurabh	30.87	66.93	91.60	0.27	7.27	10.53	1.15	1.79	5.47	1.48	1.46
60.	Arka Meghali	21.87	54.93	80.07	0.27	8.87	12.07	1.13	1.73	4.93	2.01	2.05
61.	Arka Alok	30.00	67.80	91.13	0.27	8.33	11.60	1.13	1.88	4.87	1.67	1.67
62.	Arka Abha	29.40	61.40	85.53	0.33	7.07	10.20	1.18	1.90	6.93	2.96	2.84
63.	KT 57	27.60	67.47	87.67	0.27	9.13	11.20	1.10	1.78	4.93	1.82	1.71
64.	KT58	21.00	70.13	93.53	0.27	7.20	10.27	1.13	1.80	5.67	1.72	1.76
65.	KT59	19.40	60.20	84.93	0.27	6.07	9.33	1.11	1.71	6.53	1.57	1.63
66.	KT60	25.47	57.00	80.47	0.27	5.93	9.27	1.04	1.70	5.87	1.56	1.46
67.	Arka Ashish	26.27	61.53	85.87	0.27	7.67	10.80	1.17	1.81	5.80	1.67	1.74
Mean		25.604	61.374	85.677	0.592	7.726	10.838	1.185	1.834	5.764	1.938	1.877
S.Em±		2.190	5.473	4.953	0.382	0.873	0.799	0.050	0.043	0.234	0.031	0.052
CD @ 5%		6.126	15.309	13.854	1.068	2.442	2.235	0.139	0.120	0.654	0.086	0.145
CD @ 1%		8.095	20.232	18.309	1.412	3.227	2.953	0.184	0.158	0.865	0.114	0.192
CV		14.822	15.508	10.013	112.082	19.607	12.787	7.376	4.107	7.058	2.790	4.849

DAT = Days after transplanting

(18.20%) was observed for this trait. Low heritability (27.40%) with a low GA (6.30) and moderate GAM (10.264%) was observed for this trait.

Maximum plant height at 90 DAT (Tables 7 and 8) was observed in KT 49 (106.27 cm) followed by KT 55 (102.60 cm), KT 51 (100.47 cm), KT 48 (95.67 cm) and KT 54 (95.40 cm) and minimum was observed in KT 05 (61.20 cm). Plant height on 90 DAT ranged from 61.20 cm to 106.27 cm with an average mean of 85.677 cm. Moderate GV (34.976), high PV (108.587), low GCV (6.90%), moderate PCV (12.16%) with low heritability (32.20%), low GA (6.91) and low GAM (8.065%) was observed for plant height at 90 DAT among the genotypes.

4.2.2 Number of primary branches (Tables 7 and 8)

Number of primary branches on 30 DAT (Tables 7 and 8) ranged from 0.27 (KT 05, KT 07, KT 34, KT 35, KT 37, KT 41, KT 44, KT 45, KT 47, KT 52, KT 53, KT 54, KT 57, KT 58, KT 59, KT 60, Punjab Kesari, Arka Vikas, Arka Sourabh, Arka Meghali, Arka Alok and Arka Ashish) to 2.80 (KT 11) with an average mean of 0.592. Very low estimates of GV (0.083), PV (0.523) with high GCV (48.64%) and PCV (122.18%), low heritability (15.80%) and GA (0.24) and very high GAM (40.54%) was observed for number of primary branches at 30 DAT among the genotypes.

Number of primary branches on 60 DAT (Tables 7 and 8) ranged from 4.73 (KT 05) to 10.33 (KT 49) with an averge mean of 7.726. Very low estimates of GV (0.964) and PV (3.259), moderate GCV (12.71%) and PCV (23.37%) with low heritability (29.60%) and GA (1.10) and moderate GAM (14.237%) was observed for number of primary branches at 60 DAT.

Maximum number of primary branches (Tables 7 and 8) at 90 DAT was observed in KT 49 (13.67) followed by KT 34 (13.47), KT 52 (13.13), KT 32 (13.00) and KT 56 (12.93) and minimum was observed in KT 05 (8.27). Number of primary branches on 90 DAT ranged from 8.27 to 13.67 with an average mean of 10.838. Very low estimates of GV (0.82) and PV (2.741), low GCV (8.36%), moderate PCV (15.28%) with low heritability (29.90%), low GA (1.02) and low GAM (9.411%) was observed for number of primary branches at 90 DAT.

4.1.2.3 Stem girth (Tables 7 and 8)

Stem girth at 60 DAT (Tables 7 and 8) ranged from 0.87 cm (KT 05) to 1.55 cm (KT 51) with an average mean of 1.185 cm. Very low estimates of GV (0.0084) and PV (0.0160), low GCV (7.75%) and moderate PCV (10.70%), moderate heritability (52.50%), low GA (0.14) and moderate GAM (11.814%) was observed for stem girth at 60 DAT.

Maximum stem girth at 90 DAT (Tables 7 and 8) was observed in KT 51 (2.09 cm) followed by KT 02 (2.02 cm), KT 49 (2.01 cm), KT 03 (2.00 cm), KT 04 and KT 33 (1.97 cm) and minimum was observed in Punjab Kesari (1.65 cm). Stem girth at 90 DAT ranged from 1.65 cm to 2.09 cm with an average mean of 1.834 cm. Very low estimates of GV (0.0053) and PV (0.0109). Low GCV (3.99%) and PCV (5.73%), moderate heritability (48.50%), low GA (0.11) and low GAM (5.997%) was observed for stem girth at 90 DAT.

4.1.2.4 Number of flowers per cluster (Tables 7 and 8)

Maximum number of flowers per cluster (Tables 7 and 8) was observed in KT 51 (7.53) followed by KT 28 (7.47), KT 52 (7.33), Punjab Kesari (7.27) and KT 42 (7.07) and minimum was observed in KT 35 (4.13). Number of flowers per cluster ranged from 4.13 to 7.53 with an average mean of 5.764. Very low estimates of GV (0.489) and PV (0.654), moderate GCV (12.13%) and PCV (14.04%), high heritability (74.70%) with low GA (1.25) and high GAM (21.686%) was observed for number of flowers per cluster.

4.1.2.5 Length of the flower (Tables 7 and 8)

Length of the flower (Tables 7 and 8) ranged from 1.04 cm (KT 08) to 2.96 cm (Arka Abha) with an average mean of 1.938 cm. Very low estimates of GV (0.1319) and PV (0.1348), moderate GCV (18.74%) and

PCV (18.94%) with very high heritability (97.80%), low GA (0.74) and high GAM (38.183%) was observed for length of the flower.

4.1.2.6 Breadth of the flower (Tables 7 and 8)

Breadth of the flower (Tables 7 and 8) ranged from 1.04 cm (KT 08) to 2.84 cm (Arka Abha) with an average mean of 1.877 cm. Very low estimates of GV (0.0957) and PV (0.1039), moderate GCV (16.48%) and PCV (17.18%) with very high heritability (92.00%), low GA (0.61) and high GAM (32.498%) was observed for breadth of the flower.

4.1.2.7 Days to first flowering (Tables 7 and 9)

Days to first flowering (Tables 7 and 9) ranged from 18.33 days (KT 56) to 33.67 days (Arka Abha) with an average mean of 28.024 days. Moderate estimates of GV (10.402), PV (12.643), GCV (11.51%) and PCV (12.69%) with high heritability (82.30%), low GA (6.03) and high GAM (21.517%) was observed for days to first flowering.

4.1.2.8 Days to 50 per cent flowering (Tables 7 and 9)

The genotype KT 56 took minimum number of days (20.00 days) for 50 per cent flowering (Tables 7 and 9) followed by KT 47 (21.33 days), KT 49 (21.33 days), KT 01 (22.33 days) and KT 29 (23.67 days) and the genotype KT 24 took maximum number of days (35.67 days) for 50 per cent flowering. Number of days to 50 per cent flowering ranged from

Table 9. *Per se* performance of tomato genotypes for earliness and yield parameters

Sl. No.	Genotypes	Days to First flowering	Days to 50% flowering	Days to First fruit set	Days to First fruit maturity	Average fruit weight (g)	Per cent fruit set	No. of fruits per cluster	No. of fruits per plant	Early yield per plant (kg)	Total yield per plant (kg)	Yield per hectare (t)	Polar diameter of the fruit (cm)	Equatorial diameter of the fruit (cm)
1.	KT01	21.00	22.33	28.33	59.33	80.40	85.98	4.47	39.67	1.39	3.07	68.12	4.74	5.94
2.	KT02	27.33	28.67	34.00	66.33	156.60	76.48	3.47	30.87	1.40	3.02	66.96	5.29	7.15
3.	KT03	27.00	29.33	33.67	68.67	82.27	78.92	4.00	34.07	0.93	2.06	45.95	6.30	5.18
4.	KT04	25.67	27.67	33.00	64.33	94.87	80.46	4.40	44.07	1.50	3.22	71.55	5.83	5.62
5.	KT05	23.33	25.67	30.33	61.67	48.27	74.45	4.87	26.87	0.29	0.67	14.81	3.45	4.47
6.	KT06	31.33	33.33	37.33	74.67	71.33	78.13	4.07	31.73	0.88	1.89	41.88	4.78	4.87
7.	KT07	25.33	27.33	32.67	65.00	102.33	73.16	4.53	27.47	0.84	2.08	46.26	4.77	5.45
8.	KT08	27.67	28.67	34.67	69.00	15.67	87.98	4.93	97.27	0.68	1.46	32.48	2.62	2.94
9.	KT09	26.67	29.67	34.00	66.00	73.23	79.74	4.47	19.87	0.58	1.47	32.71	5.97	4.64
10.	KT10	30.67	34.00	37.33	75.33	94.67	78.10	5.00	29.13	0.86	1.99	44.10	4.44	6.05
11.	KT11	28.67	31.00	36.33	69.00	140.13	80.93	5.07	33.27	1.03	2.30	50.96	5.18	6.78
12.	KT12	26.33	28.67	35.33	70.00	102.93	80.09	4.87	22.33	0.73	1.78	39.48	6.81	5.38
13.	KT13	28.67	31.00	36.33	72.33	97.47	78.51	4.87	31.40	1.05	2.42	54.33	5.77	5.54
14.	KT14	28.33	31.00	35.67	71.67	108.93	80.21	4.87	32.00	0.91	2.13	47.18	5.21	5.47
15.	KT15	28.00	30.00	35.00	70.67	122.40	86.07	4.80	62.87	1.46	3.27	72.51	4.77	6.39
16.	KT16	28.33	32.33	86.00	70.33	112.60	81.67	4.73	34.27	1.23	2.80	62.22	5.78	5.57
17.	KT17	27.33	30.00	34.67	69.67	140.00	83.55	4.07	36.20	1.83	4.04	89.66	5.99	5.75
18.	KT18	31.67	33.67	38.33	75.00	78.87	76.88	4.87	29.07	0.83	1.86	41.18	7.13	5.30
19.	KT19	25.67	29.00	32.67	67.33	111.73	84.21	4.80	34.00	1.18	2.72	60.33	6.22	5.66
20.	KT10	30.67	33.67	37.33	73.33	82.40	80.99	4.27	24.27	0.75	1.81	40.11	5.59	5.18
21.	KT21	82.67	35.00	39.00	74.67	66.23	81.90	4.53	43.60	1.21	2.64	58.70	5.83	4.71
22.	KT22	27.67	30.33	34.67	67.67	82.00	77.00	3.80	50.00	1.45	3.11	68.96	5.27	5.34
23.	KT23	29.33	32.67	36.67	71.00	93.93	79.15	4.33	33.07	0.96	2.07	45.96	5.42	5.59
24.	KT24	33.33	35.67	41.00	75.33	82.17	86.50	4.73	36.20	1.52	3.33	73.99	6.41	5.63
25.	KT25	29.33	32.33	35.33	68.33	70.13	72.78	4.33	34.93	0.94	2.12	47.03	5.81	5.63
26.	KT26	27.00	30.33	34.00	67.00	85.73	75.22	4.87	33.93	0.91	2.04	45.29	6.22	5.69
27.	KT27	27.33	31.33	34.67	67.33	67.40	72.05	4.73	32.33	1.29	2.97	65.88	5.18	4.97
28.	KT28	27.67	31.67	35.33	68.33	93.47	71.49	5.33	44.13	1.15	2.41	53.47	6.37	5.26
29.	KT29	21.67	23.67	27.33	59.67	60.07	71.01	4.20	31.80	0.94	2.11	46.88	6.47	5.89
30.	KT30	28.67	31.00	35.67	70.33	85.47	69.49	4.20	33.27	1.16	2.57	57.10	5.57	5.68
31.	KT31	23.33	25.33	30.33	60.00	75.80	72.54	4.40	33.67	1.01	2.18	48.33	5.15	5.01
32.	KT32	26.67	30.00	33.67	65.67	61.43	74.75	4.13	38.80	0.87	1.95	43.33	4.67	5.79
33.	KT33	29.33	32.00	36.00	71.00	95.57	76.59	4.53	30.60	0.89	2.02	44.88	4.77	5.51
34.	KT34	30.00	33.00	36.00	70.67	95.67	76.02	4.00	35.13	1.38	3.07	67.11	4.63	6.23
35.	KT35	24.33	27.33	30.33	63.67	78.60	74.28	3.07	32.20	1.60	3.60	79.96	6.97	6.49
36.	KT36	30.33	33.33	36.33	71.67	119.07	83.17	4.87	28.53	1.13	2.65	58.85	6.69	6.23
37.	KT37	29.67	35.67	35.67	72.67	145.73	75.93	3.33	36.07	1.10	2.48	55.12	6.91	6.55
38.	KT38	30.00	36.67	36.67	71.33	87.73	66.91	4.33	44.80	1.50	2.93	65.14	6.11	5.74

Table 9. Continued...

Sl. No.	Genotypes	Days to First flowe-ring	Days to 50% flowe-ring	Days to First fruit set	Days to First fruit matu-rity	Average fruit weight (g)	Per cent fruit set	No. of fruits per cluster	No. of fruits per plant	Early yield per plant (kg)	Total yield per plant (kg)	Yield per hectare (t)	Polar diameter of the fruit (cm)	Equa-torial diameter of the fruit (cm)
39.	KT39	29.33	32.00	36.00	72.67	112.73	73.39	4.47	36.67	1.56	3.44	76.44	4.92	5.99
40.	KT40	28.67	31.67	35.33	69.67	79.67	92.20	4.73	55.80	2.26	4.75	105.75	6.25	6.07
41.	KT41	29.33	32.00	36.00	70.33	113.07	73.02	4.67	31.00	1.17	2.61	57.99	4.64	6.25
42.	KT42	30.33	33.67	36.67	72.67	62.60	80.16	5.67	25.67	0.68	1.64	36.36	6.18	4.51
43.	KT43	31.33	33.33	37.67	73.00	54.00	80.57	4.27	30.80	0.98	2.25	50.03	6.01	4.02
44.	KT44	30.00	32.00	36.33	73.00	147.40	73.74	4.73	28.53	0.85	1.94	42.97	6.19	6.35
45.	KT45	26.67	29.00	33.33	66.67	210.40	79.67	3.93	28.93	1.30	2.67	59.18	8.25	7.65
46.	KT46	24.33	26.33	30.67	63.33	79.07	71.99	3.93	52.20	1.68	3.75	83.25	5.77	5.31
47.	KT47	20.33	21.33	26.33	59.33	109.80	72.32	3.80	43.47	1.77	3.16	70.14	5.33	6.63
48.	KT48	32.00	33.00	38.33	73.67	42.53	80.66	4.27	35.20	0.62	1.41	31.19	3.56	4.20
49.	KT49	19.33	21.33	26.67	58.67	43.00	77.31	4.73	145.47	1.42	2.91	64.66	3.05	4.17
50.	KT50	25.33	27.33	32.33	64.67	40.67	85.91	5.27	45.60	0.64	1.56	34.61	3.55	4.16
51.	KT51	23.67	26.33	29.67	61.67	27.20	79.61	6.00	100.80	1.14	2.36	52.41	3.35	3.63
52.	Punjab Kesari	30.67	33.67	36.33	71.33	64.27	74.07	5.33	33.33	0.75	1.58	35.14	4.57	4.33
53.	KT52	32.00	34.33	38.67	73.00	58.47	79.28	5.73	69.13	1.04	2.28	50.70	4.39	5.20
54.	KT53	32.00	34.33	38.33	73.67	82.33	75.86	4.33	42.33	1.75	3.67	81.47	5.25	5.21
55.	KT54	30.67	32.33	37.00	72.33	66.67	80.40	3.73	48.20	1.70	3.74	83.07	5.32	5.73
56.	KT55	30.00	32.33	36.33	70.33	54.73	72.12	4.13	39.53	1.06	2.29	50.85	4.77	4.65
57.	KT56	18.33	20.00	25.00	56.33	62.93	66.29	3.80	66.00	1.36	2.81	62.42	3.85	5.02
58.	Arka Vikas	32.33	33.67	39.00	71.00	109.13	75.56	4.07	25.60	1.26	2.94	65.29	4.63	5.64
59.	Arka Saurabh	26.67	29.67	33.33	67.67	78.60	75.62	4.13	52.13	1.46	3.05	67.71	4.23	5.44
60.	Arka Meghali	25.33	27.33	32.33	74.33	116.33	77.11	3.80	26.60	0.81	1.98	43.92	5.59	6.17
61.	Arka Alok	26.33	28.67	32.67	67.00	88.67	83.50	4.07	30.33	0.98	2.33	51.77	5.03	5.47
62.	Arka Abha	33.67	35.33	40.00	75.33	143.53	75.98	5.27	33.33	1.06	2.69	59.76	6.59	6.45
63.	KT 57	30.33	32.33	37.00	71.00	70.40	86.44	4.27	33.27	0.98	2.15	47.74	5.43	5.43
64.	KT58	30.00	32.33	36.67	73.00	26.07	77.73	4.40	41.00	1.50	1.05	23.36	3.52	3.89
65.	KT59	30.00	32.33	37.00	71.33	63.13	73.48	4.80	33.40	0.57	1.24	27.47	5.05	5.01
66.	KT60	31.67	33.67	38.33	73.00	101.20	72.76	4.27	22.67	0.63	1.60	35.44	5.19	5.74
67.	Arka Ashish	29.00	32.00	35.33	69.00	117.60	73.58	4.27	36.40	1.36	3.01	66.73	5.27	6.60
Mean		28.024	30.472	34.781	69.029	87.906	77.665	4.477	39.808	1.114	2.464	54.725	5.326	5.465
S.Em±		0.864	0.873	0.815	2.221	3.048	3.568	0.189	5.391	0.165	0.289	6.429	0.130	0.087
CD at 5%		2.416	2.442	2.279	6.212	8.526	9.980	0.528	15.080	0.461	0.808	17.983	0.363	0.243
CD at 1%		3.193	3.227	3.012	8.210	11.267	13.189	0.698	19.929	0.609	1.068	23.766	0.480	0.321
CV		5.341	4.970	4.060	5.575	6.006	7.958	7.343	23.456	25.747	20.349	20.347	4.232	2.795

20.00 days to 35.67 days with an average mean of 30.472 days. Moderate estimates of GV (11.525), PV (13.818), GCV (11.14%) and PCV (12.20%) with high heritability (83.40%), low GA (6.39) and high GAM (20.97%) was observed for days to 50 per cent flowering.

4.1.2.9 Days to first fruit set (Tables 7 and 9)

Days to first fruit set ranged from 25.00 days (KT 56) to 41.00 days (KT 24) with an average mean of 34.781 days. Moderate estimate of GV (10.232) and PV (12.226), low GCV (9.20%), moderate PCV (10.05%) with high heritability (83.70%), low GA (6.03) and moderate GAM (17.337%) was observed for days to first fruit set.

4.1.2.10 Days to first fruit maturity (Tables 7 and 9)

The genotype KT 56 took minimum number of days (56.33 days) for first fruit maturity (Tables 7 and 9) followed by KT 49 (58.67 days), KT 01 (59.33 days), KT 47 (59.33 days) and KT 29 (59.67 days) and Arka Abha took maximum number of days (75.33 days) for fruit maturity among the genotypes. Number of days to first fruit maturity ranged from 56.33 to 75.33 days with an average mean of 69.029 days. Moderate estimates of GV (16.466) and PV (31.276), low GCV (5.88%) and PCV (8.10%) with moderate heritability (52.60%), low GA (6.07) and GAM (8.793%) was observed for days to first fruit maturity.

4.1.2.11 Per cent fruit set (Tables 9 and 10)

Among the genotypes, maximum per cent fruit set was observed in KT 40 (92.20%) followed by KT 08 (87.98%), KT 24 (86.50%) KT 57 (86.44%) and KT 15 (86.07%) and minimum was observed in KT 38 (66.91%). Per cent fruit set ranged from 66.91 to 92.20 per cent with an average mean of 77.665 per cent. Moderate estimates of GV (13.387) and high PV (51.592), low GCV (4.71%) and PCV (9.25%) with low heritability (25.90%), low GA (3.84) and low GAM (4.944%) was observed for per cent fruit set.

4.1.2.12 Number of fruits per cluster (Tables 9 and 10)

Maximum number of fruits per cluster (Tables 9 and 10) was observed in KT 51 (6.00) followed by KT 52 (5.73), KT 28 (5.33), Punjab Kesari (5.33), KT 50 (5.27) and Arka Abha (5.27) and minimum was observed in KT 35 (3.07). Number of fruits per cluster ranged from 3.07 to 6.00 with an average mean of 4.477. Very low GV (0.2665) and PV (0.3746), moderate GCV (11.53%) and PCV (13.67%) with high heritability (71.10%), low GA (10.90) and high GAM (20.102%) was observed for number of fruits per cluster.

4.1.2.13 Number of fruits per plant (Tables 9 and 10)

Maximum number of fruits per plant (Tables 9 and 10) was observed in KT 49 (145.47) followed by KT 51 (100.80), KT 08 (97.27), KT

Table 10. Estimates of mean, range, components of variance, heritability and genetic advance for yield and quality parameters in tomato

Sl. No.	Character	Mean ± S.Em	Range	GV	PV	GCV (%)	PCV (%)	h^2 (%)	GA	GAM
a.	**Yield parameters**									
1.	Per cent fruit set	77.665 ± 3.568	66.91-92.20	13.387	51.592	4.71	9.25	25.90	3.84	4.944
2.	Number of fruits per cluster	4.477 ± 0.189	3.07-6.00	0.2665	0.3746	11.53	13.67	71.10	0.90	20.102
3.	Number of fruits per plant	39.808 ± 5.391	19.87-145.47	353.534	440.723	47.23	52.74	80.20	34.69	87.143
4.	Early yield per plant (kg)	1.114 ± 0.165	0.29-2.26	0.1107	0.1930	29.86	39.42	57.30	0.52	46.678
5.	Total yield per plant (kg)	2.464 ± 0.289	0.67-4.75	0.4853	0.7363	28.27	34.83	65.90	1.16	47.077
6.	Yield (t/ha)	54.725 ± 6.429	14.81-105.75	239.892	363.889	28.30	34.86	65.90	25.91	47.345
7.	Average fruit weight (g)	87.906 ± 3.048	15.67-210.40	1121.516	1149.393	38.10	38.57	97.60	68.15	77.525
8.	Polar diameter of the fruit (cm)	5.326 ± 0.130	2.62-8.25	0.7082	0.7315	19.72	20.17	95.60	2.15	40.368
9.	Equatorial diameter of the fruit (cm)	5.465 ± 0.087	2.94-7.65	1.1033	1.1541	15.40	15.65	96.80	1.71	31.290
b.	**Quality parameters**									
1.	Fruit shape index	0.980 ± 0.026	0.73-1.50	0.02796	0.03019	17.06	17.73	92.60	0.33	33.673
2.	Pericarp thickness (cm)	0.539 ± 0.021	0.22-0.73	0.01017	0.01169	18.68	20.03	87.00	0.19	35.250
3.	Number of locules per fruit	3.469 ± 0.175	2.20-5.87	0.7061	0.7984	24.22	25.75	88.40	1.63	46.987
4.	TSS (°Brix)	4.072 ± 0.082	3.19-5.83	0.2079	0.2287	11.20	11.74	90.90	0.90	22.102
5.	Acidity (%)	0.401 ± 0.038	0.21-0.70	0.0062	0.0106	19.70	25.74	58.60	0.12	29.925
6.	TSS : acid ratio	10.859 ± 1.229	6.81-20.64	6.597	11.136	23.65	30.73	59.20	4.07	37.480
7.	pH	4.567 ± 0.016	4.07-5.33	0.0476	0.0484	4.78	4.82	98.30	0.45	9.853
8.	Ascorbic acid (mg/100 g)	16.141 ± 1.133	9.37-22.85	6.177	10.031	15.40	19.62	61.60	4.02	24.905
9.	Lycopene (mg/100 g)	10.209 ± 0.325	4.43-17.78	12.026	12.344	33.97	34.42	97.40	7.05	69.056
10.	Fruit volume (cc)	68.587 ± 3.920	9.33-150.00	635.334	681.464	36.75	38.06	93.20	50.14	73.104
11.	Fruit density (g/cc)	1.252 ± 0.014	1.17-1.71	0.0074	0.0080	6.87	7.15	92.50	0.17	13.578
12.	Number of seeds per fruit	97.830 ± 1.169	34.67-253.33	2343.760	2347.865	49.49	49.53	99.80	99.64	101.856
13.	Thousand seed weight (g)	2.981 ± 0.007	1.46-4.13	0.2341	0.2343	16.23	16.24	99.90	1.00	33.545

GV = Genotypic variance
PV = Phenotypic variance
GCV = Genotypic coefficient of variance
PCV = Phenotypic coefficient of variance
h^2 = Heritability
GA = Genetic advance
GAM = Genetic advance (per cent mean)

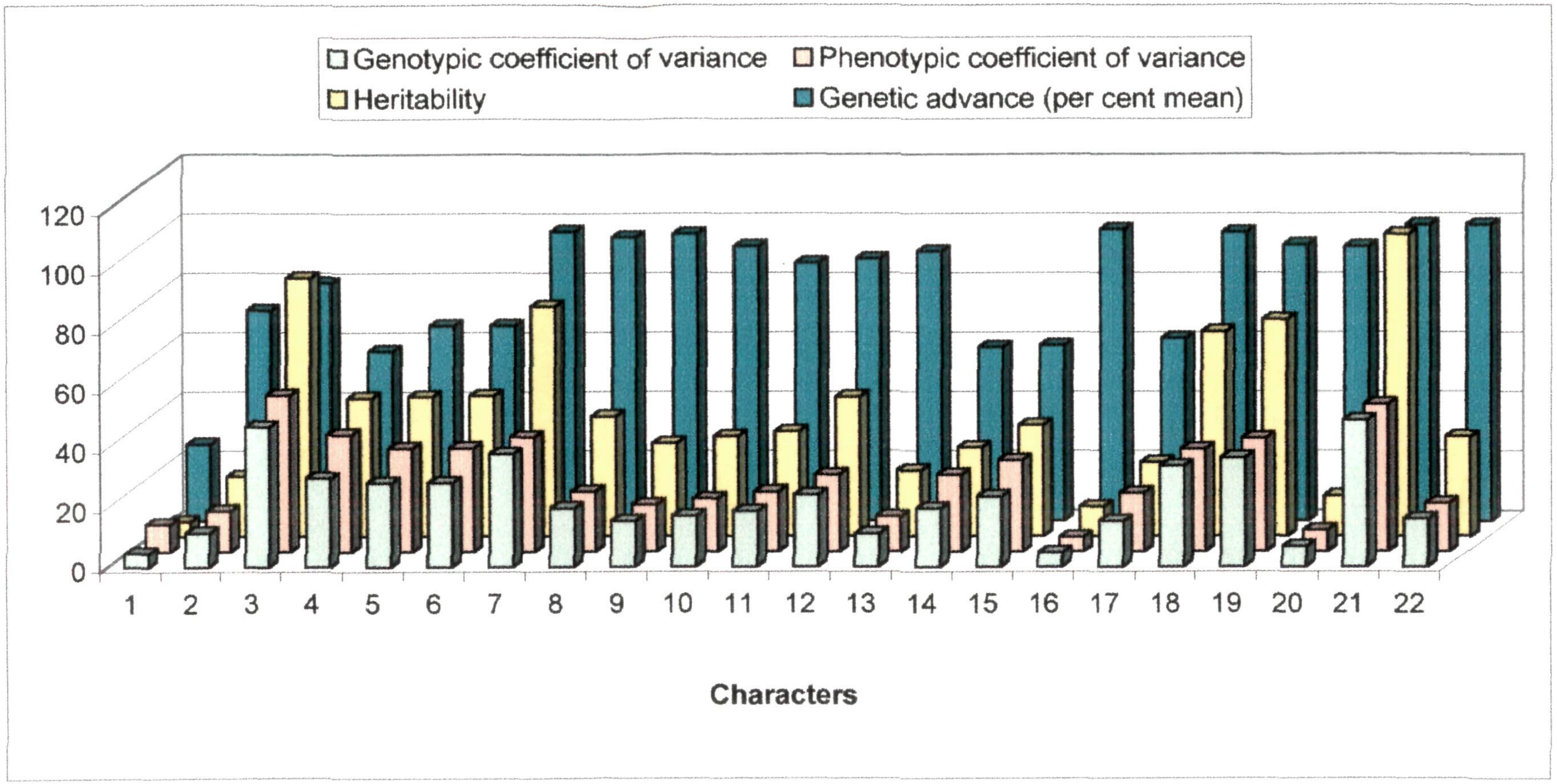

Fig. 2. GCV, PCV, GAM and heritability for yield and quality parameters in tomato

1. Per cent fruit set
2. Number of fruits per cluster
3. Number of fruits per plant
4. Early yield per plant (kg)
5. Total yield per plant (kg)
6. Yield (t/ha)
7. Average fruit weight (g)
8. Polar diameter of the fruit (cm)
9. Equatorial diameter of the fruit (cm)
10. Fruit shape index
11. Pericarp thickness (cm)
12. Number of locules per fruit
13. TSS (°Brix)
14. Acidity (%)
15. TSS : acid ratio
16. pH
17. Ascorbic acid (mg/100 g)
18. Lycopene (mg/100 g)
19. Fruit volume (cc)
20. Fruit density (g/cc)
21. Number of seeds per fruit
22. Thousand seed weight (g)

52 (69.13) and KT 56 (66.00) and minimum was observed in KT 09 (19.87). Number of fruits per plant ranged from 19.87 to 145.47 with an average mean of 39.808. Very high GV (353.534) and PV (440.723), high GCV (47.23%) and PCV (52.74%) with high heritability (80.20%), moderate GA (34.69) and very high GAM (87.143%) was observed for number of fruits per plant.

4.1.2.14 Early yield per plant (Tables 9 and 10)

Early yield per plant was maximum in KT 40 (2.26 kg) followed by KT 17 (1.83 kg), KT 47 (1.77), KT 53 (1.75 kg) and KT 54 (1.70 kg) and minimum (0.29 kg) was observed in KT 05 (Table-9). Early yield per plant ranged from 0.29 kg to 2.26 kg with an average mean of 1.114 kg. Very low estimates of GV (0.1107) and PV (0.1930), moderate GCV (29.86%) and PCV (39.42%) with moderate heritability (57.30%), low GA (0.52) and very high GAM (46.678%) was observed for early yield per plant.

4.1.2.15 Total yield per plant (Tables 9 and 10)

Total yield per plant (kg) was maximum in KT 40 (4.75 kg) followed by KT 17 (4.04 kg), KT 46 (3.75 kg), KT 54 (3.74 kg) and KT 53 (3.67 kg) and minimum (0.67 kg) was observed in KT 05 (Table-9). Total yield per plant ranged from 0.67 kg to 4.75 kg with an average mean of 2.464 kg. Very low estimates of GV (0.4853) and PV (0.7363), moderate GCV (28.27%) and PCV (34.83%) with moderate heritability (65.90%), low GA

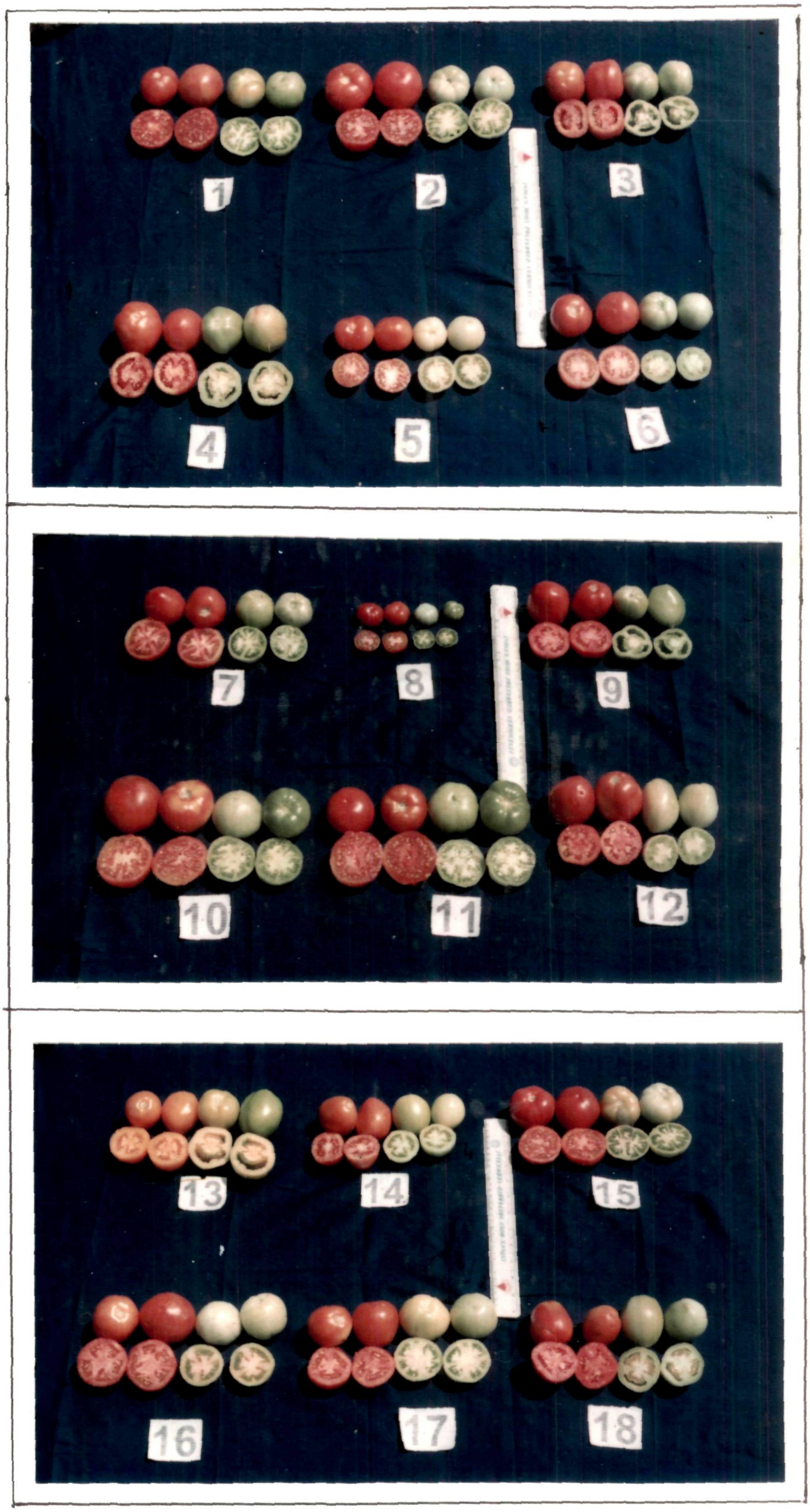

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Plate 2a. Variability in fruit characters of tomato

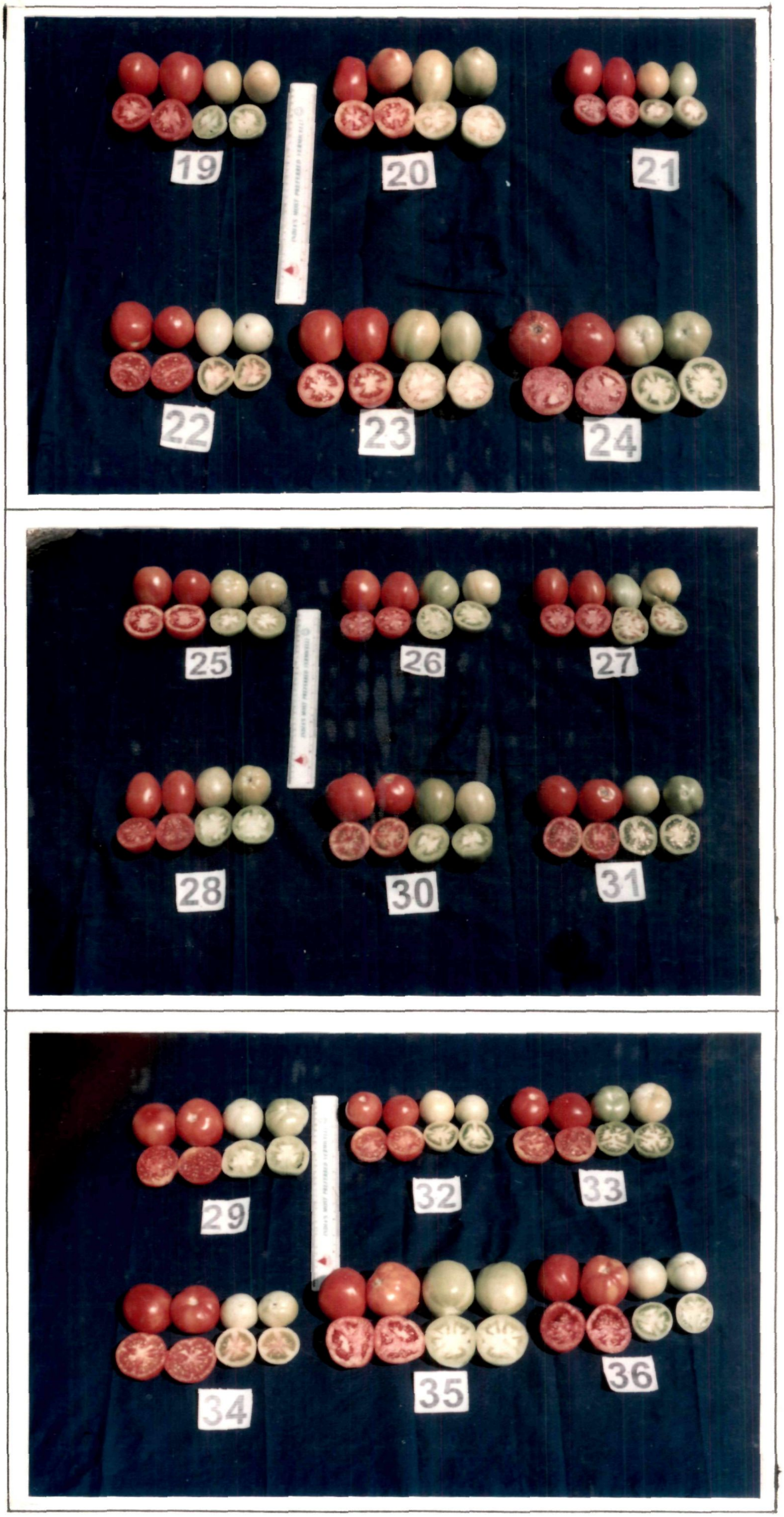

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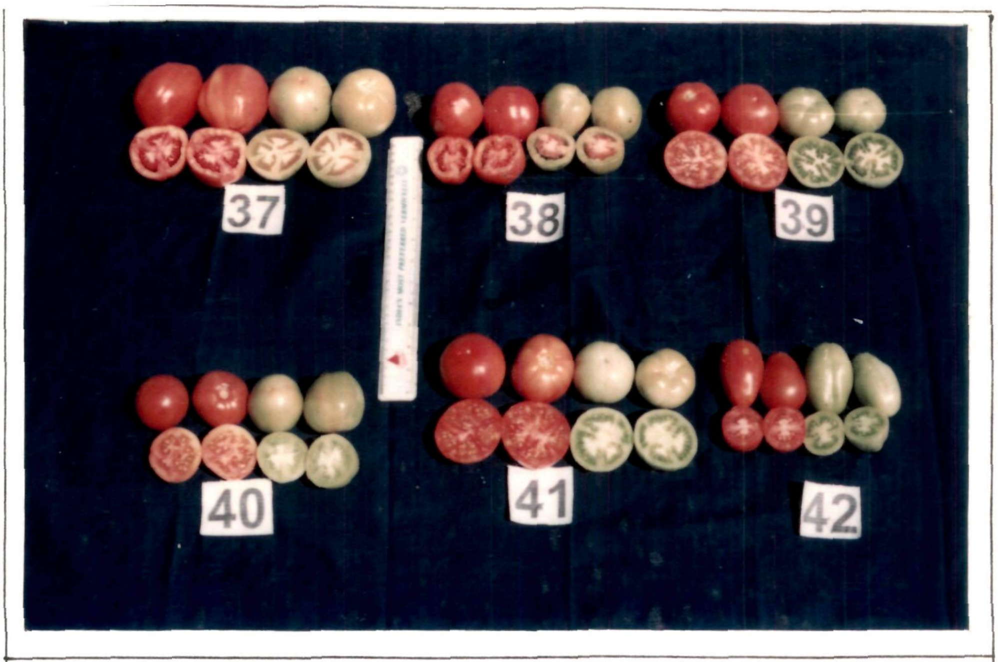
Plate 2b. Variability in fruit characters of tomato



KT37

KT38

KT39

KT40

KT41

KT42

KT43

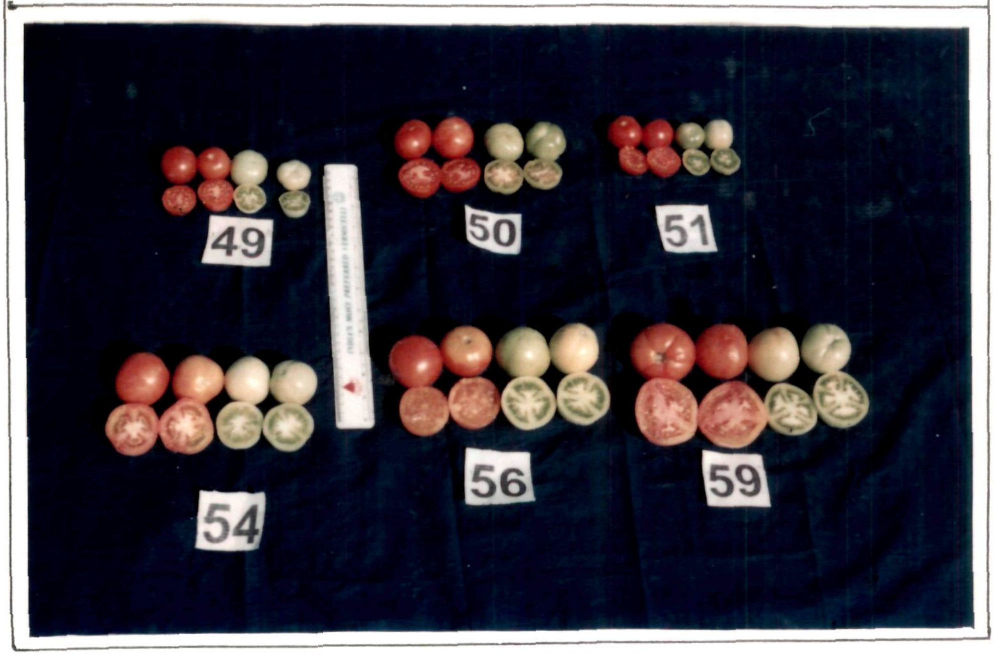
KT44

KT45

KT46

KT47

KT48



KT49

KT50

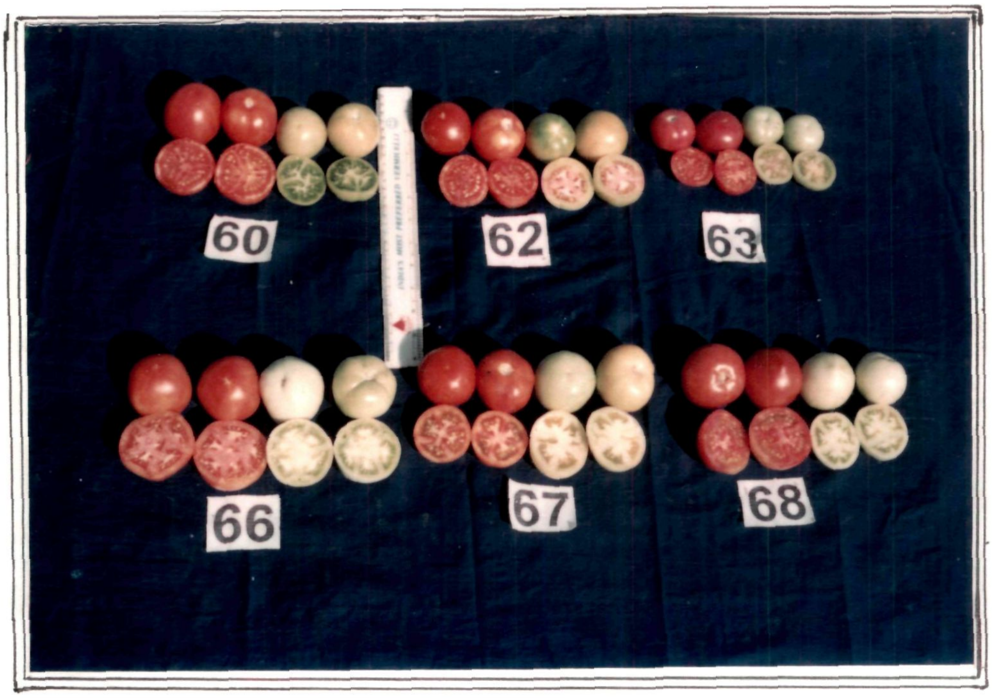
KT51

Punjab Kesari (54)

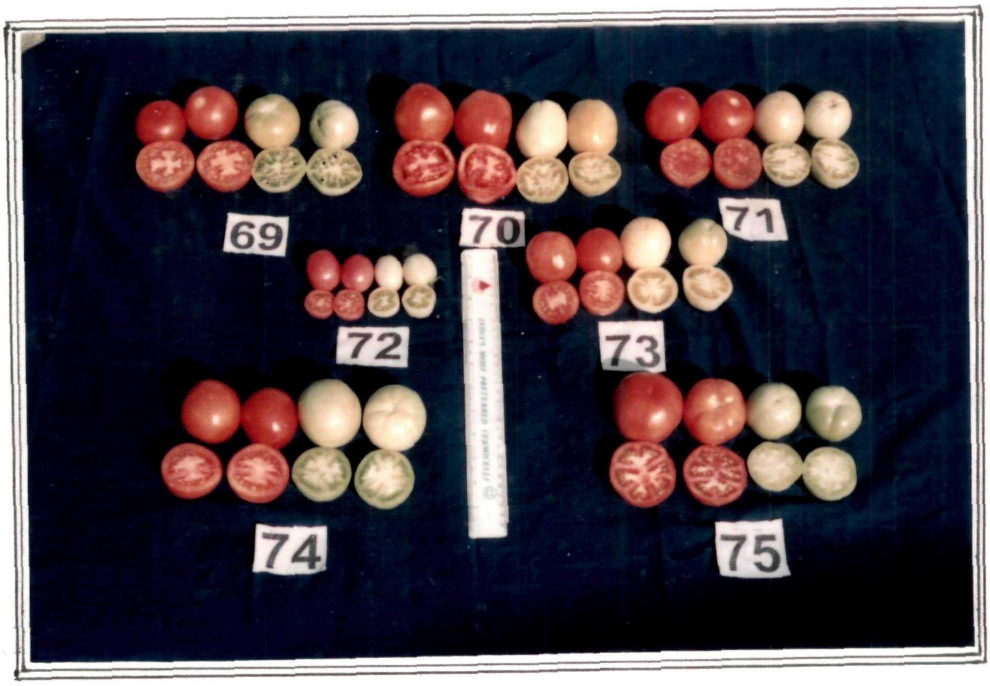
KT52 (56)

KT53 (59)

Plate 2c. Variability in fruit characters of tomato



KT54 (60)
KT55 (62)
KT56 (63)
Arka Vikas (66)
Arka Saurabh (67)
Arka Meghali (68)



Arka Alok (69)
Arka Abha (70)
KT57 (71)
KT58 (72)
KT59 (73)
KT60 (74)
Arka Ashish (75)

Plate 2d. Variability in fruit characters of tomato

(1.16) and very high GAM (47.077%) was observed for total yield per plant.

4.1.2.16 Yield per hectare (Tables 9 and 10)

Estimated yield per hectare ranged from 14.81 tonnes (KT 05) to 105.75 tonnes (KT 40) with an average mean of 54.725 tonnes. Very high GV (239.892) and PV (363.889). Moderate GCV (28.30%) and PCV (34.86%), moderate heritability (65.90%), high GA (25.91) and very high GAM (47.345%) was observed for yield per hectare.

4.1.2.17 Average fruit weight (Tables 9 and 10)

Average fruit weight (Table-9) was maximum in KT 45 (210.40 g) followed by KT 02 (156.60 g), KT 44 (147.70 g), KT 37 (145.73 g) and Arka Abha (143.53 g) and minimum was observed in KT 08 (15.67 g). Average fruit weight ranged from 15.67 g to 210.40 g with an average mean of 87.906 g. Very high GV (1121.516) and PV (1149.393), moderate GCV (38.10%) and PCV (38.57%) with very high heritability (97.60%), high GA (68.15) and very high GAM (77.525%) was observed for average fruit weight.

4.1.2.18 Polar diameter of the fruit (Tables 9 and 10)

Polar diameter of the fruit ranged from 2.62 cm (KT 08) to 8.25 cm (KT 45) (Plates 2a, 2b, 2c and 2d) with an average mean of 5.326 cm.

Very low estimates of GV (0.7082) and PV (0.7315), moderate GCV (19.72%) and PCV (20.17%) with very high heritability (95.60%), low GA (2.15) and very high GAM (40.368%) was observed for polar diameter of the fruit.

4.1.2.19 Equatorial diameter of the fruit (Tables 9 and 10)

Equatorial diameter (Plates 2a, 2b, 2c and 2d) of the fruit ranged from 2.94 cm (KT 08) to 7.65 cm (KT 45) with an average mean of 5.465 cm. Low estimates of GV (1.1033) and PV (1.1541), moderate GCV (15.40%) and PCV (15.65%) with very high heritability (96.80%), low GA (1.71) and high GAM (31.29%) was observed for equatorial diameter of the fruit.

4.1.2.20 Fruit shape index (Tables 10 and 11)

Maximum fruit shape index was observed in KT 43 (1.50) followed by KT 42 (1.38), KT 18 (1.35), KT 09 (1.29) and KT 12 (1.27) and minimum was observed in KT 10 and KT 49 (0.73). Fruit shape index ranged from 0.73 to 1.50 with an average mean of 0.98. Very low GV (0.02796) and PV (0.03019), moderate GCV (17.06%) and PCV (17.73%) with very high heritability (92.60%), very low GA (0.33) and high GAM (32.673%) was observed for fruit shape index.

4.1.2.21 Pericarp thickness (Tables 10 and 11)

Maximum pericarp thickness (Table-11) was observed in KT 15 (0.73 cm) followed by KT 23 (0.71 cm), KT 25 (0.70 cm), KT 40 (0.69 cm),

Table 11. *Per se* performance of tomato genotypes for quality characters

Sl. No.	Geno-type	Fruit shape index	Pericarp thick-ness (cm)	No. of locules per fruit	TSS (°Brix)	Acidity (%)	TSS : acid ratio	pH	Ascorbic acid (mg/ 100g)	Lyco-pene (mg/ 100g)	Fruit volume (cc)	Fruit density (g/cc)	No. of seeds per fruit	Thou-sand seed weight (g)
1.	KT01	0.80	0.53	4.20	3.73	0.28	13.55	4.55	14.74	17.05	62.67	1.24	144.67	3.08
2.	KT02	0.74	0.39	5.33	4.13	0.36	11.49	4.43	15.73	13.23	121.67	1.17	100.67	3.42
3.	KT03	1.22	0.67	3.27	4.13	0.36	11.72	4.67	15.23	17.03	64.67	1.23	80.67	3.09
4.	KT04	1.04	0.67	2.53	3.71	0.34	11.22	4.56	18.56	14.37	74.00	1.21	38.33	2.92
5.	KT05	0.77	0.35	3.27	4.25	0.36	12.02	5.33	20.18	8.64	32.67	1.37	67.67	2.20
6.	KT06	0.98	0.52	3.00	4.31	0.45	9.78	4.55	16.76	6.43	56.00	1.26	38.33	4.13
7.	KT07	0.87	0.53	4.60	4.20	0.45	9.51	4.66	16.13	11.09	79.33	1.20	67.67	3.06
8.	KT08	0.89	0.22	2.87	4.30	0.47	9.31	4.58	9.62	8.44	9.33	1.71	92.67	2.35
9.	KT09	1.29	0.45	2.60	3.73	0.43	8.79	4.55	14.22	9.29	57.67	1.25	56.67	3.37
10.	KT10	0.73	0.44	5.87	4.11	0.43	9.78	4.46	16.40	10.80	70.33	1.22	191.33	3.41
11.	KT11	0.76	0.44	4.73	4.18	0.43	9.87	4.62	22.85	10.51	106.00	1.18	253.33	3.35
12.	KT12	1.27	0.54	3.47	4.27	0.43	10.20	4.45	14.16	10.11	77.67	1.22	53.33	3.40
13.	KT13	1.05	0.57	3.07	4.11	0.30	13.91	4.85	16.37	4.43	75.33	1.20	105.67	1.97
14.	KT14	0.95	0.55	4.33	4.05	0.47	8.79	5.15	18.56	10.97	80.00	1.21	85.67	1.97
15.	KT15	0.75	0.73	5.60	4.26	0.36	11.83	4.49	15.66	12.75	90.33	1.21	186.33	3.21
16.	KT16	1.04	0.55	2.33	4.00	0.47	8.56	4.52	1632	7.39	83.00	1.19	65.67	2.83
17.	KT17	1.04	0.59	5.27	3.64	0.30	12.33	4.63	11.92	9.35	106.33	1.20	172.33	3.36
18.	KT18	1.35	0.64	2.67	4.05	0.53	7.61	4.77	15.79	10.75	61.00	1.24	37.67	2.99
19.	KT19	1.10	0.64	3.33	3.99	0.36	11.07	5.23	14.74	8.47	93.33	1.21	38.00	3.51
20.	KT10	1.08	0.56	2.27	4.09	0.45	9.27	4.58	19.44	12.55	62.67	1.23	36.33	3.37
21.	KT21	1.24	0.67	3.47	3.83	0.36	10.81	4.53	17.57	5.22	52.33	1.26	96.00	2.65
22.	KT22	0.99	0.64	3.27	3.96	0.45	8.96	4.52	17.91	17.35	63.67	1.24	133.33	2.65
23.	KT23	0.97	0.71	2.40	4.72	0.55	8.60	4.60	15.97	12.84	76.00	1.21	74.33	2.87
24.	KT24	1.14	0.64	4.20	4.87	0.41	12.07	4.43	18.84	11.55	65.67	1.23	160.00	2.51
25.	KT25	1.03	0.70	3.00	3.67	0.32	11.82	4.56	13.91	13.18	55.00	1.26	75.33	2.87
26.	KT26	1.09	0.64	3.80	3.96	0.28	14.48	4.50	16.06	5.52	72.33	1.22	89.33	3.21
27.	KT27	1.04	0.55	2.73	3.90	0.49	7.96	4.53	15.97	7.47	49.33	1.29	113.67	3.37
28.	KT28	1.21	0.51	4.80	3.87	0.36	10.95	4.80	14.22	6.81	74.67	1.21	38.00	3.77
29.	KT29	1.10	0.56	4.20	3.31	0.36	9.20	4.38	14.46	17.78	66.00	1.23	34.67	2.99
30.	KT30	0.98	0.44	3.07	3.78	0.34	11.25	4.68	12.58	8.35	67.33	1.23	66.67	2.67
31.	KT31	1.03	0.59	2.73	4.73	0.23	20.47	4.54	12.32	10.90	60.33	1.25	67.33	3.17
32.	KT32	0.81	0.53	3.47	4.47	0.38	11.83	4.45	21.69	5.88	46.67	1.26	220.33	3.17
33.	KT33	0.86	0.49	3.33	3.46	0.23	15.03	4.35	17.06	9.56	74.67	1.21	117.00	3.11
34.	KT34	0.74	0.45	2.67	4.88	0.41	12.13	5.04	14.46	12.33	81.33	1.22	103.67	2.63
35.	KT35	1.07	0.67	3.60	3.98	0.47	8.64	4.83	14.46	7.72	63.33	1.23	89.33	3.01
36.	KT36	1.08	0.61	2.93	4.06	0.58	7.11	4.51	15.89	8.93	91.00	1.19	51.67	3.13
37.	KT37	1.06	0.63	4.07	4.91	0.26	20.05	4.46	18.45	10.67	105.00	1.20	101.33	3.17
38.	KT38	1.07	0.47	2.47	3.21	0.41	7.95	4.64	14.74	8.33	71.00	1.21	34.67	3.65

Table 11. Continued...

Sl. No.	Genotype	Fruit shape index	Pericarp thick-ness (cm)	No. of locules per fruit	TSS (°Brix)	Acidity (%)	TSS : acid ratio	pH	Ascorbic acid (mg/ 100g)	Lyco-pene (mg/ 100g)	Fruit volume (cc)	Fruit density (g/cc)	No. of seeds per fruit	Thou-sand seed weight (g)
39.	KT39	0.82	0.51	3.20	4.12	0.41	10.22	4.56	18.56	9.11	87.67	1.19	100.67	3.22
40.	KT40	1.03	0.69	3.20	3.49	0.38	9.27	4.45	21.69	9.46	66.33	1.23	62.67	2.91
41.	KT41	0.74	0.42	3.27	3.63	0.30	13.64	4.59	21.23	7.65	89.33	1.19	152.00	3.41
42.	KT42	1.38	0.47	2.20	4.48	0.51	8.83	4.44	16.71	5.56	45.00	1.27	71.00	2.33
43.	KT43	1.50	0.64	4.47	3.53	0.28	13.84	4.85	21.12	8.92	40.67	1.29	206.33	3.01
44.	KT44	0.98	0.67	2.27	3.69	0.41	9.17	4.56	17.79	6.81	116.00	1.18	60.67	2.62
45.	KT45	1.08	0.63	3.40	3.77	0.36	11.31	4.53	17.06	12.67	150.00	1.32	63.00	3.81
46.	KT46	1.09	0.56	3.33	4.19	0.34	12.69	4.85	14.15	8.97	68.00	1.22	73.67	2.97
47.	KT47	0.80	0.55	2.73	4.29	0.43	10.40	4.60	16.71	13.01	88.33	1.18	89.67	3.00
48.	KT48	0.85	0.41	3.53	5.29	0.49	10.81	4.55	18.56	7.36	32.00	1.32	86.67	2.74
49.	KT49	0.73	0.32	3.47	4.13	0.45	9.57	4.54	9.37	12.93	36.00	1.28	127.00	2.03
50.	KT50	0.85	0.38	4.40	3.99	0.49	8.38	4.37	16.71	11.33	30.00	1.35	142.33	2.87
51.	KT51	0.93	0.39	2.60	3.83	0.41	9.48	4.36	9.76	8.37	17.00	1.55	68.33	2.01
52.	Punjab Kesari	1.06	0.57	3.00	3.99	0.49	8.16	4.53	15.66	6.22	49.67	1.29	57.00	2.45
53.	KT52	0.85	0.36	4.00	4.43	0.47	9.70	4.65	14.96	14.14	43.00	1.31	124.67	2.67
54.	KT53	1.01	0.54	3.13	3.55	0.32	11.42	4.45	13.18	6.35	72.00	1.33	119.00	1.46
55.	KT54	0.93	0.56	3.47	3.99	0.45	9.05	4.44	17.71	12.41	56.00	1.25	146.67	2.89
56.	KT55	1.03	0.47	3.40	3.99	0.45	9.24	4.45	15.39	16.07	44.33	1.28	67.67	3.53
57.	KT56	0.77	0.51	3.53	5.83	0.70	8.45	4.45	14.74	16.45	44.00	1.30	149.67	2.40
58.	Arka Vikas	0.82	0.53	2.80	3.19	0.47	6.81	4.76	17.98	8.11	84.33	1.20	109.00	3.11
59.	Arka Saurabh	0.78	0.57	3.73	4.03	0.36	11.36	4.43	16.25	6.82	70.67	1.22	106.33	2.64
60.	Arka Meghali	0.91	0.64	3.07	3.87	0.36	11.25	4.25	16.71	17.66	87.33	1.19	52.67	3.47
61.	Arka Alok	0.92	0.53	3.27	4.27	0.47	9.01	4.16	17.98	12.49	75.00	1.21	142.00	3.31
62.	Arka Abha	1.02	0.61	5.07	4.87	0.36	13.83	4.44	16.71	8.35	108.00	1.19	100.67	2.89
63.	KT 57	1.00	0.48	4.20	3.59	0.49	7.54	4.07	18.10	5.26	53.67	1.26	48.00	2.87
64.	KT58	0.90	0.45	2.27	4.08	0.30	14.89	4.65	12.34	6.05	17.00	1.50	84.00	2.31
65.	KT59	1.01	0.59	2.60	3.69	0.45	8.55	4.35	14.46	7.25	46.00	1.28	80.67	3.01
66.	KT60	0.91	0.53	4.00	4.02	0.41	10.15	4.36	16.40	15.92	84.67	1.19	144.33	3.13
67.	Arka Ashish	0.80	0.52	4.07	4.33	0.21	20.64	4.33	13.56	8.26	93.67	1.18	138.67	3.28
Mean		0.980	0.539	3.469	4.072	0.401	10.859	4.567	16.141	10.209	68.587	1.252	97.830	2.981
S.Em±		0.026	0.021	0.175	0.082	0.038	1.229	0.016	1.133	0.325	3.920	0.014	1.169	0.007
CD @ 5%		0.072	0.058	0.489	0.229	0.106	3.437	0.044	3.169	0.909	10.965	0.039	3.270	0.019
CD @ 1%		0.096	0.077	0.646	0.303	0.140	4.543	0.059	4.188	1.201	14.491	0.051	4.321	0.025
CV		4.820	7.228	8.758	3.546	16.570	19.620	0.635	12.163	5.525	9.902	1.960	2.071	0.469

KT 03, KT 04, KT 21, KT 35, KT 44 (0.67 cm) and minimum was observed in KT 08 (0.22 cm). Pericarp thickness ranged from 0.22 cm to 0.73 cm with an average mean of 0.539 cm (Plates 2a, 2b, 2c and 2d). Very low estimates of GV (0.01017) and PV (0.01169), moderate GCV (18.68%) and PCV (20.03%) with high heritability (87.00%), very low GA (0.19) and high GAM (35.25%) was observed for pericarp thickness.

4.1.2.22 Number of locules per fruit (Tables 10 and 11)

Number of locules per fruit ranged from 2.20 (KT 42) to 5.87 (KT 10) with an average mean of 3.469 (Plates 2a, 2b, 2c and 2d). Very low estimates of GV (0.7061) and PV (0.7984), moderate GCV (24.22%) and PCV (25.75%) with high heritability (88.40%), low GA (1.63) and very high GAM (46.987%) was observed for number of locules per fruit.

4.1.2.23 TSS (Tables 10 and 11)

Maximum TSS (Table-11) was observed in KT 56 (5.83°Brix) followed by KT 48 (5.29°Brix), KT 37 (4.91°Brix), KT 34 (4.88°Brix) and KT 24 and Arka Abha (4.87°Brix) and minimum was observed in Arka Vikas (3.19°Brix). TSS ranged from 3.19°Brix to 5.83 °Brix with an average mean of 4.072°Brix. Very low estimates of GV (0.2079) and PV (0.2287), moderate GCV (11.20%) and PCV (11.74%) with very high heritability (90.90%), very low GA (0.90) and high GAM (22.102%) was observed for TSS.

4.1.2.24 Acidity (Tables 10 and 11)

Maximum acidity (Table-11) was observed in KT 56 (0.70%) followed by KT 36 (0.58%), KT 23 (0.55%), KT 18 (0.53%) and KT 42 (0.51%) and minimum was observed in Arka Ashish (0.21%). Acidity ranged from 0.21 per cent to 0.70 per cent with an average mean of 0.401 per cent. Very low estimates of GV (0.0062) and PV (0.0106), moderate GCV (19.70%) and PCV (25.74%) with moderate heritability, very low GA (0.12) and high GAM (29.925%) was observed for acidity.

4.1.2.25 TSS : acid ratio (Tables 10 and 11)

TSS : acid ratio ranged from 6.81 (Arka Vikas) to 20.64 (Arka Ashish) with an average mean of 10.859. Low estimates of GV (6.597), moderate PV (11.136), moderate GCV (23.65%) and PCV (30.73%) with moderate heritability (59.20%), low GA (4.67) and high GAM (37.48%) was observed for TSS : acid ratio.

4.1.2.26 pH (Tables 10 and 11)

pH of fruit juice ranged from 4.07 (KT 57) to 5.33 (KT 05) with an average of 4.567. Very low estimates of GV (0.0476) and PV (0.0484), low GCV (4.78%) and PCV (4.82%) with very high heritability (98.30%), very low GA (0.45) and low GAM (9.835%) was observed for pH.

4.1.2.27 Ascorbic acid (Tables 10 and 11)

Maximum ascorbic acid content (Table-11) was observed in KT 11 (22.85 mg/100 g) followed by KT 32 and KT 40 (21.69 mg/100 g), KT 41 (21.23 mg/100 g), KT 43 (21.12 mg/100 g) and KT 05 (20.18 mg/100 g) and minimum was observed in KT 49 (9.37 mg/100 g). Ascorbic acid content ranged from 9.37 mg to 22.85 mg per 100 g with an average mean of 16.141 mg per 100 g. Low estimates of GV (6.177) and moderate PV (10.031), moderate GCV (15.40%) and PCV (19.62%) with moderate heritability (61.60%), low GA (4.02) and high GAM (24.905%) was observed for ascorbic acid content.

4.1.2.28 Lycopene (Tables 10 and 11)

Maximum lycopene content (Table-11) was observed in KT 29 (17.78 mg/100 g) followed by Arka Meghali (17.66 mg/100 g). KT 22 (17.35 mg/100 g), KT 01 (17.05 mg/100 g) and KT 03 (17.03 mg/100 g) and minimum was observed in KT 13 (4.43 mg/100 g), lycopene content ranged from 4.43 to 17.78 mg per 100 g with an average mean of 10.209 mg per 100 g. Moderate estimates of GV (12.026) and PV (12.344), moderate GCV (33.97%) and PCV (34.42%) with very high heritability (97.40%), low GA (7.05) and very high GAM (69.056%) was observed for lycopene content.

4.1.2.29 Fruit volume (Tables 10 and 11)

Fruit volume ranged from 9.33 cc (KT 08) to 150.00 cc (KT 45) with an average of 68.587 cc. Very high GV (635.334) and PV (681.464), moderate GCV (36.75%) and PCV (38.06%) with very high heritability (93.20%), very high GA (50.14) and GAM (73.104%) was observed for fruit volume.

4.1.2.30 Fruit density (Tables 10 and 11)

Fruit density ranged from 1.17 gram per cc (KT 02) to 1.71 gram per cc (KT 08) with an average mean of 1.252 gram per cc. Very low GV (0.0074) and PV (0.0080), low GCV (6.87%) and PCV (7.15%) with very high heritability (92.50%), very low GA (0.17) and moderate GAM (13.578%) was observed for fruit density.

4.1.2.31 Number of seeds per fruit (Tables 10 and 11)

Maximum number of seeds per fruit (Table-11) was observed in KT 11 (253.33) followed by KT 32 (220.33), KT 10 (191.33) KT 15 (186.33) and KT 17 (172.33) and minimum was observed in KT 29 (34.67) and KT 38 (34.67). Number of seeds per fruit ranged from 34.67 to 253.33 with an average mean of 97.83. Very high estimates of GV (2343.760) and PV (2347.865), high GCV (49.49%) and PCV (49.53%) with very high heritability (99.80%), very high GA (99.64) and very high GAM (101.85%) was observed for number of seeds per fruit.

4.1.2.32 Thousand seed weight (Tables 10 and 11)

Thousand seed weight ranged from 1.46 g (KT 53) to 4.13 g (KT 06) with an average mean of 2.981 g. Very low estimates of GV (0.2341) and PV (0.2343), moderate GCV (16.23%) and PCV (16.24%) with very high heritability (99.90%), low GA (1.00) and high GAM (33.545%) was observed for thousand seed weight.

4.1.3 Correlation studies (Tables 12 and 13)

Genotypic and phenotypic correlation coefficients for growth, earliness, quality and yield parameters are presented in Table-12 and Table-13, respectively and depicted in Fig-3.

4.1.3.1 Genotypic correlation (Table 12)

At genotypic level, number of primary branches at 90 DAT (rG=0.614) was positively and significantly (at P=0.01) associated with plant height at 60 DAT. Stem girth at 90 DAT was positively and significantly (at P=0.01) associated with plant height at 60 DAT (rG=0.463) and number of primary branches at 90 DAT (rG=0.313).

Days to first flowering was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.267), stem girth at 90 DAT (rG= -0.224) and plant height at 60 DAT (rG= -0.181). Days to 50 per cent flowering was positively and

Table 12. Genotypic correlation coefficients among growth, earliness, quality and yield parameters in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.000	0.614**	0.463**	-0.181**	-0.284**	-0.288**	-0.252**	-0.237**	-0.487**	-0.107	-0.189**	0.145*	-0.186**	-0.197**	0.383**	0.305**	-0.100	0.655**	0.288**	0.246**
2		1.000	0.313**	-0.267**	-0.294**	-0.329**	-0.262**	-0.244**	-0.246**	-0.051	-0.368**	0.155*	-0.250**	-0.239**	0.269**	-0.025	-0.249**	0.555**	0.398**	0.342**
3			1.000	-0.224**	-0.240**	-0.249**	-0.338**	-0.116	-0.127	0.037	-0.098	0.150*	0.022	0.048	0.193**	0.300**	0.013	0.484**	0.444**	0.434**
4				1.000	0.993**	0.990**	1.054**	0.094	0.208**	0.021	0.136	0.002	0.102	0.117	0.046	0.246**	0.203**	-0.401**	-0.187**	-0.119
5					1.000	0.986**	1.044**	0.152*	0.256**	0.039	0.173*	-0.025	0.112	0.125	0.024	0.223**	0.243**	-0.417**	-0.169*	-0.102
6						1.000	1.057**	0.125	0.215**	0.014	0.129	0.027	0.114	0.137	0.067	0.310**	0.252**	-0.406**	-0.200**	-0.129
7							1.000	0.059	0.252**	0.055	0.192**	0.012	0.162*	0.200**	0.014	0.390**	0.223**	-0.423**	-0.210**	-0.126
8								1.000	-0.202**	-0.315**	-0.300**	-0.078	-0.235**	-0.206**	-0.112	-0.274**	0.922**	0.155*	-0.409**	-0.415**
9									1.000	0.578**	0.698**	0.018	0.616**	0.595**	-0.287**	-0.004	-0.219**	-0.540**	0.244**	0.287**
10										1.000	0.430**	0.311**	0.899**	0.866**	0.130	-0.159*	-0.409**	-0.416**	0.476**	0.496**
11											1.000	-0.036	0.427**	0.394**	-0.119	0.100	-0.290**	-0.410**	0.310**	0.349**
12												1.000	0.289**	0.290**	0.533**	0.242**	0.007	-0.007	0.144*	0.193**
13													1.000	1.002**	0.034	-0.074	-0.294**	-0.439**	0.372**	0.408**
14														1.000	0.054	-0.046	-0.257**	-0.425**	0.319**	0.354**
15															1.000	0.197**	-0.039	0.135	0.182**	0.208**
16																1.000	0.120	0.177*	0.082	0.149*
17																	1.000	0.253**	-0.372**	-0.355**
18																		1.000	0.213**	0.147*
19																			1.000	0.994**
20																				1.000

* indicates significant at P = 0.05   ** indicates significant at P = 0.01

Critical 'rG' value at 5 per cent = 0.1382   Critical 'rG' value at 1 per cent = 0.1812

Characters:

1. Plant height at 60 DAT (cm)
2. Number of primary branches at 90 DAT
3. Stem girth at 90 DAT (cm)
4. Days to first flowering
5. Days to 50 per cent flowering
6. Days to first fruit set
7. Days to first fruit maturity
8. Number of flowers per cluster
9. Polar diameter of the fruit (cm)
10. Equatorial diameter of the fruit (cm)
11. Pericarp thickness (cm)
12. Number of locules per fruit
13. Fruit volume (cc)
14. Average fruit weight (g)
15. Number of seeds per fruit
16. Per cent fruit set
17. Number of fruits per cluster
18. Number of fruits per plant
19. Early yield per plant (kg)
20. Total yield per plant (kg)

DAT = Days after transplanting

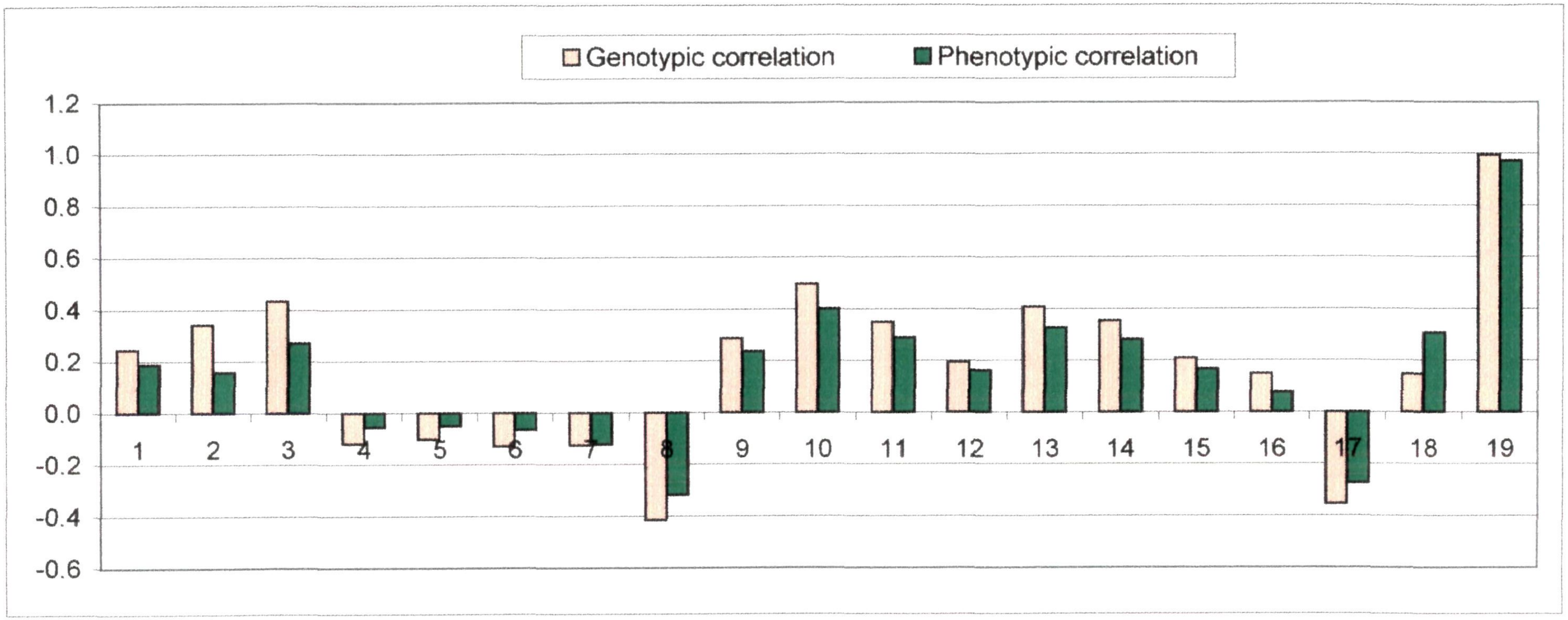


Fig. 3. Genotypic and phenotypic correlations of different characters with total yield per plant in tomato

1. Plant height at 60 DAT (cm)
2. Number of primary branches at 90 DAT
3. Stem girth at 90 DAT (cm)
4. Days to first flowering
5. Days to 50 per cent flowering
6. Days to first fruit set
7. Days to first fruit maturity
8. Number of flowers per cluster
9. Polar diameter of the fruit (cm)
10. Equatorial diameter of the fruit (cm)
11. Pericarp thickness (cm)
12. Number of locules per fruit
13. Fruit volume (cc)
14. Average fruit weight (g)
15. Number of seeds per fruit
16. Per cent fruit set
17. Number of fruits per cluster
18. Number of fruits per plant
19. Early yield per plant (kg)

significantly (at P=0.01) associated with days to first flowering (rG=0.993) and it was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.294), plant height at 60 DAT (rG= -0.284) and stem girth at 90 DAT (rG= -0.240). Days to first fruit set was positively and significantly (at P=0.01) associated with days to first flowering (rG=0.990) and days to 50 per cent flowering (rG=0.986), but it was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.329), plant height at 60 DAT (rG= -0.288) and stem girth at 90 DAT (rG= -0.249). Days to first fruit maturity was positively and significantly (at P=0.01) associated with days to first fruit set (rG=1.057), days to first flowering (rG=1.054) and days to 50 per cent flowering (rG=1.044), but it had negative and significant (at P=0.01) association with stem girth at 90 DAT (rG= -0.338), number of primary branches at 90 DAT (rG= -0.262) and plant height at 60 DAT (rG= -0.252).

Per cent fruit set was positively and significantly (at P=0.01) associated (Table-12) with days to first fruit maturity (rG=0.390), days to first fruit set (rG=0.310), plant height at 60 DAT (rG=0.305), stem girth at 90 DAT (rG=300), days to first flowering (rG=0.246), number of locules per fruit (rG=0.242), days to 50 per cent flowering (rG=0.223) and number of seeds per fruit (rG=0.197) and it was negatively and significantly (at P=0.01) associated with number of flowers per cluster (rG= -0.274). Per cent fruit set was also negatively associated with equatorial diameter of the fruit (rG= -0.159) at P=0.05.

Number of flowers per cluster was positively and significantly (at P=0.05) associated with days to 50 per cent flowering (rG=0.152), but it was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.244) and plant height at 60 DAT (rG= -0.237). Number of fruits per cluster was positively and significantly (at P=0.01) associated with number of flowers per cluster (rG=0.922), days to first fruit set (rG=0.252), days to 50 per cent flowering (rG=0.243), days to first fruit maturity (rG=0.223) and days to first flowering (rG=0.203), but it was negatively and significantly (at P=0.01) associated with equatorial diameter of the fruit (rG= -0.409), fruit volume (rG= -0.294), pericarp thickness (rG= -0.290), average fruit weight (rG= -0.257), number of primary branches at 90 DAT (rG= -0.249) and polar diameter of the fruit (rG= -0.219).

Polar diameter of the fruit was positively and significantly (at P=0.01) associated (Table-12) with days to 50 per cent flowering (rG=0.256), days to first fruit maturity (rG=0.252), days to first fruit set (rG=0.215) and days to first flowering (rG=0.208), but it was negatively and significantly (at P=0.01) associated with plant height at 60 DAT (rG= -0.487), number of primary branches at 90 DAT (rG= -0.246) and number of flowers per cluster (rG= -0.202). Equatorial diameter of the fruit was positively and significantly (at P=0.01) associated with polar diameter of the fruit (rG=0.578) and it was negatively and significantly (at P=0.01) associated with number of flowers per cluster (rG= -0.315).

Pericarp thickness was positively and significantly (at P=0.01) associated with polar (rG=0.698) and equatorial diameters of the fruit (rG=0.430), days to first fruit maturity (rG=0.192) and days to 50 per cent flowering (rG=0.173) at P=0.05, but it was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.368), number of flowers per cluster (rG= -0.300) and plant height at 60 DAT (rG= -0.189). Number of locules per fruit was positively and significantly (at P=0.01) associated with equatorial diameter of the fruit (rG=0.311) and it also associated positively with number of primary branches at 90 DAT (rG=0.155), stem girth at 90 DAT (rG=0.150) and plant height at 60 DAT (rG=145) at P=0.05. Number of seeds per fruit was positively and significantly (at P=0.01) associated with number of locules per fruit (rG=0.533), plant height at 60 DAT (rG=0.383), number of primary branches at 90 DAT (rG=0.259) and stem girth at 90 DAT (rG=0.193) and it was negatively and significantly (at P=0.01) associated with polar diameter of the fruit (rG= -0.287).

Average fruit weight was positively and significantly (at P=0.01) associated (Table-12) with fruit volume (rG=1.002), equatorial diameter of the fruit (rG=0.866), polar diameter of the fruit (rG=0.595), pericarp thickness (rG=0.394), number of locules per fruit (rG=0.290) and days to first fruit maturity (rG=0.200), but it was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.239), number of flowers per cluster (rG= -0.206) and plant height at 60 DAT (rG= -0.197). Fruit volume was positively and significantly (at P=0.01) associated with equatorial diameter of the fruit (rG=0.899), polar diameter of the fruit (rG=0.616), pericarp thickness (rG=0.427), number of locules per fruit (rG=0.289) and days to first fruit maturity (rG=0.162) at P=0.05, but it was negatively and significantly (at P=0.01) associated with number of primary branches at 90 DAT (rG= -0.250), number of flowers per cluster (rG= -0.235) and plant height at 60 DAT (rG= -0.186).

At genotypic level, number of fruits per plant was positively and significantly (at P=0.01) associated (Table-12) with plant height at 60 DAT (rG=0.655), number of primary branches at 90 DAT (rG=0.555), stem girth at 90 DAT (rG=0.484) and number of fruits per cluster (rG=0.253) and it was positively and significantly associated with per cent fruit set (rG=0.177) and number of flowers per cluster (rG=0.155) at P=0.05. It was negatively and significantly (at P=0.01) associated with polar diameter of the fruit (rG= -0.540), fruit volume (rG= -0.439), average fruit weight (rG= -0.425), days to first fruit maturity (rG= -0.423), days to 50 per cent flowering (rG= -0.417), equatorial diameter of the fruit (rG= -0.416), pericarp thickness (rG= -0.410), days to first fruit set (rG= -0.406) and days to first flowering (rG= -0.401).

Early yield per plant was positively and significantly (at P=0.01) associated (Table-12) with equatorial diameter of the fruit (rG=0.476), stem girth at 90 DAT (rG=0.444), number of primary branches at 90 DAT (rG=0.398), fruit volume (rG=0.372), average fruit weight (rG=0.319), pericarp thickness (rG=0.310), plant height at 60 DAT (rG=0.288), polar diameter of the fruit (rG=0.244), number of fruits per plant (rG=0.213), number of seeds per fruit (rG=0.182) and it was positively associated with number of locules per fruit (rG=0.144) at P=0.05. But it was negatively and significantly (at P=0.01) associated with number of flowers per cluster (rG= -0.409) and number of fruits per cluster (rG= -0.372), days to first fruit maturity (rG= -0.210), days to first fruit set (rG= -0.200), days to first flowering (rG= -0.187) and days to 50 per cent flowering (rG= -0.169) at P=0.05.

At genotypic level, total yield per plant was positively and significantly (at P=0.01) associated (Table-12) with early yield per plant (rG=0.994), equatorial diameter of the fruit (rG=0.496), stem girth at 90 DAT (rG=0.434), fruit volume (rG=0.408), average fruit weight (rG=0.354), pericarp thickness (rG=0.349), number of primary branches at 90 DAT (rG=0.342), polar diameter of the fruit (rG=287), plant height at 60 DAT (rG=0.246), number of seeds per fruit (rG=0.208), number of locules per fruit (rG=0.193) and it was positively associated with per cent fruit set (rG=0.149) and number of fruits per plant (rG=0.147) at P=0.05. But it was negatively and significantly (at P=0.01) associated with number of flowers per cluster (rG= -0.415) and number of fruits per cluster (rG= -0.355).

4.1.3.2 Phenotypic correlation (Table-13)

At phenotypic level, number of primary branches at 90 DAT (rP=0.341) had positive and significant (at P=0.01) association with plant height at 60 DAT. Stem girth at 90 DAT was positively and significantly (at P=0.01) associated with plant height at 60 DAT (rP=0.215) and number of primary branches at 90 DAT (rP=0.199).

Days to first flowering was negatively and significantly (at P=0.01) associated (Table-13) with stem girth at 90 DAT (rP= -0.200) and number of primary branches at 90 DAT (rP= -0.162) at P=0.05. Days to 50 per cent flowering was positively and significantly (at P=0.01) associated with days to first flowering (rP=0.961), but it was negatively and significantly (at P=0.01) associated with stem girth at 90 DAT (rP= -0.203) and number of primary branches at 90 DAT (rP= -0.164) at P=0.05. Days to first fruit set was positively and significantly (at P=0.01) associated with days to first flowering (rP=0.976) and days to 50 per cent flowering (rP=0.945), but it was negatively and significantly (at P=0.01) associated with stem girth at 90 DAT (rP= -0.204) and number of primary branches at 90 DAT (rP= -0.182). Days to first fruit maturity was positively and significantly (at P=0.01) associated with days to fruit set (rP=0.779), days to first flowering (rP=0.779) and days to 50 per cent

Table 13. Phenotypic correlation coefficients among growth, earliness, quality and yield parameters in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1.000	0.341**	0.215**	-0.119	-0.134	-0.133	-0.089	-0.094	-0.243**	-0.052	-0.054	0.099	-0.096	-0.098	0.198**	0.069	-0.037	0.380**	0.201**	0.189**
2		1.000	0.199**	-0.162*	-0.164*	-0.182**	-0.102	-0.109	-0.116	-0.042	-0.207**	0.077	-0.109	-0.141*	0.146*	0.058	-0.079	0.308**	0.157*	0.159*
3			1.000	-0.200**	-0.203**	-0.204**	-0.149*	-0.094	-0.084	0.029	-0.047	0.099	0.045	0.025	0.136	0.139*	0.015	0.310**	0.259**	0.273**
4				1.000	0.961**	0.976**	0.779**	0.065	0.178*	0.020	0.120	0.000	0.087	0.105	0.042	0.108	0.114	-0.319**	-0.090	-0.056
5					1.000	0.945**	0.762**	0.097	0.223**	0.033	0.156*	-0.021	0.099	0.120	0.023	0.078	0.134	-0.341**	-0.093	-0.051
6						1.000	0.779**	0.083	0.184**	0.016	0.109	0.018	0.101	0.126	0.062	0.131	0.148*	-0.324**	-0.109	-0.066
7							1.000	0.017	0.190**	0.042	0.151*	0.009	0.133	0.141*	0.011	0.085	0.051	-0.298**	-0.136	-0.122
8								1.000	-0.172*	-0.267**	-0.244**	-0.038	-0.219**	-0.185**	-0.099	-0.281**	0.748**	0.097	-0.304**	-0.319**
9									1.000	0.561**	0.649**	0.011	0.588**	0.572**	-0.280**	0.001	-0.176*	-0.472**	0.191**	0.237**
10										1.000	0.399**	0.283**	0.852**	0.838**	0.127	-0.088	-0.346**	-0.365**	0.364**	0.401**
11											1.000	-0.028	0.375**	0.362**	-0.112	0.032	-0.241**	-0.322**	0.248**	0.289**
12												1.000	0.263**	0.269**	0.500**	0.093	0.018	0.012	0.111	0.162*
13													1.000	0.952**	0.034	-0.065	-0.257**	-0.378**	0.282**	0.328**
14														1.000	0.054	-0.023	-0.216**	-0.375**	0.233**	0.282**
15															1.000	0.101	-0.033	0.118	0.136	0.167*
16																1.000	0.360**	0.089	0.056	0.077
17																	1.000	0.164*	-0.272**	-0.276**
18																		1.000	0.362**	0.308**
19																			1.000	0.972**
20																				1.000

* indicates significant at P = 0.05 ** indicates significant at P = 0.01

Critical 'rP' value at 5 per cent = 0.1382 Critical 'rP' value at 1 per cent = 0.1812

Characters:

1. Plant height at 60 DAT (cm)
2. Number of primary branches at 90 DAT
3. Stem girth at 90 DAT (cm)
4. Days to first flowering
5. Days to 50 per cent flowering
6. Days to first fruit set
7. Days to first fruit maturity
8. Number of flowers per cluster
9. Polar diameter of the fruit (cm)
10. Equatorial diameter of the fruit (cm)
11. Pericarp thickness (cm)
12. Number of locules per fruit
13. Fruit volume (cc)
14. Average fruit weight (g)
15. Number of seeds per fruit
16. Per cent fruit set
17. Number of fruits per cluster
18. Number of fruits per plant
19. Early yield per plant (kg)
20. Total yield per plant (kg)

DAT = Days after transplanting

flowering (rP=0.762), but it was negatively and significantly (at P=0.05) associated with stem girth at 90 DAT (rP= -0.149).

Per cent fruit set was positively and significantly (at P=0.05) associated with stem girth at 90 DAT (rP=0.139) and it was negatively and significantly (at P=0.01) associated with number of flowers per cluster (rP= -0.281). Number of fruits per cluster was positively and significantly (at P=0.01) associated with number of flowers per cluster (rP=0.748), per cent fruit set (rP=0.360) and days to first fruit set (rP=0.148) at P=0.05. But it was negatively and significantly (at P=0.01) associated with equatorial diameter of the fruit (rP= -0.346), fruit volume (rP= -0.257), pericarp thickness (rP= -0.241) and average fruit weight (rP= -0.216) and it was negatively and significantly associated with polar diameter of the fruit (rP= -0.176) at P=0.05.

Polar diameter of the fruit was positively and significantly (at P=0.01) associated (Table-13) with days to 50 per cent flowering (rP=0.223), days to first fruit maturity (rP=0.190), days to first fruit set (rP=0.184) and days to first flowering (rP=0.178) at P=0.05, but it was negatively and significantly (at P=0.01) associated with plant height at 60 DAT (rP= -0.243). It was also negatively and significantly associated with number of flowers per cluster (rP= -0.172) at P=0.05. Equatorial diameter of the fruit was positively and significantly (at P=0.01) associated with polar diameter of the fruit (rP=0.561) and it was negatively and significantly (at P=0.01) associated with number of flowers per cluster (rP= -0.267).

Pericarp thickness was positively and significantly (at P=0.01) associated with polar (rP=0.649) and equatorial diameter (rP=0.399) of the fruit. Pericarp thickness was positively and significantly associated with days to 50 per cent flowering (rP=0.156) and days to first fruit maturity (rP=0.151) at P=0.05. It was negatively and significantly (at P=0.01) correlated with number of flowers per cluster (rP= -0.244) and number of primary branches at 90 DAT (rP= -0.207). Number of locules per fruit had positive and significant (at P=0.01) association with equatorial diameter of the fruit (rP=0.283). Number of seeds per fruit was positively and significantly (at P=0.01) associated with number of locules per fruit (rP=0.500) and plant height at 60 DAT (rP=0.198). Seed number per fruit was positively and significantly correlated at P=0.05 with number of primary branches at 90 DAT (rP=0.145), but it was negatively and significantly (at P=0.01) associated with polar diameter of the fruit (rP= -0.280).

Average fruit weight was positively and significantly (at P=0.01) associated (Table-13) with fruit volume (rP=0.952), equatorial (rP=0.838) and polar diameter of the fruit (rP=0.572), pericarp thickness (rP=0.362), number of locules per fruit (rP=0.269) and days to first fruit maturity (rP=0.141) at P=0.05, but it was negatively and significantly associated with number of flowers per cluster (rP= -0.185) at P=0.01 and number of primary branches at 90 DAT (rP= -0.141) at P=0.05. Fruit volume was positively and significantly (at P=0.01) associated with equatorial (rP=0.852) and polar (rP=0.588) diameter of the fruit, pericarp thickness (rP=0.375) and number of locules per fruit (rP=0.263), but fruit volume had negative and significant (at P=0.01) association with number of flowers per cluster (rP= -0.219).

At phenotypic level, number of fruits per plant was positively and significantly correlated with plant height at 60 DAT (rP=0.380), stem girth at 90 DAT (rP=0.310) and number of primary branches at 90 DAT (rP=0.308) at P=0.01 and number of fruits per cluster (rP=0.164) at P=0.05, but it was negatively and significantly (at P=0.01) associated with polar diameter of the fruit (rP= -0.472), fruit volume (rP= -0.378), average fruit weight (rP= -0.375), equatorial diameter of the fruit (rP= -0.365), days to 50 per cent flowering (rP= -0.341), days to first fruit set (rP= -0.324), pericarp thickness (rP= -0.322), days to first flowering (rP= -0.319), and days to first fruit maturity (rP= -0.298).

Early yield per plant was positively and significantly associated (Table-13) with equatorial diameter of the fruit (rP=0.364), number of fruits per plant (rP=0.362), fruit volume (rP=0.282), stem girth at 90 DAT (rP=0.259), pericarp thickness (rP=0.248), average fruit weight (rP=0.233), plant height at 60 DAT (rP=0.201) and polar diameter of the fruit (rP=0.191) at P=0.01 and number of primary branches at 90 DAT (rP=0.157) at P=0.05, but it had negative and significant (at P=0.01) association with number of flowers per cluster (rP= -0.304) and number of fruits per cluster (rP= -0.272).

At phenotypic level, total yield per plant was positively and significantly correlated with early yield per plant (rP=0.972), equatorial diameter of the fruit (rP=0.401), fruit volume (rP=0.328), number of fruits per plant (rP=0.308), pericarp thickness (rP=0.289), average fruit weight (rP=0.282), stem girth at 90 DAT (rP=0.273), polar diameter of the fruit (rP=0.237) and plant height at 60 DAT (rP=0.189) at P=0.01 and number of seeds per fruit (rP=0.167), number of locules per fruit (rP=0.162) and number of primary branches at 90 DAT (rP=0.159) at P=0.05. But it had negative and significant (P=0.01) correlation with number of flowers per cluster (rP= -0.319) and number of fruits per cluster (rP= -0.276).

4.1.4 Path analysis (Tables 14 and 15)

Genotypic and phenotypic path coefficients for total yield per plant with fifteen independent parameters are presented in Table-14 and Table-15, respectively.

4.1.4.1 Genotypic path coefficients (Table-14)

Plant height at 60 DAT had no direct effect (-0.023) on total yield per plant, but it had high indirect and positive effect (0.298) through

Table 14. Genotypic path coefficient analysis for total yield per plant in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	rG
1	**-0.023**	-0.005	-0.002	0.052	0.010	0.001	-0.003	0.005	0.037	-0.039	0.002	-0.006	-0.024	-0.056	0.298	0.246**
2	-0.014	**-0.009**	-0.001	0.053	0.005	0.000	-0.007	0.005	0.050	-0.048	0.002	0.000	-0.060	-0.048	0.412	0.342**
3	-0.011	-0.003	**-0.004**	0.025	0.003	0.000	-0.002	0.005	-0.004	0.010	0.001	-0.006	0.003	-0.042	0.459	0.434**
4	0.005	0.002	0.001	**-0.218**	0.004	0.003	-0.005	-0.003	0.047	-0.041	-0.001	0.005	0.222	-0.013	-0.423	-0.415**
5	0.011	0.002	0.001	0.044	**-0.020**	-0.005	0.013	0.001	-0.123	0.119	-0.002	0.000	-0.053	0.046	0.253	0.287**
6	0.002	0.000	0.000	0.069	-0.012	**-0.008**	0.008	0.011	-0.179	0.173	0.001	0.003	-0.099	0.036	0.492	0.496**
7	0.004	0.003	0.000	0.066	-0.014	-0.004	**0.018**	-0.001	-0.085	0.079	-0.001	-0.002	-0.070	0.035	0.320	0.349**
8	-0.003	-0.001	-0.001	0.017	0.000	-0.003	-0.001	**0.035**	-0.058	0.058	0.003	-0.005	0.002	0.001	0.149	0.193**
9	0.004	0.002	0.000	0.051	-0.012	-0.008	0.008	0.010	**-0.200**	0.200	0.000	0.001	-0.071	0.038	0.384	0.408**
10	0.005	0.002	0.000	0.045	-0.012	-0.007	0.007	0.010	-0.200	**0.199**	0.000	0.001	-0.062	0.036	0.330	0.354**
11	-0.009	-0.002	-0.001	0.024	0.006	-0.001	-0.002	0.019	-0.007	0.011	**0.006**	-0.004	-0.009	-0.012	0.188	0.208**
12	-0.007	0.000	-0.001	0.060	0.000	0.001	0.002	0.008	0.015	-0.009	0.001	**-0.019**	0.029	-0.015	0.085	0.149*
13	0.002	0.002	0.000	-0.201	0.004	0.003	-0.005	0.000	0.059	-0.051	0.000	-0.002	**0.241**	-0.022	-0.385	-0.355**
14	-0.015	-0.005	-0.002	-0.034	0.011	0.003	-0.008	0.000	0.088	-0.085	0.001	-0.003	0.061	**-0.086**	0.220	0.147*
15	-0.007	-0.003	-0.002	0.089	-0.005	-0.004	0.006	0.005	-0.074	0.064	0.001	-0.002	-0.090	-0.018	**1.034**	0.994**

Residual (R) = -0.0006. * indicates significant at P=0.05 ** indicates significant at P=0.01

rG = Genotypic correlation coefficients of total yield per plant. Diagonal values indicate direct effects.

Characters:

1. Plant height at 60 DAT (cm)
2. Number of primary branches at 90 DAT
3. Stem girth at 90 DAT (cm)
4. Number of flowers per cluster
5. Polar diameter of the fruit (cm)
6. Equatorial diameter of the fruit (cm)
7. Pericarp thickness (cm)
8. Number of locules per fruit
9. Fruit volume (cc)
10. Average fruit weight (g)
11. Number of seeds per fruit
12. Per cent fruit set
13. Number of fruits per cluster
14. Number of fruits per plant
15. Early yield per plant (kg)

DAT = Days after transplanting

early yield per plant on total yield. Number of primary branches at 90 DAT had no direct effect (-0.009) on total yield per plant, but it had high indirect and positive effect (0.412) through early yield per plant on total yield. Stem girth at 90 DAT had no direct effects (-0.004) on total yield per plant, but it had high indirect and positive effects (0.459) through early yield per plant on total yield.

Number of flowers per cluster had high direct and negative effect (-0.218) on total yield, whereas it had high indirect effects through number of fruits per cluster (0.222) and early yield per plant (-0.423) on total yield. Number of fruits per cluster had high direct and positive effect (0.241) on total yield and it also had high indirect and negative effects through early yield per plant (-0.385) and number of flowers per cluster (-0.201) on total yield.

Polar diameter of the fruit had no direct effect (-0.020) on total yield per plant (Table-14), but it had high indirect and positive effects through early yield per plant (0.253) and average fruit weight (0.119), but it also had high indirect and negative effect through fruit volume (-0.123) on total yield. Equatorial diameter of the fruit had no direct effect (-0.008) on total yield, but it had high indirect and positive effects through early yield per plant (0.492) and average fruit weight (0.173), but it had negative and high indirect effect through fruit volume (-0.179) on total yield.

Pericarp thickness had no direct effect (0.018) on total yield, but it had high indirect and positive effect (0.320) through early yield per plant on total yield. Number of locules per fruit had no direct effect (0.035) on total yield, but it had high indirect and positive effect (0.149) through early yield per plant on total yield. Number of seeds per fruit had no direct effect (0.006) on total yield, but it had high indirect and positive effect (0.188) through early yield per plant on total yield.

Average fruit weight had high direct and positive effect (0.199) on total yield per plant (Table-14) and it also had high indirect effects through early yield per plant (0.330) and fruit volume (-0.200) on total yield. Fruit volume had high direct and negative effect (-0.200) on total yield per plant and it also had high indirect and positive effects through early yield per plant (0.384) and average fruit weight (0.200) on total yield.

Early yield per plant had high direct and positive effect (1.034) on total yield per plant. Number of fruits per plant had no direct effect (-0.086) on total yield per plant, but it had high indirect and positive effect (0.220) through early yield per plant on total yield.

4.1.4.2 Phenotypic path coefficients (Table-15)

Plant height at 60 DAT had no direct effect (-0.004) on total yield per plant, but it had high indirect and positive effect (0.191) through

Table 15. Phenotypic path coefficient analysis for total yield per plant in tomato

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	rP
1	**-0.004**	0.006	0.006	-0.002	-0.007	0.001	-0.000	0.003	-0.001	-0.002	0.006	0.002	0.001	-0.009	0.191	0.189**
2	0.001	**0.019**	0.005	-0.003	-0.003	0.001	-0.007	0.003	-0.002	-0.003	0.004	0.002	0.003	-0.007	0.149	0.159*
3	-0.001	0.004	**0.026**	-0.002	-0.002	-0.001	-0.002	0.004	0.001	0.001	0.004	0.005	0.000	-0.007	0.246	0.273**
4	0.000	-0.002	-0.002	**0.025**	-0.005	0.007	-0.008	-0.001	-0.003	-0.004	-0.003	-0.009	-0.024	-0.002	-0.288	-0.319**
5	0.001	-0.002	-0.002	-0.004	**0.027**	-0.015	0.021	0.000	0.009	0.012	-0.008	0.000	0.006	0.011	0.181	0.237**
6	0.000	-0.001	0.001	-0.007	0.015	**-0.026**	0.013	0.010	0.013	0.017	0.004	-0.003	0.011	0.009	0.345	0.401**
7	0.000	-0.004	-0.001	-0.006	0.018	-0.010	**0.032**	-0.001	0.006	0.008	-0.003	0.001	0.008	0.008	0.235	0.289**
8	0.000	0.001	0.003	-0.001	0.000	-0.007	-0.001	**0.035**	0.004	0.006	0.014	0.003	-0.001	0.000	0.106	0.162*
9	0.000	-0.002	0.001	-0.006	0.016	-0.022	0.012	0.009	**0.015**	0.020	0.001	-0.002	0.008	0.009	0.268	0.328**
10	0.000	-0.003	0.001	-0.005	0.016	-0.022	0.012	0.010	0.015	**0.021**	0.002	-0.001	0.007	0.009	0.221	0.282**
11	-0.001	0.003	0.003	-0.003	-0.008	-0.003	-0.004	0.018	0.001	0.001	**0.028**	0.003	0.001	-0.003	0.129	0.167*
12	0.000	0.001	0.004	-0.007	0.000	0.002	0.001	0.003	-0.001	0.000	0.003	**0.033**	-0.012	-0.002	0.053	0.077
13	0.000	-0.001	0.000	0.019	-0.005	0.009	-0.008	0.001	-0.004	-0.004	-0.001	0.012	**-0.032**	-0.004	-0.258	-0.276**
14	-0.002	0.006	0.008	0.002	-0.013	0.010	-0.010	0.000	-0.006	-0.008	0.003	0.003	-0.005	**-0.024**	0.343	0.308**
15	-0.001	0.003	0.007	-0.008	0.005	-0.010	0.008	0.004	0.004	0.005	0.004	0.002	0.009	-0.009	**0.948**	0.972**

Residual (R) = 0.0461. * indicates significant at P=0.05 ** indicates significant at P=0.01

rP = Phenotypic correlation coefficients of total yield per plant. Diagonal values indicate direct effects.

Characters:

1. Plant height at 60 DAT
2. Number of primary branches at 90 DAT
3. Stem girth at 90 DAT (cm)
4. Number of flowers per cluster
5. Polar diameter of the fruit (cm)
6. Equatorial diameter of the fruit (cm)
7. Pericarp thickness (cm)
8. Number of locules per fruit
9. Fruit volume (cc)
10. Average fruit weight (g)
11. Number of seeds per fruit
12. Per cent fruit set
13. Number of fruits per cluster
14. Number of fruits per plant
15. Early yield per plant (kg)

DAT = Days after transplanting

early yield per plant on total yield. Number of primary branches at 90 DAT had no direct effect (0.019) on total yield, but it had high indirect and positive effect (0.149) through early yield per plant on total yield. Stem girth at 90 DAT also had no direct effect (0.026) on total yield, but it had high indirect and positive effect (0.246) through early yield per plant on total yield.

Number of flowers per cluster had no direct effect (0.025) on total yield, but it had high indirect and negative effect (-0.288) through early yield per plant on total yield. Number of fruits per cluster had no direct effect (-0.032) on total yield, but it had high indirect and negative effect (-0.258) through early yield per plant on total yield.

Polar diameter of the fruit had no direct effect (0.027) on total yield, but it had high indirect and positive effect (0.181) through early yield per plant on total yield. Equatorial diameter of the fruit also had no direct effect (-0.026) on total yield, but it had high indirect and positive effect (0.345) through early yield per plant on total yield.

Pericarp thickness had no direct effect (0.032) on total yield (Table-15), but it had high indirect and positive effect (0.235) through early yield per plant on total yield. Number of locules had no direct effect (0.035) on total yield, but it had high indirect and positive effect (0.106) through early yield per plant on total yield. Number of seeds per fruit also had no direct effect (0.028) on total yield, but it had high indirect and positive effect (0.129) through early yield per plant on total yield.

Average fruit weight had no direct effect (0.021) on total yield, but it had high indirect and positive effect (0.221) through early yield per plant on total yield. Fruit volume also had no direct effect (0.015) on total yield, but it had high indirect and positive effect (0.268) through early yield per plant on total yield.

Early yield per plant had high direct and positive effect (0.948) on total yield (Table-15). Number of fruits per plant had no direct effect (-0.024) on total yield, but it had high indirect and positive effect (0.343) through early yield per plant on total yield.

4.2 GENETIC DIVERGENCE

Sixty-seven genotypes of different locations were assessed for 21 characters and data obtained was subjected to D^2 statistics to assess the genetic diversity. As many as seven divergent clusters were constructed using Tocher's method.

4.2.1 Relative contribution of different characters towards divergence (Table-16)

The relative contributions of different characters for genetic divergence (D^2) is given in Table-16. Number of seeds per fruit (56.63%) contributed maximum to the genetic diversity among the genotypes

Table 16. Relative per cent contribution of different characters to divergence in tomato

Sl. No.	Character / Source	Times ranked first	Per cent contribution
1.	Days to first flowering	0	0.00
2.	Days to 50 per cent flowering	0	0.00
3.	Days to first fruit set	1	0.05
4.	Days to first fruit maturity	6	0.27
5.	Plant height at 60 DAT (cm)	29	1.31
6.	Number of primary branches at 90 DAT	0	0.00
7.	Number of flowers per cluster	0	0.00
8.	Pericarp thickness (cm)	0	0.00
9.	Number of locules per fruit	0	0.00
10.	TSS (°Brix)	0	0.00
11.	Acidity (%)	0	0.00
12.	Ascorbic acid (mg/100 g)	0	0.00
13.	Lycopene (mg/100 g)	2	0.09
14.	Average fruit weight (g)	702	31.75
15.	Fruit volume (cc)	45	2.04
16.	Number of seeds per fruit	1252	56.63
17.	Per cent fruit set	5	0.23
18.	Number of fruits per cluster	0	0.00
19.	Number of fruits per plant	169	7.64
20.	Early yield per plant (kg)	0	0.00
21.	Total yield per plant (kg)	0	0.00

DAT = Days after transplanting

followed by average fruit weight (31.75%), number of fruits per plant (7.64%) and fruit volume (2.04%). However, there was no substantial contribution from plant height at 60 DAT (1.31%), days to first fruit maturity (0.27%), per cent fruit set (0.23%), lycopene content (0.09%) and days to first fruit set (0.05%).

4.2.2 Classification of tomato genotypes (Table-17)

Following the method suggested by Tocher, 67 genotypes were grouped into seven clusters by treating estimated D^2 values as the square of the generalised distance. The distribution of entries into various clusters is given in Table-17.

Cluster I was the largest having 44 genotypes followed by cluster II with 11 genotypes, cluster IV with 7 genotypes, cluster II with 2 genotypes (KT 32 and KT 43) and cluster V (KT 45), cluster VI (KT 49) and cluster VII (KT 11) had one genotype each (Table-17).

Intra- and inter-cluster average D^2 values have been given in Table-18. Among the seven clusters, cluster IV with 7 number of genotypes showed maximum intra-cluster diversity (D^2=68.998) followed by cluster I (D^2=61.060), cluster II (D^2=57.251) and cluster IV (D^2=23.327). The cluster V, VI and VII had no intra-cluster distance (D^2=0.000) as they possessed single genotype in each.

Table 17. Classification of tomato genotypes into different clusters based on D^2 values

Cluster No.	Number of genotypes	Name of the genotype
I	44	KT 02 KT 03 KT 04 KT 06 KT 07 KT 09 KT 12 KT 13 KT 14 KT 16 KT 18 KT 19 KT 20 KT 21 KT 22 KT 23 KT 25 KT 26 KT 27 KT 28 KT 29 KT 30 KT 31 KT 33 KT 34 KT 35 KT 36 KT 37 KT 38 KT 39 KT 40 KT 42 KT 44 KT 46 KT 47 KT 53 KT 55 KT 57 KT 59 Punjab Kesari Arka Vikas Arka Saurabh Arka Meghali Arka Abha
II	11	KT 01 KT 10 KT 15 KT 17 KT 24 KT 41 KT 54 KT 56 KT 60 Arka Alok Arka Ashish
III	02	KT 32 KT 43
IV	07	KT 05 KT 08 KT 48 KT 50 KT 51 KT 52 KT 58
V	01	KT 45
VI	01	KT 49
VII	01	KT 11

Table 18. Average intra- and inter-cluster D^2 values along with their 'D' values (in paranthesis) for 21 characters formed by 67 genotypes of tomato

Cluster	I	II	III	IV	V	VI	VII
I	61.060	100.910	152.372	100.683	148.365	146.309	192.943
	(7.814)	(10.045)	(12.343)	(10.034)	(12.180)	(12.095)	(13.890)
II		57.351	86.717	117.993	169.519	137.105	116.576
		(7.573)	(9.312)	(10.862)	(13.019)	(11.709)	(10.797)
III			23.327	132.551	239.740	145.533	111.742
			(4.829)	(11.513)	(15.483)	(12.063)	(10.570)
IV				68.998	222.521	106.005	211.820
				(8.294)	(14.917)	(10.295)	(14.554)
V					0.000	243.700	207.860
					(0.000)	(15.610)	(14.417)
VI						0.000	209.086
						(0.000)	(14.459)
VII							0.000
							(0.000)

Note: Diagonal values indicate intra-cluster distances.

Based on distance between clusters i.e., inter-cluster distance, the maximum divergence was observed between cluster V and VI (D^2=243.70) closely followed by cluster II and V (D^2=239.740), cluster IV and V (D^2=222.521), cluster IV and VII (D^2=211.820), cluster VI and VIII (D^2=209.459) and cluster V and VII (D^2=207.860). The cluster II revealed the least distance relationship with the cluster III (D^2=86.717).

4.2.3 Cluster means (Table-19)

The mean values of 21 characters for seven clusters are summarised in Table-19.

4.2.3.1 Days to first flowering

The lowest cluster mean for this character (Table-19) was observed in cluster VI (19.33 days) followed by cluster V (26.67 days) and cluster IV (27.71 days) and highest cluster mean was observed in cluster III (29.00 days).

4.2.3.2 Days to 50 per cent flowering

The lowest cluster mean for this character (Table-19) was observed in cluster VI (21.33 days) followed by cluster V (29.00 days) and cluster IV (29.66 days) and highest cluster mean was observed in cluster III (31.66 days).

Table 19. The mean values of 21 characters for 7 clusters in tomato

Sl. No.	Character	Cluster						
		I	II	III	IV	V	VI	VII
1.	Days to first flowering	28.30	27.78	29.00	27.71	26.67	19.33	28.67
2.	Days to 50 per cent flowering	30.87	30.06	31.66	29.66	29.00	21.33	31.00
3.	Days to first fruit set	35.02	34.60	35.67	34.38	33.33	26.67	36.33
4.	Days to first fruit maturity	69.47	68.93	69.33	68.09	66.67	58.67	69.00
5.	Plant height at 60 DAT (cm)	59.77	63.95	59.47	64.29	61.80	81.67	66.07
6.	Number of primary branches at 90 DAT	10.66	10.81	12.03	11.23	10.20	13.67	11.20
7.	Number of flowers per cluster	5.75	5.54	5.43	6.27	4.93	6.13	6.27
8.	Pericarp thickness (cm)	0.57	0.54	0.58	0.36	0.63	0.32	0.44
9.	Number of locules per fruit	3.25	4.25	3.97	3.27	3.40	3.47	4.73
10.	TSS (°Brix)	4.00	4.23	4.00	4.31	3.77	4.13	4.18
11.	Acidity (%)	0.40	0.39	0.33	0.42	0.36	0.45	0.43
12.	Ascorbic acid (mg/100 g)	16.09	16.28	21.40	14.59	17.06	9.37	22.85
13.	Lycopene (mg/100 g)	9.86	12.24	7.40	9.19	12.67	12.93	10.51
14.	Average fruit weight (g)	92.09	97.25	57.71	36.98	210.40	43.00	140.13
15.	Fruit volume (cc)	72.65	76.18	43.67	25.85	150.00	36.00	106.00
16.	Number of seeds per fruit	74.78	157.15	213.33	95.19	63.00	127.00	253.33
17.	Per cent fruit set	76.70	79.06	77.66	80.80	79.67	77.31	80.93
18.	Number of fruits per cluster	4.42	4.35	4.20	5.06	3.93	4.73	5.07
19.	Number of fruits per plant	34.89	39.87	34.80	73.67	28.93	145.47	33.27
20.	Early yield per plant (kg)	1.13	1.30	0.92	0.70	1.30	1.42	1.03
21.	Total yield per plant (kg)	2.51	2.89	2.10	1.54	2.67	2.91	2.30

DAT = Days after transplanting

4.2.3.3 Days to first fruit set

The lowest cluster mean for this character (Table-19) was observed in cluster VI (26.67 days) followed by cluster V (33.33 days) and cluster IV (34.38 days) and highest cluster mean was observed in cluster VII (36.33 days).

4.2.3.4 Days to first fruit maturity

For days to first fruit maturity, the lowest cluster mean (Table-19) was observed in cluster VI (58.67 days) followed by cluster V (66.67 days) and cluster IV (68.09 days) and highest cluster mean was observed in cluster I (69.47 days).

4.2.3.5 Plant height at 60 DAT (cm)

The highest cluster mean for this character (Table-19) was observed in cluster VI (81.67 cm) followed by cluster VII (66.07 cm) and cluster IV (64.29 cm) and the lowest cluster mean was observed in cluster III (59.47 cm).

4.2.3.6 Number of primary branches at 90 DAT

Cluster mean for number of primary branches at 90 DAT (Table-19) was the highest in cluster VI (13.67) followed by cluster III (12.03), cluster IV (11.23) and cluster VII (11.20) and the lowest cluster mean was observed in cluster V (10.20).

4.2.3.7 Number of flowers per cluster

The highest cluster mean for this character (Table-19) was observed in cluster IV (6.27) and cluster VII (6.27) followed by cluster VI (6.13) and cluster I (5.75) and the lowest cluster mean was observed in cluster V (4.93).

4.2.3.8 Pericarp thickness

The highest cluster means for pericarp thickness (Table-19) was observed in cluster V (0.63 cm) followed by cluster III (0.58 cm) and cluster I (0.57 cm) and the lowest cluster mean was observed in cluster VI (0.32 cm).

4.2.3.9 Number of locules per fruit

The highest cluster means for locule number (Table-19) was observed in cluster VII (4.73) followed by cluster II (4.25) and cluster III (3.97) and the lowest cluster mean was observed in cluster I (3.25).

4.2.3.10 TSS (°Brix)

Cluster mean for TSS was the highest (Table-19) in cluster IV (4.31°Brix) followed by cluster II (4.23°Brix) and cluster VII (4.18°Brix) and the lowest cluster mean was observed in cluster V (3.77°Brix).

4.2.3.11 Acidity (%)

The highest cluster mean for acidity (Table-19) was observed in cluster VI (0.45%) followed by cluster VII (0.43%) and cluster IV (0.42%) and the lowest cluster mean was observed in cluster III (0.33%).

4.2.3.12 Ascorbic acid (mg/100 g)

The highest cluster mean for ascorbic acid content (Table-19) was observed in cluster VII (22.85 mg) followed by cluster III (21.40 mg) and cluster V (17.06 mg) and the lowest cluster mean was observed in cluster VI (9.37 mg).

4.2.3.13 Lycopene (mg/100 g)

The highest cluster mean for lycopene content (Table-19) was observed in cluster VI (12.93 mg) followed by cluster V (12.67 mg) and cluster II (12.24 mg) and the lowest cluster mean was observed in cluster IV (9.19 mg).

4.2.3.14 Number of seeds per fruit

For number of seeds per fruit, the highest cluster mean (Table-19) was observed in cluster VII (253.33) followed by cluster III (213.33) and cluster II (157.15) and the lowest cluster mean was observed in cluster V (63.00).

4.2.3.15 Average fruit weight (g)

For average fruit weight, the highest cluster mean (Table-19) was observed in cluster V (210.40 g) followed by cluster VII (140.13 g) and cluster II (97.25 g) and the lowest cluster mean was observed in cluster IV (36.08 g).

4.2.3.16 Fruit volume (cc)

The highest cluster mean for fruit volume (Table-19) was observed in cluster V (150.00 cc) followed by cluster VII (106.00 cc) and cluster II (76.18 cc) and the lowest cluster mean was observed in cluster IV (25.85 cc).

4.2.3.17 Per cent fruit set

Cluster mean for per cent fruit set (Table-19) was the highest in cluster VII (80.93%) followed by cluster IV (80.80%), cluster V (79.67%) and cluster II (79.06%) and the lowest cluster mean was observed in cluster I (76.70%).

4.2.3.18 Number of fruits per cluster

Cluster mean for number of fruits per cluster (Table-19) was the highest in cluster VII (5.07) followed by cluster IV (5.06) and cluster VI (4.73) and the lowest cluster mean was observed in cluster V (3.93).

4.2.3.19 Number of fruits per plant

The highest cluster mean for fruit number (Table-19) was observed in cluster VI (145.47) followed by cluster IV (73.67) and cluster II (39.87) and the lowest cluster mean was observed in cluster V (28.93).

4.2.3.20 Early yield per plant (kg)

For early yield per plant, the highest cluster mean (Table-19) was observed in cluster VI (1.42 kg) followed by cluster II (1.30 kg), cluster V (1.30 kg) and cluster I (1.13 kg) and the lowest cluster mean was observed in cluster IV (0.70 kg).

4.2.3.21 Total yield per plant (kg)

Cluster mean for total yield (Table-19) was the highest in cluster VI ((2.91 kg) followed by cluster II (2.89 kg), Cluster V (2.67 kg) and cluster I (2.51 kg) and the lowest cluster mean was observed in cluster IV (1.54 kg).

DISCUSSION

V. DISCUSSION

Success of crop improvement programme depends on the extent of genetic variability existing in the population or germplasm. Magnitude of genetic variability can determine the pace and quantum of genetic improvement through selection or through hybridisation followed by selection. Therefore, in the present investigation, assessment of genetic variability in tomato was carried out and the results of the experiments are discussed in this chapter.

5.1 GENETIC VARIABILITY

Existence of genetic variability among the genotypes for the character to be improved is the most basic requirement for successful selection. In the present investigation, variance due to genotypes was highly significant (at p=0.01) for plant height at 30, 60 and 90 days after transplanting (DAT), number of primary branches (at 30, 60 and 90 DAT), stem girth (at 60 and 90 DAT), number of flowers per cluster, length of the flower, breadth of the flower, days to first flowering, days to 50 per cent flowering, days to first fruit set, days to first fruit maturity, per cent fruit set, number of fruits per cluster, number of fruits per plant, average fruit weight, early yield per plant, total yield per plant, yield per hectare, polar and equatorial diameter of the fruit, fruit shape index, pericarp thickness, number of locules per fruit, total soluble solids

(TSS), acidity, TSS : acid ratio, fruit pH, ascorbic acid, lycopene, fruit volume, fruit density, number of seeds per fruit and thousand seed weight.

Means of genotypes varied greatly for several traits, indicating the higher magnitude of variability. The range in the values reflects the amount of phenotypic variability. Mean values of genotypes ranged greatly when compared to previous findings for plant height (at 60 and 90 DAT), number of primary branches (at 90 DAT), number of flowers per cluster, days to first fruit maturity, per cent fruit set, number of fruits per plant, total yield per plant, average fruit weight, number of locules per fruit and seed weight (Reddy and Gulshanlal, 1987), stem girth (at 90 DAT), TSS, acidity and ascorbic acid (Paranjothi and Muthukrishnan, 1979), days to first flowering (Prasad and Prasad, 1976), days to 50 per cent flowering, fruit shape index and pericarp thickness (Pujari *et al.*, 1995), number of fruits per cluster (Narendrakumar and Arya, 1995), yield per hectare (Mohanty, 2003), polar and equatorial diameter of the fruit (Das *et al.*, 1998), TSS : acid ratio (Padda *et al.*, 1971), fruit pH, fruit density (Kasrawi and Amr, 1990), lycopene (Pradeepkumar and Tewari, 1999) and number of seeds per fruit (Bhutani *et al.*, 1983).

Range in mean values is not reliable since it includes genotypic, environment and genotypic x environment interactions. Hence, estimates of genotypic variance and phenotypic variance was carried out.

Genotypic and phenotypic variances were high for several traits, like plant height, number of primary branches, number of fruits per cluster, number of fruits per plant, total yield per plant (Narendrakumar and Arya, 1995), average fruit weight, polar and equatorial diameter of the fruit (Singh *et al.*, 1988). Difference between genotypic and phenotypic variance was very low for characters like TSS, acidity, fruit pH, ascorbic acid and lycopene content (Mala and Vadivel, 1999) and it implies that, there is less influence of environment and consequently selection can be very effective for these traits.

Genotypic variance and phenotypic variances are influenced by the units used for measuring the particular plant character. Coefficient of variation will nullify such effects and comparisons can be made across the traits and across the findings. In the present investigation, high genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for number of primary branches at 30 DAT (Mohanty, 2003), number of fruits per plant (Pujari *et al.*, 1995; Reddy and Gulshanlal, 1987) and number of seeds per fruit (Bhutani *et al.*, 1983). High GCV was also reported for number of seeds per fruit in watermelon (Rajendran and Thamburaj, 1994). It indicates existence of broad genetic base, which would be amenable for further selection. Moderate GCV and PCV were observed for early and total yield per plant (Bora *et al.*, 1993; Reddy and Gulshanlal, 1987) and average fruit weight (Mohanty, 2003; Rattan *et al.*, 1983). In contrast to the present findings, high GCV and PCV were reported for average fruit weight by Mala and Vadivel (1999) and Krishnaprasad and Mathurarai (1999). Moderate GCV and PCV was also observed for number of locules per fruit (Pradeepkumar and Tewari, 1999; Das *et al.*, 1998), acidity (Pradeepkumar and Tewari, 1999; Arora *et al.*, 1982), TSS : acid ratio, lycopene (Pradeepkumar and Tewari, 1999; Mala and Vadivel, 1999) and fruit volume, which indicates presence of moderate amount of variability for these traits.

Low GCV and PCV was observed for plant height at 30, 60 and 90 DAT (Singh *et al.*, 1988; Sahu and Mishra, 1995), number of primary branches at 60 and 90 DAT (Narendrakumar and Arya, 1995; Sahu and Mishra, 1995), stem girth at 90 DAT (Paranjothi and Muthukrishnan, 1979), number of flowers per cluster (Reddy and Gulshanlal, 1987), days to first flowering (Parvindarsingh *et al.*, 2002; Sahu and Mishra, 1995) and days to 50 per cent flowering. Low GCV and PCV was also observed for days to first fruit set (Singh *et al.*, 1988), days to first fruit maturity (Das *et al.*, 1998; Reddy and Gulshanlal, 1987) and per cent fruit set. For per cent fruit set moderate GCV and PCV was reported by Reddy and Gulshanlal (1987). Low GCV and PCV was observed for number of fruits per cluster (Narendrakumar and Arya, 1995; Bora *et al.*, 1993), polar and equatorial diameter of the fruit (Sahu and Mishra, 1995; Singh *et al.*, 1988), fruit shape index, pericarp thickness, TSS (Pujari *et al.*, 1995), fruit pH (Padda *et al.*, 1971), ascorbic acid (Mala and Vadivel, 1999;

Pradeepkumar and Tewari, 1999), fruit density (Pradeepkumar and Tewari, 1999) and thousand seed weight. For thousand seed weight, high GCV and PCV was reported by Reddy and Gulshanlal (1987). Low GCV and PCV observed for all these characters indicated the narrow genetic base and hence variability has to be generated either through introduction or by hybridising divergent genotypes to recover transgressive segregants.

Coefficient of variation indicates only the extent of variability present in germplasm for different characters, but for the prediction of response to selection heritability estimates are useful. Very high broad sense heritability (>90%) was observed for length of the flower, breadth of the flower and average fruit weight (Parvindarsingh *et al.*, 2002), polar and equatorial diameter of the fruit (Mala and Vadivel, 1999) and fruit shape index. Very high broad sense heritability was also observed for TSS, lycopene and fruit density (Pradeepkumar and Tewari, 1999; Mala and Vadivel, 1999), fruit pH (Mala and Vadivel, 1999), fruit volume and number of seeds per fruit (Bhutani *et al.*, 1983) and thousand seed weight (Reddy and Gulshanlal, 1987; Arora *et al.*, 1982). Hence, these characters can be improved through selection.

Very oftenly, heritability in broad sense is not the true indicator of inheritance of traits, since, only additive component of genetic variance is efficiently transferred from generation to generation. Therefore, heritability in broad sense may mislead in judging the effectiveness of selection for the trait. Considering heritability in broad sense along with genetic advance may reveal the prevalence of specific components (additive or non-additive) of genetic variance and thus helps in judging the effectiveness of selection for the trait more accurately. High heritability accompanied with high genetic advance indicates the prevalence of additive gene effects and hence, selection would be effective for such traits. The high values of genetic advance over mean (GAM) coupled with high estimates of heritability was observed for characters, viz., number of flowers per cluster, length of the flower, breadth of the flower, days to first flowering, days to 50 per cent flowering, number of fruits per cluster (Bora *et al.*, 1993), number of fruits per plant (Mohanty, 2003; Mala and Vadivel, 1999), average fruit weight (Das *et al.*, 1998; Pujari *et al.*, 1995), polar and equatorial diameter of the fruit (Mala and Vadivel, 1999; Das *et al.*, 1998), fruit shape index (Pujari *et al.*, 1995), pericarp thickness and number of locules per fruit (Pradeepkumar and Tewari, 1999), TSS and lycopene content (Mala and Vadivel, 1999). This indicates predominance of additive component for these traits and hence direct selection would be more effective in improving these traits.

High heritability with low genetic advance (GA) indicates the importance of non-additive gene action. High heritability with moderate to low GAM observed for days to first fruit set, fruit density and fruit pH, indicated the prevalence of non-additive components and there can be little response to selection and these traits can be exploited through heterosis breeding.

Low heritability with high GA indicates the importance of additive gene effects. Moderate heritability with high GAM was obtained for characters, viz., early yield per plant, total yield per plant (Srivastava and Sachan, 1973), acidity (Paranjothi, and Muthukrishnan, 1979), TSS : acid ratio and ascorbic acid. Low heritability with high GAM was also observed for number of primary branches at 30 DAT (Narendrakumar and Arya, 1995). This indicates the importance of additive gene effects for these traits and there can be better response to selection.

Low heritability with low GA indicates that, the character is highly influenced by environmental effects and selection would be ineffective. Moderate heritability with moderate GAM was obtained for characters, plant height at 30 DAT and stem girth at 60 DAT. Moderate heritability with low GAM was obtained for characters, stem girth at 90 DAT and days to first fruit maturity. Low heritability with moderate GAM was obtained for the characters like plant height at 60 DAT (Narendrakumar and Arya, 1995) and number of primary branches at 60 DAT. Low heritability coupled with low GAM was obtained for the characters plant height at 90 DAT (Singh *et al.*, 1988), number of primary branches at 90 DAT (Sahu and Mishra, 1995) and per cent fruit set. These findings elucidate prevalence of higher influence of environment on these traits and hence, selection would be ineffective.

Prevalence of high degree of additive components of genetic variance and presence of high GCV and PCV for characters, number of fruits per plant, yield per plant, average fruit weight, fruit volume and number of seeds per fruit indicated the possibility of achieving higher degree of genetic improvement for these traits through selection using the existing germplasm stock at the centre.

5.2 CORRELATION AND PATH ANALYSIS

For rational approach towards the improvement of yield, selection has to be made for the components of yield, since there may not be genes for yield *per se*, but only for various yield components (Grafius, 1959). Many of these yield contributing characters are interacted in desirable and undesirable direction. Hence, knowledge of association between the traits can greatly help in avoiding inversely related compensation effects during selection.

A narrow difference between the genotypic and phenotypic correlation coefficients was observed for various traits in the present findings and this indicates the lesser influence of environment in the expression of these traits and presence of strong inherent association among the traits. Number of primary branches at 90 DAT was positively and significantly correlated with plant height at 60 DAT at both genotypic and phenotypic level (Mohanty, 2003; Raijadhav *et al.*, 1996). Stem girth at 90 DAT was positively and significantly correlated with plant height at 60 DAT and number of primary branches at 90 DAT at both genotypic and phenotypic levels. This indicates there is strong association between vegetative traits.

Days to first flowering, days to fifty per cent flowering, days to first fruit set and days to first fruit maturity were significantly and negatively associated with plant height (at 60 DAT), number of primary branches (at 90 DAT) and stem girth (at 90 DAT) at genotypic level. These results elucidated the inverse relationship between earliness and growth parameters. Days to first flowering, days to fifty per cent flowering, days to first fruit set and days to first fruit maturity were significantly (at $p=0.01$) and positively associated among themselves with greater than 0.760 correlation coefficients at phenotypic as well as at genotypic levels. This indicates the presence of very strong association among the earliness parameters.

Per cent fruit set was positively and significantly correlated with plant height at 60 DAT, stem girth at 90 DAT, number of locules per fruit and number of seeds per fruit, but it had negative and significant association with number of flowers per cluster (Raijadhav *et al.*, 1996) and equatorial diameter of the fruit at genotypic level. This indicates the inverse relationship between per cent fruit set and number of flowers per cluster. Better growth results into more photosynthetic area and production of more photosynthates resulting into better fruit set. When there is more competition for photosynthates through increased number of flowers per cluster, fruit set is reduced.

Number of fruits per cluster was positively and significantly associated with number of flowers per cluster at genotypic and phenotypic levels. Similar results were reported by Sharma and Kishanswaroop (2000) in brinjal. Number of fruits per cluster was positively and significantly associated with per cent fruit set (Dhankar *et al.*, 2001) at phenotypic level. These results indicated that, per cent fruit set has greatly contributed for increased number of fruits per cluster. Number of fruits per cluster had negative and significant association with equatorial diameter of the fruit (Srivastava and Sachan, 1973), fruit volume, pericarp thickness and average fruit weight (Fageria and Kohli, 1996), number of primary branches at 90 DAT and polar diameter of the fruit at genotypic and phenotypic levels. This implies that increase in number of fruits per cluster consequently decreases polar and equatorial diameter of the fruit, average fruit weight and fruit volume and it is attributed to competition between sinks (fruits) for source (photosynthates). This negative association need to be broken by *inter se* mating, since number of fruits per cluster is a strong contributor for total number of fruits, which is an ultimate yield contributing trait.

Polar diameter of the fruit was negatively and significantly associated with plant height at 60 DAT (Krishnaprasad and Mathurarai, 1999), number of primary branches at 90 DAT (Mala and Vadivel, 1999), number of flowers per cluster, both at genotypic and phenotypic level. And hence, plants with indeterminate growth habit had decreased polar diameter of the fruit. Equatorial diameter of the fruit was positively and significantly associated with polar diameter of the fruit (Singh *et al.*, 1988). Therefore, for improvement of fruit size, both polar and equatorial diameter of the fruit should be considered simultaneously for selection.

Pericarp thickness was positively and significantly associated with polar and equatorial diameter of the fruit at genotypic and phenotypic levels. Pericarp thickness was negatively and significantly associated with number of primary branches at 90 DAT, number of flowers per cluster and plant height at 60 DAT (Fageria and Kohli, 1996), indicating inverse relationship between pericarp thickness and vegetative parameters. This is attributed to increased fruit number with indeterminate growth habit as the fruit number is positively associated with growth parameters and negatively associated with pericarp thickness. Number of locules per fruit was positively and significantly associated with equatorial diameter of the fruit (Singh *et al.*, 1974), number of primary branches (at 90 DAT), stem girth (at 90 DAT) and plant height (at 60 DAT) at genotypic level. This is attributed to better growth resulting into better fruit size and more number of locules as revealed by correlation studies.

Number of seeds per fruit was positively and significantly associated with number of locules per fruit, plant height (at 60 DAT), number of primary branches (at 90 DAT) and stem girth (at 90 DAT) at both genotypic and phenotypic levels. Number of seeds per fruit was negatively and significantly associated with polar diameter of the fruit at genotypic and phenotypic level. Better growth resulted into better fruit size and more number of locules and more seeds. High seed number is a desirable traits for getting higher seed yield, but for processing purpose, less number of seeds per fruit is preferred. Hence, selection can be exercised to reduce or increase the number of locules to alter number of seeds per fruit.

Average fruit weight was positively and significantly associated with fruit volume, polar and equatorial diameter of the fruit, number of locules per fruit (Krishnaprasad and Mathurarai, 1999), pericarp thickness (Dudi and Kalloo, 1982) at both genotypic and phenotypic levels. Thus, average fruit weight is greatly contributed by these traits. Averge fruit weight was inversely associated with number of primary branches at 90 DAT (Raijadhav *et al.*, 1996; Mala and Vadivel, 1999), number of flowers per cluster (Reddy and Gulshanlal, 1987; Raijadhav *et al.*, 1996) and plant height at 60 DAT (Fageria and Kohli, 1996; Mohanty, 2003) at both genotypic and phenotypic levels. This is attributed to its (average fruit weight) inverse relation with number of fruits, where more competition for photosynthates resulted into reduced fruit size.

Correlation studies also revealed that, average fruit weight is inversely associated with earliness parameters.

Number of fruits per plant was positively and significantly associated with plant height at 60 DAT, (Raijadhav *et al.*, 1996), number of primary branches at 90 DAT (Mala and Vadivel, 1999), stem girth at 90 DAT, number of fruits per cluster (Narendrakumar and Arya, 1995) per cent fruit set and number of flowers per cluster (Reddy and Gulshanlal, 1987). Number of fruits per plant was negatively and significantly associated with polar diameter of the fruit (Singh *et al.*, 1974), fruit volume, average fruit weight (Mohanty, 2003; Raijadhav *et al.*, 1996), equatorial diameter of the fruit (Singh *et al.*, 1974; Das *et al.*, 1998), pericarp thickness (Dudi and Kalloo, 1982), days to first fruit maturity, days to 50 per cent flowering, days to first fruit set and days to first flowering at both genotypic and phenotypic levels, indicating the inverse relationship. Correlation studies indicated that increased fruit number is the result of better growth, early flowering, good fruit set and higher number of flowers and fruits per cluster. Increased fruit number has resulted into reduced fruit size in terms of polar and equatorial diameter, weight of fruits and fruit volume. These negative associations need to be broken by *inter se* mating and selection, since number of fruits as well as fruit size greatly contributed for total yield.

Early yield per plant was positively and significantly associated with stem girth (at 90 DAT), number of primary branches (at 90 DAT) and plant height (at 60 DAT), equatorial diameter of the fruit, fruit volume, average fruit weight, pericarp thickness, polar diameter of the fruit and number of fruits per plant (Dudi and Kalloo, 1982) at genotypic level. Thus, number of fruits, fruit size and growth traits have greatly contributed for early yield. Early yield per plant was negatively and significantly associated with days to first fruit maturity, days to first fruit set, days to first flowering, days to 50 per cent flowering at genotypic level and it (early yield) was negatively and significantly associated with number of flowers per cluster and number of fruits per cluster at both genotypic and phenotypic levels. The strong association between earliness traits is thus evident. For getting higher early and total yield negative selection needs to exercise on number of flowers and fruits per cluster.

Total yield per plant was positively and significantly associated with early yield per plant (Dudi and Kalloo, 1982), equatorial diameter of the fruit (Mala and Vadivel, 1999), fruit volume, average fruit weight, polar diameter of the fruit, number of fruits per plant (Das *et al.*, 1998), per cent fruit set, stem girth (at 90 DAT), number of locules per fruit (Raijadhav *et al.*, 1996), plant height (at 60 DAT), pericarp thickness and number of seeds per fruit at both genotypic and phenotypic levels. Total yield per plant was negatively and significantly associated with number of flowers per cluster and number of fruits per cluster (Fageria and Kohli,

1996) at both genotypic and phenotypic levels. Correlation studies revealed that yield can be improved by selecting genotypes for better growth, high fruit set, big fruit size, thick pericarp, more number of fruits per plant and less number of flowers and fruits per cluster.

5.2.1 Path analysis

Though correlation analysis indicates the association pattern of component traits with yield, they simply represent the overall influence of a particular trait on yield rather than providing cause and effect relationship. The technique of path coefficient analysis developed by Wright (1921) and demonstrated by Dewey and Lu (1957) facilitates the partitioning of correlation coefficients into direct and indirect contribution of various characters on yield. It is standardised partial regression coefficient analysis. As such, it measures the direct influence of one variable upon other. Such information would be great value in enabling the breeder to specifically identify important component traits of yield and utilise the genetic stock for improvement in a planned way. In the present study, path coefficient analysis between the components of tomato yield was worked. As the genotypic association are inherent, the path analysis is discussed at genotypic level.

Average fruit weight was positively and significantly correlated ($rG=0.354$) with total yield and it had positive and high direct effects (0.199) on total yield (Mohanty, 2003; Dhankar *et al.*, 2001), but it had high indirect and positive effects through early yield per plant (0.330) and negative effects through fruit volume (-0.200) on total yield. Therefore, for improvement of yield, average fruit weight needs to be considered along with early yield and fruit volume.

Fruit volume was positively and significantly correlated (rG=0.408) with total yield and it had negative and high direct effects (-0.200) on total yield, but it had high indirect and positive effects through early yield per plant (0.384) and average fruit weight (0.200) on total yield. Under these circumstances, the indirect causal factors like early yield and fruit weight also need to be given due consideration along with fruit volume simultaneously for selection.

Number of flowers per cluster was negatively and significantly correlatd (rG=-0.415) with total yield and it had negative and high direct effects (-0.218) on total yield, but it had high indirect and negative effects through early yield per plant (-0.423) and high indirect and positive effects through number of fruits per cluster (0.222) on total yield. Similar results were reported by Sharma and Kishanswaroop (2000) in brinjal. Under these circumstances, the indirect causal factors also need to be considered simultaneously for selection.

Number of fruits per cluster was negatively and significantly correlated (rG=-0.355) with total yield and it had positive and high direct effects (0.241) on total yield (Dhankar *et al.*, 2001) and it had high indirect and negative effects through early yield per plant (-0.385) and number of flowers per cluster (-0.201) on total yield. Under these circumstances, a restricted simultaneous selection model (Singh and Kokar, 1977) can be followed, i.e., restrictions are to be imposed to nullify the undesirable indirect effects through early yield per plant and number of flowers per cluster in order to make use of direct effects of number of fruits per cluster on total yield.

The correlation coefficient between total yield and early yield (rG=0.994) is almost equal to the direct effects (1.034) of early yield per plant on total yield (Dudi and Kalloo, 1982), Hence, direct selection for early yield per plant will be more reliable for yield (total) improvement.

Polar (rG=0.287) and equatorial (rG=0.496) diameter of the fruit were positively and significantly correlated with total yield, and these characters had no direct effects on total yield, but both of these traits had high indirect and positive effects through early yield per plant and average fruit weight. Similar results were reported in brinjal by Ingale and Patil (1995). Therefore, the indirect causal factors also need to be considered for simultaneous selection.

Plant height at 60 DAT, number of primary branches at 90 DAT, stem girth at 90 DAT, pericarp thickness, number of locules per fruit, number of seeds per fruit and number of fruits per plant were positively and significantly correlated with total yield and these traits had no direct effects on total yield. These characters had high indirect and positive effects through early yield per plant on total yield. Similar results were reported by Dudi and Kalloo (1982). Hence, the indirect causal factors also need to be considered for selection.

5.3 GENETIC DIVERGENCE

The genus *Lycopersicon* possesses a wealth of genetic diversity and cultivated tomato (*Lycopersicon esculentum* Mill.) is one of the nine species belonging to this genus. Apart from the cultivated species, the wild species do have a great potential value because of diversity of their germplasm (Rick, 1978). The importance of genetic diversity has been widely appreciated. Recognising and estimating such diversity has always been a difficult task. Multivariate analysis utilising the concept of statistical distance has been found to be a very powerful statistical tool in estimating diversity in biological populations. It has been successfully employed even in situations where overlapping of characters rendered the conventional methods of classification ineffective (Sokal, 1965 and Murthy *et al.*, 1967).

Ecological diversity has been regarded as a reasonable index of genetic diversity (Vavilov, 1926; Moll *et al.*, 1962 and Ram and Panwar, 1970). Assuming this, the cultivars from widely separated localities have been included in the hybridisation programme by most of the plant breeders for recovering promising segregants. But, Sachan and Sharma

(1971) could not find any direct relationship between geographic distribution and genetic diversity in crops belonging to different breeding systems. The material for present study includes 67 genotypes. Nevertheless, considerable diversity was implied by the magnitude of all the possible D^2 values, which ranged from 86.717 to 243.70. Sixty-seven genotypes were grouped into 7 clusters, which had considerably high intra- and inter-cluster D^2 values (Table-18).

Intra-cluster distance revealed that, cluster IV with 7 numbers of genotypes showed maximum intra-cluster diversity (D^2=68.998) followed by cluster I (D^2=61.060) with 44 genotypes, cluster II (D^2=57.351) with 11 genotypes and cluster III (D^2=23.327) with 2 genotypes. The clusters V, VI and VII had no intra-cluster distance (D^2=0.000) as they possessed single genotype in each.

Based on distance between clusters, i.e., inter-cluster distance, the maximum divergence was observed between cluster V and VI (D^2=243.700), closely followed by cluster III and V (D^2=239.740), cluster IV and V (D^2=222.521), cluster IV and VII (D^2=211.82), cluster VI and VII (D^2=209.086) and cluster V and VII (D^2=207.860). The cluster II revealed the least distance relationship with the cluster III (D^2=86.717).

These clusters have been formed based on the contribution of different characters to the divergence which includes number of seeds per fruit contributing maximum (56.63%) to genetic diversity followed by average fruit weight (31.75%), number of fruits per plant (7.64%) and fruit volume (2.04%). However, plant height at 60 DAT (1.31%), days to first fruit maturity (0.27%), per cent fruit set (0.23%), lycopene content (0.09%) and days to first fruit set (0.05%) have contributed meagrely to the divergence.

For number of seeds per fruit, the highest cluster mean (Table-19) was shown by the cluster VII followed by cluster III, cluster II and cluster VI. The inter-cluster distance between cluster VII and VI (D^2=209.086), cluster III and VI (D^2=145.533) and cluster II and VI (D^2=137.105) were comparatively high. Hence, hybridisation between the genotypes of these respective clusters can be attempted to get fruits with high number of seeds which is necessary for the seed industry. However, this may not be useful for developing varieties suited for processing.

For average fruit weight and fruit volume, the highest cluster mean (Table-19) was shown by cluster V followed by cluster VII, cluster II and cluster I. The inter-cluster distance between the cluster V and VII (D^2=207.860) and cluster VII and cluster I (D^2=192.943) were comparatively high. Hence, the crosses between the genotypes of these respective clusters may be tried for improvement of average fruit weight, which ultimately contribute to the total yield.

For number of fruits per plant, the highest cluster means (Table-19) was shown by the cluster VI, followed by cluster IV. The inter-cluster distance between cluster VI and IV (D^2=106.005) was high. Hence, crosses can be made between the genotypes of these respective clusters for improvement of number of fruits per plant, which will ultimately contribute for yield improvement. Although, early and total yield had not contributed for divergence, the highest cluster mean for these traits (Table-19) was shown by cluster VI followed by cluster II, cluster V and cluster I. The inter-cluster distance between cluster VI and V (D^2=243.700) and cluster II and V (D^2=169.519) were comparatively high and hence crosses between the genotypes of these respective clusters may be tried for improvement in early and total yield.

For plant height at 60 DAT, the highest cluster means (Table-19) was shown by cluster VI, followed by cluster VII, cluster IV and cluster II and cluster V. The highest inter-cluster distance was observed between cluster VI and V (D^2=243.700), followed by cluster IV and V (D^2=222.521), cluster VII and IV (D^2=211.820) and cluster VI and VII (D^2=209.086). Therefore, crosses between the genotypes belonging to these respective clusters may be tried to isolate genotypes with tall plants, which ultimately help in increasing the branches, flowers, fruit set and finally the yield as revealed by correlation studies.

For days to first flowering, days to 50 per cent flowering, days to first fruit set and days to first fruit maturity, the lowest cluster mean (Table-19) was observed in cluster VI followed by cluster V and cluster

IV. The inter-cluster distance between cluster VI and V (D^2=243.700) was comparatively high. Therefore, the crosses between the genotypes KT 49 (cluster VI) and KT 45 (cluster V) may be tried to improve earliness characters.

For per cent fruit set, the highest cluster mean (Table-19) was shown by cluster VII, followed by cluster IV, cluster V and cluster II. The inter-cluster distance was between cluster IV and V (D^2=222.521) followed by cluster VII and IV (D^2=211.82) and cluster VII and V (D^2=207.860). Hence, crosses between the genotypes of these respective clusters can be attempted to improve per cent fruit set to realise higher number of fruits, which ultimately help in yield improvement as supported by correlation studies.

For lycopene content, the highest cluster mean (Table-19) was shown by cluster VI followed by cluster V and cluster II. Inter-cluster distance between cluster VI and V (D^2=243.700) was comparatively high and hence, the hybridisation programme may be employed between the genotypes of these clusters to improve lycopene content, which is a potential anti-oxidant used to counter cancer diseases.

FUTURE LINE OF WORK

1. Number of fruits per plant, yield per plant, average fruit weight, fruit volume and number of seeds per fruit can be improved through direct selection from the existing germplasm stock, as there is high degree of additive components of genetic variance and high GCV and PCV for these traits.

2. Yield can be improved by selecting genotypes for better growth, high fruit set, big fruit size, thick pericarp, more number of fruits per plant, less number of flowers per cluster and fruits per cluster. For improvement of total yield per plant, breeder should give due consideration for early yield per plant, average fruit weight, fruit volume, number of flowers per cluster and number of fruits per cluster, since these traits had high direct and indirect effects on total yield as revealed by genotypic path analysis studies.

3. For recovering improved progenies for growth, yield and quality parameters, crosses can be attempted between the genotypes belonging to cluster V and VI, cluster III and IV, cluster IV and V and cluster IV and VII as revealed by divergence studies.

4. The high yielding genotypes KT 40, KT 17 and KT 46 which had firm fruits can be further assessed for stability before exploiting them for commercial cultivation.

SUMMARY

VI. SUMMARY

The investigations on genetic variability and divergence in tomato were undertaken with the objectives of studying the nature and extent of genetic variability and divergence in tomato germplasm for growth, earliness, flowering, yield and quality parameters and to study the association of growth, earliness, yield and quality parameters in tomato germplasm. The experiment on genetic variability was carried out in the fields of Olericulture Unit of Kittur Rani Channamma College of Horticulture, Arabhavi, Belgaum district of Karnataka involving 67 genotypes. Entries were evaluated in randomised block design with three replications. Various growth, yield and quality parameters recorded were subjected to statistical analysis using SPAR 1 and INDOSTAT softwares.

Variability studies

The variance due to genotypes was highly significant for all the characters studied. Means of genotypes varied greatly for several traits indicating the higher magnitude of variability in the germplasm. High (>40%) genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for number of primary branches at 30 days after transplanting (DAT), number of fruits per plant and number of seeds per fruit. Moderate (10-39%) GCV and PCV were observed for early and total yield, average fruit weight, number of locules per fruit, acidity, TSS : acid ratio, lycopene content and fruit volume. Low (<10%) GCV and PCV were observed for plant height at 30, 60 and 90 days after transplanting (DAT), number of primary branches at 60 and 90 DAT, stem girth at 90 DAT, number of flowers per cluster, days to first flowering, days to 50 per cent flowering, days to first fruit set, days to first fruit maturity, per cent fruit set, number of fruits per cluster, polar and equatorial diameter of the fruit, fruit shape index, pericarp thickness, TSS, fruit pH, ascorbic acid content, fruit density and thousand seed weight.

Higher (>20%) values of genetic advance over mean (GAM) coupled with high (>70%) estimates of heritability (h^2) was observed for characters, viz., number of flowers per cluster, length of the flower, breadth of the flower, days to first flowering, days to 50 per cent flowering, number of fruits per cluster, number of fruits per plant, average fruit weight, polar and equatorial diameter of the fruit, fruit shape index, pericarp thickness, number of locules per fruit, TSS and lycopene content indicating predominance of additive genetic components for these traits. High heritability (>70%) with moderate to low GAM (<20%) was observed for days to first fruit set, fruit density and fruit pH, indicating the prevalence of non-additive genetic components for these traits. Moderate heritability (40-69%) with high GAM (>20%) was observed for characters, viz., early yield per plant, total yield per plant, acidity, TSS : acid ratio and ascorbic acid content. Low heritability

(<40%) with high GAM (>20%) was observed for number of primary branches at 30 DAT. This indicates the importance of additive gene effects for these traits. Moderate heritability (40-69%) with moderate GAM (10-20%) was observed for characters, viz., plant height at 30 DAT and stem girth at 60 DAT. Moderate heritability (40-69%) with low GAM (<10%) was obtained for characters, viz., stem girth at 90 DAT and days to first fruit maturity. Low heritability (<40%) with moderate GAM (10-20%) was observed for the characters, viz., plant height at 60 DAT and number of primary branches at 60 DAT. Low heritability (<40%) coupled with low GAM (<10%) was obtained for characters, viz., plant height at 90 DAT, number of primary branches at 90 DAT and per cent fruit set, indicating higher influence of environment on these traits.

Correlation studies

Number of fruits per plant was positively and significantly associated with plant height at 60 DAT, number of primary branches at 90 DAT, stem girth at 90 DAT, number of fruits per cluster, per cent fruit set and number of flowers per cluster at genotypic level. It was negatively and significantly (at P=0.01) associated with polar diameter of the fruit, fruit volume, average fruit weight, days to first fruit maturity, days to 50 per cent flowering, equatorial diameter of the fruit, pericarp thickness, days to first fruit set and days to first flowering.

Total yield per plant was positively and significantly associated with early yield per plant, equatorial diameter of the fruit, stem girth at 90 DAT, fruit volume, average fruit weight, pericarp thickness, number of primary branches at 90 DAT, polar diameter of the fruit, plant height at 60 DAT, number of seeds per fruit, number of locules per fruit, per cent fruit set and number of fruits per plant at genotypic level. Total yield per plant was negatively and significantly associated with number of flowers per cluster and number of fruits per cluster at both genotypic and phenotypic level.

Path analysis

Early yield per plant had high direct and positive effects on total yield at both genotypic (1.034) and phenotypic (0.948) level. Number of flowers per cluster had high direct and negative effect (-0.218) and high indirect effects through number of fruits per cluster (0.222) and early yield per plant (-0.423) on total yield. Average fruit weight had high direct and positive effects (0.199) and high indirect effects through early yield per plant (0.330) and fruit volume (-0.200) on total yield. Number of fruits per cluster had high direct and positive effects (0.241) on total yield and it also had high indirect and negative effects through early yield per plant (-0.385) and number of flowers per cluster (-0.201) on total yield.

Genetic divergence

A study on genetic diversity was carried out for 67 genotypes using Mahalanobis's D^2 statistic with Tocher's method. The 67 genotypes were grouped into 7 clusters. A maximum of 44 genotypes entered in cluster I, followed by 11 genotypes in cluster II, 7 genotypes in cluster IV, two genotypes in cluster III and the clusters V, VI and VII had solitary genotype in each.

The cluster IV showed maximum intra-cluster distance (D^2=68.998) followed by cluster I (D^2=61.060), cluster II (D^2=57.351) and cluster IV (D^2=23.327). The clusters V, VI and VII had no intra-cluster distance (D^2=0.000) as they possessed single genotype in each.

Based on inter-cluster distance, the maximum divergence was observed between clusters V and VI (D^2=243.700), closely followed by cluster III and V (D^2=239.740), cluster IV and V (D^2=222.521), clusters IV and VII (D^2=211.820), cluster VI and VII (D^2=209.459) and cluster V and VII (D^2=207.860).

Among the 21 characters included for D^2 analysis, number of seeds per fruit contributed maximum (56.63%) to genetic diversity followed by average fruit weight (31.75%), number of fruits per plant (7.64%) and fruit volume (2.04%).

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VII. REFERENCES

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* Originals not seen.

APPENDICES

APPENDIX-I

Chemical properties of soil from experimental site

Sl. No.	Particulars	Olericulture unit	Method adopted
1	Available nitrogen (kg/ha)	280.0	Micro Kjeldahl's method (Black, 1965)
2	Available phosphorus (kg/ha)	28.5	Olsen's method (Jackson, 1967)
3	Available potassium (kg/ha)	440.0	Flame photometer (Jackson, 1967)
4	Soil pH	8.4	pH meter (Jackson, 1967)

APPENDIX-II

Meteorological data recorded during the period of experimentation (2002-2003) from Agricultural Research Station, Arabhavi

Month	Rainfall (mm)	Temperature (°C)		Relative humidity (%)
		Maximum	Minimum	
April 2002	33.00	36.42	25.25	60.50
May 2002	12.60	35.90	26.66	68.85
June 2002	75.20	29.76	24.63	77.54
July 2002	3.60	29.70	22.20	80.74
August 2002	85.60	27.67	24.00	81.04
September 2002	6.60	26.20	23.10	77.15
October 2002	83.80	29.58	23.48	65.48
November 2002	14.20	29.43	21.93	69.48
December 2002	-	28.80	18.83	62.82
January 2003	-	29.45	19.25	60.45
February 2003	-	32.53	21.42	54.68
March 2003	-	34.35	19.48	69.43