LINE x TESTER STUDIES IN SOME GENOTYPES OF TOMATO

Thesis

by

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Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE

in

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(VEGETABLE CROPS)

COLLEGE OF HORTICULTURE
Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan - 173 230 (H.P.) INDIA

2003

Dedicated to my
Dadi Maa
and
Bhaiya

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Senior Vegetable Breeder

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CERTIFICATE-I

This is to certify that the thesis entitled **"Line x Tester Studies in Some Genotypes of Tomato"**, submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (VEGETABLE CROPS)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Kuldeep Kumar Mishra (H-2k-18-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

20.1.03

Place : Nauni, Solan
Dated : January, 2003

(M.C. Thakur)
Chairman
Advisory Committee

CERTIFICATE-II

This is to certify that the thesis entitled **"Line x Tester Studies in Some Genotypes of Tomato"**, submitted by **Mr. Kuldeep Kumar Mishra (H-2k-18-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE** in **HORTICULTURE (VEGETABLE CROPS)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

20.1.03

(M.C. Thakur)
Chairman
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20/1/2003

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'गुरू: ब्रह्मा गुरू: विष्णु गुरू: देवो महेश्वर:
गुरू: साक्षात् परं ब्रह्म तस्मै श्री गुरुवे नम:'

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Needless to say, errors and omissions are mine.

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KMishra

(*Kuldeep Kumar Mishra*)

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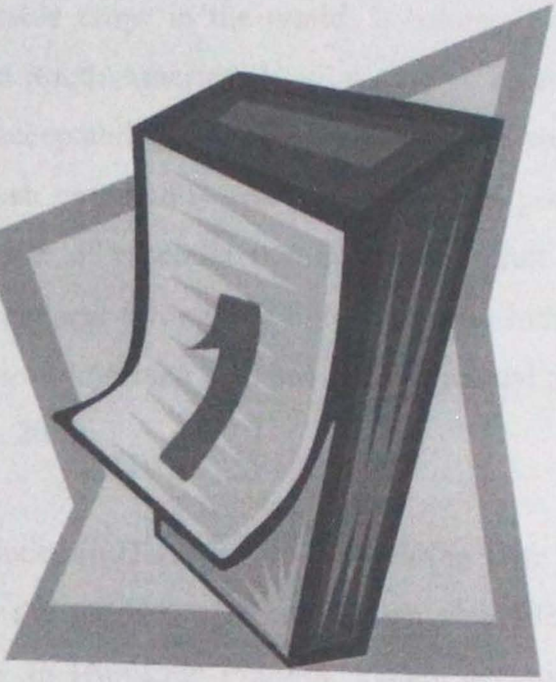


INTRODUCTION

Chapter-1

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and widely grown vegetable crops in the world. It belongs to family Solanaceae. It is native to Central and South America (Vavilov, 1951). Its consumption has reached a new peak with its acceptability for fast food, nutritive value and varied processed vegetables. As a fresh commodity and as a processed product, tomato represent a major vegetable source of essential nutrients. Fresh fruit of tomato are in greater demand round the year and throughout the country. In India, it is a prime vegetable and occupies an area of 4.66 lakh hectares with an annual production of 2.04 million tonnes (Anonymous, 2000).

Tomato produced in Himachal Pradesh during June to November becomes off season vegetable in the markets of North Indian plains fetching very remunerative price to the farmers. In Himachal Pradesh, tomato occupies an area of about 4500 hectares with total annual production of 1,30,900 tonnes (Anonymous, 2000).

The scenario of tomato production in the country has tremendously changed over the past few decades with the increasing popularity of hybrid varieties in commercial cultivation. Keeping in view, the pace with which the hybrids (F_1) of tomato are gaining popularity, it is imperative to obtain such hybrids which have excellent quality and yield stability. The quality refers to many aspects such as colour, size, nutrient content, firmness etc.

The selection of parents in any hybridization programme is of paramount importance. It largely depends upon the character(s), the breeder is looking for in the resultant hybrid. In the pursuit of rendering paramount genetic improvement in crop plants, the plant breeder must possess an adequate knowledge of gene action including combining ability and allied genetic parameters such as heritability associations between yield and quality traits and degree of dominance, because of the fact that *per-se* performance of parent is not always a true indicator of its potential in hybrid combinations. Progeny testing under the field conditions based on phenotypic performance is a more pragmatic approach than laboratory testing to ascertain breeding value of an individual. In the initial stages for the screening of parents, the line x tester approach given by Kempthorne (1957) is helpful in selecting the lines on the basis of their general combining ability. This mating design (line x tester) is useful to select suitable parents from a large number of germplasm. The lines, thus, selected could be used in hybridization programme for developing superior F_1 hybrids.

Realizing the economic potential of the crop, there is urgent need to isolate such breeding lines having desirable horticultural traits and better quality coupled with high yield potential. Therefore, the present investigations were undertaken with the following objectives:

i) To estimate the magnitude of heterosis for yield and horticultural traits.

ii) To evaluate tomato lines for general combining ability (gca) and specific combining ability (sca).

REVIEW OF LITERATURE

Chapter-2

REVIEW OF LITERATURE

Selection of parents and knowledge of gene action of traits to be improved or incorporated are essential for the development of an efficient crop improvement programme. Genetic information, especially about the nature of combining, the type of gene action governing the inheritance of economic characters and the heterosis, is a prerequisite in fixing the suitable parents and designing the appropriate breeding programme. Different methods have been developed to estimate the general and specific combining abilities. The line x tester analysis is one of the important method to study the combining ability and gene action. "Line x tester" mating design as proposed by Kempthorne (1957) is useful to select the suitable parents from a large number of germplasm.

Literature on various aspects of the present investigations has been reviewed under the following heads:

2.1 Heterosis

2.2 Combining ability

2.1 HETEROSIS

Heterosis is defined as superiority of the hybrids over their parents in vegetative, adaptiveness and productivity (Shull, 1908, 1914; East, 1936; Gustafsson, 1946 and Hayes, 1952).

The phenomenon of hybrid vigour in tomato was first discovered by Hedrick and Booth (1907) and later on Wellington (1912), Stuckey (1916) and Frimmel (1925). They reported that tomato hybrids were superior to their respective better parent for yield and its components.

Since the discovery of the phenomenon of heterosis by Shull (1914) tremendous improvement has been made in various aspects of exploitation of heterosis in vegetable crops. Extensive work on different aspects of heterosis in tomato has been carried out over the past several years. Short review of informations pertaining to different characters has been broughtout hereunder:

2.1.1 Days to first flowering

Significant negative heterosis for days to first flowering was reported by Powers (1945) and Reddy and Mathai (1979). Similarly heterosis for early yield was observed by Anbu *et al.* (1980), Ahmed *et al.* (1988), Boe (1988), Nassar, (1988), Kravchenko (1990), Dod *et al.* (1992), Singh and Singh (1993), Pujari and Kale (1994) and Ghosh *et al.* (1997). Positive heterosis for earliness was reported by Singh and Nandpuri (1970) and Tesi *et al.* (1970), whereas, Popova and Mikhaliov (1973), Avdeev (1974), Kurganskaya (1982) and Singh *et al.* (1983) reported the intermediate earliness between those of the parents.

2.1.2 Number of fruits per cluster

Sharma (1988) and Dev *et al.* (1994) observed heterosis over mid and better parent for number of fruits per cluster. Similarly Patgaonkar *et al.* (1993), Pujari and Kale (1994) and Hegazi *et al.* (1995) reported heterosis for number of fruits per cluster.

2.1.3 Number of fruits per plant

Heterosis for number of fruits per plant in tomato have been reported by Chaudhary and Khanna 1972; Reddy and Mathai, 1979; Dixit *et al.*, 1980; Sidhu *et al.*, 1981; Govindarasu *et al.*, 1983; Singh *et al.*, 1983; Jamwal *et al.*, 1984; Ahmed *et al.*, 1988; Araujo and Campos, 1991; Dod *et al.*, 1992; Singh and Singh, 1993; Dev *et al.*, 1994; Hegazi *et al.*, 1995. Whereas, Crill *et al.* (1987) and Valicek and Obeidat (1987) reported number of fruits per plant were intermediate between their parents.

2.1.4 Yield per plant

Increased yield by hybrids in tomato have been reported by Wellington, 1912; William, 1959; Singh and Nandpuri, 1970; Palaniappan *et al.*, 1981; Bhuiyan *et al.*, 1986; Mandal *et al.*, 1989; Dod *et al.*, 1992; Patgaonkar *et al.*, 1993; Dev *et al.*, 1994; Pujari and Kale, 1994; Hegazi *et al.*, 1995.

Heterosis over superior parent for fruit yield was reported by Frimmel (1925), Anbu *et al.* (1980), Sidhu *et al;* (1981). Gotovtseva and Garrish (1987), Ahmed *et al.* (1988), Mandal *et al.* (1992), Bora *et al*, (1993), Singh and Singh (1993), Singh *et al.* (1995) and Ghosh *et al.* (1997).

2.1.5 Fruit weight

The heterosis over better parent for fruit weight was reported by Singh and Nandpuri (1970), Dixit *et al.* (1980), Sidhu *et al*, (1981), Singh *et al.* (1983), Ahmed *et al.* (1988), Araujo and Campos (1991), Reddy and Reddy (1994), Pujari and Kale (1994), Dev *et al.* (1994), Kumar *et al.* (1995) and Singh *et al.* (1995). However, hybrid exhibiting average fruit weight less than mid parental values, indicating negative heterosis was observed by Currence *et al.* (1944), Power (1955), Williams (1959), Shevelev (1976), Alvarez (1985) and Bora *et al.* (1993), whereas, Valicek and Obeidat (1987). Nassar (1988) and Ghosh *et al.* (1997) reported intermediate fruit weight by hybrids.

2.1.6 Fruit size

Powers (1945) reported that hybrids exhibit intermediate fruit size between those of the parents. Quinones (1957) found that in some crosses, fruit size was 2.1 per cent less than the mid value of the parents but in some others it was significantly superior to the better parent. Power (1941) reported that small fruit size was found to be partially dominant to large fruit size and the hybrids were smaller than that of the parents, thus showing negative heterosis. Similarly, Mac Arthar (1941) found that fruit size in the hybrids was intermediate with a tendency towards the smaller fruit size parent and is controlled by polygenes. Butler (1973) reported that fruit size was inherited in a logrithemic manner with partial dominance of small size. Stoner and Thompson (1966) observed that all crosses of small x small fruited strains and some small x large fruited strains showed heterosis in the F_1's with the mean exceeding the better parent. Heterosis for fruit size was also observed by Chaudhary and Khanna

(1972), Banerjee *et al.* (1973) and Govindarasu *et al.* (1983). Boe (1988) reported increase of 110-318 per cent of fruit size. Singh *et al.* (1995) and Ghosh *et al.* (1997) also reported heterosis over better parent for fruit length.

2.1.7 Whole fruit firmness

Wang *et al.* (1995) observed that the whole fruit firmness of hybrids tends to be intermediate between parents and heterosis was observed only in few combinations. Similar observations have been recorded by Sharma (1996), Joshi (1998) and Dobhal (1999).

2.1.8 Pericarp thickness

Pericarp thickness is an important component of whole fruit firmness in tomato. Sidhu *et al.* (1981), Patil and Patil (1988), Bhutani and Kalloo (1991) and Ghosh *et al.* (1997) reported a positive heterosis for pericarp thickness. Heterobeltiosis for this trait was observed by Yadav *et al.* (1991) and Dundi and Mandalageri (1991).

2.1.9 Number of locules per fruit

Roy and Chaudhary (1972) reported lower number of locules in oval and pear shaped varieties like Roma and Italian Red Pear. Sethi and Anand (1986) have recorded the locule number between 4 or 5 among F_1 hybrids.

Dod and Kale (1992) and Ghosh *et al.* (1997) reported heterosis for number of locules per fruit.

2.1.10 Stem end scar size

Joshi (1998) observed positive heterosis for the trait.

2.1.11 Total soluble solids

Total soluble solids have been recognized as the most desirable attribute for processing (Shipton, 1960). Heterosis for total soluble solids was reported by

Allard (1960) stressed the need to study the combining ability in case of self pollinated crops by stating that phenotypically equally promising parents do not always produce superior progenies in segregating generations, while certain combinations mix well and give superior segregants. The information on the nature and magnitude of gene action is of vital importance in breeding a better type. The present review of work done on combining ability and gene action of different characters is given hereunder:

2.2.1 Days to first flowering

Brandolini *et al.* (1974), Singh and Singh (1980), Sonone *et al.* (1986) and Natarajan (1992) reported that the variance component due to gca was higher than sca, indicating the preponderance of additive gene action for the expression of this trait. Whereas, Govindarasu *et al.* (1983), Sharma (1988), Dev (1991), and Cheema *et al.* (1996) reported that the variance component due to sca was higher than that of gca depicting the importance of non-additive gene action for earliness.

2.2.2 Number of fruits per cluster

Peter and Rai (1980) and Vozdova *et al.* (1990) reported that the magnitude of variance due to sca was higher than gca for number of fruits per cluster, indicating major role of non-additive gene action. Whereas, Singh and Singh (1980) and Natarajan (1992) observed higher magnitude of variance due to gca, indicating role of additive gene action for number of fruits per cluster.

2.2.3 Number of fruits per plant

The variance component due to gca was higher than sca depicting preponderance of additive gene action for this trait (Dixit *et al.*, 1980; Singh and Singh, 1980; Swamy and Mathai, 1982; Sonone *et al.*, 1986 and Dev, 1991). Whereas, Rattan and Saini (1976), Anbu *et al.* (1980), Peter and Rai (1980), Govindarasu *et al.* (1983), Patil and Bojappa (1986 b) and Sharma (1988) reported that sca variance was higher than gca, indicating the role of non-additive gene action for number of fruits per plant.

2.2.4 Yield per plant

Higher magnitude of the variance due to gca variance than sca depicting preponderance of additive gene action for this trait was reported by Kalloo *et al.* (1974), Trinklein (1975), Dixit *et al.* (1980), Singh and Singh (1980), Swamy and Mathai, (1982), Dholaria and Dadri (1983), Das *et al.* (1988), Omara *et al.* (1988), Younis *et al.* (1988), Lonkar and Borikar (1988), Khattra *et al.* (1990), Hassan *et al.* (1995), whereas, Nandpuri *et al.* (1974), Rattan and Saini (1976), Peter and Rai (1980), Singh and Singh (1980), Govindarasu *et al.* (1983), Sonone *et al.* (1986), Chandrasekhar and Rao (1989), Dod *et al.* (1990, 1995) reported that sca variance was higher than gca variance, indicating the importance of non-additive gene action for this character.

2.2.5 Fruit weight

Higher gca variance than sca depicting the prepondenance of of additive gene action for fruit weight was reported by Kalloo *et al.* (1974), Mittal *et al.* (1974), Singh and Singh (1980), Swamy and Mathai (1982), Sonone *et al.* (1986), Omara *et al.* (1988) and Farkas (1993).

Patil and Bojappa (1986a) and Chandrasekhar and Rao (1989) reported that variance component due to sca was higher than gca indicating non-additive gene action for fruit weight. Most of the workers hold the opinion that fruit weight in tomato is under additive gene control, with small fruitedness being partially dominant, except a report by Trinklein (1975).

Tomato fruit weight has been reported to be under control of few (Power, 1955) to as many as 20 genetic factors (Brandolini *et al.*, 1974 and Khalil *et al.*, 1986) indicated that average fruit weight was controlled by additive genes with partial dominance for low fruit weight.

2.2.6 Whole fruit firmness

Whole fruit firmness is characterized by high level of alcohol insoluble compounds, outer pericarp thickness and smaller locular area (Kalloo, 1993). El-Sayed *et al.* (1968) reported that firmness is controlled by single gene with dominance effect for soft fruits. Drokin (1977) found the intermediate inheritance for this trait. Al-Fallauji *et al.* (1982) observed the additive gene action. Farkas (1989) found that firmness is controlled by monogenically as well as polygenically. Dominant effects for this character was reported by Bhutani and Kalloo (1991). Similar results were reported by Yadav *et al.* (1991). Khalil *et al.* (1988) observed incomplete and partial dominance, whereas, Farkas (1993) and Wang-Fu *et al.* (1995) reported the significance of gca, indicating the importance of additive gene action for whole fruit firmness. However, Chandrasekhar and Rao (1989) reported the significance of sca effects for whole fruit firmness.

2.2.7 Fruit size

The variance components due to sca has been reported to be higher than that of gca, indicating non-additive gene action for fruit size (Anbu *et al.*, 1980; Govindarasu *et al.*, 1983; Patil and Bojappa, 1986b and Sharma, 1988). Singh and Singh (1980) observed that variance component due to gca was higher than sca, indicating preponderance of additive gene action for this character, whereas, Moya *et al.* (1986) reported that additive and non-additive gene action were equally important for this trait.

2.2.8 Pericarp thickness

Patil and Patil (1988), Dod *et al.* (1995), Fageria *et al.* (1997) and Rai *et al.* (1997) reported that gca variance was more important than that of sca variance for pericarp thickness, whereas, Patil and Bojappa (1986b) and Yadav *et al.* (1991) observed significant gca and sca variance pointing towards the importance of both additive and non-additive gene action for this trait.

2.2.9 Number of locules per fruit

Kalloo *et al.* (1974) and Vijaymohan *et al.* (1986) observed higher magnitude of variance due to sca indicating pre-ponderance of non-additive gene action, whereas, Bhutani and Kalloo (1993) and Dod *et al.* (1995) found that variance due to gca was significant.

2.2.10 Stem and scar size

Significance of non-additive gene effects for the expression of this trait was observed by Joshi (1998).

2.2.11 Total soluble solids

Higher magnitude of variance due to gca than sca depicting that additive gene effects were more important for total soluble solid was reported by Swamy and Mathai (1982), Khalif Allah (1985) and Sonone *et al.* (1986). Whereas, Rattan and Saini (1979), Peter and Rai (1980), Govindarasu *et al.* (1983), Patil and Bojappa (1986a), Patil and Patil (1988), Patgaonkar *et al.* (1993) and Kurian and Peter (1995) observed that variance component due to sca was higher than that of gca indicating preponderance of non-additive gene action for this character.

2.2.12 Plant height

The variance component due to sca was higher than that of gca, indicating non-additive gene action for this trait (Kalloo *et al.*, 1974; Misra and Khanna, 1977; Peter and Rai, 1980; Bhutani, 1981; Govindarasu *et al.*, 1983; Sharma, 1988; Dod *et al.*, 1990; Farkas, 1993; Dev *et al.*, 1994 and Sharma, 1996). Whereas, predominantly additive gene action for plant height was reported by Singh and Singh (1980).

2.2.13 Harvest duration

Joshi (1998) reported that the magnitude of sca variance was more than gca. Similarly, Dobhal (1999) observed significant sca variance for this trait pointing towards the role of non-additive gene action.

MATERIALS AND METHODS

Chapter-3

MATERIALS AND METHODS

3.1 LOCATION AND CLIMATE

The present investigations were carried out at the experimental farm of the Department of Vegetable Crops, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni-Solan (H.P.). The experimental farm is located at an altitude of 1200 m above mean sea level at latitude of 30°50′ N and longitude of 70°80′ E and falls under sub-temperate zone of Himachal Pradesh. The maximum rainfall occurs from June to September. The total rainfall for the crop season was 770.2 mm. Mean temperature varied from 29.88 to 18.3°C, while the relative humidity ranged from 40 to 81 per cent during the growth period. The agro-meteorological data is given in Appendix –I.

3.2 EXPERIMENTAL MATERIAL

The lines and testers were selected from the collection being maintained by the Department of Vegetable Crops. The distinguishing features of different lines, testers and check are presented in Table 1. Out of large collection fifteen lines and three testers were selected and grown during kharif 2001. The crosses were made between lines and testers, using testers as male and lines as female.

3.3 LAYOUT OF THE EXPERIMENT

During summer 2002, the experimental material comprising of 64 entries (45 F_1's, 15 lines, 3 testers and one check) were transplanted on 2nd May in a randomized block design with three replications. Each entry consisting of 12 plants were planted at a spacing of 90x30 cm. Standard cultural practices recommended to raise a good crop of tomato in the mid-hills were followed as mentioned in the package of practices for vegetable crops (Anonymous, 1996).

3.4 OBSERVATIONS RECORDED

3.4.1 Days to first flowering

The number of days taken from the date of transplanting to first flowering in ten randomly selected plants were recorded to work out days to first flowering.

3.4.2 Number of fruits per cluster

Number of fruits in ten plants per cluster were counted to arrive at mean

3.4.3 Number of fruits per plant

Number of fruits were counted at every picking which were finally added to workout the average number of fruits per plant.

3.4.4 Yield per plant

Yield was computed on per plant basis. The pickings were made at half ripe stage. Yield was recorded at every picking in grams and added up for all the pickings to arrive at the total yield per plant.

3.4.5 Fruit weight

Total weight of ten randomly picked mature fruits plucked at every picking was recorded to compute the mean fruit weight in grams.

3.4.6 Whole fruit firmness

An objective value for whole fruit firmness was obtained by the use of fruit pressure tester model FT011 (50 g – 5 kg) manufactured by EFFEGI 48011, Alfonsine-Italy. Vine ripe tomatoes at full pink stage were randomly picked and pressure with plunger after peeling a bit of outer skin was applied and recorded in g per 0.503 cm^2 surface area. Average of ten fruits were taken. This method was earlier used by Fageria (1994).

3.4.7 Fruit length

Polar diameter of ten randomly selected fruits from each treatment was measured and recorded in centimeters and averaged.

Table 1. Source and distinguishing features of tomato cultivars used in the present study

Accession number/variety	Source	Description
Lines		
Sioux	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plant indeterminate (110-150 cm), fruit weight 60-80 g, firm fruited, round, borne in cluster of 3-5.
BT-12	Department of Horticulture, OUAT, Bhubaneshwar	Indeterminate (110-140 cm), fruits round and borne in cluster of 2-3, fruit weight 50-65 g.
T-777	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Semideterminate (85-120 cm), fruit weight 50-60 g, firm fruited and pear shaped, borne in cluster for 3-4.
1794	IIHR, Bangalore	Indeterminate (100-130 cm), fruit weight 100-120 g, round and borne in cluster of 3-4
2694	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Semideterminate (90-120 cm), fruit weight 70-85 g, round and borne in cluster of 2-4.
AI-14	AVRDC, Taiwan	Indeterminate (100-125 cm), fruit weight 60-75 g, round and borne in cluster of 2-3.
V-16	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Determinate (90-110 cm), fruit weight 65-80 g, round with prominent beak, borne in cluster of 2-3
FT-13	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Indeterminate (100-140 cm), fruit weight 70-85 g, round and borne in cluster of 3-4.
Sel-6	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Indeterminate (100-135 cm), fruit weight 60-80 g, round, borne in cluster of 2-4.
S-12	PAU Ludhiana	Determinate (50-75 cm), fruit weight 70-85 g, round, borne in cluster of 2-3.
101	RHRS, Kandaghat, Himachal Pradesh	Plants determinate (70-100 cm), fruit weight 70-80 g, round, borne in cluster of 2-3.
Pepsi-92	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plant determinate (50-90 cm), fruit weight 60-75 g, round, borne in cluster of 3-4.
Solan Gola	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plants indeterminate (100-135 cm), fruit weight 70-85 g, round, borne in cluster of 2-4.
Money maker	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plants indeterminate (100-130 cm), fruit weight 45-60 g, round, borne in cluster of 3-4.
FT-9	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plants indeterminate (80-110 cm), fruit weight 70-80 g, round, borne in cluster of 2-3.
Testers		
Solan Vajr	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plants indeterminate (120-150 cm), fruit weight 70-90 g, firm fruited and round, borne is cluster of 2-4.
FT-5	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plants indeterminate (155-190 cm), fruit weight 80-100 g, round, borne in cluster 3-4.
603	Department of Vegetable Crops Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan	Plants determinate (40-70 cm), round fruited, borne in cluster of 2-3, fruit weight 70-85 g.
Check		
Naveen-2000	Indo American Hybrid Seeds Company, Bangalore	Indeterminate, fruit weight 80-100 g, borne in cluster of 5-6, fruits are oblong and highly firm

3.4.8 Fruit breadth

Equatorial diameter of ten randomly selected fruits was measured and recorded in centimeters and averaged to work out fruit breadth.

3.4.9 Pericarp thickness

Randomly selected fruits were cut transversely into two pieces and pericarp thickness was measured with the help of ordinary transparent scale and recorded in millimeters. Mean was computed on the average of ten fruits.

3.4.10 Number of locules per fruit

The fruit was transversely cut with sharp knife and number of locules per fruit were calculated. Average of ten fruits was taken.

3.4.11 Stem end scar size

Diameter of stem end scar was measured in millimeters with an ordinary scale after cutting the fruits longitudinally.

3.4.12 Total soluble solids

The ripe fruits were crushed and their juice passed through a double layer of fine mesh cheese cloth. A drop of juice was placed on the plate of hand refractometer (0-32%, ERMA, Japan) and the reading was noted. A mean of five readings was taken in every replication.

3.4.13 Plant height

Plant height of ten randomly selected plants was measured from the base of plant to the highest tip at the end of the crop season.

3.4.14 Harvest duration

The period from first marketable picking to last marketable picking formed the basis for ascertaining the harvest duration in days.

3.5 STATISTICAL ANALYSIS

The mean values for all the characters in each replication were subjected to statistical analysis at Computer Centre, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan for estimating different values of characters studied.

Analysis of variance (ANOVA)

The analysis of variance for randomized block design were computed as suggested by Panse and Sukhatme (1967) to test the genetic differences among the generation mean for every character.

$$P_{ij} = u + g_i + b_j + e_{ij}$$

where ,

P_{ij} = phenotypic observation of ith genotype in jth replication

u = general population mean

g_i = effect of ith genotype

b_j = effect of jth replication

e_{ij} = random error associated with ith genotype in jth replication.

On the basis of the linear model the analysis of variance was done as follows:

Source of variance	Degree of freedom (df)	Mean sum of squares (MSS)	Expectation of mean of squares	F ratio
Replication	(b-1)	Mr	$\sigma^2e + g\sigma^2b$	Mr/Me
Genotypes	(g -1)	Mg	$\sigma^2e + b\sigma^2g$	Mg/Me
Error	(b-1) (g-1)	Me	σ^2g	

$$\text{Genotypic variance } (\sigma^2g) = \frac{Mg-Me}{b}$$

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

where,

b = Number of replications

g = Number of genotypes

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

$\sigma^2 g$ = Variance due to genotype

$\sigma^2 e$ = Experimental error variance

From this analysis, the following standard errors were calculated where the F-test was significant.

$$\text{Standard error for different genotype mean SE(d)} = \frac{2\ Me}{b}$$

The critical difference at 5 per cent level significance was obtained by multiplying standard error of difference by t-value for error degree of freedom.

Estimation of Heterosis

Heterosis was measured for all the characters as the proportion of deviation of F_1 value from the value of better parent and Naveen–2000 and expressed in percentage.

$$\text{Heterosis (\%) over BP} = \frac{\overline{F}_1 - \overline{BP}}{BP} \times 100$$

Where,

$\overline{F}_1$ = Mean value of the F_1

$\overline{BP}$ = Mean value of better parent

Similarly, per cent increase/decrease over hybrid Naveen–2000 were calculated as:

$$(N) = \frac{\overline{F}_1 - \overline{N}}{N} \times 100$$

Where,

$\overline{N}$ = Mean of standard hybrid Naveen -2000

SE (H_1) = $(2Me/r)^{1/2}$

SE (N_2) = $(2Me/r)^{1/2}$

Where,

Me = Error mean square of the analysis using parents and F_1's

r = Number of replication

Significance of the F_1 means from the better parent (H_1) and Naveen –2000 (N_2) check was tested by t-test

$$t(H_1) = \frac{\bar{F}_1 - \bar{BP}}{SE\ (H_1)}$$

$$t(N_2) = \frac{\bar{F}_1 - \bar{N}_2}{SE\ (N_2)}$$

The calculated t-value was compared with tabulated value at error degree of freedom.

Combining ability

The line x tester data were subjected to analysis of variance advanced by Kempthorne (1957). This analysis gives an estimate for variance due to general combining ability of females, males and the interaction of males and females in the crosses. The actual analysis for combining ability variance, their effects were carried out by the methods given by Singh and Chaudhary (1985). All the characters were analysed separately.

The Model

The analysis for combining ability was based on the following model:

Pijk = m + gii + gjj + sij + rk + eijk

Where,

Pijk	=	phenotype of the ijkth observation
m	=	general mean
gii	=	general combining ability of female parent
sij	=	specific combining ability of cross between ith female and jth male
gjj	=	general combining ability of male parent.
rk	=	the kth replication effect
eijk	=	random error effect associated with ijkth observation.
i	=	number of female parent = 1,2 ….f(f=15)
j	=	number of male parent = 1,2 ….m(m=3)
k	=	number of replication = 1,2 ….r(r=3)

Based upon the above model, the following ANOVA was set up:

Analysis of variance for combining ability

Source of variance	df	MSS	Expected mean sum of squares
Blocks (Replications)	r-1		$\sigma^2 e+p.\sigma^2 r$
Females	f-1	M_1	$\sigma^2 e+r.\sigma^2 fm + rm.\ \sigma^2 f$
Males	m-1	M_2	$\sigma^2 e+r.\sigma^2 fm + rf.\sigma^2 m$
Females x males	(f-1) (m-1)	M_3	$\sigma^2 e+r.\sigma^2 fm^2$
Error	(r-1) (fm-1)	M_4	$\sigma^2 e$
Total	(rfm-1)		

Where,

f, m and r represent the number of females, males and replications, respectively.

$\sigma^2 e$ = Error variance among individuals from the same mating

$\sigma^2 f$ = Progeny variance arising from the differences among female parents.

$\sigma^2 m$ = Progeny variance arising from the differences among the male parents

$\sigma^2 fm$ = Progeny variance arising from the interaction of the contribution of the male and female parents.

Estimation of variance components of gca and sca

Estimation of variance components was done by the normal procedure of equating the expectation of mean squares to the actual mean squares and solving the resulting simultaneous equations for the various components. The estimates were as follows:

$$\sigma^2 f = \frac{M_1 - M_2}{rm}$$

$$\sigma^2 m = \frac{M_2 - M_3}{rf}$$

$$\sigma^2 f\,m = \frac{M_3 - M_4}{r}$$

$$\sigma^2 gca\ (\sigma^2 g) = \sigma^2 f + \sigma^2 m$$

$$\sigma^2 sca\ (\sigma^2 s) = \frac{M_3 - M_4}{R}$$

Combining ability effects

The general and specific combining ability effects were obtained from two ways table of females v/s males in which each figure was a pooled data over replications (plot totals). The combining ability effects were estimated as follows.

$$u = \frac{X......}{r.f.m}$$

Where,

u = Over all general effect common to all hybrids in all the replication.

X...... = The total of all hybrids

$$\sum_{i=1}^{f} \quad E_{j=1}^{m} \quad E_{k=1}^{r}$$

Estimation of gca effects

Lines

$$gi = \frac{X_{i.....}}{r.m} - \frac{X......}{k.f.m}$$

Where,

$$Xi = \sum_{j=1}^{m} \sum_{k=1}^{r} Xijk$$

Total of i^{th} female parent over all male parents and replications.

Check: $\sum gi = 0$

Testers

$$g_j = \frac{X.j}{r.f} - \frac{X....}{r.f.m}$$

Where,

$$Xj = \sum_{i=1}^{f} \sum_{k=1}^{r} Xijk$$

= total of j^{th} male parent over all female parents and replications.

Check: $\sum gj = 0$

Estimation of sca effects

$$Sij = \frac{Xij}{r} - \frac{X_{i}....}{r.m} - \frac{Xj}{r.f} + \frac{X....}{r.f.m}$$

Where,

$$Xij = \sum_{k=1}^{r} Xijk$$

$=$ ijth combination, totals over all replications

Check:

$$\sum_{i=1}^{f} Sij = \sum_{j=1}^{m} Sij = \sum_{i=1}^{f} \sum_{j=1}^{m} Sij = 0$$

Standard error for combining ability effects

The standard error of effects was calculated as square root of the variance of effects. The variance of the various effects were calculated as follows.

gca effect of lines

$$Var\ (gi) = \frac{\sigma^2 e(f\text{-}1)}{r.f.m}$$

$$Var\ (gi\text{-}\ gi) = \frac{2.\sigma^2 e}{r.m} \qquad j \neq i$$

gca effect of testers

$$Var\ (gi) = \frac{\sigma^2 e(m\text{-}1)}{r.f.m}$$

$$Var\ (gi) = \frac{2.\sigma^2 e}{r.f} \qquad j \neq i$$

sca effect of crosses

$$Var\ (sij) = \frac{\sigma^2 e\ (f\text{-}1).\ (m\text{-}1)}{r.f.m} \qquad i \neq j$$

$$Var\ (sij\text{-}\ ski) = \frac{2\sigma^2 e\ (f\text{-}1)}{r.f} \qquad j \neq k$$

$$Var(sij-skj) = \frac{2\sigma^2 e(m-1)}{r.m} \qquad i \neq k$$

Critical differences

The critical differences (CD) were calculated by multiplying respective standard error with 't' value at 5 per cent level of significance and error degree of freedom.

EXPERIMENTAL RESULTS

Chapter-4

EXPERIMENTAL RESULTS

The present investigations were carried out to estimate the magnitude of heterotic response and combining ability in a line x tester crosses involving fifteen lines and three testers for the important horticultural and quality attributes in tomato.

4.1 HETEROSIS

The mean performance of lines, testers, crosses and magnitude of heterosis over better parent and check (Naveen-2000) for various characters is presented in Tables 2 to 15. The results obtained for different traits are described as under:

4.1.1 Days to first flowering

Days taken to appear first flower in lines ranged from 32.33 (Solan Gola) to 38.00 (FT-9). Whereas, testers Solan Vajr, FT-5 and 603 took 35.67, 34.33 and 31.50 days, respectively. Amongst the hybrids days to first flowering varied from 30.67 to 38.33. Cross (S-12 x Solan Vajr) being the earliest while Solan Gola x FT-5 was the last in flowering.

The heterobeltiotic effects of days to first flowering ranged from –10.35 (S-12 x Solan Vajr) to 21.52 (V-16 x 603) per cent. The per cent increase or decrease for earliness over check (Naveen-2000) ranged from –4.81 (S-12 x Solan Vajr) to 18.96 (Solan Gola x FT-5). Out of fourty five hybrid combinations studied only two were early in flowering as compared to check (Naveen-2000), whereas the crosses V-16 x FT-5, 101 x FT-5 and 101 x 603 were statistically at par in days to first flower.

4.1.2 Number of fruits per cluster

Mean number of fruits per cluster in lines varied from 2.40 (BT-12) to 3.40 (Money Maker) and in hybrids from 2.60 (Sel-6 x Solan Vajr) to 4.57 (Money Maker x FT-5). The testers Solan Vajr, FT-5 and 603 had 2.56, 3.37 and 2.57 number of fruits per cluster, respectively. The line Money Maker had significantly higher number of fruits per cluster than the others except FT-13.

The heterotic effect ranged from –18.99 (BT-12 x FT-5) to 58.98 (AI-14 x Solan Vajr) per cent. Among fourty five cross combination only thirteen crosses exhibited significant positive heterosis over better parent for this trait. When compared with hybrid Naveen–2000 (5.23), none of the cross excelled for this trait. However, the cross Solan Gola x 603 showed statistical proximity with the check.

4.1.3 Number of fruits per plant

Among lines maximum number of fruits per plant was observed in Money Maker (25.43) which was statistically superior to all other lines. Minimum number (14.33) was recorded in Pepsi-92. The testers Solan Vajr, FT-5 and 603 had 17.67, 15.17 and 13.67 fruits per plant, respectively. Among F_1's, the cross 1794 x FT-5 had maximum number (27.33) of fruits, while Sioux x 603 showed minimum number (14.00) of fruits per plant. Cross combination 1794 x FT-5 was statistically at par with 101 x FT-5, Money Maker x 603, FT-9 x FT-5, FT-9 x 603, FT-9 x Solan Vajr and check Naveen –2000.

The range for heterosis over better parent was –18.34 (T-777 x FT-5) to 72.65 (1794 x FT-5) per cent. Only three hybrid combinations exhibited positive heterosis over check Naveen-2000.

4.1.4 Yield per plant (gm)

The yield per plant for the lines varied from 938.36 (Pepsi-92) to 1591.60 gm (1794). The testers, Solan Vajr, FT-5 and 603 recorded yield per plant of 1303.67, 1307.24 and 1018.67 gm, respectively. Amongst the F_1's the mean performance ranged from 1076.67 (Solan Gola x 603) to 2316.12 g (1794 x FT-5). The cross 1794 x FT-5 was statistically at par with FT-9 x FT-5 and check Naveen-2000. Out of 45 cross combination only four were statistically at par with check Naveen-2000. The heterobeltiosis effects over better parent ranged from –7.42 (Money Maker x FT-5) to 59.98 per cent being highest in AI-14 x 603. Twenty-five crosses showed significantly positive heterosis over better parent.

Table 2. **Mean performance of parents, crosses, check and heterotic response for days to first flowering**

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	36.33		
2. BT-12	37.00		
3. T-777	35.00		
4. 1794	37.67		
5. 2694	35.67		
6. AI-14	37.67		
7. V-16	36.21		
8. FT-13	35.67		
9. Sel-6	35.33		
10. S-12	34.21		
11. 101	36.67		
12. Pepsi-92	34.67		
13. Solan Gola	32.33		
14. Money Maker	33.65		
15. FT-9	38.00		
TESTERS			
16. Solan Vajr	35.67		
17. FT-5	34.33		
18. 603	31.50		
CROSSES			
1. SIOUX x FT-5	34.33	0.00	6.55
2. SIOUX x 603	34.33	8.98	6.55
3. SIOUX x Solan Vajr	36.33	1.85	12.76
4. BT-12 x FT-5	34.67	0.99	7.60
5. BT-12 x 603	37.33	18.51*	15.86*
6. BT-12 x Solan Vajr	37.33	4.65	15.86*
7. T-777 x FT-5	35.00	1.95	8.63
8. T-777 x 603	35.67	13.24	10.71
9. T-777 x Solan Vajr	34.67	-9.43	7.60
10. 1794 x FT-5	35.33	2.91	9.65
11. 1794 x 603	36.00	14.29*	11.73
12. 1794 x Solan Vajr	36.67	2.80	13.81
13. 2694 x FT-5	33.21	-3.26	3.07
14. 2694 x 603	35.00	12.90	8.63
15. 2694 x Solan Vajr	36.33	1.85	12.76

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	36.33	5.83	12.76
17. AI-14 x 603	36.10	16.45*	12.04
18. AI-14 x Solan Vajr	36.33	1.85	12.76
19. V-16 x FT-5	32.52	5.27	0.93
20. V-16 x 603	37.67	21.52*	10.71*
21. V-16 x Solan Vajr	33.67	-5.61	10.71*
22. FT-13 x FT-5	35.33	2.91	9.65
23. FT-13 x 603	34.33	10.74	6.55
24. FT-13 x Solan Vajr	32.17	-9.81	-0.16
25. Sel-6 x FT-5	35.33	2.91	9.65
26. Sel-6 x 603	35.67	15.06	10.71
27. Sel-6 x Solan Vajr	35.33	0.00	9.65
28. S-12 x FT-5	34.33	0.35	6.55
29. S-12 x 603	33.33	7.52	3.45
30. S-12 x Solan Vajr	30.67	-10.35	-4.81
31. 101 x FT-5	32.31	-5.88	0.28
32. 101 x 603	32.33	4.29	0.34
33. 101 x Solan Vajr	32.98	-7.54	2.36
34. Pepsi-92 x FT-5	32.67	-4.84	1.40
35. Pepsi-92 x 603	35.00	12.90	8.63
36. Pepsi-92 x Solan Vajr	35.33	1.90	9.65
37. Solan Gola x FT-5	38.33	18.56*	18.96*
38. Solan Gola x 603	36.47	15.78*	13.19
39. Solan Gola x Solan Vajr	34.67	7.34	7.60
40. Money Maker x FT-5	35.67	6.00	10.71
41. Money Maker x 603	35.33	12.16	9.65
42. Money Maker x Solan Vajr	36.67	8.97	13.81
43. FT-9 x FT-5	35.67	3.90	10.71
44. FT-9 x 603	37.33	18.51*	15.86*
45. FT-9 x Solan Vajr	38.22	7.15	18.62*
CHECK			
46. Naveen-2000	32.22		
SE(d)$\pm$	2.44		
$CD_{0.05}$	4.80		

Table 3. Mean performance of parents, crosses, check and heterotic response for number fruits per cluster

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	3.10		
2. BT-12	2.40		
3. T-777	3.20		
4. 1794	3.03		
5. 2694	2.93		
6. AI-14	2.53		
7. V-16	2.60		
8. FT-13	3.33		
9. Sel-6	2.77		
10. S-12	2.63		
11. 101	2.67		
12. Pepsi-92	3.13		
13. Solan Gola	2.97		
14. Money Maker	3.40		
15. FT-9	2.80		
TESTERS			
16. Solan Vajr	2.56		
17. FT-5	3.37		
18. 603	2.57		
CROSSES			
1. SIOUX x FT-5	3.30	-2.08	-36.90*
2. SIOUX x 603	2.97	-4.19	-43.21*
3. SIOUX x Solan Vajr	2.87	-7.42	-45.12*
4. BT-12 x FT-5	2.73	-18.99*	-47.80*
5. BT-12 x 603	3.53	37.35*	-32.50*
6. BT-12 x Solan Vajr	3.13	22.27	-40.15*
7. T-777 x FT-5	3.17	-5.93	-39.38*
8. T-777 x 603	3.33	4.06	-36.33*
9. T-777 x Solan Vajr	3.40	6.25	-34.99*
10. 1794 x FT-5	3.20	-5.04	-38.81*
11. 1794 x 603	2.73	-9.90	-47.80*
12. 1794 x Solan Vajr	3.00	-0.99	-42.64*
13. 2694 x FT-5	3.23	-4.15	-38.24*
14. 2694 x 603	3.00	2.39	-42.64*
15. 2694 x Solan Vajr	2.73	-6.83	-47.80*

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	3.07	-8.90	-41.30*
17. AI-14 x 603	3.47	35.02*	-33.65*
18. AI-14 x Solan Vajr	4.07	58.98*	-22.18*
19. V-16 x FT-5	3.33	-1.19	-36.33*
20. V-16 x 603	2.87	10.38	-45.12*
21. V-16 x Solan Vajr	3.47	33.46*	-33.65*
22. FT-13 x FT-5	3.67	8.90	-29.82*
23. FT-13 x 603	3.43	3.00	-34.42*
24. FT-13 x Solan Vajr	3.93	18.02	-24.86*
25. Sel-6 x FT-5	3.47	2.97	-33.65*
26. Sel-6 x 603	3.50	26.35*	-33.08*
27. Sel-6 x Solan Vajr	2.60	-6.14	-50.29*
28. S-12 x FT-5	3.00	-10.98	-42.64*
29. S-12 x 603	3.43	30.42*	-34.42*
30. S-12 x Solan Vajr	3.40	29.28*	-34.99*
31. 101 x FT-5	2.97	-11.87	-43.21*
32. 101 x 603	3.73	39.70*	-28.69*
33. 101 x Solan Vajr	3.15	17.98	-39.77*
34. Pepsi-92 x FT-5	3.07	-8.90	-41.30*
35. Pepsi-92 x 603	2.73	-12.78	-47.80*
36. Pepsi-92 x Solan Vajr	3.40	8.63	-34.99*
37. Solan Gola x FT-5	3.87	14.84	-26.00*
38. Solan Gola x 603	3.25	9.43	-37.86
39. Solan Gola x Solan Vajr	3.15	6.06	-39.77*
40. Money Maker x FT-5	4.57	34.41*	-12.62*
41. Money Maker x 603	3.20	-5.88	-38.81*
42. Money Maker x Solan Vajr	3.27	-3.82	-37.48*
43. FT-9 x FT-5	4.40	30.56*	-15.87*
44. FT-9 x 603	3.47	23.90*	-33.65*
45. FT-9 x Solan Vajr	4.13	47.50*	-21.03*
CHECK			
46. Naveen-2000	5.23		
SE(d)±	0.30		
$CD_{0.05}$	0.59		

Table 4. Mean performance of parents, crosses, check and heterotic response for number of fruits per plant

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	15.97		
2. BT-12	18.33		
3. T-777	19.67		
4. 1794	15.83		
5. 2694	15.33		
6. AI-14	14.67		
7. V-16	18.67		
8. FT-13	17.33		
9. Sel-6	16.67		
10. S-12	20.83		
11. 101	18.33		
12. Pepsi-92	14.33		
13. Solan Gola	16.70		
14. Money Maker	25.43		
15. FT-9	19.10		
TESTERS			
16. Solan Vajr	17.67		
17. FT-5	15.17		
18. 603	13.67		
CROSSES			
1. SIOUX x FT-5	24.00	50.28*	-2.16
2. SIOUX x 603	14.00	-12.33	-42.93*
3. SIOUX x Solan Vajr	17.33	-1.92	-29.35*
4. BT-12 x FT-5	21.67	-18.22*	-11.66
5. BT-12 x 603	19.33	5.46	-21.20*
6. BT-12 x Solan Vajr	19.67	7.31	-19.81*
7. T-777 x FT-5	19.33	-17.29	-21.20*
8. T-777 x 603	21.67	10.17	-11.66
9. T-777 x Solan Vajr	19.77	0.51	-19.40*
10. 1794 x FT-5	27.33	72.65*	11.41
11. 1794 x 603	20.33	28.43*	-17.12*
12. 1794 x Solan Vajr	23.67	33.96*	-3.51
13. 2694 x FT-5	20.33	32.62*	-17.12*
14. 2694 x 603	20.67	34.83*	-15.74*
15. 2694 x Solan Vajr	18.67	5.66	-23.89*

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	18.53	22.15*	-24.46*
17. AI-14 x 603	21.33	45.40*	-13.05*
18. AI-14 x Solan Vajr	19.33	9.39	-21.20*
19. V-16 x FT-5	23.33	24.96*	-4.89
20. V-16 x 603	16.67	-10.71	-32.04
21. V-16 x Solan Vajr	17.33	-7.18	-29.35
22. FT-13 x FT-5	22.67	30.81*	-7.58
23. FT-13 x 603	17.88	3.17	-27.11*
24. FT-13 x Solan Vajr	18.67	5.66	-23.89*
25. Sel-6 x FT-5	21.67	29.99*	-11.66*
26. Sel-6 x 603	18.67	12.00	-23.89*
27. Sel-6 x Solan Vajr	17.87	1.13	-27.15*
28. S-12 x FT-5	20.67	-0.77	-15.74*
29. S-12 x 603	21.33	2.40	-13.05*
30. S-12 x Solan Vajr	18.68	-10.32	-23.85*
31. 101 x FT-5	24.33	32.73*	-0.82
32. 101 x 603	20.33	10.91	-17.12*
33. 101 x Solan Vajr	19.67	7.31	-19.81*
34. Pepsi-92 x FT-5	19.52	28.68*	-20.42*
35. Pepsi-92 x 603	18.33	27.91*	-25.28*
36. Pepsi-92 x Solan Vajr	22.33	26.37*	-8.97
37. Solan Gola x FT-5	18.33	9.76	-25.28*
38. Solan Gola x 603	14.33	-14.19	-41.58*
39. Solan Gola x Solan Vajr	16.33	-7.58	-33.43*
40. Money Maker x FT-5	23.43	-7.86	-4.48
41. Money Maker x 603	24.21	-4.80	-1.30
42. Money Maker x Solan Vajr	23.52	-7.51	-4.12
43. FT-9 x FT-5	26.11	36.70*	6.44
44. FT-9 x 603	25.67	34.40*	4.65
45. FT-9 x Solan Vajr	24.33	27.38*	-0.82
CHECK			
46. Naveen-2000	24.53		
SE(d)±	1.59		
$CD_{0.05}$	3.13		

Table 5. Mean performance of parents, crosses, check and heterotic response for fruit yield (g)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	1029.33		
2. BT-12	1015.27		
3. T-777	1191.67		
4. 1794	1591.60		
5. 2694	1223.33		
6. AI-14	966.67		
7. V-16	1266.67		
8. FT-13	1228.33		
9. Sel-6	1148.83		
10. S-12	1516.67		
11. 101	1403.33		
12. Pepsi-92	938.36		
13. Solan Gola	1228.67		
14. Money Maker	1209.67		
15. FT-9	1476.34		
TESTERS			
16. Solan Vajr	1303.67		
17. FT-5	1307.24		
18. 603	1018.67		
CROSSES			
1. SIOUX x FT-5	1856.33	42.00*	-15.15*
2. SIOUX x 603	1186.67	15.29	-45.76*
3. SIOUX x Solan Vajr	1512.87	16.05*	-30.85*
4. BT-12 x FT-5	1605.03	22.78*	-26.63*
5. BT-12 x 603	1503.88	47.63*	-31.26*
6. BT-12 x Solan Vajr	1318.33	1.12	-39.74*
7. T-777 x FT-5	1342.14	2.67	-38.65*
8. T-777 x 603	1268.33	6.43	-42.02*
9. T-777 x Solan Vajr	1401.20	7.48	-35.95*
10. 1794 x FT-5	2316.12	45.52*	5.87
11. 1794 x 603	1541.68	-3.14	-29.53*
12. 1794 x Solan Vajr	1824.83	14.65*	-16.59*
13. 2694 x FT-5	1845.10	41.14*	-15.66*
14. 2694 x 603	1632.67	33.46*	-25.37*
15. 2694 x Solan Vajr	1598.33	22.60*	-26.94*

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	1554.50	18.91*	-28.94*
17. AI-14 x 603	1629.68	59.98*	-25.51*
18. AI-14 x Solan Vajr	1540.67	18.18*	-29.58*
19. V-16 x FT-5	1704.67	30.40*	-22.08*
20. V-16 x 603	1278.83	0.96	-41.54*
21. V-16 x Solan Vajr	1361.74	4.45	-37.76*
22. FT-13 x FT-5	1891.42	44.69*	-13.54*
23. FT-13 x 603	1355.95	10.39	-38.02*
24. FT-13 x Solan Vajr	1524.34	16.93	-30.32*
25. Sel-6 x FT-5	1616.67	23.67*	-26.10*
26. Sel-6 x 603	1487.00	29.44*	-32.03*
27. Sel-6 x Solan Vajr	1368.67	4.99	-37.44*
28. S-12 x FT-5	1615.93	6.54	-26.14*
29. S-12 x 603	1695.63	11.80	-22.49*
30. S-12 x Solan Vajr	1490.00	-1.76	-31.89*
31. 101 x FT-5	2004.27	42.82*	-8.39
32. 101 x 603	1592.67	13.49	-27.20*
33. 101 x Solan Vajr	1568.67	11.78	-28.30*
34. Pepsi-92 x FT-5	1608.12	23.02*	-26.49*
35. Pepsi-92 x 603	1385.67	36.03*	-36.66*
36. Pepsi-92 x Solan Vajr	1758.69	34.90*	-19.61*
37. Solan Gola x FT-5	1243.67	-4.86	-43.15*
38. Solan Gola x 603	1076.67	12.37	-50.79*
39. Solan Gola x Solan Vajr	1310.50	0.52	-40.10*
40. Money Maker x FT-5	1210.25	-7.42	-44.68*
41. Money Maker x 603	1842.66	50.67*	-16.69*
42. Money Maker x Solan Vajr	1848.62	41.80*	-15.50*
43. FT-9 x FT-5	2230.23	51.06*	1.94
44. FT-9 x 603	2085.23	41.24*	-4.68
45. FT-9 x Solan Vajr	1936.50	31.17*	-11.48*
CHECK			
46. Naveen-2000	2187.71		
SE(d)±	101.81		
$CD_{0.05}$	200.46		

4.1.5 Fruit weight (g)

The mean fruit weight in the lines varied from 47.57 gm (Money Maker) to 100.43 g (1794). The testers Solan Vajr, FT-5 and 603 had fruit weight of 73.67, 85.83 and 74.32 gm, respectively. The range for F_1's varied from 58.43 (T-777 x 603) to 90.61 gm (2694 x FT-5). The crosses 2694 x 603, Sioux x Solan Vajr, 2694 x Solan Vajr and FT-9 x FT-5 had significantly higher fruit weight compared to other crosses. The heterosis over better parent ranged from –28.06 (Money Maker x FT-5) to 18.42 (Sioux x Solan Vajr) per cent. None of F_1's recorded significant positive heterosis for fruit weight over better parent, while nineteen crosses exhibited negative heterosis. None of F_1's exhibited significant increase in fruit weight over the check Naveen–2000 (89.51 g).

4.1.6 Whole fruit firmness (g/0.503 cm^2)

A perusal of the data (Table 7) revealed that the fruit firmness ranged from 743.33 (Money Maker) to 1133.00 g/0.503 cm^2 (S-12) in lines. The tester FT-5 had more whole fruit firmness (1628.67 g/0.503 cm^2) than Solan Vajr (1081.00 g/0.503 cm^2) and 603 (905.33 g/0.503 cm^2). Amongst the F_1's, 1794 x FT-5 (1604.33 g/0.503 cm^2) exhibited highest whole fruit firmness, while the cross Money Maker x Solan Vajr (829.33 g/0.503 cm^2) had lowest whole fruit firmness. The heterotic effects over the better parent ranged from –26.14 (FT-9 x FT-5) to 10.94 (BT-12 x 603) per cent. Except one cross 1974 x FT-5 all other cross combinations had lesser whole fruit firmness than Naveen–2000 (1501.33 g/0.503 cm^2).

4.1.7 Fruit length (cm)

It is evident from Table –8 that the mean fruit length in the lines varied from 2.85 to 5.59 cm, the lowest being in Money Maker and highest in Pepsi-92. The tester Solan Vajr, FT-5 and 603 showed 5.32 cm, 4.06 cm and 4.99 cm fruit length, respectively. Amongst F_1's, it ranged from 4.07 (V-16 x Solan Vajr) to 5.54 cm (Solan Gola x 603).

The heterobeltiotic effects of fruit length ranged from –23.50 to 13.30 per cent. The minimum was recorded in cross combination V-16 x Solan Vajr and maximum in Solan Gola x 603. All the hybrid combinations recorded less fruit length than hybrid Naveen -2000 (5.89 cm) which was statistically at par with twelve cross combinations.

4.1.8 Fruit breadth (cm)

The line V-16 had maximum fruit breadth of 5.83 cm and Money Maker had the minimum of 3.57 cm. The testers Solan Vajr, FT-5 and 603 had 5.83 cm, 4.92 cm and 5.48 cm fruit breadth, respectively. Amongst F_1's, it was highest in cross combination 1794 x FT-5 (5.82 cm) and lowest in cross S-12 x Solan Vajr (4.20 cm).

The heterotic effects for fruit breadth over better parents ranged from –27.96 (S-12 x Solan Vajr) to 17.07 (2694 x FT-5) per cent. Only six cross combinations exhibited higher fruit breadth than check Naveen–2000 (5.41 cm), however, all were statistically at par with Naveen–2000. Maximum increase of 7.58 per cent over Naveen-2000 was recorded by cross 1794 x FT-5.

4.1.9 Pericarp thickness (mm)

The pericarp thickness in lines ranged from 2.88 (Money Maker) to 6.47 mm (Pepsi-92). The tester Solan Vajr, FT-5 and 603 showed 6.53 mm, 6.70 mm and 5.68 mm pericarp thickness, respectively. Amongst the F_1's, the pericarp thickness was highest in the cross FT-13 x Solan Vajr (7.40 mm) and it was lowest in FT-13 x 603 (4.72 mm). The heterobeltiotic effects over better parent for pericarp thickness varied from –27.46 (101 x FT-5) to 22.89 (Sel-6 x 603) per cent. None of the cross combination excelled Naveen-2000 (7.48 mm) for this trait, however, it was statistically at par with twenty cross combinations.

4.1.10 Number of locules per fruit

The number of locules per fruit in lines varied from 3.07 (2694) to 4.80 (T-777). The testers Solan Vajr, FT-5 and 603 had 3.73, 3.28 and 3.47 number of locules per fruit, respectively. Amongst F_1's lowest number of locules were recorded in Sioux x FT-5 (3.20) while it was highest in FT-13 x Solan Vajr (5.07), which was statistically at par with seven cross combinations.

The heterotic effects over better parent ranged from –27.27 to 42.07 per cent in Sioux x FT-5 and FT-13 x Solan Vajr, respectively. Compared to Naveen –2000 (3.46) only five cross combinations had lesser number of locules per fruit.

Table 6. Mean performance of parents, crosses, check and heterotic response for fruit weight (g)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	65.58		
2. BT-12	55.17		
3. T-777	60.25		
4. 1794	100.43		
5. 2694	79.58		
6. AI-14	65.83		
7. V-16	67.67		
8. FT-13	70.80		
9. Sel-6	68.67		
10. S-12	72.72		
11. 101	76.51		
12. Pepsi-92	65.33		
13. Solan Gola	73.58		
14. Money Maker	47.57		
15. FT-9	77.22		
TESTERS			
16. Solan Vajr	73.67		
17. FT-5	85.83		
18. 603	74.32		
CROSSES			
1. SIOUX x FT-5	77.25	-10.00	-13.70
2. SIOUX x 603	84.75	14.03	-5.32
3. SIOUX x Solan Vajr	87.24	18.42	-2.54
4. BT-12 x FT-5	74.02	-13.76	-17.31
5. BT-12 x 603	77.80	4.68	-13.82
6. BT-12 x Solan Vajr	66.98	-9.08	-25.17*
7. T-777 x FT-5	69.33	-19.22	-22.54*
8. T-777 x 603	58.43	-21.38	-34.72*
9. T-777 x Solan Vajr	70.87	-3.80	-20.82*
10. 1794 x FT-5	84.71	-15.65	-5.36
11. 1794 x 603	75.78	-24.54*	-15.34
12. 1794 x Solan Vajr	76.94	-23.39*	-14.04
13. 2694 x FT-5	90.61	5.57	0.01
14. 2694 x 603	80.86	1.61	-9.66
15. 2694 x Solan Vajr	85.58	7.54	-4.39

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	83.33	-2.91	-6.90
17. AI-14 x 603	76.32	2.69	-14.74
18. AI-14 x Solan Vajr	79.61	8.06	-11.06
19. V-16 x FT-5	73.00	-14.95	-18.44
20. V-16 x 603	76.28	2.64	-14.78
21. V-16 x Solan Vajr	78.67	6.79	-12.11
22. FT-13 x FT-5	83.08	-3.20	-7.18
23. FT-13 x 603	75.80	1.99	-15.32
24. FT-13 x Solan Vajr	81.83	11.08	-8.58
25. Sel-6 x FT-5	74.50	-13.20	-16.77
26. Sel-6 x 603	79.54	7.02	-11.14
27. Sel-6 x Solan Vajr	76.51	3.86	-14.52
28. S-12 x FT-5	78.08	-9.03	-12.77
29. S-12 x 603	83.48	12.33	-6.74
30. S-12 x Solan Vajr	79.68	8.16	-10.98
31. 101 x FT-5	82.42	-3.97	-7.92
32. 101 x 603	78.25	2.27	-12.58
33. 101 x Solan Vajr	79.75	4.23	-10.90
34. Pepsi-92 x FT-5	82.23	-4.19	-8.13
35. Pepsi-92 x 603	75.21	1.33	-15.86
36. Pepsi-92 x Solan Vajr	78.57	6.65	-12.22
37. Solan Gola x FT-5	67.69	-21.13	-24.38*
38. Solan Gola x 603	75.08	1.02	-16.12
39. Solan Gola x Solan Vajr	80.21	8.86	-10.39
40. Money Maker x FT-5	61.75	-28.06*	-31.01*
41. Money Maker x 603	75.17	1.14	-16.02
42. Money Maker x Solan Vajr	78.42	6.45	-12.39
43. FT-9 x FT-5	85.57	-0.30	-4.40
44. FT-9 x 603	81.34	5.34	-9.13
45. FT-9 x Solan Vajr	79.58	3.06	-11.09
CHECK			
46. Naveen-2000	89.51		
SE(d)±	9.44		
$CD_{0.05}$	18.59		

Table 7. **Mean performance of parents, crosses, check and heterotic response for whole fruit firmness (g/0.503 cm^2)**

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	1053.43		
2. BT-12	763.33		
3. T-777	1074.67		
4. 1794	883.33		
5. 2694	888.67		
6. AI-14	885.33		
7. V-16	1126.33		
8. FT-13	946.67		
9. Sel-6	884.67		
10. S-12	1133.00		
11. 101	1100.67		
12. Pepsi-92	1020.67		
13. Solan Gola	892.67		
14. Money Maker	743.33		
15. FT-9	790.00		
TESTERS			
16. Solan Vajr	1081.00		
17. FT-5	1628.67		
18. 603	905.33		
CROSSES			
1. SIOUX x FT-5	1331.33	-18.26*	-11.32*
2. SIOUX x 603	916.67	-12.98*	-38.94*
3. SIOUX x Solan Vajr	1010.00	-6.57*	-32.73*
4. BT-12 x FT-5	1186.67	-27.14*	-20.96*
5. BT-12 x 603	1004.34	10.94*	-33.10*
6. BT-12 x Solan Vajr	985.33	-8.85*	-34.37*
7. T-777 x FT-5	1262.33	-22.49*	-15.92*
8. T-777 x 603	986.33	-8.22*	-34.30*
9. T-777 x Solan Vajr	1042.00	-3.61	-30.59*
10. 1794 x FT-5	1604.33	-1.49	6.86*
11. 1794 x 603	842.00	-7.00	-43.92*
12. 1794 x Solan Vajr	1096.67	1.45	-26.95*
13. 2694 x FT-5	1242.00	-23.74*	-17.27*
14. 2694 x 603	906.67	0.15	-39.61*
15. 2694 x Solan Vajr	952.67	-11.87*	-36.54*

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	1208.33	-25.81*	-19.52*
17. AI-14 x 603	865.00	-4.45	-42.38*
18. AI-14 x Solan Vajr	950.67	-12.06*	-36.68*
19. V-16 x FT-5	1350.00	-17.11*	-10.08*
20. V-16 x 603	1006.67	-10.62*	-32.95*
21. V-16 x Solan Vajr	1137.33	0.98	-24.25*
22. FT-13 x FT-5	1310.00	-19.57*	-12.74*
23. FT-13 x 603	933.33	-1.41	-37.83*
24. FT-13 x Solan Vajr	1031.33	-4.59	-31.31*
25. Sel-6 x FT-5	1250.00	-23.25*	-16.74*
26. Sel-6 x 603	880.00	-2.80	-41.39*
27. Sel-6 x Solan Vajr	986.67	-8.73*	-34.28*
28. S-12 x FT-5	1360.00	-16.50*	-9.41*
29. S-12 x 603	1016.67	-10.27*	-32.28*
30. S-12 x Solan Vajr	1113.33	-1.74	-25.84*
31. 101 x FT-5	1342.00	-17.60*	-10.61*
32. 101 x 603	973.33	-11.57*	-35.17*
33. 101 x Solan Vajr	1053.33	-4.30	-29.84*
34. Pepsi-92 x FT-5	1316.33	-19.18*	-12.32*
35. Pepsi-92 x 603	961.67	-5.78	-35.95*
36. Pepsi-92 x Solan Vajr	1033.33	-4.49	-31.17*
37. Solan Gola x FT-5	1253.33	-23.05*	-16.52*
38. Solan Gola x 603	923.11	1.96	-38.51*
39. Solan Gola x Solan Vajr	980.00	-9.34	-34.72*
40. Money Maker x FT-5	1163.33	-25.57*	-22.51*
41. Money Maker x 603	829.33	-8.73*	-44.76*
42. Money Maker x Solan Vajr	927.00	-14.25*	-38.25*
43. FT-9 x FT-5	1203.00	-26.14*	-19.87*
44. FT-9 x 603	858.00	-5.23	-42.85*
45. FT-9 x Solan Vajr	945.33	-12.55*	-37.03*
CHECK			
46. Naveen-2000	1501.33		
SE(d)±	33.08		
$CD_{0.05}$	65.13		

Table 8. Mean performance of parents, crosses, check and heterotic response for fruit length (cm)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	4.51		
2. BT-12	5.08		
3. T-777	4.89		
4. 1794	4.95		
5. 2694	4.46		
6. AI-14	4.85		
7. V-16	5.11		
8. FT-13	4.77		
9. Sel-6	4.65		
10. S-12	4.54		
11. 101	4.86		
12. Pepsi-92	5.59		
13. Solan Gola	4.76		
14. Money Maker	2.85		
15. FT-9	4.34		
TESTERS			
16. Solan Vajr	5.32		
17. FT-5	4.06		
18. 603	4.99		
CROSSES			
1. SIOUX x FT-5	4.48	-0.67	-23.94*
2. SIOUX x 603	4.92	-1.40	-16.47*
3. SIOUX x Solan Vajr	5.12	-3.76	-13.07*
4. BT-12 x FT-5	4.97	-2.17	-15.62*
5. BT-12 x 603	5.36	5.51	-9.00
6. BT-12 x Solan Vajr	5.39	1.32	-8.49
7. T-777 x FT-5	4.47	-8.59	-24.11*
8. T-777 x 603	4.40	-11.82	-25.30*
9. T-777 x Solan Vajr	4.99	-6.20	-15.28*
10. 1794 x FT-5	5.14	3.84	-12.73*
11. 1794 x 603	4.69	-6.01	-20.37*
12. 1794 x Solan Vajr	5.16	-3.01	-12.39*
13. 2694 x FT-5	4.34	-2.70	-26.32*
14. 2694 x 603	5.18	3.81	-12.05
15. 2694 x Solan Vajr	5.45	2.44	-7.47

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	4.95	2.06	-15.96*
17. AI-14 x 603	4.83	-3.21	-18.00*
18. AI-14 x Solan Vajr	5.11	-3.95	-13.24*
19. V-16 x FT-5	5.41	5.87	-8.15
20. V-16 x 603	5.12	0.20	-13.07*
21. V-16 x Solan Vajr	4.07	-23.50*	-30.90*
22. FT-13 x FT-5	5.35	12.16	-9.15
23. FT-13 x 603	4.74	-5.01	-19.52*
24. FT-13 x Solan Vajr	5.23	-1.70	-11.21
25. Sel-6 x FT-5	4.96	6.44	-15.79*
26. Sel-6 x 603	5.28	5.81	-10.36
27. Sel-6 x Solan Vajr	4.77	-10.34	-19.02*
28. S-12 x FT-5	4.53	-0.22	-23.09*
29. S-12 x 603	5.07	1.60	-13.92*
30. S-12 x Solan Vajr	4.98	-6.39	-15.45*
31. 101 x FT-5	4.81	-1.02	-18.34*
32. 101 x 603	4.82	-3.41	-18.17*
33. 101 x Solan Vajr	5.19	-2.44	-11.88
34. Pepsi-92 x FT-5	4.74	-15.51*	-19.52*
35. Pepsi-92 x 603	5.26	-6.24	-10.70
36. Pepsi-92 x Solan Vajr	4.44	-20.86*	-24.62*
37. Solan Gola x FT-5	4.88	2.31	-17.15*
38. Solan Gola x 603	5.54	11.02	-5.94
39. Solan Gola x Solan Vajr	5.20	-2.26	-11.71
40. Money Maker x FT-5	4.60	13.30	-21.90*
41. Money Maker x 603	5.01	0.40	-14.94*
42. Money Maker x Solan Vajr	4.44	-16.54*	-24.62*
43. FT-9 x FT-5	4.12	-5.07	-30.05*
44. FT-9 x 603	4.48	-10.22	-23.94*
45. FT-9 x Solan Vajr	4.62	-13.16	-21.56*
CHECK			
46. Naveen-2000	5.89		
SE(d)±	0.36		
$CD_{0.05}$	0.71		

Table 9. Mean performance of parents, crosses, check and heterotic response for fruit breadth (cm)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	5.21		
2. BT-12	4.59		
3. T-777	4.99		
4. 1794	5.38		
5. 2694	4.39		
6. AI-14	5.54		
7. V-16	5.83		
8. FT-13	5.78		
9. Sel-6	5.42		
10. S-12	5.10		
11. 101	4.55		
12. Pepsi-92	5.63		
13. Solan Gola	4.77		
14. Money Maker	3.57		
15. FT-9	5.68		
TESTERS			
16. Solan Vajr	5.83		
17. FT-5	4.92		
18. 603	5.48		
CROSSES			
1. SIOUX x FT-5	5.13	-1.54	-5.18
2. SIOUX x 603	5.30	-3.28	-2.03
3. SIOUX x Solan Vajr	5.60	-3.95	3.51
4. BT-12 x FT-5	4.78	-2.85	-11.65
5. BT-12 x 603	5.49	0.18	1.48
6. BT-12 x Solan Vajr	5.37	-7.89	-0.74
7. T-777 x FT-5	4.83	-1.83	-10.72
8. T-777 x 603	5.68	3.65	4.99
9. T-777 x Solan Vajr	5.47	-6.17	1.11
10. 1794 x FT-5	5.82	8.78	7.58
11. 1794 x 603	5.51	0.55	1.85
12. 1794 x Solan Vajr	5.74	-1.54	-5.42
13. 2694 x FT-5	5.76	17.07*	6.27
14. 2694 x 603	5.51	0.55	1.85
15. 2694 x Solan Vajr	5.63	-3.43	4.07

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. Al-14 x FT-5	5.12	-7.58	-5.54
17. Al-14 x 603	5.31	-4.50	-1.85
18. Al-14 x Solan Vajr	5.51	-5.49	1.85
19. V-16 x FT-5	5.40	-7.38	-0.18
20. V-16 x 603	5.42	-7.20	0.18
21. V-16 x Solan Vajr	4.83	-17.15*	-10.72
22. FT-13 x FT-5	5.81	0.35	7.39
23. FT-13 x 603	5.23	-9.67	-3.32
24. FT-13 x Solan Vajr	5.02	-13.89*	-7.21
25. Sel-6 x FT-5	4.92	-9.22	-9.06
26. Sel-6 x 603	5.52	0.73	2.03
27. Sel-6 x Solan Vajr	5.25	-9.95	-2.96
28. S-12 x FT-5	4.90	-3.92	-9.43
29. S-12 x 603	4.60	-16.06*	-14.97*
30. S-12 x Solan Vajr	4.20	-27.96*	-22.37*
31. 101 x FT-5	4.52	-8.13	-16.45*
32. 101 x 603	4.59	-16.24*	-15.16*
33. 101 x Solan Vajr	4.92	-15.61*	-9.05
34. Pepsi-92 x FT-5	4.37	-22.38*	-19.22*
35. Pepsi-92 x 603	5.10	-9.41	-5.73
36. Pepsi-92 x Solan Vajr	5.19	-10.98	-4.07
37. Solan Gola x FT-5	4.71	-4.27	-12.94*
38. Solan Gola x 603	5.12	-6.57	-5.36
39. Solan Gola x Solan Vajr	4.92	-15.61*	-9.05
40. Money Maker x FT-5	4.82	-2.03	-10.91
41. Money Maker x 603	5.06	-7.66	-6.47
42. Money Maker x Solan Vajr	4.78	-18.01*	-11.65
43. FT-9 x FT-5	5.09	-10.39	-5.91
44. FT-9 x 603	4.84	-14.79*	-10.54
45. FT-9 x Solan Vajr	5.19	-10.98	-4.07
CHECK			
46. Naveen-2000	5.41		
SE(d)±	0.35		
$CD_{0.05}$	0.69		

Table 10. Mean performance of parents, crosses, check and heterotic response for pericarp thickness (mm)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	5.62		
2. BT-12	5.25		
3. T-777	5.86		
4. 1794	5.19		
5. 2694	5.00		
6. AI-14	5.01		
7. V-16	4.99		
8. FT-13	6.03		
9. Sel-6	5.22		
10. S-12	5.61		
11. 101	6.22		
12. Pepsi-92	6.47		
13. Solan Gola	4.90		
14. Money Maker	2.88		
15. FT-9	5.53		
TESTERS			
16. Solan Vajr	6.53		
17. FT-5	6.70		
18. 603	5.68		
CROSSES			
1. SIOUX x FT-5	6.85	2.24	-8.42
2. SIOUX x 603	6.56	15.49	-12.30
3. SIOUX x Solan Vajr	6.79	3.98	-9.22
4. BT-12 x FT-5	6.78	1.19	-9.36
5. BT-12 x 603	6.71	18.13	-10.29
6. BT-12 x Solan Vajr	6.59	0.92	-11.90
7. T-777 x FT-5	6.24	-6.87	-16.57*
8. T-777 x 603	6.00	2.39	-19.79*
9. T-777 x Solan Vajr	6.13	-6.13	-18.05*
10. 1794 x FT-5	6.91	3.13	-7.62
11. 1794 x 603	6.20	9.15	-17.65*
12. 1794 x Solan Vajr	6.16	-5.67	-17.65*
13. 2694 x FT-5	6.03	-10.00	-19.39*
14. 2694 x 603	6.22	9.51	-16.84*
15. 2694 x Solan Vajr	6.70	2.60	-10.43

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	7.13	6.42	-4.68
17. AI-14 x 603	6.54	15.14	-12.57
18. AI-14 x Solan Vajr	5.47	-16.23	-26.87*
19. V-16 x FT-5	6.35	-5.22	-15.11
20. V-16 x 603	6.93	22.01*	-7.35
21. V-16 x Solan Vajr	6.83	4.59	-8.69
22. FT-13 x FT-5	7.12	6.27	-4.81
23. FT-13 x 603	4.72	-21.72*	-36.90*
24. FT-13 x Solan Vajr	7.40	13.32	-1.07
25. Sel-6 x FT-5	5.89	-12.09	-21.26*
26. Sel-6 x 603	6.98	22.89*	-6.68
27. Sel-6 x Solan Vajr	6.02	-7.81	-19.52*
28. S-12 x FT-5	6.50	-2.99	-13.10
29. S-12 x 603	5.62	-1.06	-24.87*
30. S-12 x Solan Vajr	5.76	-11.79	-23.00*
31. 101 x FT-5	4.86	-27.46*	-35.03*
32. 101 x 603	6.28	0.96	-16.04*
33. 101 x Solan Vajr	6.02	-7.81	-19.52*
34. Pepsi-92 x FT-5	6.89	2.84	-12.29
35. Pepsi-92 x 603	7.19	11.13	-3.88
36. Pepsi-92 x Solan Vajr	5.59	-14.40	-25.27*
37. Solan Gola x FT-5	6.04	-9.85	-19.25*
38. Solan Gola x 603	5.98	5.28	-20.05*
39. Solan Gola x Solan Vajr	5.38	-17.61	-28.07*
40. Money Maker x FT-5	5.67	-15.37	-24.20*
41. Money Maker x 603	6.80	19.72	-9.09
42. Money Maker x Solan Vajr	4.91	-24.81*	-34.36*
43. FT-9 x FT-5	5.82	-13.13	-22.19*
44. FT-9 x 603	5.75	1.23	-23.13*
45. FT-9 x Solan Vajr	5.76	-11.79	-23.10*
CHECK			
46. Naveen-2000	7.48		
SE(d)±	0.59		
$CD_{0.05}$	1.16		

Table 11. Mean performance of parents, crosses, check and heterotic response for number of locules per fruit

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	4.15		
2. BT-12	3.68		
3. T-777	4.80		
4. 1794	3.27		
5. 2694	3.07		
6. AI-14	4.53		
7. V-16	4.00		
8. FT-13	3.57		
9. Sel-6	3.87		
10. S-12	3.33		
11. 101	3.11		
12. Pepsi-92	3.47		
13. Solan Gola	3.80		
14. Money Maker	3.41		
15. FT-9	3.47		
TESTERS			
16. Solan Vajr	3.73		
17. FT-5	3.28		
18. 603	3.47		
CROSSES			
1. SIOUX x FT-5	3.20	-27.77*	-7.51
2. SIOUX x 603	3.30	-20.48	-4.62
3. SIOUX x Solan Vajr	4.13	-0.48	19.36
4. BT-12 x FT-5	3.80	3.26	9.83
5. BT-12 x 603	3.67	-0.27	6.07
6. BT-12 x Solan Vajr	3.47	-6.97	0.29
7. T-777 x FT-5	3.75	-21.88*	8.38
8. T-777 x 603	4.00	-16.67	15.61
9. T-777 x Solan Vajr	3.47	-27.71*	0.29
10. 1794 x FT-5	4.53	38.11*	30.92*
11. 1794 x 603	4.30	23.92*	24.28
12. 1794 x Solan Vajr	3.77	1.07	8.96
13. 2694 x FT-5	3.60	9.76	4.05
14. 2694 x 603	3.93	13.26	13.58
15. 2694 x Solan Vajr	3.94	5.63	13.87

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	3.67	-18.98	6.07
17. AI-14 x 603	3.98	-12.14	15.03
18. AI-14 x Solan Vajr	4.27	-5.74	23.41
19. V-16 x FT-5	3.93	-1.75	13.58
20. V-16 x 603	3.53	-11.75	2.02
21. V-16 x Solan Vajr	3.87	-3.25	11.85
22. FT-13 x FT-5	3.85	7.84	11.27
23. FT-13 x 603	3.67	2.80	6.07
24. FT-13 x Solan Vajr	5.07	35.92*	46.53*
25. Sel-6 x FT-5	4.10	5.94	18.50
26. Sel-6 x 603	4.03	4.13	16.47
27. Sel-6 x Solan Vajr	3.87	0.00	11.85
28. S-12 x FT-5	4.27	28.23*	23.41
29. S-12 x 603	3.94	13.54	13.87
30. S-12 x Solan Vajr	4.47	19.84	29.19*
31. 101 x FT-5	3.40	3.66	-1.73
32. 101 x 603	3.83	10.37	10.69
33. 101 x Solan Vajr	3.80	1.88	9.83
34. Pepsi-92 x FT-5	3.48	0.29	0.87
35. Pepsi-92 x 603	4.93	42.07*	42.49*
36. Pepsi-92 x Solan Vajr	3.78	1.34	9.25
37. Solan Gola x FT-5	4.33	13.95	25.14
38. Solan Gola x 603	3.88	2.11	12.14
39. Solan Gola x Solan Vajr	3.98	4.74	15.03
40. Money Maker x FT-5	3.35	-2.33	-3.18
41. Money Maker x 603	3.63	4.61	4.91
42. Money Maker x Solan Vajr	3.27	-12.33	-5.49
43. FT-9 x FT-5	3.79	9.22	9.54
44. FT-9 x 603	3.76	8.36	8.67
45. FT-9 x Solan Vajr	3.98	6.70	15.03
CHECK			
46. Naveen-2000	3.46		
SE(d)±	0.46		
$CD_{0.05}$	0.91		

4.1.11 Stem end scar size (mm)

The line Pepsi–92 recorded maximum stem end scar size (11.55 mm) and minimum was found in line Money Maker (6.70 mm). The testers Solan Vajr, FT-5 and 603 had 9.90 mm, 8.79 mm and 9.24 mm stem end scar size, respectively. Amongst F_1's the stem end scar size ranged from 7.08 mm (101 x 603) to 12.91 mm (BT-12 x FT-5). Minimum stem end scar size was observed in 101 x 603 which was statistically at par with fourteen cross combinations.

The heterosis over better parent ranged from –27.84 (V-16 x Solan Vajr) to 33.81 (BT-12 x FT-5) per cent. Out of fourty-five hybrids only eleven were less in stem end scar size when compared with hybrid Naveen–2000 (9.01 mm).

4.1.12 Total soluble solids (TSS)

Total soluble contents for lines ranged from 3.27 (2694) to 4.43 (Sel-6). The testers Solan Vajr, FT-5 and 603 had 4.37, 4.25 and 4.03°B total soluble solids, respectively. In F_1's the total soluble solid ranged from 3.53 to 5.83°B.

The heterobeltiotic effects ranged from –17.33 to 44.67 per cent in 1794 x FT-5 and AI-14 x 603 cross combinations, respectively. Out of thirty six crosses which exhibited higher soluble solids over Naveen-2000, only three were statistically superior to it. Maximum increase over Naveen-2000 was to the tune of 37.83 (AI-14 x 603) per cent.

4.1.13 Plant height (cm)

Lot of variation for plant height among lines was observed. The plant height for lines ranged from 58.33 to 134.33 cm. It being highest in BT-12 and lowest in S-12. The plant height in testers was 122.20, 170.00 and 47.43 cm in Solan Vajr, FT-5 and 603, respectively. Amongst the hybrids the highest plant height was recorded in the cross of Sel-6 x FT-5 (199.33 cm).

The heterobeltiotic effects of plant height ranged from 2.75 to 38.85 per cent, being lowest in the cross of T-777 x FT-5 and highest in the cross FT-13 x Solan Vajr. The majority of F_1's indicated significant positive heterosis over better parents for plant height. Compared to Naveen–2000 (178.33 cm), the plant height was significantly less in twenty hybrids.

4.1.14 Harvest duration (days)

Days for harvest duration ranged from 31.00 (BT-12) to 42.33 (AI-14 and S-12) days in lines while the testers Solan Vajr, FT-5 and 603 recorded 41.67, 34.00 and 37.20 days, respectively. Amongst the F_1's, the harvest duration ranged from 32.33 to 41.67 days being lowest in BT-12 x FT-5 and highest in AI-14 x Solan Vajr.

The heterosis over better parent ranged from –24.00 (Sel-6 x Solan Vajr) to 11.57 (Money Maker x FT-5) per cent. None of the hybrid combinations showed significant positive heterosis over better parent for this trait. None of the hybrid exhibited positive heterosis over the check Naveen–2000 (46.33 days).

4.2 COMBINING ABILITY EFFECTS

The estimates of general combining ability of the parents (lines and testers) and specific combining ability effects of their crosses for different traits of tomato under study are presented in the Tables 16-17 and described as under:

4.2.1 Days to first flowering

The variance due to general combining ability and specific combining ability was significant (Appendix –II). The component due to σ^2g being more than σ^2s indicated the preponderance of additive genetic effect for the trait.

The line 101 and S-12 were good general combiners as they exhibited the significant gca estimates with negative values. The line FT-13 (-1.17), Pepsi-92 (-0.78), V-16 (-0.50) were the medium general combiners for the trait. The tester Solan Vajr had (-0.38) good and FT-5 and 603 had the poor general combining ability estimates for early flowering. Amongst F_1's, the cross S-12 x Solan Vajr showed the significant negative specific combining ability effects. The highest negative sca effects were recorded in the cross S-12 x Solan Vajr (-2.15) followed by Solan Gola x Solan Vajr (-1.86), which involved good x good and poor x good general combiners, respectively.

Table 12. Mean performance of parents, crosses, check and heterotic response for stem end scar size (mm)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	10.06		
2. BT-12	9.85		
3. T-777	10.12		
4. 1794	11.33		
5. 2694	8.17		
6. AI-14	8.63		
7. V-16	10.20		
8. FT-13	8.59		
9. Sel-6	7.75		
10. S-12	7.67		
11. 101	7.13		
12. Pepsi-92	11.55		
13. Solan Gola	8.34		
14. Money Maker	6.70		
15. FT-9	10.67		
TESTERS			
16. Solan Vajr	9.90		
17. FT-5	8.79		
18. 603	9.24		
CROSSES			
1. SIOUX x FT-5	10.01	-0.50	11.10
2. SIOUX x 603	9.22	-8.35	2.33
3. SIOUX x Solan Vajr	12.39	23.16*	37.51*
4. BT-12 x FT-5	12.91	33.81*	43.29*
5. BT-12 x 603	11.80	19.80	30.97*
6. BT-12 x Solan Vajr	12.66	28.53*	40.51*
7. T-777 x FT-5	9.95	-1.68	10.43
8. T-777 x 603	10.11	-0.10	12.21
9. T-777 x Solan Vajr	9.08	-10.28	0.78
10. 1794 x FT-5	10.55	-6.88	17.09
11. 1794 x 603	10.87	-4.06	20.64
12. 1794 x Solan Vajr	12.66	11.74	40.51*
13. 2694 x FT-5	10.42	18.54	15.65
14. 2694 x 603	9.91	7.25	9.99
15. 2694 x Solan Vajr	12.58	27.07*	39.62*

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	9.55	8.65	5.99
17. AI-14 x 603	10.26	11.04	13.87
18. AI-14 x Solan Vajr	11.69	18.08	29.74*
19. V-16 x FT-5	11.36	11.37	26.82*
20. V-16 x 603	10.02	-1.76	11.21
21. V-16 x Solan Vajr	7.36	-27.84*	-18.31
22. FT-13 x FT-5	11.00	25.14	22.07
23. FT-13 x 603	8.62	-6.71	-4.33
24. FT-13 x Solan Vajr	11.56	16.77	28.30*
25. Sel-6 x FT-5	11.54	31.29*	28.08*
26. Sel-6 x 603	11.87	28.46*	31.74*
27. Sel-6 x Solan Vajr	12.65	27.78*	40.40*
28. S-12 x FT-5	8.86	0.80	-1.66
29. S-12 x 603	9.44	2.16	4.77
30. S-12 x Solan Vajr	9.84	-0.61	9.21
31. 101 x FT-5	7.32	-16.72	-18.76
32. 101 x 603	7.08	-23.38	-21.42
33. 101 x Solan Vajr	8.21	-17.07	-8.88
34. Pepsi-92 x FT-5	10.02	-13.25	11.21
35. Pepsi-92 x 603	9.14	-20.87	1.44
36. Pepsi-92 x Solan Vajr	9.72	-15.84	7.88
37. Solan Gola x FT-5	9.92	12.86	10.10
38. Solan Gola x 603	9.04	-2.16	0.33
39. Solan Gola x Solan Vajr	9.35	-5.56	3.77
40. Money Maker x FT-5	7.24	-17.63	-19.64
41. Money Maker x 603	8.42	-8.87	-6.55
42. Money Maker x Solan Vajr	8.93	-9.80	-0.89
43. FT-9 x FT-5	8.25	-22.68	-8.44
44. FT-9 x 603	8.29	-22.31	-7.99
45. FT-9 x Solan Vajr	11.05	3.56	22.64
CHECK			
46. Naveen-2000	9.01		
SE(d)±	1.13		
$CD_{0.05}$	2.22		

Table 13. Mean performance of parents, crosses, check and heterotic response for total soluble solids (^oB)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	4.13		
2. BT-12	4.00		
3. T-777	4.17		
4. 1794	4.27		
5. 2694	3.27		
6. AI-14	3.53		
7. V-16	4.23		
8. FT-13	4.07		
9. Sel-6	4.43		
10. S-12	4.33		
11. 101	4.13		
12. Pepsi-92	3.87		
13. Solan Gola	4.15		
14. Money Maker	3.57		
15. FT-9	4.30		
TESTERS			
16. Solan Vajr	4.37		
17. FT-5	4.25		
18. 603	4.03		
CROSSES			
1. SIOUX x FT-5	4.25	0.00	0.47
2. SIOUX x 603	4.07	-1.45	-3.78
3. SIOUX x Solan Vajr	4.29	-1.83	1.42
4. BT-12 x FT-5	4.31	1.41	1.89
5. BT-12 x 603	4.05	0.50	-4.26
6. BT-12 x Solan Vajr	4.47	5.18	5.67
7. T-777 x FT-5	4.40	5.52	4.02
8. T-777 x 603	4.05	-2.88	-4.26
9. T-777 x Solan Vajr	4.50	2.97	6.38
10. 1794 x FT-5	3.53	-17.33	-16.55
11. 1794 x 603	4.10	-3.98	-3.07
12. 1794 x Solan Vajr	4.65	6.41	9.93
13. 2694 x FT-5	3.97	-6.59	-6.15
14. 2694 x 603	3.80	-5.71	-10.17
15. 2694 x Solan Vajr	4.88	0.21	15.37

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	4.92	15.76	16.31
17. AI-14 x 603	5.83	44.67*	37.83*
18. AI-14 x Solan Vajr	4.87	11.44	15.13
19. V-16 x FT-5	5.10	20.00*	20.57*
20. V-16 x 603	4.88	15.37	15.37
21. V-16 x Solan Vajr	5.23	19.68*	23.64*
22. FT-13 x FT-5	4.62	8.71	9.22
23. FT-13 x 603	4.75	16.71	12.29
24. FT-13 x Solan Vajr	4.89	11.90	15.60
25. Sel-6 x FT-5	4.80	8.35	13.48
26. Sel-6 x 603	4.99	12.64	17.97
27. Sel-6 x Solan Vajr	4.46	0.68	5.44
28. S-12 x FT-5	4.73	9.24	11.82
29. S-12 x 603	4.26	-1.62	0.71
30. S-12 x Solan Vajr	4.77	9.15	12.77
31. 101 x FT-5	4.63	8.94	9.46
32. 101 x 603	3.87	-6.30	-8.51
33. 101 x Solan Vajr	4.76	8.92	12.53
34. Pepsi-92 x FT-5	4.44	4.47	4.96
35. Pepsi-92 x 603	4.18	3.72	-1.18
36. Pepsi-92 x Solan Vajr	4.58	4.81	8.27
37. Solan Gola x FT-5	4.56	7.29	7.80
38. Solan Gola x 603	4.28	3.13	1.18
39. Solan Gola x Solan Vajr	4.68	7.09	10.64
40. Money Maker x FT-5	4.64	9.18	9.69
41. Money Maker x 603	4.27	5.96	0.95
42. Money Maker x Solan Vajr	4.70	7.55	11.11
43. FT-9 x FT-5	4.42	2.79	4.49
44. FT-9 x 603	4.26	-0.90	0.71
45. FT-9 x Solan Vajr	4.60	5.26	8.75
CHECK			
46. Naveen-2000	4.23		
SE(d)±	0.39		
$CD_{0.05}$	0.77		

Table 14. Mean performance of parents, crosses, check and heterotic response for plant height (cm)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	121.67		
2. BT-12	134.33		
3. T-777	97.00		
4. 1794	112.00		
5. 2694	98.20		
6. AI-14	112.67		
7. V-16	96.80		
8. FT-13	113.92		
9. Sel-6	118.33		
10. S-12	58.33		
11. 101	75.00		
12. Pepsi-92	59.00		
13. Solan Gola	128.13		
14. Money Maker	113.53		
15. FT-9	85.80		
TESTERS			
16. Solan Vajr	122.20		
17. FT-5	170.00		
18. 603	47.43		
CROSSES			
1. SIOUX x FT-5	176.67	3.92	-0.93
2. SIOUX x 603	131.67	8.22	-26.16*
3. SIOUX x Solan Vajr	127.07	3.99	-28.74*
4. BT-12 x FT-5	180.00	5.88	0.94
5. BT-12 x 603	151.67	12.91	-14.95
6. BT-12 x Solan Vajr	145.80	8.54	-18.24*
7. T-777 x FT-5	174.67	2.75	-2.05
8. T-777 x 603	105.00	8.25	-41.12*
9. T-777 x Solan Vajr	127.80	4.58	-28.34*
10. 1794 x FT-5	176.33	3.72	-1.12
11. 1794 x 603	139.33	24.40	-21.87*
12. 1794 x Solan Vajr	158.00	29.30*	-11.40
13. 2694 x FT-5	181.67	6.86	1.87
14. 2694 x 603	125.80	28.11	-29.46*
15. 2694 x Solan Vajr	155.07	26.90*	-13.04

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	187.36	10.21	5.06
17. AI-14 x 603	153.33	36.08*	-14.02
18. AI-14 x Solan Vajr	148.67	21.66	-16.63
19. V-16 x FT-5	189.33	11.37	6.17
20. V-16 x 603	130.00	34.30*	-27.10*
21. V-16 x Solan Vajr	162.00	32.57*	-9.16
22. FT-13 x FT-5	190.00	11.76	6.54
23. FT-13 x 603	135.33	18.79	-4.86
24. FT-13 x Solan Vajr	169.67	38.85*	-5.05
25. Sel-6 x FT-5	199.33	17.25	11.78
26. Sel-6 x 603	138.33	16.90	-22.43*
27. Sel-6 x Solan Vajr	167.61	37.16*	-6.01
28. S-12 x FT-5	192.67	13.34	8.04
29. S-12 x 603	69.33	18.86	-61.12*
30. S-12 x Solan Vajr	155.67	27.39*	-12.71
31. 101 x FT-5	195.33	14.90	9.53
32. 101 x 603	91.57	22.09	-48.65*
33. 101 x Solan Vajr	142.67	16.75	-20.00*
34. Pepsi-92 x FT-5	193.67	13.92	8.60
35. Pepsi-92 x 603	75.00	27.71	-57.94*
36. Pepsi-92 x Solan Vajr	136.87	12.00	-23.25*
37. Solan Gola x FT-5	188.53	10.90	5.72
38. Solan Gola x 603	135.87	6.04	-23.81*
39. Solan Gola x Solan Vajr	141.33	10.30	-20.75*
40. Money Maker x FT-5	189.67	11.57	6.36
41. Money Maker x 603	124.67	9.81	-30.09*
42. Money Maker x Solan Vajr	138.67	13.48	-22.24*
43. FT-9 x FT-5	188.33	10.78	5.61
44. FT-9 x 603	100.67	17.33	-43.55*
45. FT-9 x Solan Vajr	125.60	2.78	-29.57*
CHECK			
46. Naveen-2000	178.33		
SE(d)±	15.26		
$CD_{0.05}$	30.05		

Table 15. Mean performance of parents, crosses, check and heterotic response for harvest duration (days)

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
LINES			
1. SIOUX	37.00		
2. BT-12	31.00		
3. T-777	34.67		
4. 1794	36.33		
5. 2694	37.33		
6. AI-14	42.33		
7. V-16	40.00		
8. FT-13	36.00		
9. Sel-6	41.33		
10. S-12	42.33		
11. 101	39.67		
12. Pepsi-92	40.33		
13. Solan Gola	42.00		
14. Money Maker	34.67		
15. FT-9	33.33		
TESTERS			
16. Solan Vajr	41.67		
17. FT-5	34.00		
18. 603	37.20		
CROSSES			
1. SIOUX x FT-5	34.05	-7.97	-26.51*
2. SIOUX x 603	36.00	-3.23	-22.30*
3. SIOUX x Solan Vajr	36.33	-12.81	-21.58*
4. BT-12 x FT-5	32.33	-4.91	-30.22*
5. BT-12 x 603	34.10	-8.33	-26.40*
6. BT-12 x Solan Vajr	36.00	-13.61	-22.30*
7. T-777 x FT-5	35.00	0.95	-24.45*
8. T-777 x 603	38.00	2.15	-17.98*
9. T-777 x Solan Vajr	35.10	-15.77*	-24.24*
10. 1794 x FT-5	35.00	-3.66	-24.45*
11. 1794 x 603	36.10	-2.96	-22.08*
12. 1794 x Solan Vajr	38.33	-8.01	-17.27*
13. 2694 x FT-5	35.20	-5.71	-24.02*
14. 2694 x 603	36.30	-2.76	-21.65*
15. 2694 x Solan Vajr	39.33	-5.61	-15.11*

Contd....

PARENTS	Mean	Per cent increase or decrease over	
		Better parents	Check Naveen-2000
16. AI-14 x FT-5	38.33	-9.45	-17.27*
17. AI-14 x 603	36.67	-13.37	-20.85*
18. AI-14 x Solan Vajr	41.67	-1.56	-10.06
19. V-16 x FT-5	36.05	-9.88	-22.19*
20. V-16 x 603	37.67	-5.83	-18.69*
21. V-16 x Solan Vajr	37.33	-10.42	-19.43*
22. FT-13 x FT-5	35.10	-2.50	-24.24*
23. FT-13 x 603	35.33	-5.03	-23.74*
24. FT-13 x Solan Vajr	38.34	-7.99	-17.25*
25. Sel-6 x FT-5	37.34	-9.65	-19.40*
26. Sel-6 x 603	37.67	-8.86	-18.69*
27. Sel-6 x Solan Vajr	40.67	-2.40	-12.22
28. S-12 x FT-5	35.30	-16.61*	-23.81*
29. S-12 x 603	34.33	-18.90*	-25.90*
30. S-12 x Solan Vajr	40.00	-5.50	-13.66
31. 101 x FT-5	35.33	-10.94	-23.74*
32. 101 x 603	33.67	-15.12	-27.33*
33. 101 x Solan Vajr	39.00	-6.41	-15.82*
34. Pepsi-92 x FT-5	35.40	-12.22	-23.59*
35. Pepsi-92 x 603	35.67	-11.55	-23.00*
36. Pepsi-92 x Solan Vajr	39.33	-5.62	-15.11*
37. Solan Gola x FT-5	37.10	-11.67	-19.92*
38. Solan Gola x 603	36.67	-12.69	-20.85*
39. Solan Gola x Solan Vajr	38.35	-8.69	-17.22*
40. Money Maker x FT-5	38.68	11.57	-16.51*
41. Money Maker x 603	38.69	4.01	-16.49*
42. Money Maker x Solan Vajr	35.08	-15.81*	-24.28*
43. FT-9 x FT-5	35.33	3.87	-23.74*
44. FT-9 x 603	36.33	-2.34	-21.58*
45. FT-9 x Solan Vajr	37.67	-9.60	-18.69*
CHECK			
46. Naveen-2000	46.33		
SE(d)±	3.17		
$CD_{0.05}$	6.24		

Table 16. Estimation of general combining ability effects of parents for different characters in tomato.

Parents	Days to first flowering	No. of fruits/ cluster	No.of fruits /plant	Yield per plant	Fruit weight	Whole fruit firmness	Fruit length	Fruit breadth	Pericarp thickness	No. of locules/f ruit	Stem end scar size	Total soluble solids	Plant height	Harvest duration
Lines														
Sioux	-0.12	-0.29*	-2.07*	-71.41*	5.25	7.53	-0.06	0.19	0.49*	-0.34*	0.48	-0.31*	-8.06	-1.23
BT-12	1.33	-0.19	-0.29	-114.29*	-4.89	-19.69	0.34*	0.06	0.44*	-0.23	2.40*	-0.24	5.96	-2.55*
T-777	-0.01	-0.02	-0.25	-252.81*	-11.62*	18.42	-0.28*	0.17	-0.12	-0.14	-0.35	-0.20	-17.37*	-0.66
1794	0.88	-0.34*	3.27*	304.17*	1.32	102.53*	0.09	0.54*	0.18	0.32*	1.30*	-0.42*	4.69	-0.22
2694	-0.27	-0.33*	-0.62	102.00*	7.86*	-44.69*	0.09	0.48*	0.07	-0.06	0.91*	-0.30*	0.98	0.25
Al-14	1.14	0.21*	-0.78	-15.09	1.93	-70.47*	0.06	0.16	0.14	0.09	0.44	0.69*	9.91	2.19*
V-16	-0.50	-0.10	-1.40*	-141.62*	-1.84	86.20*	-0.04	0.06	0.46*	-0.10	-0.48	0.55*	7.25	0.32
FT-13	-1.17	0.36*	-0.77	0.53	2.41	13.09	0.20	0.20	0.17	0.32*	0.33	0.24	11.80*	-0.44
Sel-6	0.33	-0.13	-1.18*	-99.26*	-0.98	-39.58*	0.10	0.08	0.05	0.12	1.96*	0.23	15.23*	1.86
S-12	-2.34*	-0.04	-0.28	10.48	2.59	84.86*	-0.04	-0.59*	-0.29	0.35*	-0.68	0.07	-13.97*	-0.15
101	-2.58*	-0.04	0.93	131.83*	2.31	44.42*	0.03	-0.48*	-0.53*	-0.20	-2.52*	-0.10	-10.01	-0.69
Pepsi 92	-0.78	-0.25*	-0.45	-5.88	0.88	25.32*	-0.09	-0.27*	0.31	0.18	-0.44	-0.12	3.98	0.11
Solan Gola	1.37	0.10	-4.18*	-379.76*	-3.50	-26.32*	0.30*	-0.24	-0.45*	0.18	-0.62	-0.01	2.05	0.68
Money Maker	0.77	0.36*	3.21*	37.14	-6.65	-105.2*	-0.22	-0.27*	-0.45*	-0.46*	-1.87*	0.02	-2.10	0.79
FT-9	1.96*	0.68*	4.86*	494.95*	4.34	-76.36*	-0.49*	-0.11	-0.47*	-0.04	-0.86*	-0.09	-10.33	-0.25
Testers														
Solan Vajr	-0.38	0.08*	1.57*	119.59*	0.01	213.73*	-0.12*	-0.09*	0.09	-0.08	-0.13	-0.03	33.73*	-0.99*
FT-5	0.34	-0.08*	-0.86*	-87.15*	-0.88	-151.6*	0.08	0.07	0.05	0.01	-0.45*	-0.14*	-27.36*	-0.48
603	0.04	-0.01	-0.71*	-32.44*	0.87	-62.13*	0.04	0.02	-0.15*	0.06	0.59*	0.17*	-6.36*	1.47*
SE(gi)	0.78	0.10	0.54	36.33	3.47	10.55*	0.12	0.13	0.19	0.16	0.37	0.13	5.57	1.11
SE(gj)	0.29	0.04	0.20	13.73	1.31	3.99*	0.05	0.04	0.07	0.06	0.14	0.05	2.11	0.42
SE(gi-gj)line	1.40	0.17	0.92	59.08	5.47	19.24*	0.20	0.20	0.34	0.26	0.65	0.23	8.82	1.85
SE(gj-gi)tester	0.63	1.08	0.41	26.42	2.45	8.60*	0.09	0.09	0.15	0.12	0.29	0.10	3.94	0.83

*Significant at 5% level of significance

4.2.2 Number of fruits per cluster

The variance due to general combining ability and specific combining ability were significant (Appendix –II), however, the component σ^2s was higher than σ^2g depicting the greater role of non-additive genetic variance.

The line FT-9 had significantly higher gca effects (0.68) followed by FT-13 (0.36) and Money Maker (0.36) indicating them to be good general combiners for the trait. The tester Solan Vajr (0.08) had higher gca effects than FT-5 (-0.08) and 603 (-0.01). Amongst F_1's, only three cross combinations viz., Money Maker x FT-5, AI-14 x Solan Vajr and 101 x 603 exhibited the significant positive sca effects for the trait.

4.2.3 Number of fruits per plant

The perusal of data in Appendix –II revealed that the variance due to general combining ability and specific combining ability were significant. The variance due to sca was higher than variance due to gca indicating the predominance of non-additive genetic effects in the expression of this trait.

The line FT-9 (4.86), 1794 (3.27) and Money Maker (3.21) were good general combiners for the number of fruits per plant as they exhibited significantly higher gca effects while the line Solan Gola (-4.18), Sioux (-2.07) were the poor general combiners for the trait. The tester Solan Vajr (1.57) had good gca. The crosses Sioux x FT-5 (3.98), Pepsi –92 x Solan Vajr (2.98) and V-16 x FT-5 (2.65) had significant sca effects and involved poor x poor, poor x good and poor x poor general combiners, respectively.

4.2.4 Yield per plant

The analysis of combining ability showed that variance due to general combining ability and specific combining ability was significant (Appendix-II). The estimates of variance due to sca being more than those of gca, indicated the greater role of non-additive genetic variances. The best general combiners among the lines were FT-9 (494.95) and 1794 (304.17), as these lines had highly significant positive gca effect, whereas Solan Gola (-379.76), T-777 (-252.81) and V-16 (-141.62) were poor general combiners for yield per plant. Tester Solan Vajr (119.59) had good gca effects, whereas, FT-5 (-87.15) and 603 (-32.44) proved to be poor general combiners for yield per plant.

Amongst F_1's only twelve hybrid combinations showed significant positive sca effects. The combination 1794 x FT-5 (302.32) exhibited highest sca effect followed by Money Maker x 603 (282.64), Money Maker x Solan Vajr (253.88), Sioux x FT-5 (218.11) and Pepsi-92 x Solan Vajr (206.97) which involved good x poor, good x poor, good x good, poor x poor and poor x good general combiners.

4.2.5 Fruit weight

It is evident from Appendix –II that the variance due to general and specific combining ability were significant. The variance due to sca (σ^2s) was greater than gca (σ^2g) indicating the greater role of non-additive genetic variance for fruit weight.

The lines 2694 (7.86), Sioux (5.25) and FT-9 (4.34) were good general combiners, while lines T-777 (-11.62), Money Maker (-6.65) and BT-12 (-4.89) were poor general combiners showing significant negative gca values. The tester 603 (0.87) had higher magnitude of gca effects than that of Solan Vajr (0.01) and FT-5 (-0.88).

Only one F_1's exhibited significant negative sca effects. The highest sca effects were observed in cross combination of BT-12 x 603 (5.75) followed by 1794 x FT-5 (5.55).

4.2.6 Whole fruit firmness

The variances due to general combining ability and specific combining ability were significant (Appendix-II), however, the magnitude of variance due to sca was greater than that of gca indicating greater role of non-additive genetic variance for expression of this trait.

The line 1794 (102.53) showed significant positive gca effects over other lines for whole fruit firmness followed by V-16 (86.20) and S-12 (84.86) and were good general combiners for this trait. The lines Money Maker (-105.25), FT-9 (-76.36), AI-14 (-70.47) and 2694 (-44.69) were considered to be poor general combiners for the

Table 17. Estimation of specific combining ability effects of hybrids for different characters.

HYBRIDS	Days to first flowering	No. of fruits/ cluster	No. of fruits/ plant	Yield per plant	Fruit Weight	Whole fruit firmness	Fruit length	Fruit breadth	Pericarp thickness	No. of locules/ fruit	Stem end scar size	Total soluble solids	Plant height	Harvest duration
Sioux x FT-5	-0.28	0.18	3.98*	218.11*	-5.84	31.60*	-0.24	-0.13	0.02	-0.27	-0.39	0.08	-2.19	-0.42
Sioux x 603	-1.01	-0.02	-3.58*	-244.8*	2.55	-17.74	0.00	-0.11	-0.23	-0.26	-0.87	0.01	13.89	1.02
Sioux x Solan Vajr	1.29	-0.16	-0.40	26.69	3.29	-13.87	0.24	0.23	0.20	0.53*	1.26*	-0.08	-11.70	-0.60
BT-12 x FT-5	-1.40	-0.48*	-0.13	9.69	1.07	-85.14*	-0.15	-0.35*	-0.01	0.23	0.59	0.06	-12.88	-0.82
BT-12 x 603	0.55	0.48*	-0.03	115.29*	5.75	97.16*	0.04	0.21	-0.04	0.01	-0.20	-0.09	19.87*	0.44
BT-12 x Solan Vajr	0.85	0.01	0.16	-124.98*	-6.82	-11.31	0.11	0.14	0.04	-0.24	-0.38	0.02	-6.99	0.38
T-777 x FT-5	0.27	-0.22	-2.50*	-114.68*	3.11	-48.29*	-0.03	-0.41*	0.02	0.09	0.37	0.11	5.12	-0.04
T-777 x 603	0.21	0.11	2.27*	18.26	-6.90	41.04*	-0.30	0.29	-0.18	0.25	0.85	-0.13	-3.46	2.45
T-777 x Solan Vajr	-0.48	0.11	0.23	96.41	3.97	7.25	0.33	0.12	0.15	-0.33	-1.23*	0.01	-1.66	-2.41
1794 x FT-5	-0.29	0.14	1.98*	302.32*	5.55	209.60*	0.26	0.22	0.39	0.41	-0.68	-0.53*	-15.28	-0.49
1794 x 603	-0.34	-0.17	-2.59*	-265.37*	-2.48	-187.40*	-0.38*	-0.24	-0.28	0.09	-0.03	0.15	8.80	0.10
1794 x Solan Vajr	0.63	0.03	0.60	-36.94	-3.07	-22.20	0.12	0.03	-0.12	-0.49*	0.71	0.39*	6.48	0.38
2694 x FT-5	-1.26	0.16	-1.13	33.47	4.91	-5.51	-0.53*	0.21	-0.38	-0.15	-0.42	-0.22	-6.24	-0.75
2694 x 603	-0.19	0.09	1.64*	27.79	-3.94	24.48	0.11	-0.19	-0.15	0.10	-0.61	-0.27	-1.02	-0.16
2694 x Solan Vajr	1.45	-0.25	-0.51	-61.26	-0.97	-18.98	0.42*	-0.03	0.53*	0.05	1.02*	0.49*	7.26	0.92
AI-14 x FT-5	0.46	-0.55*	-2.78*	-140.04*	3.57	-13.40	0.11	-0.11	0.66*	-0.23	-0.82	-0.26	-9.50	0.44
AI-14 x 603	-0.50	0.01	2.46*	141.89*	-2.55	8.60	-0.21	-0.07	0.11	-0.01	0.21	0.76*	17.58*	-1.74
AI-14 x Solan Vajr	0.04	0.54*	0.31	-1.84	-1.02	4.80	0.11	0.18	-0.77*	0.23	0.60	-0.51*	-8.08	1.30
V-16 x FT-5	-1.72	0.03	2.65*	136.66*	-2.99	-28.40	0.66*	0.27	-0.44	0.23	1.91*	0.06	-4.84	0.03
V-16 x 603	2.71*	-0.28*	-1.58*	-82.43	1.18	-6.40	0.18	0.14	0.18	-0.26	0.89	-0.05	-3.08	1.13
V-16 x Solan Vajr	-0.99	0.25	-1.07	-54.23	1.82	34.80*	-0.84*	-0.41	0.27	0.03	-2.81*	-0.01	7.92	-1.16
FT-13 x FT-5	1.77	-0.09	1.36	181.26*	2.83	4.71	0.36*	0.54*	0.61*	-0.27	0.74	-0.10	-8.73	-0.16
FT-13 x 603	0.05	-0.17	-1.00	-147.47*	-3.56	-6.63	-0.45*	-0.19	-1.74*	-0.54*	-1.32*	0.14	-2.31	-0.44
FT-13 x Solan Vajr	-1.82	0.26	-0.36	-33.79	0.72	1.91	0.08	0.36*	1.13*	0.81*	0.58	-0.03	11.03	0.61
Sel-6 x FT-5	0.27	0.19	0.76	6.29	-2.36	-2.62	0.08	-0.22	-0.50	0.18	-0.35	0.08	-2.82	-0.23
Sel-6 x 603	-0.12	0.39*	0.19	83.38	3.57	-7.29	0.20	0.22	0.63	0.02	0.31	0.38*	-2.73	-0.41
Sel-6 x Solan Vajr	-0.15	-0.58*	-0.95	-89.67	-1.21	9.91	-0.28	0.00	-0.13	-0.20	0.04	-0.46*	5.55	0.64
S-12 x FT-5	1.94	-0.36*	-1.13	-104.18*	-2.34	-17.06	0.21	0.42*	0.45	0.12	-0.39	0.18	19.72*	-0.25
S-12 x 603	0.21	0.23	1.97*	182.26*	3.95	4.93	0.14	-0.03	-0.39	-0.30	0.51	-0.19	-42.53*	-1.73

Hybrids	Days to first flowering	No. of fruits/ cluster	No. of fruits/ plant	Yield per plant	Fruit Weight	Whole fruit firmness	Fruit Length	Fruit Breadth	Pericarp Thickness	No. of locules/ Fruit	Stem end scar size	Total soluble solids	Plant Height	Harvest Duration
S-12 x Solan Vajr	-2.15*	0.13	-0.83	-78.08	-1.60	12.13	0.08	-0.39*	-0.06	0.18	-0.12	0.01	22.81*	1.98
101 x FT-5	0.15	-0.40*	1.32	162.81*	2.27	5.38	-0.01	-0.07	-0.95*	-0.20	-0.08	0.24	18.42*	0.33
101 x 603	-0.55	0.53*	-0.25	-42.05	-1.01	2.04	-0.20	-0.15	0.51	0.14	0.00	-0.41*	-24.26*	-1.85
101 x Solan Vajr	0.40	-0.13	-1.07	-120.76*	-1.26	-7.42	0.21	0.22	0.45	0.06	0.08	0.17	5.84	1.53
Pepsi-92 x FT-5	-1.28	-0.08	-2.12*	-95.63	3.52	-1.18	0.05	-0.43*	0.24	-0.51*	0.53	0.07	2.76	-0.41
Pepsi-92 x 603	0.32	-0.26	-0.87	-111.34*	-2.51	9.48	0.37*	0.15	0.58*	0.85*	-0.03	-0.08	11.18	-0.65
Pepsi-92 x Solan Vajr	0.96	0.34*	2.98*	206.97*	-1.00	-8.29	-0.42*	0.28	-0.82*	-0.34	0.50	0.01	-13.94	1.06
Solan Gola x FT-5	2.22*	0.36*	0.43	-86.20	-6.65	-12.54	-0.21	-0.12	0.15	0.34	0.61	0.08	-0.44	0.72
Solan Gola x 603	-0.36	-0.09	-1.14	-46.46	1.64	22.56	0.26	0.14	0.13	-0.20	0.06	-0.08	7.98	-0.22
Solan Gola x Solan Vajr	-1.86	-0.27	0.71	132.66*	5.01	-10.01	-0.05	-0.02	-0.27	-0.15	-0.68	0.00	-7.55	-0.50
Money Maker x FT-5	0.16	0.81*	-1.86*	-536.62*	-10.04*	-23.62	0.04	0.02	-0.21	0.01	-0.82	0.13	5.14	2.19
Money Maker x 603	-0.90	-0.40*	1.35	282.64*	4.27	7.71	0.25	0.11	0.95*	0.20	0.68	-0.13	0.93	1.69
Money Maker x Solan Vajr	0.74	-0.41*	0.51	253.88*	5.77	15.91	-0.28	-0.13	-0.74*	-0.21	0.15	0.00	-6.07	-3.88*
FT-9 x FT-5	-1.02	0.32*	-0.83	26.65	3.39	-12.84	-0.17	0.14	-0.05	0.02	-0.81	0.02	11.74	-0.12
FT-9 x 603	-0.08	-0.46*	1.16	88.40	0.06	7.48	0.00	-0.26	-0.08	-0.10	-0.45	-0.02	-0.84	0.37
FT-9 x Solan Vajr	1.11	0.14	-0.32	-115.05*	-3.45	5.36	0.17	0.13	0.13	0.07	1.26*	0.00	-10.90	-0.25
SE (sij)	1.10	0.14	0.76	51.38	4.91	14.93	0.17	0.17	0.26	0.22	0.52	0.19	7.88	1.57
SE (sij-skj)	2.31	0.25	1.58	108.96	10.31	31.65	0.32	0.33	0.51	0.41	1.05	0.35	16.66	3.29
SE (sij-ski)	2.26	0.29	1.56	105.30	10.06	30.59	0.35	0.36	0.54	0.46	1.07	0.38	16.66	3.22

*Significant at 5% level of significance trait. In male parent Solan Vajr was a good general combiner which exhibited significant positive gca effects (213.73), whereas FT-5 and 603 were poor combiners.

Amongst F_1's, only five hybrid combinations showed significant positive sca effects. The highest positive sca effects were observed in cross 1794 x FT-5 (209.60) followed by BT-12 x 603 (97.16).

4.2.7 Fruit length

The analysis of variance for general combining ability and specific combining ability were significant (Appendix-II). The component of variance due to sca (σ^2s) was greater than gca (σ^2g) indicating the preponderance of non-additive genetic effect for the trait.

The estimates of gca were significant and positive in line BT-12 (0.34) and Solan Gola (0.30). The magnitude of gca was also positive but non-significant in line FT-13 (0.20) and Sel-6 (0.10). The tester FT-5 (0.08) had higher gca effects than 603 (0.04) and Solan Vajr (-0.12). The highest positive sca effects were observed in cross V-16 x FT-5 (0.66) followed by 2694 x Solan Vajr (0.42), Pepsi-92 x 603 (0.37), FT-13 x FT-5 (0.36) and T-777 x Solan Vajr (0.33).

4.2.8 Fruit breadth

The analysis of variance (Appendix-II) showed that differences due to females, males and females x males were significant. The component σ^2s was lesser than σ^2g indicating the greater role of additive genetic variance for the expression of the trait.

The line 1794 (0.54) which was statistically at par with 2694 (0.48) exhibited the highest significant positive gca effects for fruit breadth. The lines S-12 (-0.59) and 101 (-0.48) were the poor general combiners. The tester FT-5 (0.07) had better gca effects than 101 (0.02) and Solan Vajr (-0.12) for the character. Amongst F_1's, only two cross combinations viz., FT-13 x FT-5 (0.54) and S-12 x FT-5 (0.42) exhibited the significant positive sca effects.

4.2.9 Pericarp thickness

The analysis of variance for combining ability showed significant variance due to females, males and females x males (Appendix –II). The magnitude of σ^2s was higher than that of σ^2g and their ratio indicated the predominant role of non –additive genetic variances for pericarp thickness in tomato.

The line Sioux (0.49) showed highest positive gca followed by V-16 (0.46) and BT-12 (0.44), while the lines 101 (-0.53) and FT-9 (-0.47) were poor general combiners for the trait. The tester Solan Vajr (0.09) exhibited higher gca than FT-5 (0.05) and 603 (-0.15). Among F_1's six cross combinations exhibited significant positive sca effects. The combination FT-13 x Solan Vajr (1.13) showed highest sca effects followed by Money Maker x 603 (0.95) and AI-14 x FT-5 (0.66).

4.2.10 Number of locules per fruit

It is evident from analysis of variance that the differences for variances due to females, males and females x males were significant for combining ability effects (Appendix-II).

The estimates of σ^2s was higher in magnitude than σ^2g, indicating the greater role of non-additive genetic variances for number of locules per fruit. The line Money Maker (-0.46) exhibited significant gca effects with negative value showing good general combining ability for the expression of trait followed by Sioux (-0.34) ad BT-12 (-0.23). The line S-12 (0.35), 1794 (0.32), FT-13 (0.32) exhibited significant positive gca effects indicating poor general combining ability for this trait. The tester Solan Vajr (-0.08) had good general combining ability for number of locules per fruit. Out of twenty F_1's which exhibited negative sca effects, FT-13 x 603 (-0.54) recorded the highest significant negative value closely followed by Pepsi–92 x FT-5 (-0.51) and 1794 x Solan Vajr (-0.49) for number of locules per fruit.

4.2.11 Stem end scar size

The analysis of variance for combining ability is presented in Appendix –II. The variance due to general combining ability and specific combining ability were significant. The magnitude of variance due to gca was lesser than that of sca effects, indicating the role of non-additive genetic variances.

The lines 101 (-2.52) and Money Maker (-1.87) showed significant gca effects with negative values exhibited good general combining ability for the expression of trait. Whereas, the lines BT-12 (2.40) and Sel-6 (1.96) showed significant positive gca effects indicating them to be poor general combiners followed by 1794 (1.30). The tester FT-5 (-0.45) was good general combiner for the expression of trait as it had higher magnitude of gca with negative value, whereas 603 was poor general combiner.

Among F_1's, the sca effects were significantly negative in V-16 x Solan Vajr (-2.81) followed by FT-13 x 603 (-1.32) and T-777 x Solan Vajr (-1.23) for stem end scar size, however highest positive sca effects was exhibited by V-16 x FT-5 (1.91).

4.2.12 Total soluble solids

The variances due to general combining ability of females and males and specific combining ability of females x males were significant for total soluble solids (Appendix-II). The magnitude of variance due to sca was higher than the variance due to gca, indicating the greater role of non-additive genetic variances for the expression of this trait.

The lines AI-14 (0.69) and V-16 (0.55) were good general combiners for expression of this trait, as these lines exhibited significant positive gca effects, whereas lines 1794 (-0.42), Sioux (-0.31) and 2694 (-0.30) were the poor general combiners for the trait. The tester 603 (0.17) had higher magnitude of gca effects than that of Solan Vajr and FT-5.

Amongst F_1's the significant positive sca effects were higher in cross AI-14 x 603 (0.76) followed by 2694 x Solan Vajr (0.49). These crosses involved good x good and poor x poor general combiners.

4.2.13 Plant height

The analysis of variance for plant height (Appendix-II) revealed that differences due to females, males and female x males were significant. The magnitude of variance due to sca was higher than gca indicating the greater role of non-additive genetic variance for the expression of the trait.

The lines Sel-6 (15.23) and FT-13 (11.80) exhibited highly significant gca effects enabling to draw the conclusion that these lines could be good general combiners for plant height, whereas, lines T-777 (-17.37) and S-12 (-13.97) were the poor general combiners. The tester Solan Vajr (33.73) had significantly higher magnitude of gca effects than FT-5 and 603.

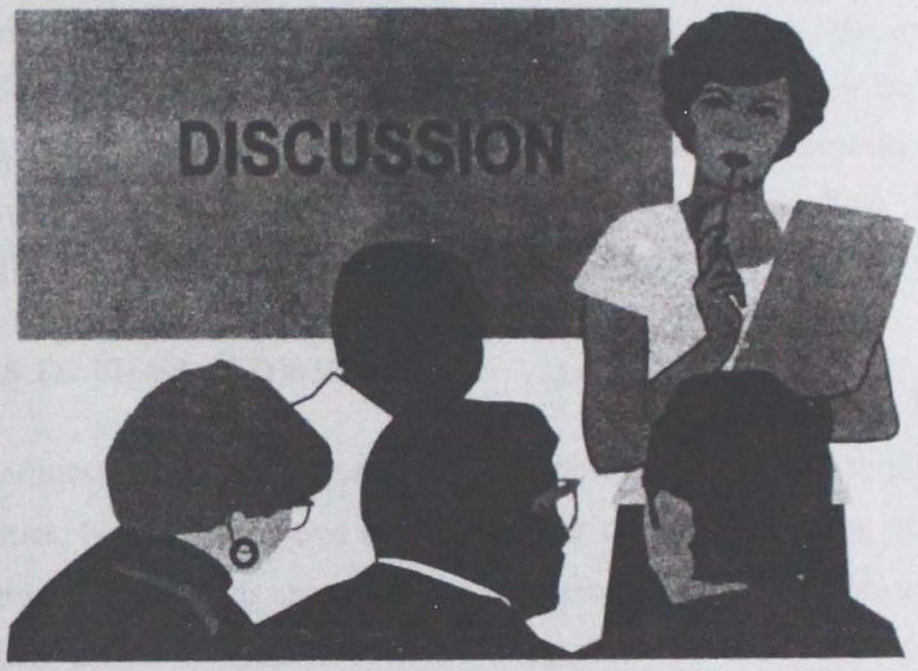
Five F_1's had significantly positive specific combining ability effects being highest in the Cross S-12 x Solan Vajr (22.81) followed by BT-12 x 603 (19.87). These crosses involved poor x good and good x poor general combiners.

4.2.14 Harvest duration

The variances due to general combining ability and specific combining ability were significant (Appendix-II). The component $\sigma^2 s$ was more than $\sigma^2 g$ indicating greater role of non-additive genetic variances in the manifestation of this trait.

The line AI-14 (2.19) had highest significant positive gca effects indicating that the line is a good general combiner for this trait. The positive gca effects were also observed in lines Sel-6 (1.86), Money Maker (0.79) and Solan Gola (0.68), whereas, lines BT-12 (-2.55), Sioux (-1.23), 101 (-0.69) and T-777 (-0.66) were poor general combiners for the expression of trait. The tester 603 (1.47) had highest magnitude of gca effects than that of FT-5 (-0.48) and Solan Vajr (-0.99).

Among F_1's the highest magnitude of sca effects was observed in cross T-777 x 603 (2.45) followed by Money Maker x FT-5 (2.19) and S-12 x Solan Vajr (1.98) for harvest duration.


DISCUSSION

Chapter-5

DISCUSSION

World wide popularity of tomato as food crop has attracted the attention of breeders as well as growers more than any other vegetable crop. It is one of the major cash crop of mid hills of Himachal Pradesh. Because of increased interest of growers for hybrids having high yield, uniformity, earliness, wider adaptability and thicker pericarp, the present investigation line x tester studies in tomato was carried out to obtain information on the general and specific combining ability effects and estimation of heterosis for various economic characters, so that superior F_1 hybrid combination(s) of tomato could be identified for commercial use in the state. The experimental material generated through crossing 15 lines with three testers alongwith parents were compared with better parents and check Naveen-2000. The salient research findings are discussed as under :

5.1 DAYS TO FIRST FLOWERING

Earliness is one of the major consideration for preferring hybrids over pure line varieties. Negative heterosis is desirable for this character. Out of fourty-five combinations eight hybrids showed negative heterobeltiosis. The combination S-12 x Solan Vajr and T-777 x Solan Vajr flowered significantly earlier than their respective early parent. Out of these two combinations, (S-12 x Solan Vajr) was earlier in flowering to check (Naveen-2000). Early flowering in hybrids have also been reported by Jamwal et al. (1984), Kravchenko (1990), Dev (1991), Dod *et al.* (1992), Singh and Singh (1993), Pujari and Kale (1994) and Joshi (1998).

The combining ability studies indicated that variances due to gca and sca were significant, suggesting the importance of both additive and non-additive gene effects. These results are in line with findings of Govindarasu *et al.* (1983), Sharma (1988), Dev (1991) and Cheema *et al.* (1996). The lines 101 and S-12 and tester Solan Vajr were good general combiners for early flowering. The cross combination S-12 x Solan Vajr exhibited highest negative sca estimates followed by Solan Gola x Solan Vajr which involved good x good and poor x good general combiners, respectively.

5.2 NUMBER OF FRUITS PER CLUSTER

The maximum increase in number of fruits per cluster over better parent (58.98%) was recorded in the hybrid AI-14 x Solan Vajr. In general most of the hybrids gave negative heterosis over better parent for fruits per cluster. Only thirteen crosses showed positive heterosis. The results are in close conformity with those of Jamwal *et al.* (1984), Sharma (1988) and Dev *et al.* (1994).

The magnitude of variance due to sca was greater than gca, depicting the greater role of non-additive gene effects. Similar findings were obtained by Peter and Rai (1980), Vozdova *et al.* (1990) and Dev (1991). Among the lines FT-9, FT-13 and Money Maker and tester Solan Vajr were good general combiners. The crosses Money Maker x FT-5, AI-14 x Solan Vajr and 101 x 603 exhibited the highest sca effects. These crosses involved good x poor, good x poor and poor x poor general combining parents. This emphasized the importance of both general and specific combining ability estimates.

5.3 NUMBER OF FRUITS PER PLANT

In general most of the hybrids showed positive heterosis for number of fruits per plant, indicating the character being under the control of dominant genes. The heterobeltiotic effects were significantly positive in nineteen hybrid combinations out of fourty-five. Similar findings of heterobeltiosis for the trait have been reported by Govindarasu *et al.* (1983), Jamwal *et al.* (1984), Araujo and Decampos (1991), Dev *et al.* (1994), Kumar *et al.* (1995), Singh *et al.* (1995) and Joshi (1998).

The gca and sca variances were significant suggesting the importance of both additive and non-additive genetic components. However, higher magnitude of σ^2sca over σ^2gca for this trait indicated predominant role of non-additive gene action. These results are in agreement with the findings of Anbu *et al.* (1980), Govindarasu *et al.* (1983), Patil and Bojappa (1986b) and Sharma (1988). General combining ability of parents revealed that the lines FT-9, 1794 and Money Maker and tester Solan Vajr were good general combiners. The cross combination Sioux x FT-5 exhibited the highest positive sca estimates.

5.4 FRUIT YIELD PER PLANT

The character which makes a variety/ hybrid commercially popular is yield per plant. It is the major objective of all the breeding programme. If yield per plant is more, yield per unit area will also be more out of fourty-five F_1's, as many as fourty-one exhibited positive heterosis over their better parents for this trait. The highest percentage of heterosis was recorded in hybrid AI-14 x 603 (59.98%) which also depicts the dominance of genes controlling high fruit yield per plant. The present findings are in conformity with the findings of Anbu *et al.* (1980), Ahmed *et al* (1988), Bora *et al.* (1993), Singh and Singh (1993) and Singh *et al.* (1995).

The combining ability analysis revealed the predominance of non-additive genes which play a major role in expression of yield per plant. Similar results were also reported by Rattan and Saini (1976), Jamwal *et al.* (1984), Sonone *et al.* (1986), Chandrasekhar and Rao (1989), Dod *et al.* (1995) and Rai *et al.* (1997). The lines FT-9 and 1794 and tester Solan Vajr were observed to be good general combiners for fruit yield per plant. Hybrids 1794 x FT-5, Money Maker x 603, Money Maker x Solan Vajr, Sioux x FT-5 and Pepsi –92 x Solan Vajr which exhibited high sca effects, involved very good x poor, good x poor, good x good, poor x poor and poor x good general combiners. Sangha (1960) was of the view that a combination involving both the parents with high gca was the best specific combiners, while Khalif Allah (1985) and Rudas and Blashchuk (1979) observed that in order to produce hybrid with high yield, one of the parents should have high gca estimates.

5.5 FRUIT WEIGHT

Prashar and Enevoldesen (1993) reported that acceptable fruit weight in fresh market tomato should be more or equal to 120 g per fruit, however, these days most preferred fruit weight ranges from 65 to 85 gm.

In the present investigation the average fruit weight ranged from 47.57 to 100.43 g in parents. In general most of the hybrids showed negative heterosis over the better parent. The cross 2694 x FT-5 showed the maximum average fruit weight (90.61 g). None hybrid combinations recorded significant positive heterosis over their corresponding better parent. The highest magnitude of heterotic effect was observed in cross Sioux x Solan Vajr (18.42%). Similar findings of heterosis for fruit weight have also been reported by Sidhu *et al.* (1981), Singh *et al.* (1983), Ahmed *et al.* (1988), Araujo and Decampos (1991), Reddy and Reddy (1994), Dev *et al.* (1994), Kumar *et al.* (1995) and Singh *et al.* (1995).

The variance due to gca and sca were significant, indicating the role of both additive and non-additive gene action, though the non-additive gene actions were predominant. Similar findings have been reported by Patil and Bajappa (1986a) and Chandrasekhar and Rao (1989). Lines 2694, Sioux, FT-9 and tester 603 were found to be good general combines for this trait. Among the crosses Money Maker x Solan Vajr exhibited the highest significant positive sca estimates. This combination involved poor x average general combiner.

5.6 WHOLE FRUIT FIRMNESS

Firm fruited tomatoes have better shelf life and can withstand long transportation. In the present studies, only one hybrid showed significant positive heterosis over its better parent. However, most of the hybrids showed negative heterobeltioses for this trait. These results are in close conformity with those of Fageria (1994) and Sharma (1996), Joshi (1998) and Dobhal (1999).

Combining ability analysis revealed the significance of both additive and non-additive genetic variances for this trait. Higher magnitude of σ^2s over σ^2g indicated the preponderance of non-additive gene actions, for the expression of this trait. Chandrasekhar and Rao (1989) also expressed similar views as the present one with regard to combining ability effects of whole fruit firmness. Among lines 1794, V-16, S-12 and tester, Solan Vajr had good gca for whole fruit firmness. The cross 1794 x FT-5 exhibited the highest significant sca estimates followed by BT-12 x 603. These crosses involved good x poor and poor x poor general combiners, respectively.

5.7 FRUIT LENGTH

The maximum increase in fruit length over better parent was 13.30 per cent (Money Maker x FT-5). In general most of the hybrids gave negative heterosis for fruit length. Out of forty-five hybrids, sixteen cross combinations showed positive heterosis for fruit length. Increase in fruit length over better parent have also been reported by Chaudhary and Khanna (1972), Banerjee *et al.* (1973), Govindarasu *et al.* (1983), Jamwal *et al.* (1984) and Dev (1991).

The magnitude of variance due to sca was greater than gca, indicating the greater role of non-additive gene action. These results are in close conformity with those of Anbu *et al.* (1980), Govindarasu *et al.* (1983), Patil and Bajappa (1986b) and Sharma (1988). The lines BT-12 and Solan Gola and tester, FT-5 were good general combiners. However, among F1's, crosses V-16 x Ft-5, 2694 x Solan Vajr, Pepsi-92 x 603 and FT-13 x FT-5 exhibited the highest sca estimates. These crosses involved poor x good, good x poor, poor x good and good x good, general combiners.

5.8 FRUIT BREADTH

In general most of the hybrids showed negative heterosis for fruit breadth over their respective better parent, indicating that the character is under the control of additive genes. Out of fourty-five hybrids, eight combinations gave positive heterosis for fruit breadth. The increase in fruit breadth over better parent have also been reported by Banerjee *et al.* (1973), Jamwal *et al.* (1984), Boe (1988) and Dev (1991).

The combining ability studies revealed that both the additive and non-additive gene actions were important. Comparison of σ^2s and σ^2g indicated the preponderance of additive gene action for the expression of this trait. These results are in line with the findings of Singh and Singh (1980), Govidarasu *et al.* (1983) and Sharma (1988). Among the lines 1794 and 2694 and tester, FT-5 were good general combiners. Hybrid combinations FT-13 x FT-5 and S-12 x FT-5 had higher sca estimates. These combinations involved good x good and poor x good general combiners, respectively.

5.9 PERICARP THICKNESS

Pericarp thickness is the primary character contributing towards the whole fruit firmness (Ahrens *et al.*, 1987). In the present findings most of the hybrids showed negative heterosis over the better parent. The highest significant positive heterosis was observed in cross Sel-6 x 603 (22.89%) for pericarp thickness over its better parent. Heterosis for pericarp thickness have also been reported by Rattan and Saini (1976) and Yadav *et al.* (1991).

Combining ability analysis revealed, that the magnitude of non-additive variances (σ^2s) was higher than additive variance (σ^2g) indicating preponderance of non-additive gene actions. Similar findings have also been reported by Sidhu *et al.* (1981), Bhutani (1981), Dixit *et al.* (1980) and Patil and Bojappa (1986b).

Amongst the lines Sioux V-16 and BT-12 and tester, Solan Vajr were good general combiners. The cross FT-13 x Solan Vajr exhibited higher significant sca estimates which involved good x good general combiners.

5.10 NUMBER OF LOCULES PER FRUIT

Generally varieties/hybrids with less number of locules and higher pericarp thickness are preferred in processing industry. Dundi and Mandalageri (1991) reported that less number of locules per fruit indicated the firmness in tomato fruit. In the present studies maximum negative heterosis over the better parent was observed in cross Sioux x FT-5.

Present findings suggested that number of locules per fruit was under control of non-additive genes as the ratio of the gca and sca variance was less than one, which is in close conformity with the results of Kalloo *et al.* (1974) and Vijaymohan *et al.* (1986). Among the lines Money Maker, Sioux and tester Solan Vajr were good general combiners. However, the crosses FT-13 x 603, Pepsi-92 x FT-5 and 1794 x Solan Vajr showed significantly higher negative sca. These crosses involved poor x poor, poor x medium and poor x good general combiners, respectively.

5.11 STEM AND SCAR SIZE

Stem end scar size is relatively new aspect studied during the present course of investigations. Very little work have been done on this aspect in past. A smaller stem end scar size is preferred from processing and fresh consumption point of view. Moreover, the smaller stem end scar size avoids attack of fruit fly (Kohli, 1998). In the present findings, the most of the hybrids showed positive heterosis over the better parent, indicating that the larger stem end scar size is under the control of dominant genes. Though, the highest negative heterosis was observed in cross V-16 x Solan Vajr (-27.84%).

Combining ability analysis revealed the importance of both additive and non-additive gene actions for this trait. Among the lines 101 and Money Maker and tester, FT-5 were found to be good general combiners. The hybrids V-16 x Solan Vajr, FT-13 x 603 and T-777 x Solan Vajr exhibited significantly higher negative sca effects. These crosses involved medium x medium, poor x poor, medium x poor general combiners.

5.12 TOTAL SOLUBLE SOLIDS

High soluble solids content is the desirable quality attribute in processing of tomato products. Out of forty-five hybrids, three hybrids recorded significant positive heterosis over their corresponding better parents. All three hybrids also exhibited significant positive increase over the check (Naveen–2000), which indicates the dominance of higher TSS over lower TSS value in tomato. Heterobeltiosis for total soluble solids has also been reported by Rattan and Saini (1979), Govindarasu *et al.* (1983) and Legon *et al.* (1984).

The variance due to gca and sca were significant. The magnitude of variance component of gca (σ^2g) was less than the sca (σ^2s), indicating the preponderance of non-additive genetic variance. These results are in close conformity with those of Singh and Nandpuri (1970), Rattan and Saini (1979), Patil and Bojappa (1986a), Patgaonkar *et al.* (1993) and Kurian and Peter (1995). Among the lines AI-14 and V-16 and tester 603 were the best general combiners. The crosses AI-14 x 603 and 2694 x Solan Vajr exhibited the highest significant positive sca effects. These combinations involved good x good and poor x poor general combiners, respectively. This suggested the importance of both additive and non-additive gene effects.

5.13 PLANT HEIGHT

Plant height assumes significance in the wake of longer harvest duration and high incidence of buck eye fruit rot in mid hills of Himachal Pradesh where indeterminate cultivars/ hybrids are preferred over dwarf ones.

Positive heterobeltiosis effects were observed in all the hybrid combinations for this trait, which shows that more plant height was under the control of dominant genes. Increase in plant height due to heterotic effects has also been reported by Sidhu *et al.* (1981), Jamwal *et al.* (1984), Dev *et al.* (1994) and Sharma (1996).

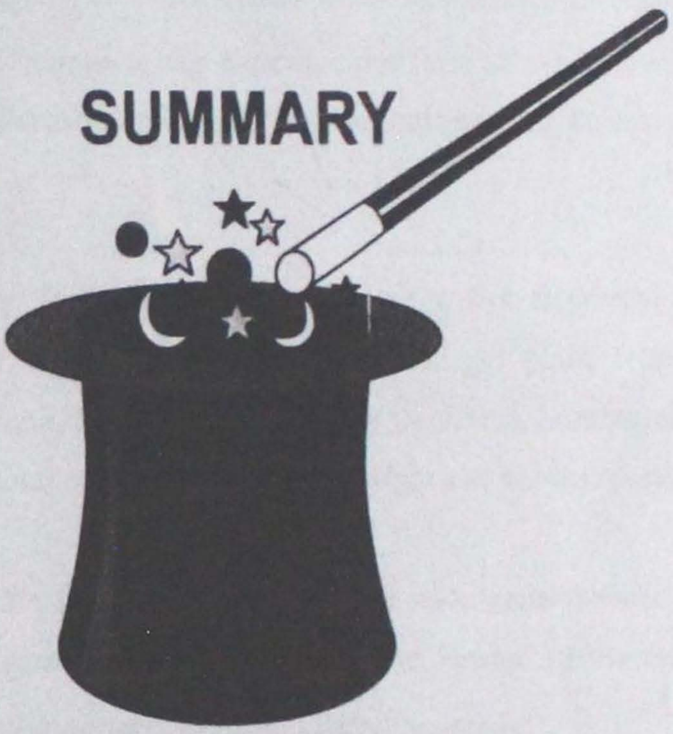
Present studies revealed that magnitude of variance due to sca (σ^2s) was higher than gca (σ^2g) indicating that the non-additive gene action is controlling the expression of the trait. Over all it suggest that heterosis breeding can bring substantial improvement in plant height. The results are in close conformity with those of Kalloo *et al.* (1974), Bhutani (1981), Dod *et al.* (1990), Farkas (1993), Dev *et al.* (1994) and Sharma (1996). The lines Sel-6 and FT-13 and tester Solan Vajr were good general combines for plant height. Among the crosses S-12 x Solan Vajr and BT-12 x 603 exhibited the highest sca estimates.

5.14 HARVEST DURATION

Prolonged harvest duration is desirable for fresh market production of tomatoes, as it assures continuous supply of vine ripe tomato and avoid glut in the markets. Out of fourty-five hybrids only five exhibited positive heterosis over their respective better parent for harvest duration. Similar findings has also been reported by Sharma (1996).

The additive and non-additive gene actions were found to be equally important for this trait.

Among the lines AI-14, Sel-6 and tester 603 were good general combiners. However, the cross T-777 x 603, Money Maker x FT-5 and S-12 x Solan Vajr exhibited highest magnitude of sca estimates. These combinations involved poor x good, good x poor and poor x poor general combiners, respectively.


SUMMARY

Chapter-6

SUMMARY

The present investigations entitled "Line x Tester Studies in Some Genotypes of Tomato" were undertaken to study general and specific combining ability, involving 15 lines and three testers. The magnitude of heterosis over the better parent and per cent increase or decrease over Naveen-2000 (Check) was also worked out, to identify the best hybrid(s) for commercial utilization. The parents (15 lines and 3 testers) and their F_1's and a check (Naveen-2000) were transplanted in Randomised Block Design with three replications at the experimental farm of the Department of Vegetable Crops, Dr. Y.S. Parmar University of Horticulture and Forestry, Solan during Kharif, 2002.

The characters selected for observations were days to first flowering, number of fruits per cluster, number of fruits per plant, fruit yield per plant, fruit weight, whole fruit firmness, fruit length, fruit breadth, pericarp thickness, number of locules per fruit, stem end scar size, total soluble solids, plant height and harvest duration.

Analysis of variance for the experiment revealed wide genetic variability for all the characters. Hybrid vigour in F_1's was exhibited in almost all the characters. Salient findings of present investigations are summarized hereunder:

6.1 HETEROSIS STUDIES

Cross S-12 x Solan Vajr was significantly earlier in flowering than its better parent. Significant increase in number of fruits per cluster was observed in thirteen hybrid combinations. Seventeen hybrid combinations showed significant heterobeltiosis for number of fruits per plant. Cross 1794 x FT-5 exhibited highest number of fruits per plant (27.33). Same combination recorded 11.41 per cent higher number of fruits per plant than the check (Naveen-2000). The highest yield was recorded in the cross 1794 x FT-5 (2316.12 g/plant), which was 5.87 per cent higher than the check (Naveen-2000).

Twenty five hybrid combinations significantly over yielded their respective parents. Among forty five hybrids, maximum fruit weight was observed in cross 2694 x FT-5. In general, most of the hybrids showed negative heterosis over the check Naveen-2000 for this character. The whole fruit firmness is a very important character for tomato. This character was studied with the help of penetrometer. Most of the F_1's were poor for this trait to their better parent and as well as to the check (Naveen-2000). The maximum whole fruit firmness was observed in cross 1794 x FT-5 (1604.33 g/0.503 cm^2), 6.86 per cent higher than check (Naveen-2000).

Increase in fruit length and breadth was to the extent of 13.30 (Money Marker x FT-5) and 17.07 (2694 x FT-5) per cent, respectively. Pericarp thickness of tomato is an important parameter for shelf life of tomato fruit. The cross FT-13 x Solan Vajr showed highest pericarp thickness (7.40 mm). The minimum number of locules per fruit was observed in cross Sioux x FT-5 (3.20) and it was significantly lower (-7.51%) when compared with check (Naveen-2000). To obtain a hybrid with lesser number of locules, it is suggested that both the parents must have less number of locules per fruit. The cross 101 x 603 had smallest stem end scar size (7.08 mm) and it was significantly lower (-21.42%) than the check (Naveen-2000).

Significant positive heterobeltiosis for total soluble solids was observed in three combinations. The highest being in cross. AI-14 x 603 (5.83°B) and it was 37.83 per cent higher than Naveen-2000 (4.23°B). All the hybrid combinations were taller than their better parent. The highest plant height was observed in Sel-6 x FT-5 (199.33 cm) which was significantly higher (11.78%) than check (Naveen-2000). Indeterminate varieties are better suited for rainy season production as these helps to ensure longer harvesting span. The longest harvest duration was observed in cross AI-14 x Solan Vajr (41.67), while the combination BT-12 x FT-5 recorded minimum days (32.33) of harvest duration.

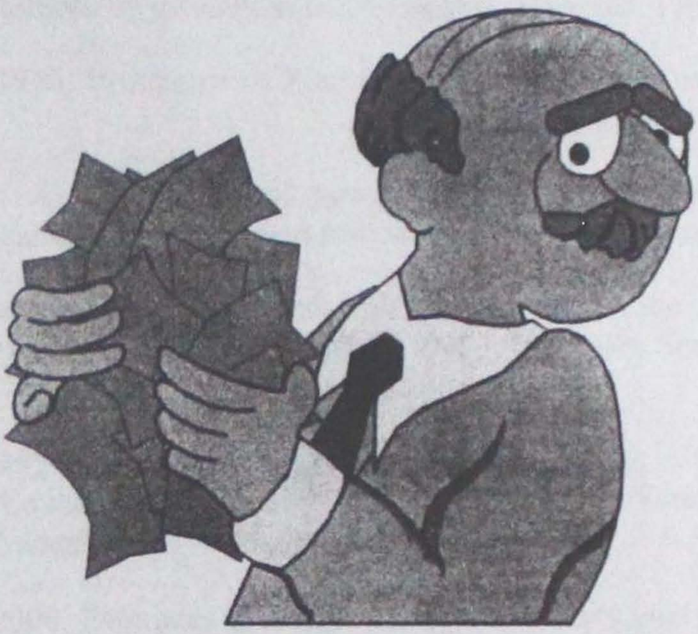
6.2 COMBINING ABILITY ANALYSIS

The variance due to general combining ability and specific combining ability were significant for all the characters, suggesting the importance of both additive and non-additive gene actions.

The magnitude of variance due to sca (σ^2s) was greater than variance due to gca (σ^2g) indicating the preponderance of non-additive gene actions for all the characters studied except days to first flowering and fruit breadth.

The line FT-9 exhibited good general combining ability effects for yield per plant, number of fruits per plant and number of fruits per cluster. The line BT-12 exhibited high general combining ability for fruit length and stem and scar size. In respect of days to first flowering line 101 showed good general combining ability. Line 1794 showed good general combining ability for whole fruit firmness and fruit breadth. Whereas, for fruit weight, total soluble solids, plant height and harvest duration good general combining ability were observed by 2694, AI-14, Sel-6 and AI-14, respectively. However, good general combining ability for pericarp thickness and number of locules per fruit was shown by Sioux and Money Maker, respectively.

The crosses S-12 x Solan Vajr, Money Maker x FT-5 and Sioux x FT-5 had the high specific combining ability for days to first flowering and plant height, number of fruits per cluster and number of fruits per plant, respectively. However, the cross 1794 x FT-5 exhibited the high specific combining ability for yield per plant and whole fruit firmness. The crosses BT-12 x 603, FT-13 x Solan Vajr, V-16 x Solan Vajr, AI-14 x 603 and T-777 x 603 exhibited high specific combining ability for fruit weight, pericarp thickness, stem end scar size, total soluble solids and harvest duration, respectively.



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*Original not seen

APPENDICES

APPENDIX-I

Meteorological data for the year 2002

Month	Temperature (^{o}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
March	24.4	8.8	61	119.4
April	30.0	12.9	52	89.4
May	33.0	17.0	40	26.6
June	31.4	19.1	60	92.6
July	30.5	20.2	67	118.4
August	27.9	19.9	81	302.0
September	26.6	15.3	76	230.6

Source: Meteorological Observatory, Department of Soil Science and Water Management, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) – 173 230 INDIA

APPENDIX-II

ANALYSIS OF VARIANCE FOR COMBINING ABILITY

Source of variance	d.f.	Days to first flowering	No. of fruits/cluster	No. of fruits/plant	Yield/ plant	Fruit weight	Whole fruit firmness	Fruit length	Fruit breadth	Pericarp thickness	No. of locules/ fruit	Stem end scar size	Total soluble solids	Plant height	Harvest duration
Females	14	15.86	0.78	30.99	119650.2	305.21	53474.82	0.43	0.93	1.18	0.56	4.89	0.96	2315.81	11.74
Males	2	5.96	0.29	16.77	195031.1	94.31	233816.30	0.50	0.29	0.73	0.22	3.38	0.004	449.28	8.34
Females x Males	28	5.62	0.48	20.81	109456.9	96.21	48657.39	0.38	0.26	1.28	0.44	2.99	0.31	572.10	16.96
Error	88	8.21	0.14	4.96	14768.7	30.77	2655.58	0.19	0.20	0.47	0.33	0.14	0.11	140.81	11.87
$\sigma^2 g$		1.11	0.05	0.10	1596.13	19.96	3166.27	-0.01	0.07	0.04	0.03	0.20	0.01	27.01	-0.23
$\sigma^2 s$		-0.86	0.11	5.28	31562.72	21.81	15333.94	0.06	0.02	0.27	0.04	0.95	0.07	143.77	1.70
$\sigma^2 g/\sigma^2 s$		1.29	0.45	0.02	0.05	0.92	0.21	-0.17	3.5	0.15	0.75	0.21	0.14	0.19	-0.14

CURRICULUM VITAE

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Father's Name : Sh. K.P. Mishra

Date of Birth : 20.02.1980

Sex : Male

Marital Status : Unmarried

Nationality : Indian

Educational Qualifications :

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10+2	First*	UP Board, Allahabad	1996
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Whether sponsored by some state/ Central Govt./Univ./SAARC : ICAR Nominee

Scholarship/ Stipend/ Fellowship, any other financial assistance received during the study period : No

Mishra

(Kuldeep Kumar Mishra)