

**INHERITANCE OF YIELD, YIELD  
COMPONENTS AND RESISTANCE TO ToLCV  
IN TOMATO [*Solanum lycopersicum* (Mill.)]**

**JAFARSHAREEF SUTAR**

**PHK 507/PHL 001**

**DIVISION OF HORTICULTURE  
UNIVERSITY OF AGRICULTURAL SCIENCES  
BANGALORE-560 065**

**2012**

**INHERITANCE OF YIELD, YIELD  
COMPONENTS AND RESISTANCE TO ToLCV  
IN TOMATO [*Solanum lycopersicum* (Mill.)]**

**JAFARSHAREEF SUTAR**

**PHK 507/PHL 001**

*Thesis submitted to the  
University of Agricultural Sciences, Bangalore  
in partial fulfillment of the requirements  
for the award of the degree of*

***MASTER OF SCIENCE (Horticulture)***

**in**

**VEGETABLE SCIENCE**

BANGALORE


FEBRUARY, 2012

*Affectionately Dedicated to*  
*My Beloved Parents*

**DIVISION OF HORTICULTURE**  
**UNIVERSITY OF AGRICULTURAL SCIENCES**  
**BANGALORE**  
**CERTIFICATE**

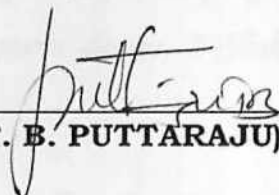
*This is to certify that the thesis entitled "INHERITANCE OF YIELD, YIELD COMPONENTS AND RESISTANCE TO ToLCV IN TOMATO [*Solanum lycopersicum* (Mill.)]" submitted by Mr. JAFARSHAREEF SUTAR, ID No. PHL 001 for the award of the degree of MASTER OF SCIENCE (Horticulture) in VEGETABLE SCIENCE to the University of Agricultural Sciences, Bangalore, is a record of bonafide research work carried out by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.*

**Bangalore**  
**February, 2012**

  
**Dr. T. B. PUTTARAJU**  
Prof. of Horticulture  
UAS, GKVK, Bangalore

**Approved by:**

**Chairman:**

  
\_\_\_\_\_  
**(T. B. PUTTARAJU)**


**Members : 1.**

\_\_\_\_\_  
**(A. T. SADASHIVA)**

**2.**

  
\_\_\_\_\_  
**(H. B. LINGAIAH)**

**3.**

  
\_\_\_\_\_  
**(J. SHIVANNA)**

## ACKNOWLEDGEMENT

*I have immense pleasure to express my sincere and heartfelt gratitude to Dr. T.B. PUTTARAJU, Professor of Horticulture, & Technical Officer Dean(PGS) G.K.V.K, UAS, Bangalore and chairman of my advisory committee whose ideas, guidance, inspiring encouragement and constant supervision formed source of inspiration in execution and completion of this study*

*I owe my thanks to, Dr. A.T. SADASHIVA, Principal Scientist & Head, Division of Vegetable Crops, Indian institute of Horticulture Research, Hesaraghatta, who was my advisory committee member for his utmost help and invaluable suggestions.*

*I wish to thank my advisory committee members, Dr. H.B. LINGIAH, Special Officer and Campus Head, PG Centre UHS Campus GKVK Bangalore Dr. J. Shivanna, Professor of Horticulture, FTI G.K.V.K, UAS, Bangalore, for their kind concern and valuable suggestions to bring this manuscript.*

*I wish to acknowledge special thanks to my close friends Shivanand, Rajesab, and chotu Ramesh, for their constant encouragement, help, cheerful company, constant support, concern and co-operation throughout my master's degree. I Shall forever remember them.*

*It is my duty to express sincere thanks to my friends Nataraja A, JP, Ramakrishna Hari, Ravi, S., for refreshing company and help during my stay at the college and department.*

*I am thankful to field staff of vegetable crop Plots, for their co-operation during field operation.*

*In a personal note, I record my respectful indebtedness and gratitude to my beloved parents, wife Aasma, son Farhaan Aareeb, Brother Ajju, Sister shahanaz and Ruma Zaara for their ambitious, unquantifiable love, continued calm endurance, constant support and affection showed on me throughout my educational endeavor.*

*I would like to extend my deep sense of gratitude to all those who have contributed and helped directly and indirectly.*

Bangalore  
February, 2012

  
(JAFAR SHAREEF SYTAR)

## THESIS ABSTRACT


Investigation on Inheritance of yield, yield components and resistance To TOLCV in Tomato (*Solanum lycopersicon*, L.) was undertaken during 2006-07 in Department of Horticulture, University of Agricultural Sciences, Bangalore. The study was mainly contemplated to know the genetics of yield, yield components, resistance to TOLCV.

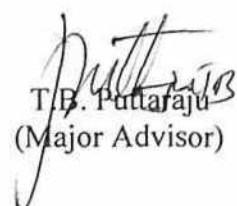
The entries under the investigation comprised Arka Abha, Arka Alok and Vybhav as parents, respective F1 hybrids, F2 generation and their back cross generations.

Higher estimates of phenotypic and genotypic coefficients of variability, heritability and genetic advance were observed for number of primary branches, number of fruit per plant, number of locules per fruit, average fruit weight, TSS of fruit, symptoms expression and disease score for TOLCV.

TOLCV disease resistance was governed by completely dominant gene in an in history gene action for both the crosses (Vybhav x Arka Alok and Vybhav x Arka Abha).

In the present investigation Vybhav x Arka Alok and Vybhav x Arka Abha performed better for the reason that no plants of F1 were susceptible till the end of cropping period and there was enhanced fruit weight with reduced fruit yield. Further, this cross led to identification of more number of transgressive segregants for fruit yield and resistance to TOLCV.

  
Jafarshareef Sutar

  
T.B. Puttaraju  
(Major Advisor)

ಟೋಮೋಟೋ (ಸೋಲ್ಯಾನಮ್ ಲೈಕೋಪರ್ಸಿಕಮ್, ಮಿಲ್) ಬೆಳೆಯಲ್ಲಿ ಇಳುವರಿ,  
ಇಳುವರಿ ಪೂರಕ ಗುಣಗಳು ಮತ್ತು ಎಲೆ ಮುಟುರು ರೋಗ ನಿರೋಧಕತೆಯ  
ಅನುವಂಶೀಯ ಅಧ್ಯಯನ

### ಪ್ರಭಂದ ಸಾರಾಂಶ

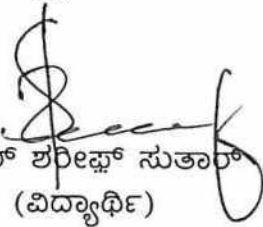
ಟೋಮ್ಯಾಟೋ ಬೆಳೆಯಲ್ಲಿ ಇಳುವರಿ, ಇಳುವರಿಗೆ ಪೂರಕವಾದ ಗುಣಗಳು ಮತ್ತು ಎಲೆ ಮುಟುರು ರೋಗದ ನಿರೋಧಕತ್ವ ವಂಶವಾಹಿನಿಯ ಅಧ್ಯಯನವನ್ನು 2006-07 ನೇ ಸಾಲಿನಲ್ಲಿ ಗಾಂಧಿ ಕೃಷಿ ವಿಶ್ವವಿದ್ಯಾನಿಲಯದ ತೋಟಗಾರಿಕೆ ವಿಭಾಗದಲ್ಲಿ ಕೈಗೊಳ್ಳಲಾಯಿತು. ಟೋಮ್ಯಾಟೋ ಬೆಳೆಯಲ್ಲಿ ಇಳುವರಿ, ಇಳುವರಿಗೆ ಪೂರಕವಾದ ಗುಣಗಳು ಮತ್ತು ಎಲೆ ಮುಟುರು ರೋಗದ ನಿರೋಧಕತ್ವ ವಂಶವಾಹಿನಿಯನ್ನು ತಿಳಿದುಕೊಳ್ಳುವಿಕೆಯನ್ನು ಪ್ರಸಕ್ತ ಅಧ್ಯಯನವು ಒಳಗೊಂಡಿದೆ.

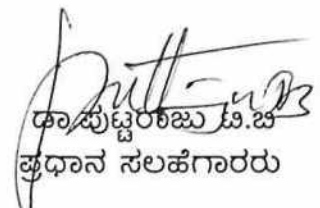
ವೈಭವ, ಅರ್ಕಾ ಅಲೋಕ್ ಮತ್ತು ಅರ್ಕಾ ಅಭಾ ತಳಿಗಳ F1 ಸಂಕರಣಗಳು, F2 ಸಂಕರಣಗಳು ಮತ್ತು ಬ್ಯಾಕ್ ಕ್ರಾಸ್ ಸಂಕುಲಗಳನ್ನು ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ಬಳಸಲಾಯಿತು.

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವು ಎಲ್ಲಾ ಗುಣಲಕ್ಷಣಗಳಿಗೆ ಅತ್ಯಂತ ಗಮನಾರ್ಹ ವ್ಯತ್ಯಾಸವನ್ನು ಬಹಿರಂಗಪಡಿಸಿದೆ. ಅತೀ ಹೆಚ್ಚು ಜಿ.ಸಿ.ವಿ., ಮತ್ತು ಪಿ.ಸಿ.ವಿ. ಅನುವಂಶೀಯತೆ ಮತ್ತು ಅನುವಂಶೀಯ ಪ್ರಗತಿಯ ಮುಂಚಿತವನ್ನು ಪ್ರಾರ್ಥಮಿಕ ಗೊಂಚಲುಗಳು, ಪ್ರತಿ ಗಿಡದ ಕಾಯಿಗಳ ಸಂಖ್ಯೆ, ಕಾಯಿಯ ಟೋಳಿನ ಗಾತ್ರ, ಸರಾಸರಿ ಕಾಯಿಯ ತೂಕದಲ್ಲಿ ನೇರ ಮತ್ತು ಪ್ರತ್ಯಕ್ಷ ಹಾಗೂ ಇನ್ನುಳಿದ ಗುಣಲಕ್ಷಣಗಳಲ್ಲಿ ಪರೋಕ್ಷ ಪ್ರಭಾವ ಕಂಡುಬಂದಿದೆ.

ವೈಭವ.. ಅರ್ಕಾ ಅಲೋಕ್ ಮತ್ತು ವೈಭವ ಅರ್ಕಾ ಅಭಾ ಎರಡೂ ಸಂಕರಣಗಳಲ್ಲಿ ಎಲೆ ಮುಟುರು ರೋಗದ ನಿರೋಧಕತ್ವತೆಯನ್ನು ಸಂಪೂರ್ಣ ಧನಾತ್ಮಕ ವಂಶವಾಹಿನಿಯಿಂದ ನಿರ್ಧರಿಸಲ್ಪಟ್ಟಿದೆ. ಮತ್ತು ಅದರ ಅಂಶ ಪ್ರಸ್ತುತ ಅಧ್ಯಯನದಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ.

ಮೇಲೆ ವಿವರಿಸಿದ ಎರಡೂ ಸಂಕರಣಗಳಲ್ಲಿನ F1 ಪ್ರಭೇದದಲ್ಲಿ ಯಾವುದೇ ಸಸ್ಯವು ರೋಗ ಬಾಧೆಗೆ ತುತ್ತಾಗಿರುವುದಿಲ್ಲ. ಮುಂದುವರೆದು ಎರಡೂ ಸಂಕರಣಗಳಲ್ಲಿನ ಹೆಚ್ಚಿನ ಇಳುವರಿ ಮತ್ತು ಎಲೆ ಮುಟುರು ರೋಗ ನಿರೋಧಕತೆ F1 ಪ್ರಭೇದವು ಹೆಚ್ಚಿನ ಸಂಖ್ಯೆಯ ಟ್ರಾನ್ಸ್‌ಗ್ರೆಸಿವ್ ಸೆಗ್ರಿಗಂಟ್ ಗುರುತಿಸಲ್ಪಟ್ಟಿರುವುದರಿಂದ ಅವುಗಳನ್ನು ಹೆಚ್ಚಿನ ಅಧ್ಯಯನದಲ್ಲಿ ಬಳಸಬಹುದಾಗಿದೆ.

  
ಜಾಷ್ವರ್ ಶ್ರೀಫಲ್ ಸುತಾರ್  
(ವಿದ್ಯಾರ್ಥಿ)

  
ಡಾ. ಪ್ರಭಾಕರ ಜು.ಬಿ.  
ಪ್ರಧಾನ ಸಲಹೆಗಾರರು

## CONTENT

Chapter No.	Title	Page No.
I	INTRODUCTION	1-3
II	REVIEW OF LITERATURE	4-13
III	MATERIAL AND METHODS	14-29
IV	EXPERIMENTAL RESULTS	30-56
V	DISCUSSION	57-76
VI	SUMMARY	77-78
VII	REFERENCES	79-90

## LIST OF TABLES

Sl No.	Particulars	Page No.
2.1	Review of literature on gene action for different developmental and reproductive traits in tomato	5-6
2.2	Review of literature on fruit quality attributes in tomato	7
3.1	Salient features of the tomato material used in the investigation	15
1	Standard error means and variances for developmental and reproductive traits in two different crosses of tomato	31-32
2	Mean, Standard errors and Variances for fruit quality attributes in two different crosses of tomato	33
3	Mean, Standard errors and Variances for ToLCV disease in two different crosses of tomato	34
4	Scaling tests and gene effects for developmental and reproductive traits in two different crosses of tomato	40
5	Scaling tests and gene effects for fruit quality attributes in two different crosses of tomato	41
6	Components of Variance (Mather, 1949) for developmental and reproductive traits in two different crosses of tomato	44
7	Components of Variance (Mather, 1949) for fruit quality attributes in two different crosses of tomato	45
8	Per cent ToLCV incidence and disease scale for different generation in two crosses of tomato	47
9	Co-efficient of infection and reaction of ToLCV infected plants of different generations in two different crosses of tomato	48
10	Estimates of genetic parameters for different traits in two crosses of tomato	50
11	Estimates of additive, dominance and interaction effects of ToLCV disease index in two different crosses of tomato	52
12	Scaling test for ToLCV disease index in tomato	52

## LIST OF PLATES

Sl. No.	Particulars	Between Pages
1	ToLCV susceptible Arka Abha	15-16
2	Resistant to ToLCV Vybha	15-16
3	Fruit shape and plant type of A.Alok and A.Abha	17-18
4	Resistant F1 Vybhav x A.Alok	53-54
5	Resistant F1 Vybhav x A.Abha	53-54

# INTRODUCTION

# I INTRODUCTION

Tomato [*Solanum lycopersicum* (Mill.)] is one of the most important and widely grown vegetable crops, both in tropics and subtropics of the world, belonging to the family Solanaceae. It is a diploid with chromosome number  $2n=24$ . The origin of tomato is believed to be in Andes mountain region, Peru and Ecuador.

Tomato is the world's largest vegetable crop after potato and sweet potato, but it tops the list of canned vegetables. The popularity of tomato is due to its pleasing acid taste, which is retained in soup, salads, pickles, ketchup and sauces. Tomato is a good source of vitamins A and B and an excellent source of Vitamin C.

In India, tomato has become the popular vegetable during last five decades because of its suitability for growing in all seasons. Hence, cultivation of tomato remains in the focus of the horticulture industry.

Tomato occupies an area of 3.7 million hectares in the world with a production of 102 million tonnes (Anon., 2001). In India, it is cultivated in about 0.46 million hectares with a production of 72 million tonnes (Anon., 2002). Karnataka produces 17.6 lakh tonnes of tomato in an area of 46,788 hectares (Anon., 2000).

Tomato is susceptible to a number of diseases incited by fungi, bacteria, nematodes, mycoplasmas and viruses. Of all these diseases, the tomato leaf curl virus (ToLCV) is devastating. The occurrence of ToLCV on tomato is a major constraint in cultivation of tomato during summer in South India and autumn in North India. Saikia and Muniyappa (1989) reported cent per cent infection and fruit yield losses up to 90 per cent due to ToLCV.

ToLCV is a monopartite, gemini virus known to be transmitted by the vector white fly, *Bemisia tabaci*. Genn. it is known to infect the crop at all the stages starting from nursery to fruit formation. The affected tomato plant exhibits interveinal chlorosis, curling and puckering, reduction in leaflet size, severe stunting and also reduction in fruit set. However, severely infected young plants almost fail to produce any fruit.

Host plant resistance is an important disease control strategy and environmentally safe, with low running costs. Therefore, breeding tomato cultivars possessing inbuilt resistance is an appropriate approach for disease management. For the development of resistant variety donors of resistance is a prerequisite and should be identified by germplasm screening. Scientists have reported that resistance to ToLCV in certain accessions of *L. esculentum* and in wild relatives of *Lycopersicon* such as *L. pimpinellifolium*, *L. peruvianum*, *L. chilense* and *L. cheesmani*. In general, the wild species of genus *Lycopersicon* are well documented as rich reservoirs of several useful genes including disease resistance (Banerjee and Kalloo, 1987a).

The resistant genotypes should also possess other desirable economic traits to make them viable at commercial level. Therefore, emphasis should be towards understanding the genetics of resistance in order to regulate fruit yield and fruit quality attributing characters in association with disease resistance.

Various biometrical approaches have been developed to decipher the genetic architecture and mode of inheritance of different characters related to yield and disease resistance. Generation Mean Analysis (Hayman, 1958; Jinks and Jones, 1958) is one such approach, which gives information about nature of gene action with an unambiguous test for epistasis. The information obtained from Generation Mean Analysis is highly reliable as it is based on first order statistics. Generation Mean Analysis also provides information about the type of epistasis

operating in inheritance of a character. This information cannot be elicited by Diallel analysis or Line x Tester analysis.

None of the varieties among the numerous cultivars were found to possess resistance for ToLCV. In the light of the above, present investigation was undertaken with the following objectives to evolve a variety having disease resistance with higher yield.

- To know the genetics of yield, yield components and resistance to ToLCV.
- To study the inheritance pattern of resistance to ToLCV.

## REVIEW OF LITERATURE

# REVIEW OF LITERATURE

## II REVIEW OF LITERATURE

Tomato [*Solanum lycopersicum* (Mill.)] is an important crop, in terms of nutritive value as a vegetable and its amenability as experimental material in various genetic investigations. As a result, knowledge about various areas of genetics and tomato breeding is enormous. In this section, an attempt has been made to review the past literature under the following heads:

- 2.1. Genetics of developmental, reproductive traits and fruit quality attributes
- 2.2. Screening and Genetics of ToLCV resistance
- 2.3. Heterosis
- 2.4. Variability, heritability and genetic advance

### **2.1 Genetics of developmental, reproductive and fruit quality attributes**

A thorough understanding of genetics of the character under consideration is a prerequisite for a breeder to plan breeding programme for getting efficient results and to formulate a breeding strategy to develop a variety. A comprehensive character wise review of literature on gene action for fruit yield and fruit quality attributes are presented in Tables 2.1 and 2.2.

### **2.2 Screening and Genetics of ToLCV resistance**

#### **2.2.1 Screening**

Kasrawi *et al.* (1988) screened sixteen accessions of three wild species and fifty five fresh market *L. esculentum* cultivars were also included for resistance to ToLCV. All six *L. peruvianum* accessions, *L. peruvianum f. humifusum* and *L. hirsutum* showed zero incidence to ToLCV. The three *L. pimpinellifolium* accessions showed moderate to low severity.

**Table 2.1 : Review of literature on gene action for different developmental and reproductive traits in tomato**

Sl. No.	Characters	Method used	Gene action	References
1.	Plant height (cm)	Generation Mean Analysis L x T analysis Diallel analysis 10 x 10 diallel analysis 9 x 9 diallel Generation Mean Analysis Generation Mean Analysis Lx T analysis	Additive Additive Additive Non-additive Additive, Dominance Dominance, DXD interactions Dominance, Dx D interactions Non-additive	Aswathappa (1980) Sonone <i>et al.</i> (1986) Yassin (1987) Patil and Bojappa (1989) Ghosh and Syamal (1995) Bhattacharjee (1999) Bhushana (2000) Grace Sharon (2002)
2.	Number of primary branches	10 x 10 diallel analysis Generation Mean Analysis Diallel analysis Generation Mean Analysis Generation Mean Analysis L x T analysis	Non-additive Additive Additive Dominance Additive x Additive Non-additive	Patil and Bojappa (1989) Kanthaswamy (1988) Ghosh and Syamal (1994 b) Bhattacharjee (1999) Bhushana (2000) Grace Sharon (2002)
3.	Number of frurits per cluster	Generation Mean Analysis Generation Mean Analysis Generation Mean Analysis L x T analysis	Additive Additive, Dominance epistasis Additive, A x A, D x D Dominance, D x D Additive	Kanthaswamy (1988) Ramamohan (1988) Bhattacharjee (1999) Bhushana (2000) Grace Sharon (2002)
4.	Number of fruits per plant	12 x 12 diallel analysis 10 x 10 diallel analysis 10 x 10 diallel analysis 10 x 10 diallel analysis Generation Mean Analysis 9 x 9 diallel analysis L x T analysis Generation Mean analysis Generation Mean analysis L x T analysis L x T analysis	Additive, Non-additive Additive Additive, Dominance Non-additive Dominance, Additive Partial dominance Non-additive Additive, Ax A interactions Dominance, Dx D interactions Non-additive Non-additive	Dudi <i>et al.</i> (1979) Swamy and Mathai (1982) Singh and Singh (1980) Patil and Bojappa (1989) Ghosh and Syamal (1995) Ghosh <i>et al.</i> (1996) Kumar <i>et al.</i> (1997) Bhattacharjee (1999) Bhushana (2000) Dhaliwal (2000) Grace Sharon (2002)

5.	Average fruit weight (g/fruit)	L x T analysis Generation Mean Analysis 6 x 6 diallel analysis Generation Mean Analysis Generation Mean Analysis 6 x 6 diallel analysis 9 x9 diallel analysis L x T analysis Generation Mean Analysis Generation Mean Analysis L x T analysis L x T analysis L x T analysis	Additive Additive Additive Additive, Dominance Additive, Dominance Additive , non –additive Additive , Non-additive Additive Additive , A x A interactions Dominance , D x D interactions Additive Non-additive Additive	Sonone <i>et al.</i> (1986) Kanthaswamy (1988) Butnaru (1988) Ramamohan(1988) Khattra <i>et al.</i> (1990) Natarajan (1992) Ghosh and Syamal (1995) Kumar <i>et al.</i> (1997) Bhattacharjee (1999) Bhushana (2000) Dhaliwal <i>et al.</i> (2000) Grace Sharon (2002) Sanjay Chada <i>et al.</i> (2002)
6.	Fruit Yield (kg/plant)	L x T analysis Generation Mean Analysis 6 x 6 diallel analysis Partial diallel analysis Diallel analysis L x T analysis	Non-additive Additive Additive Non –additive Non-additive Non-additive	Sonone <i>et al.</i> (1986) Kanthaswamy (1988) Butnaru (1988) Chandrashekar and Ramarao (1989) Ghosh and Syamal ( 1994b) Ghosh and Syamal (1995)
		L x T analysis L x T analysis Generation Mean Analysis Generation Mean Analysis L x T analysis L x T analysis	Non-additive Non-additive A x D, D x D interactions AxD, Dx D interactions Non-additive Non-additive	Kumar <i>et al.</i> (1997) Pradeep kumar <i>et al.</i> (1997) Bhattacharjee ( 1999) Bhushana (2000) Dhaliwal <i>et al.</i> (2000) Grace Sharon (2002)
7.	Estimated yield/ha.	Generation Mean Analysis L x T analysis Diallel analysis L x T analysis L x T analysis	Additive Non- additive Additive Additive Non-additive	Ghosh and Syamal (1995) Sonone <i>et al.</i> (1986) Yassin (1987) Srivastava <i>et . al.</i> (1999) Dhaliwal <i>et al.</i> (2000)

**Table 2.2: Review of literature on fruit quality attributes in tomato**

Sl. No.	Characters	Method used	Gene action	References
1.	pH	8 x 8 diallel analysis Generation Mean Analysis Diallel analysis Generation Mean Analysis Generation Mean Analysis L x T analysis	Additive, Dominance, AxA D x D , A x D interactions Non-additive Additive, Dominance Non-additive Non-additive	Conti <i>et al.</i> (1988) Khattra <i>et al.</i> (1992) Ghosh and Syamal (1994b) Ghosh and Syamal (1995) Bhushana (2000) Grace Sharon (2002)
2	Total Soluble Solids (°Brix)	L x T analysis Diallel analysis Diallel analysis Partial Diallel Generation Mean Analysis Diallel analysis L x T analysis Generation Mean Analysis Generation Mean Analysis Generation Mean Analysis L x T analysis L x T analysis	Additive Non-additive Additive, Dominance, A xA Non-additive D xD, A x A interactions Non-additive Non-additive Dominance Non-additive Non-additive Non-additive Non-additive	Sonone <i>et al.</i> (1986) Patil and Bojappa ( 1986) Conti <i>et al.</i> (1988) Chandrashekar& Ramarao(1989) Khattra <i>et al.</i> (1992) Ghosh and Syamal (1994b) Ghosh and Syamal (1995) Kumar <i>et al.</i> (1997) Bhattacharjee(1999) Bhushana (2000) Dhaliwal (2000) Grace Sharon (2002)

Kaloo and Banerjee (1990) developed five breeding lines viz., LCP-22, LCP-2, LCP-3, LCP-9 and LCP-15 through introgression of tolerance from *L. pimpinellifolium* LA 1921 to *L. esculentum* cultivars HS 102 and Punjab Chuhara. These lines exhibited 28.3, 30.3, 30.2, 33.3 and 35.0 per cent disease incidence respectively compared with 91.7 per cent for cv. HS 101 and 100 per cent for HS 102 and Punjab chuhara. The Co-efficient of Variation ranged from 2.6 to 4.6 in resistant lines and 55.5 to 96.2 in susceptible varieties.

Bisht *et al.* (1990) evaluated a total of 88 germplasm collections for resistance to various diseases such as ToLCV, Fusarium wilt, fruit rot and early blight. Most of *L. pimpinellifolium* lines were resistant to fusarium wilt, root rot and early blight but did not show marked resistance to leaf curl. *L. hirsutum* and *L. peruvianum* showed high degree of resistance to ToLCV.

Zakay *et al.* (1991) screened 23 *Lycopersicum* accessions for resistance to ToLCV. Plants were grown in natural infested condition and the genotypes were examined for presence of viral DNA and symptom development at two weeks interval. An accession of *L. chilense* showed highest level of resistance.

Kaloo and Banerjee (2000) developed lines H2, H11, H17, H23, H24 and H36 by controlled introgression of *L. hirsutum fsp. glabratum* into *L. esculentum*. Disease incidence after 120 days from inoculation ranged from 8.3 to 35 per cent where as in susceptible varieties it ranged from 95.0 to 100 per cent. Values for co-efficient of infection in resistant lines were very low, ranging from 0.25 to 4.55 where as in susceptible varieties it ranged from 60.6 to 89.0. Line H2 had highest resistance showing lowest disease incidence and coefficient values.

Raghupathi *et al.* (1997) screened one hundred and sixty germplasm entries of tomato against ToLCV. Under natural conditions only two wild species

namely *L. hirsutum* (LA 1353) and *L. hirsutum f. glabratum* (LA 1223) were free from ToLCV infection.

Sadashiva *et al.* (2002) evaluated advanced tomato breeding lines resistant to both bacterial wilt and ToLCV. Seedlings of these lines were artificially exposed to virulent whiteflies and also artificially inoculated with bacterial suspensions. Three entries *viz.*, CLN-2114-DC<sub>1</sub>F<sub>1</sub>-50-2-16-8-2-17-0, CLN-2116-DC<sub>1</sub>F<sub>1</sub>-180-31-9-34-4-0 and CLN-2116-DC<sub>1</sub>F<sub>1</sub>-180-31-10-25-8-0 were found to exhibit resistance both for ToLCV and bacterial wilt.

### 2.2.2 Genetics and Breeding

Once the resistant genotypes are identified, it is important to characterize the gene controlling the resistant mechanism. Such information is used to propose breeding strategies for disease management.

Resistance for ToLCV in *L. pimpinellifolium* was reported to be due to a single incomplete dominant gene (Pilowsky and Cohen, 1974) and incompletely dominant polygenes govern the trait (Som and Chaudhary, 1977).

Hassan *et al.* (1984) studied the inheritance of resistance to tomato yellow leaf curl virus derived from *L. hirsutum*. The cross *L. esculentum* cv. UC 82 x *L. hirsutum* (LA 386) was studied. Population of this cross was inoculated prior to transplanting using viruliferous white flies and later evaluated. Reactions of parents, F<sub>2</sub> and F<sub>3</sub> plants and backcrosses of resistant plants to UC 82 indicated that resistance derived from *L. hirsutum* is dominant and controlled by more than one gene.

Vidavsky and Czosnek (1984) reported that progeny of a cross of *L. hirsutum* with *L. esculentum* showed resistance to ToLCV and among the selfed lines, some lines in BC<sub>1</sub>F<sub>4</sub> showed resistance. Analysis of segregation of

susceptibility and resistance during BC<sub>1</sub>F<sub>1</sub>- BC<sub>1</sub>F<sub>4</sub> suggested that resistance was controlled by two or three additive recessive genes.

Yassin (1987) reported that *L. pimpinellifolium* (LA 5182) carried a dominant factor for ToLCV resistance. Banerjee and Kalloo (1987a) tested the reaction for local Hissar strain of ToLCV using viruliferous whiteflies and found that the resistance of *L. pimpinellifolium* (LA 1921) was due to a single incompletely dominant gene.

Banerjee and Kalloo (1987b) assessed the inheritance of resistance to ToLCV in progenies derived for interspecific cross is based on two epistatic genes one from the wild and other from the crop species resulting in 13 :3 segregation in F<sub>2</sub> generation.

Pilowsky and Cohen (1990) studied the inheritance of tolerance to tomato yellow leaf curl virus derived from wild tomato, *L. peruvianum* by crossing the cultivated tomato (*L. esculentum*) line M60 with line 10 (TYLCV susceptible). F<sub>1</sub>, F<sub>2</sub> and backcross populations were inoculated by means of vector and genetic data indicated that tolerance to TYLCV was controlled by five recessive genetic factors.

Shoba and Arumugam (1991) studied the association of leaf curl virus resistance in tomato. They observed that the simple correlation co-efficient between disease incidence and some important characters were not significant indicating the independent nature of resistance of leaf curl virus with other traits.

Jalikop (1992) reported complementary gene action (9 susceptible : 7 resistant) in four crosses of *L. esculentum* x *L. hirsutum*. Days to ToLCV symptom expression and ToLCV score showed predominance of additive effect in the crosses involving *L. pimpinellifolium*.

Zamir *et al.* (1994) reported that tolerance of *Lycopersicum chilense* to ToLCV was due to partial dominant gene.

Dharmatti (1995) observed complementary type of gene action (9 resistant : 7 susceptible) involving two pairs of genes for ToLCV resistance in F<sub>2</sub> generation of the cross 20/5 Alcobasa x N 2298 MF<sub>6</sub>.

Nagaraja (1995) studied generation mean analysis for resistance to ToLCV in two interspecific crosses of tomato. The variation for days to ToLCV symptom expression was explained adequately by additive dominance model. Days to ToLCV symptom expression was predominantly governed by additive gene effects without non-allelic interaction. For symptom severity, both additive and additive x additive effects were predominant.

Freidmann *et al.* (1998) developed a breeding line, TY 172 which was resistant to ToLCV. When TY 172 was crossed with susceptible cultivar, the hybrids exhibited milder symptoms than susceptible parent, but higher than TY 172, suggesting a partial dominance for the resistance. F<sub>2</sub> population segregation suggested that at least three genes may account for resistance.

Bhattacharjee (1999) evaluated F<sub>2</sub> generation material of four different crosses of tomato under natural field conditions and reported that ToLCV resistance is governed by two incompletely dominant genes in an inhibitory manner of gene action with a segregation ratio of 13 resistant : 3 susceptible plants.

Hassan and Abdel (1999) studied the inheritance of ToLCV in crosses between tomato, *L. esculentum* as a female parent and *L. pimpinellifolium* PI 407543, PI 407544, PI 407555 and *L. pennelli* LA 716 as male parents. Evaluation of parental, F<sub>1</sub>, F<sub>2</sub> and backcross populations revealed complete dominance in crosses involving PI 407543 and PI 407544, partial dominance in cross with PI

407555 and recessiveness in cross with LA 716. Gene action was additive with PI 407543 and LA 716, while additive, dominance and non-allelic interactions were involved in crosses with PI 407544 and PI 407555.

Bhushana (2000) evaluated  $F_2$  generation material of four different crosses of tomato under field conditions and reported that in three of the four crosses ToLCV resistance was governed by two incompletely dominant genes in a inhibitory gene action (13 resistant : 3 susceptible in  $F_2$ , 3 resistant : 1 susceptible in  $B_1$  and 3 resistant : 0 susceptible in  $B_2$  generation). One of the four crosses exhibited completely dominant duplicate gene action (15 resistant : 1 susceptible in  $F_2$ , 3 resistant : 1 susceptible in  $B_1$  and 3 resistant : 0 susceptible in  $B_2$ ).

Chandrashekara (2000) assessed the genetics of ToLCV resistance in two crosses of tomato using triple test cross analysis and reported that the magnitude of dominance variance was higher for ToLCV symptom expression.

Nainar and Pappiah (2002) assessed inheritance of resistance to ToLCV under field conditions in eight crosses of tomato cultivars PKM 1, CO 2, CO 3 and Pusa Ruby and resistant wild parents *L. hirsutum* and *L. pimpinellifolium*. The individual plants of six generations viz.,  $P_1$ ,  $P_2$ ,  $F_1$ ,  $F_2$ ,  $B_1$  and  $B_2$  were scored for disease incidence. The resistance to ToLCV in *L. hirsutum* was reported to be controlled by three recessive genes and a single incompletely dominant gene in *L. pimpinellifolium*.

Frimpong Adams and Kantaka (2002) studied the genetics of ToLCV resistance in interspecific crosses involving the wild tomato variety, Cherry. It was observed that the ToLCV is controlled by duplicate dominant epistatic genes ( $F_2$  ratio of healthy: diseased plants was 15:1). The hybrids especially  $F_1$ ,  $B_1$ ,  $B_2$  and some  $F_2$  were observed to be close to wild cherry in most of the characters.

Sadashiva *et al.* (2002) developed high yielding tomato lines and hybrids with combined resistance to bacterial wilt and ToLCV. TLBR-1, TLBR-2, TLBR-3 were developed through backcross where as TLBR-4, TLBR-5, TLBR-6 were developed by pedigree method. TLBR-1 recorded maximum fruit yield followed by TLBR-3, TLBR-5. These were crossed with elite tomato breeding lines from AVRDC, Taiwan *viz.*, IIHR-2195, IIHR-2187, IIHR-2198, IIHR-2199, 2200, 2201, 2202 in diallel mating design. Most promising hybrids with combined resistance to ToLCV and bacterial wilt were TLBR-3 x IIHR -2202, TLBR-3 x IIHR 2200, TLBR-4 x IIHR 2200 and TLBR-3 x IIHR 2199.

### **2.3 Heterosis**

Phenomenon of exploitation of heterosis in tomato has become a reality because of significant increase in the important traits in  $F_1$  hybrids over their parental values. Heterosis helps in developing early, high yielding, disease resistant, uniform maturity cultivars and other valuable economic fruit quality characters in the quickest possible time.

### **2.4 Variability, Heritability and Genetic Advance**

Planning and execution of a breeding programme for the improvement of quantitative attributes depends to a great extent upon magnitude of existing genetic variability.

# MATERIAL AND METHODS

### III. MATERIAL AND METHODS

The present investigation was conducted at the Division of Horticulture, Gandhi Krishi Vigyana Kendra, University of Agricultural Sciences Bangalore during 2006-07. The experimental field is located at an attitude of 930 m above mean sea level with an latitude of  $12^{\circ}, 28^1$  N and longitude of  $79^{\circ}, 35^1$  E. the crop was raised on sandy loam soils. The details of material and methods adopted in the present study have been elaborated experiment wise below.

#### 3.1 Experimental material and layout

The material for the present study comprised of three genotypes, which were procured from. Indian Institute of Horticultural Research, Hessaraghatta, Bangalore and Department of Plant Pathology, Gandhi Krishi Vigyana Kendra, Bangalore.

##### 3.1.1 Nursery practices

Seeds are sown in pro trays. Before sowing pro trays are cleanly washed, and filled with sand, soil and farm yard manure in the proportion of 1:1:1. Seeds of different genotypes were sown in required number of rows to one cm depth. Thereafter trays were drenched with 0.2 per cent captan to protect the seedlings from soil born pathogens. The trays were watered regularly. Furadon was sprinkled around the trays to avoid seed damage due to ants. Regular watering and weeding were carried out. 0.2 per cent Bavistin was sprayed at on interval of seven days after ten days of seedling emergence so as to prevent the occurrence of damping off disease.



**Plate 1: ToLCV susceptible Arka Abha**



**Plate 2: Vybhav Resistant to ToLCV**



**Plate 3: Fruit shape and plant type of A. Alok and A. Abha**

**Table 3.1: Salient features of tomato material used in the investigation**

Genotypes	Growth habit	Fruit shape	Reaction to ToLCV	Collection Source
Arka Abha	Semi determinate	Round to obovate fruits.	Susceptible	IIHR Bangalore
Arka Alok	Determinate	Round fruits	Susceptible	IIHR Bangalore
Vybhav	Semi determinate	Square to oblong	Resistant	UAS, Bangalore

### 3.1.2 Preparation of main field and planting

The main field was brought to a fine filth by disc ploughing followed by disc harrow and crop cultivator. FYM at the rate of 25 tonnes per hectare was applied well in the soil at the time of land preparation. Ridges and furrows were prepared at 60 cm spacing. Basal fertilizer dose at the rate of 90 kg N, 75 kg P<sub>2</sub>O<sub>5</sub> and 60 kg K<sub>2</sub>O per hectare was applied before transplanting. The crop top dressed with 90 kg N, 75 kg P<sub>2</sub>O<sub>5</sub> and 60 kg K<sub>2</sub>O 30 days after transplanting. Regular watering and weeding was carried out to keep the experimental plots free from weeds. Staking of the plants was taken up after 45 days of transplanting.

### 3.1.3 Hybridization programme

Hand emasculation technique was followed in tomato as the flowers are big and are amenable for easy emasculation and pollination. Healthy flower buds expected to open next morning were emasculated in the evening hours of previous day between 5 to 7 pm. The buds were opened carefully and the anther cones alone were removed with the help of sterilized forceps. Due care was taken to avoid damage to the pistil. The emasculated flowers were tagged with a crossing

ring to identify them. In the next morning, in between 7 to 9 am, the receptive stigma was pollinated with pollen grains of male parents. Soon after pollination, crossed flowers were covered with butter paper over. All the necessary precautions were taken to protect the set fruits.

#### 3.1.4 Development of hybridized material

The resistant line Vybhav and the susceptible lines Arka Alok and Arka Abha were used in hybridization programme to study the inheritance of yield, yield components and resistance to ToLCV. The crossing programme was started in rabi 2006, the F<sub>1</sub> hybrids and their parents were transplanted in a crossing block. Backcrosses were made with both parents in each cross combinations to obtain backcrosses (B<sub>1</sub> and B<sub>2</sub>) generation seeds. In the same season, F<sub>2</sub> seeds were collected from the selfed F<sub>1</sub> plants.

Thus, the seeds of six generations of the two sets were obtained as outlined below.

**Set 1/cross 1:** Vybhav (P<sub>1</sub>), Arka Alok (P<sub>2</sub>), their F<sub>1</sub> and their progenies F<sub>2</sub>, B<sub>1</sub> and B<sub>2</sub>.

**Set 2/cross 2:** Vybhav (P<sub>1</sub>), Arka Abha (P<sub>2</sub>), their F<sub>1</sub> and their progenies F<sub>2</sub>, B<sub>1</sub> and B<sub>2</sub>.

### 3.2

#### 3.2.1 Virus culture

The culture of ToLCV Van 4 (Muniyappa *et al.* 2000) was obtained from the stock culture that has been maintained in glasshouse on cv Arka vikas, the culture was maintained by frequently inoculating 10 to 15 days old tomato seedlings cv Arka vikas by *Bemisia tabaci* viruliferous whiteflies in the insect proof glasshouse.

### 3.2.2 Whitefly culture

Type culture of whitefly (*B. tabaci* Genn) originally collected from horsegram *Macrotyloma uniflorum* at the University of Agricultural Sciences, Hebbal farm, Bangalore was maintained on cotton (*Gossypium hirsutum* cv Laxmi) plants in wooden cages and used for inoculation experiments. Wooden cage (45 x 45 x 30 cm) was constructed and muslin cloth was fixed on three sides and top with an adhesive fevicol. The front side was fixed with movable glass plate. Healthy cotton plants grown in polythene bags (4"x 6" ) were introduced into cages, while removing old plants. The cages were maintained at temperature range of 28 to 30<sup>0</sup>C in an insect proof glass house.

### 3.2.3 Raising of healthy tomato seedling.

Tomato genotypes were sown in earthen pots of 30 cm diameter containing sterilized farm yard manure. Seedlings were transplanted into polythene bags of size 13 x 18 cm filled with sterilized farm yard manure and kept in insect proof glass house for inoculation.

### 3.2.4 Cages used for acquisition access

Whiteflies were collected from the colonies reared in an insect cage with the help of an aspirator. Whiteflies were released into a round PVC bottle, which measured 20 cm long and 7.5 cm in diameter at one end and tapering towards the narrow end. The bottom portion was removed with the help of soldering rod and was covered with muslin cloth. Whiteflies were released into the acquisition bottle and the ToLCV infected branch was inserted and closed with cotton plug.

### 3.2.5 Preparation of cages for inoculation of seedling

Plastic tubes of different size were taken and the base of the tube was removed with help of soldering rod and muslin cloth was fixed. A small hole (0.5

cm) was made on the middle portion of the tube to facilitate release of whiteflies. Such cages were used for inoculation of young healthy seedlings.

### **3.2.6 Incubation of young tomato seedlings**

Ten days after sowing tomato seedlings were transplanted into polythene bags. Mean while adult whiteflies collected from stock culture were released into the PVC tubes containing ToLCV infected twig. Whiteflies were given 24 hour as acquisition access period. Healthy tomato seedlings at two leaf stage were individually covered with plastic. PVC tube (7.5 x 2.5 cm) and 10 to 15 viruliferous adults were released into each seedling with the help of an aspirator through the hole on the body of the tube and plugged with cotton. After 24 hour acquisition access period the viruliferous whiteflies were allowed for inoculation access on healthy seedlings. The open end of the tube was plugged with cotton plug after inserting the young leaflets in to the tube and the whiteflies were released in to the cage through small hole and plugged the hole with cotton.

Whiteflies were allowed to feed for 24 hr as inoculation access period (IAP). After IAP plastic PVC tubes were removed and seedlings were kept in glass house for symptom expression.

### **3.3 Evaluation of segregation populations ( $F_2$ , $B_1$ and $B_2$ ) $F_1$ s and parents for genetical studies.**

Observation were recorded on ten plants each of  $P_1$ ,  $P_2$  and  $F_1$ . 80 plants of  $F_2$  and 40 plants each of  $B_1$  and parameters as given below.

#### **3.3.1 Development and reproductive traits**

##### **3.3.1.1 Plant height (cm)**

Plant height was measured in centimeters from the ground level to growing tip on 70<sup>th</sup> day after transplanting

### 3.3.1.2 Number of primary branches

Number of primary branches were recorded on 70<sup>th</sup> day after transplanting.

### 3.3.1.3 Number of fruits per cluster

Number of fruits bearing in each cluster of the plant were counted on 70<sup>th</sup> day after transplanting.

### 3.3.1.4 Number of fruits per plant

Total number of fruits in a plant was recorded taking fivefruits from all the harvests.

### 3.3.1.5 Average fruit weight (g/fruit)

$$\text{Average fruit weight} = \frac{\text{Total fruit weight per plant}}{\text{Total number of fruits per plant}}$$

### 3.3.1.6 Yield per plant (kg/plant)

Yield was recorded from all the plants in each treatment per replication at various pickings and expressed in kilograms per plant.

### 3.3.1.7 Estimated yield per hectare (tonnes)

Yield per plant was multiplied by the number of plans per hectare expressed in tonnes per hectare.

## 3.3.2 Fruits quality parameters

### 3.3.2.1 Total soluble solids (TSS) (°Brix)

A drop of the juice extract prepared from red ripe fruit was placed over the prism of hand refractometer and brix value was noted. Five fruits were randomly

selected during the first harvest per replication were used to record this observation. The final value was the mean of readings of five fruits.

### 3.3.2.2 Pericarp thickness

Each fruit was cut at equatorial plain and pericarp thickness was measured with the help of vernier callipers and expressed in terms of millimeter, five fruits per plant were used for recording the observations.

### 3.3.2.3 Number of locules per fruits

Number of locules were counted from five fruits taken at random by cutting the fruits transversely in the middle.

### 3.3.3 ToLCV parameters

#### 3.3.3.1 Days to ToLCV symptom expression

It is based on days at which first external disease symptoms got manifested after transplanting under field conditions.

#### 3.3.3.2 Per cent ToLCV incidence

The incidence of ToLCV infection was recorded at every two weeks interval after transplanting. The number of plants infected in each generation was recorded and computed by using the formula.

$$\text{Per cent ToLCV incidence} = \frac{\text{Total number of plants infected with ToLCV}}{\text{Total number of plants}} \times 100$$

### 3.3.3.3 ToLCV symptom severity in F<sub>2</sub> population

The disease severity was scored as described by Muniyappa *et al.* (1991).

Resistant	No symptoms	0
Mild infection	Light yellowing along the margin but no curling	1
Moderate infection	Light yellowing along margins, slight curling and stunting	2
Severe infection	Severe curling, puckering, stunting reduction in leaf size and reduced fruit formation	3
Very severe infection	Very severe curling, puckering, stunting, severe reduction in leaf size, barely produce, small sized fruits.	4

### 3.3.3.4 ToLCV co-efficient of infection

Co-efficient of infection is the parameter with combined amount of infection and severity (Banerjee and Kalloo, 1989). Co-efficient of infection is obtained as a product of per cent infection and response value as given in the following table.

Symptom	Symptom severity grade	Response value	Ratings	Reaction
Symptom absent	0	0	0-4	Highly resistant
Very mild curling	1	0.25	5-9	Resistant
Curling, puckering of 26-50 % leaves	2	0.50	10-19	Moderately resistant
Curling, puckering of 51-75 % leaves	3	0.75	20-39	Moderately susceptible
Severe curling, puckering of >75% of leaves	4	1.00	40-69 70-100	Susceptible, highly susceptible

### 3.4 Statistical analysis

Data on six generations *viz.*, P<sub>1</sub>, P<sub>2</sub>, F<sub>1</sub>, F<sub>2</sub>, B<sub>1</sub> and B<sub>2</sub> for all characters were condensed by computing means for all the generations in each of the characters. Standard errors were computed for all the observation in each of the generations of two crosses. Genetic analysis was performed in the crosses separately for characters on which observations were taken. Genetic analysis included Chi-square test, Components of Variance (D, H, E), Mather's scaling test, Cavalli's joint scaling test and Hayman's six generation mean analysis and genetic parameters of F<sub>2</sub> generations.

#### 3.4.1 Chi-square test

Segregation ratios of resistant (R) and susceptible (S) disease reactions were subjected to chi-square tests. Chi-square tests is the goodness of fit between expected and observed segregation ratios. (Snedecor and Cochran, 1967).

The Chi-square was calculated as follows:

$$X^2 = \sum \frac{(O-E)^2}{E}$$

Where ,      O = Observed frequency  
                   E – Expected frequency  
                    $\sum$  = Summation over all crosses

#### 3.4.2 Components of Variance (Mather, 1949)

The components of variance *viz.*, heritable fixable (D), heritable non fixable (H) and nonheritable non-fixable (E) were computed using he following formulae:

$$VF_2 = \frac{1}{2} D + \frac{1}{4} H + E$$

$$VB_1 + VB_2 = \frac{1}{2} D + \frac{1}{2} H + 2E$$

Where, 
$$E = \frac{VP_1 + VP_2 + VF_1}{3}$$

Standard error obtained from error mean sum of squares was used to test the significance of the estimates using 't' test. The calculated 't' value at 5 per cent and 1 per cent level of significance was tested against table 't' value.

### 3.4.3 Test of epistasis

#### 3.4.3.1 Mather's Scaling Test

To detect the presence of epistasis A, B, C scaling tests as outlined by Mather (1949) were performed for a given character. By using the following formulae the values of A, B, C were computed.

$$A = 2B_1 - P_1 - F_1$$

$$B = 2B_2 - P_2 - F_1$$

$$C = 4F_2 - 2F_1 - P_1 - P_2$$

Where  $P_1, P_2, F_1, F_2, B_1$  and  $B_2$  are mean values of the respective generations

The respective variance of A, B and C were calculated as follows:

$$V_A = 4VB_1 + VP_1 + VF_1$$

$$V_B = 4VB_2 + VP_2 + VF_1$$

$$V_C = 16VF_2 + 4VF_1 + VP_1 + VP_2$$

Standard error was calculated from variances and the 't' test was employed to test the significance both at 1 per cent and 5 per cent level of significance.

#### 3.4.3.2 Joint Scaling Test

Parameters such as (m), (d) and (h) were estimated by using Cavalli's joint scaling test (1952). These parameters were estimated using a weighted least square analysis. The reciprocal of variance of each of the means is used as a weight. The

weights were multiplied with respective co-efficient to get observed means and then they were compared with expected means and significance of chi square value was calculated.

Generation	Weight	Co-efficient		
		(m)	(d)	(h)
P <sub>1</sub>	1/variance	1	1	-
P <sub>2</sub>	1/variance	1	-1	-
F <sub>1</sub>	1/variance	1	-	1
F <sub>2</sub>	1/variance	1	-	½
B <sub>1</sub>	1/variance	1	½	½
B <sub>2</sub>	1/variance	1	-½	½

Three normal equations required to estimate three parameters *viz.*, (m), (d), (h) were obtained by multiplying each element of the row in the above Table by the product of weight and co-efficient of (m) and adding over six generations. In a similar manner, each element of other rows were multiplied by the product of their respective weights and co-efficient of (m). In a similar fashion, other two normal equations were obtained by multiplying each element of each row by the product of co-efficient (d) weight and co-efficient (h) weight.

The three normal equations derived were arranged in a matrix form and the components (m), (d) and (h) were calculated by taking inverse of the matrix and multiplying with the elements of the normal matrix obtained from the three equations. Standard error calculated and the 't' test was employed to test the significance both at 1 and 5 per cent level of significance.

### 3.4.3.3 Six generation mean analysis

The method proposed by Hayman (1958) as well as Jinks and Jones (1958) for analysis was followed to obtain information on nature of gene effect and the

nonallelic interaction components governing the traits under study. The notation for the various gene effects (Hayman, 1958) used here in are means (m), additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l). These components were estimated by using the equations.

$$(m) = F_2$$

$$(d) = B_1 - B_2$$

$$(h) = 2 (B_1 + B_2) + F_1 - 4F_1 - 1/2 (P_1 + P_2)$$

$$(i) = 2 (B_1 + B_2) + 4F_2$$

$$(j) = 2 (B_1 + B_2) + (P_1 + P_2)$$

$$(l) = P_1 + P_2 + 2F_1 + 4F_2 - 4(B_1 + B_2)$$

The variances of these gene effects were estimated as follows

$$V(m) = VF_2$$

$$V(d) = VB_1 - VB_2$$

$$V(h) = VF_1 + 16 VF_2 + 1/4 (VP_1 + P_2v) + 4 (VB_1 + VB_2)$$

$$V(i) = 4 (VB_1 + VB_2) + 16VF_2$$

$$V(j) = VB_1 + VB_2 + 1/4 (VP_1 + VP_2)$$

$$V(l) = VP_1 + VP_2 + 4VF_1 + 16 (VF_2 + VF_1 + VB_1 + VB_2)$$

The square root of these respective variances was estimated as their standard error. It was later used to test the significance of the estimates using 't' test. The calculated 't' value at 5 per cent and 1 per cent level of significance was tested against table 't' value.

#### 3.4.4 Estimation of genetic parameters

The co-efficient of variability both at genotypic and phenotypic level for all the characters were computed according to the formula suggested by Burton and De Vane (1953) and Burton (1952).

### 3.4.4.1 Phenotypic and Genotypic Co-efficient of Variation (PCV and GCV)

$$\text{PCV (\%)} = \frac{\text{Phenotypic standard deviation of } F_2}{F_2 \text{ mean of the character}} \times 100$$

$$\text{GCV (\%)} = \frac{\text{Genotypic standard deviation of } F_2}{F_2 \text{ mean of the character}} \times 100$$

The value of PCV and GCV were categorized as given by Sivasubramanian and Menon (1973).

0-10%	=	Low
10% - 20%	=	Moderate
> 20%	=	High

### 3.4.4.2 Heritability

It was estimated by following the procedure suggested by Webber and Moorthy (1952) and Robinson *et al.* (1949).

$$h_2 \text{ (narrow sense)} = V_A/V_P$$

$$h_2 \text{ (broad sense)} = V_G/V_P$$

Where, Additive Variance  $V_A = 2VF_2 - (VB_1 + VB_2)$

Where, Phenotypic Variance,  $VF_2 =$  total  $F_2$  variance observed for the trait

Genotypic Variance  $V_G = (VF_2 - V_E)$

Environmental variance,  $V_E =$  Average of all the non – segregating generations

It was categorized as suggested by Robinson *et al.* (1949).

0-30%	=	Low
30% - 60%	=	Moderate
60-90%	=	High

### 3.4.4.3 Genetic Advance

The Genetic Advance was predicted by using the formula

$$GA = h^2 \times \sigma_p \times k$$

(Lush, 1949 and Johnson *et al.* 1955)

Where  $h^2$  = heritability in board sense  
 $\sigma_p$  = standard deviation of phenotypic variance of  $F_2$   
 $k$  = selection differential at 5 per cent (2.06)

$$GA \text{ as per cent mean} = \frac{GA}{F_2 \text{ Mean}} \times 100$$

The GA as per cent mean was categorized as suggested by Johnson *et al.* (1955) and the same is given below

0-10%	=	Low
10% - 20%	=	Moderate
20% and above	=	High

### 3.4.4.4 Minimum number of effective factors

The minimum number of effective factors was calculated using the formula,

$$N = \frac{0.25 (0.75 - h + h^2) D^2}{VF_2 - F_1}$$

(Wright, S., 1968)

Where  $h = \frac{F_1 + P_1}{P_2 - P_1}$   
 $D = P_2 - P_1$

### 3.4.4.5 Extent of dominance in backcrosses

It is computed by the formula

$$\frac{\frac{1}{4} H}{\frac{1}{4} D + \frac{1}{4} H+E}$$

### 3.4.4.6. Potence ratio

The degree of dominance can be calculated using components of variances and is given by the formula,

$$\text{Potence ratio} = (H/D)^{\frac{1}{2}}$$

Potence ratio was categorized as follows

0 = complete dominance

0-1 = incomplete dominance

>1 = over dominance

### 3.4.4.7 Estimation of heterosis

The mean values for each character were used for the estimation of heterosis. Heterosis over mid parent and better parent were calculated by using the formula.

$$\text{Heterosis (\% over Mid Parent (MP))} = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Heterosis (\% over Better Parent (BP))} = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Heterosis (\% over Standard Check)} = \frac{F_1 - \text{check}}{\text{check}} \times 100$$

Standard error obtained from error mean sum of squares was used to test the significance of estimates using 't' test. The calculated 't' value at 5 per cent and 1 per cent level of significance was test against tale 't' value.

#### 3.4.4.8 Estimation of inbreeding depression

Inbreeding depression was compared as the percentage decrease from  $F_1$  to  $F_2$  generations by considering overall means of  $F_1$  and  $F_2$  generations.

$$\text{Inbreeding depression from } F_1 \text{ to } F_2 = \frac{F_1 - F_2}{F_1} \times 100$$

# EXPERIMENTAL RESULTS

## **IV. EXPERIMENTAL RESULTS**

The experimental findings pertaining to the investigation of the present study are presented in this chapter under the following headings.

### **4.1 Generation mean analysis**

#### **4.1.1 Population mean and variances**

#### **4.1.2 Scaling tests**

#### **4.1.3 Estimation of gene effects**

#### **4.1.4 Estimation of heritability and genetic advances**

#### **4.1.5 Estimation of heterosis and inbreeding depression**

### **4.2 Studies on inheritance of ToLCV resistance**

#### **4.2.1 Inheritance of ToLCV resistance**

#### **4.2.2 Co-efficient of infection and reaction of ToLCV infected plants.**

#### **4.2.3 Per cent ToLCV incidence and disease scale**

### **4.1 Generation mean analysis**

#### **4.1.1 Population mean and variances**

The mean standard errors of means and variances of six generation ( $P_1$ ,  $P_2$ ,  $F_1$ ,  $F_2$ ,  $B_1$  and  $B_2$ ) of the two crosses Vybhav x Arka Alok (Cross-I) and Vybhav x Arka Abha (Cross-II) are presented with respect to developmental and reproductive traits, fruit quality attributes and ToLCV related parameters in table 1, 2, and 3 respectively.

##### **4.1.1.1 Plant height**

###### **4.1.1.1a Vybhav x Arka Alok**

Among the parents Arka Alok recorded the highest plant height (70.57 cm) compared to other parent Vybhav (66.56 cm). Mean plant height of  $F_1$  plants is

**Table 1: standard error of mean and variance for developmental and reproductive traits in two different crosses of tomato**

Generations		Plant height (cm)		No. of branches		No. of fruits / cluster		No. of fruits / plant	
		Mean $\pm$ SE	Variance	Mean $\pm$ SE	Variance	Mean $\pm$ SE	Variance	Mean $\pm$ SE	Variance
P <sub>1</sub>	C <sub>1</sub>	66.56 $\pm$ 2.89	83.52	3.78 $\pm$ 0.18	0.32	4.25 $\pm$ 0.20	0.40	28.37 $\pm$ 2.87	82.36
	C <sub>2</sub>	71.12 $\pm$ 3.27	106.92	4.20 $\pm$ 0.16	0.25	4.39 $\pm$ 0.23	0.52	37.51 $\pm$ 3.74	139.87
P <sub>2</sub>	C <sub>1</sub>	70.57 $\pm$ 2.79	7784	4.53 $\pm$ 0.24	0.57	4.70 $\pm$ 0.20	0.44	38.95 $\pm$ 2.89	83.52
	C <sub>2</sub>	70.42 $\pm$ 3.00	90.00	4.32 $\pm$ 0.21	0.44	4.81 $\pm$ 0.10	0.10	37.72 $\pm$ 2.81	78.96
F <sub>1</sub>	C <sub>1</sub>	70.34 $\pm$ 2.78	77.28	4.00 $\pm$ 0.58	3.33	4.59 $\pm$ 0.20	0.40	29.49 $\pm$ 2.95	87.02
	C <sub>2</sub>	69.34 $\pm$ 2.92	85.26	4.30 $\pm$ 0.20	0.40	4.63 $\pm$ 0.20	0.40	40.64 $\pm$ 2.92	82.26
F <sub>2</sub>	C <sub>1</sub>	65.52 $\pm$ 2.78	618.27	3.30 $\pm$ 0.35	9.80	3.96 $\pm$ 0.03	0.07	25.18 $\pm$ 2.91	677.44
	C <sub>2</sub>	65.05 $\pm$ 2.94	691.48	4.07 $\pm$ 0.07	0.39	4.13 $\pm$ 0.09	0.64	35.61 $\pm$ 2.66	566.04
BC <sub>1</sub>	C <sub>1</sub>	70.71 $\pm$ 2.94	345.744	4.59 $\pm$ 0.02	0.01	4.76 $\pm$ 0.08	0.25	32.74 $\pm$ 2.99	357.60
	C <sub>2</sub>	75.38 $\pm$ 2.40	230.40	7.74 $\pm$ 0.07	0.19	4.80 $\pm$ 0.09	0.32	42.24 $\pm$ 2.73	298.11
BC <sub>2</sub>	C <sub>1</sub>	75.03 $\pm$ 2.71	293.76	5.01 $\pm$ 0.04	0.06	4.94 $\pm$ 0.10	0.40	42.86 $\pm$ 3.04	369.66
	C <sub>2</sub>	74.42 $\pm$ 2.38	226.57	4.75 $\pm$ 1.10	0.40	4.96 $\pm$ 0.04	0.06	43.53 $\pm$ 2.99	357.60

Table 1 contd...

Generations		Average fruit weight (g)		Total yield /plant (kg)		Estimated yield / ha (t)	
		Mean $\pm$ SE	Variance	Mean $\pm$ SE	Variance	Mean $\pm$ SE	Variance
P <sub>1</sub>	C <sub>1</sub>	72.75 $\pm$ 2.98	88.80	2.24 $\pm$ 0.19	0.36	42.81 $\pm$ 2.34	54.75
	C <sub>2</sub>	76.29 $\pm$ 2.87	82.36	158 $\pm$ 0.05	0.02	32.41 $\pm$ 2.08	43.26
P <sub>2</sub>	C <sub>1</sub>	65.99 $\pm$ 2.90	84.10	2.46 $\pm$ 0.25	0.62	48.16 $\pm$ 2.72	73.98
	C <sub>2</sub>	65.87 $\pm$ 2.98	88.80	2.34 $\pm$ 0.17	0.28	48.33 $\pm$ 2.86	81.79
F <sub>1</sub>	C <sub>1</sub>	73.65 $\pm$ 3.09	95.48	1.78 $\pm$ 0.09	0.08	38.87 $\pm$ 2.60	67.60
	C <sub>2</sub>	76.40 $\pm$ 2.90	84.10	1.80 $\pm$ 0.15	0.22	47.75 $\pm$ 1.82	33.12
F <sub>2</sub>	C <sub>1</sub>	68.77 $\pm$ 3.48	968.83	1.44 $\pm$ 0.03	0.07	35.54 $\pm$ 3.18	808.2
	C <sub>2</sub>	71.54 $\pm$ 2.57	528.39	1.41 $\pm$ 0.08	6.40	42.82 $\pm$ 1.44	165.8
BC <sub>1</sub>	C <sub>1</sub>	77.17 $\pm$ 2.47	244.03	2.68 $\pm$ 0.07	0.19	46.26 $\pm$ 2.19	191.84
	C <sub>2</sub>	80.58 $\pm$ 1.73	119.71	1.85 $\pm$ 0.02	0.01	37.72 $\pm$ 1.81	131.04
BC <sub>2</sub>	C <sub>1</sub>	71.18 $\pm$ 2.94	345.74	2.86 $\pm$ 0.08	0.25	50.05 $\pm$ 2.32	215.29
	C <sub>2</sub>	71.56 $\pm$ 3.17	401.95	2.65 $\pm$ 1.10	0.40	51.73 $\pm$ 2.74	300.30

\* - Significant at 5% level

\* Cross 1 - Vybhav x Arka Alok \* Cross 2 - Vybhav x Arka Abha

\*\* - Significant at 1% level

**Table 2: Mean standard error and variances for fruit quality attributes in two different cross of tomato**

Generations		No. of locules / fruits		Pericarp thickness (mm)		TSS of fruit ( <sup>0</sup> Brix)	
		Mean ± SE	Variance	Mean ± SE	Variance	Mean ± SE	Variance
P <sub>1</sub>	C <sub>1</sub>	3.79 ± 0.06	0.03	4.15 ± 0.07	0.04	4.07 ± 0.07	0.04
	C <sub>2</sub>	3.73 ± 0.16	0.25	4.77 ± 0.18	0.32	3.74 ± 0.20	0.40
P <sub>2</sub>	C <sub>1</sub>	3.51 ± 0.12	0.14	5.94 ± 0.20	0.40	4.33 ± 0.10	0.10
	C <sub>2</sub>	3.46 ± 0.13	0.16	5.83 ± 3.00	90.00	4.14 ± 0.02	0.40
F <sub>1</sub>	C <sub>1</sub>	3.34 ± 0.20	0.40	3.24 ± 0.05	0.02	4.41 ± 0.06	0.03
	C <sub>2</sub>	4.56 ± 0.5	0.22	5.81 ± 0.11	0.12	3.72 ± 0.21	0.44
F <sub>2</sub>	C <sub>1</sub>	3.10 ± 0.12	0.15	3.02 ± 0.01	0.08	4.17 ± 0.06	0.28
	C <sub>2</sub>	4.12 ± 0.07	0.39	5.27 ± 0.17	2.31	3.22 ± 0.12	1.15
BC <sub>1</sub>	C <sub>1</sub>	3.93 ± 0.03	0.03	4.52 ± 0.06	1.44	4.68 ± 0.03	0.03
	C <sub>2</sub>	4.13 ± 0.11	0.48	5.11 ± 0.10	0.40	3.96 ± 0.07	2.80
BC <sub>2</sub>	C <sub>1</sub>	3.72 ± 0.11	0.48	6.20 ± 0.15	0.90	4.83 ± 0.05	0.10
	C <sub>2</sub>	3.90 ± 0.08	0.25	6.11 ± 0.17	1.15	4.69 ± 0.13	0.67

\*-Significant at 5% level, \*\* - Significant at 1% level

\* Cross 1 - Vybhav x Arka Alok \* Cross 2 - Vybhav x Arka Abha

Table 3: Mean standard error and variances for ToLCV disease of tomato

Generation		ToLCV disease index	Variance
		Mean $\pm$ SE	
P <sub>1</sub>	C <sub>1</sub>	0.35 $\pm$ 0.2	0.40
	C <sub>2</sub>	0.38 $\pm$ 0.03	0.09
P <sub>2</sub>	C <sub>1</sub>	3.40 $\pm$ 0.12	0.14
	C <sub>2</sub>	3.21 $\pm$ 0.03	0.09
F <sub>1</sub>	C <sub>1</sub>	0.2 $\pm$ 0.1	0.10
	C <sub>2</sub>	0.85 $\pm$ 0.05	0.02
F <sub>2</sub>	C <sub>1</sub>	0.98 $\pm$ 0.24	4.60
	C <sub>2</sub>	0.75 $\pm$ 0.06	0.28
BC <sub>1</sub>	C <sub>1</sub>	0.66 $\pm$ 0.11	0.48
	C <sub>2</sub>	0.84 $\pm$ 0.05	0.10
BC <sub>2</sub>	C <sub>1</sub>	0.42 $\pm$ 0.14	1.57
	C <sub>2</sub>	0.35 $\pm$ 0.03	0.03

\* - Significant at 5% level

\*\* - Significant at 1% level

\* Cross 1 - Vybhav x Arka Alok

\* Cross 2 - Vybhav x Arka Abha

(70.34 cm). However, a decreasing trend was recorded in  $F_2$  with (65.52 cm). Highest variance was recorded in  $F_2$  population.

#### **4.1.1.1b Vybhav x Arka Abha**

Resistant parent Vybhav was taller (71.12 cm) than the susceptible parent Arka Abha (70.42 cm).  $F_1$  of the cross recorded plant height of (69.34 cm). An increasing trend in plant height was recorded in segregating populations except in  $F_2$  (65.05 cm). Highest variance was recorded in  $F_2$  population.

#### **4.1.1.2 Number of primary branches**

##### **4.1.1.2a Vybhav Arka Alok**

Susceptible parent Arka Alok possessed more number of primary branches (4.53) than that of Vybhav (3.78).  $F_1$  did surpass the mean value of resistant parent (4.00). An increasing trend in the mean number of primary branches was recorded in segregating population except in  $F_2$  (3.30). Highest magnitude of variance was expressed in  $F_2$  population.

##### **4.1.1.2b Vybhav x Arka Abha**

Vybhav had more number of primary branches (4.32) than its counterpart Arka Abha (4.20). Similar to above cross,  $F_1$  (4.30) did surpass the mean value of susceptible parent Arka Abha. An increasing trend was registered in segregating population except in  $F_2$  (4.07). Highest variance was recorded in  $F_1$  population.

#### **4.1.1.3 Number of fruits per cluster**

##### **4.1.1.3a Vybhav x Arka Alok**

Among the parents Arka Alok bears more fruits (4.70) per cluster than its counterpart Vybhav (4.25).  $F_1$  were intermediate (4.59) to both parents. An

increasing trend was registered in segregating population except  $F_2$  (3.96). Highest variance was recorded in  $F_2$  population.

#### **4.1.1.3b Vybhav x Arka Abha**

Arka Abha bears more fruits per cluster (4.81) than that of Vybhav (4.39).  $F_1$  of the cross recorded intermediate mean (4.63) to both parents. Highest variances was noticed in  $F_2$  population.

#### **4.1.1.4 Number of fruits per plant**

##### **4.1.1.4a Vybhav x Arka Alok**

The number of fruits per plant was more in Arka Alok (38.45) than that of Vybhav (28.37).  $F_1$  were intermediate (29.49) compared to parents.  $F_2$  and  $B_1$  populations expressed decreasing trend and highest variance as exhibited in  $F_2$  population.

##### **4.1.1.4b Vybhav x Arka Abha**

The mean number of fruits per plants was ore in Arka Abha (37.72) than is Vybhav (37.51).  $F_1$  surpass both the parents. Highest variance was recorded in  $F_2$  population.

#### **4.1.1.5 Average fruit weight (gm / fruit)**

##### **4.1.1.5a Vybhav x Arka Alok**

Average fruit weight was lesser in Arka Alok (65.99g) compared to Vybhav (72.75g). The average fruit weight of  $F_1$  (73.65g) was intermediate to both the parents. The decreasing trend registered in segregating population. Maximum variance was recorded in  $F_2$  population.

#### 4.1.1.5b Vybhav x Arka Abha

Average fruit weight of Vybhav (76.29g) was maximum compared to its counter part Arka Abha (65.87g). The  $F_1$  registered an intermediate mean value to both the parents. Highest variances was recorded in  $F_2$  population.

#### 4.1.1.6 Total yield per plant (kg)

##### 4.1.1.6a Vybhav x Arka Alok

Among the parents Arka Alok (2.46 kg) recorded higher yield compared to the parent Vybhav (2.24 kg). The mean value of  $F_1$  was (1.78 kg) and increasing trend was noticed for segregating population. Highest magnitude of variances was manifested in  $F_2$  population.

##### 4.1.1.6b Vybhav x Arka Abha

Vybhav recorded lower yield (1.58 kg) compared to Arka Abha (2.34kg).  $F_1$  were (1.80 kg) intermediate to both the parents. Decreasing trend for yield per plant was noticed in  $F_2$  and  $B_1$  population. Highest variance was recoded in  $F_2$  population.

#### 4.1.1.7 Estimated yield per hectare (tonnes)

##### 4.1.1.7a Vybhav x Arka Alok

Highest fruit yield per hectare was noticed in Arka Alok (48.16 t) compared to Vybhav (42.81 t).  $F_1$ s did not surpass the mean values of both parents. Decreasing trend was noticed except in  $B_2$  population. Highest variance was noticed in  $B_1$  population.

##### 4.1.1.7b Vybhav x Arka Abha

The highest fruit yield per hectare was recorded in Arka Abha (48.33 t) compared to Vybhav (32.41 t).  $F_1$ s were intermediate (47.75 t) to both parents. Highest variance was registered in  $F_2$  population.

**Table 4: Joint scaling test for developmental and reproductive characters of tomato**

Characters	Cross	m	d	h	Chi square value
Plant height	C <sub>1</sub>	68.89**.	-25.5	2.11	5.1295
	C <sub>2</sub>	71.85**	5.83	0.66	9.4876*
No. of primary branches	C <sub>1</sub>	4.24**	-0.40	1.08**	24.0593**
	C <sub>2</sub>	4.31**	0.06	0.22	56.6442**
No. of fruits / cluster	C <sub>1</sub>	4.47**	-0.01	-0.64*	155.9363**
	C <sub>2</sub>	4.58**	-0.31	0.30	53.0196**
No. of fruits / plant	C <sub>1</sub>	34.05**	-5.95	-3.21	13.9490**
	C <sub>2</sub>	38.37**	-0.49	2.63	5.1949
Average fruit weight (gm)	C <sub>1</sub>	69.92**	4.14**	4.90	2.7201
	C <sub>2</sub>	71.73**	6.85**	6.06	4.4659
Total yield / plant (kg)	C <sub>1</sub>	1.97**	0.12**	-0.30*	493.0850**
	C <sub>2</sub>	1.98**	-0.38**	0.04	81.6559
Estimated yield / ha	C <sub>1</sub>	46.70**	-2.96*	-5.27	15.2399**
	C <sub>2</sub>	40.21**	-9.15**	6.91*	3.2130

\* - Significant at 5% level

\*\* - Significant at 1% level

\* Cross 1 - Vybhav x Arka Alok

\* Cross 2 - Vybhav x Arka Abha

Table 5: Joint scaling test for quality parameters of tomato

Characters	Cross	m	d	h	Chi square value
No. of locules / fruit	C <sub>1</sub>	3.62**	0.24**	0.25*	46.3232**
	C <sub>2</sub>	3.59**	0.18**	0.93**	1.9062
Pericarp thickness (mm)	C <sub>1</sub>	3.33**	0.72**	0.34**	1201.8330**
	C <sub>2</sub>	5.2**	-0.64**	0.55**	6.5063
TSS of fruit ( <sup>o</sup> Brix)	C <sub>1</sub>	4.43**	-0.09*	0.23**	141.6653**
	C <sub>2</sub>	3.92**	-0.21**	0.02	66.3324

\* - Significant at 5% level

\*\* - Significant at 1% level

\* Cross 1 - Vybhav x Arka Alok

\* Cross 2 - Vybhav x Arka Abha

#### **4.1.1.8 Number of locules per fruit**

##### **4.1.1.8a Vybhav x Arka Alok**

Maximum number of locules per fruit were noticed in Vybhav (3.79) compared to Arka Alok (3.51).  $F_1$  did not surpass the mean values of both the parents. Decreasing trend was recorded except in  $B_1$  (3.93) population. Highest variance was noticed in  $F_2$  population.

##### **4.1.1.8b Vybhav x Arka Alok**

Highest number of locules per fruit were recorded Vybhav (3.73) compared to other parent Arka Alok (3.46).  $F_1$ s did not surpass the mean values of both parents. An increasing trend was noticed in segregating generations. Highest variance was recorded in  $B_1$  population.

#### **4.1.1.9 Pericarp thickness (mm)**

##### **4.1.1.9a Vybhav x Arka alok**

Highest mean value for pericarp thickness was recorded in Arka Alok (5.94 mm) compared to Vybhav (4.15 mm).  $F_1$  did not surpass the mean values of both the parents. The decreasing trend was noticed in  $F_2$  and  $B_1$  population.  $B_1$  population recorded the highest magnitude of variance.

##### **4.1.1.9b Vybhav x Arka Abha**

Highest mean value for pericarp thickness was noticed in Arka Abha (5.83 mm) compared to Vybhav (4.77 mm). Decreasing trend was noticed in  $F_2$  and  $B_1$  population. Highest magnitude of variance was noticed in  $P_2$  population.

#### 4.1.1.10 Total soluble solids (<sup>0</sup>Brix)

##### 4.1.1.10a Vybhav x Arka Alok

Higher TSS was recorded in Arka Alok (4.33) compared to its counterpart Vybhav (4.07). However, the mean of  $F_1$  (4.41) surpassed both the parental means. An increasing trend was observed in segregating population. While, highest variance was recorded in  $F_2$  population.

##### 4.1.1.10b Vybhav x Arka Abha

Among the parents Arka Abha (4.14) recorded maximum TSS when compared to its counterpart Vybhav (3.74). The mean of  $F_1$  did not surpass mean values of both the parents. An increasing trend was noticed in backcross populations. Highest variance was recorded in  $B_1$  population.

#### 4.1.2 Scaling tests

The estimates of additive (d) and dominance (h) gene effects and significance of the chi square test have been furnished in the tables 4 and 5. The characterwise results are presented below in the following paragraphs.

##### 4.1.2.1 Plant height

Both the additive (d) and dominance (h) effect were non significant in both crosses. The mean value is significant in both crosses and the cross-II exhibited highest mean of 71.85. The chi square test was significant in cross-II (Vybhav x Arka Abha).

##### 4.1.2.2 Number of primary branches

This trait shown significant dominance (h) effects in cross-I. Highest mean was recorded in cross-II (4.31). Chi square test was significant in both the crosses.

**Table 6: Estimates of additive dominance and interaction effects on development and reproductive characters of tomato**

Characters	Cross	m	d	h	i	j	l	Type of epitasis
Plant height	C <sub>1</sub>	65.50**	-4.32	31.11*	29.4*	-2.31*	-43.01*	D
	C <sub>2</sub>	65.00**	0.96	38.01**	39.41**	0.61	-0.58**	D
No. of primary branches	C <sub>1</sub>	33.03**	0.42**	5.84**	5.99**	-0.04	-8.89**	D
	C <sub>2</sub>	4.07**	-667.00	2.74**	2.69**	0.05	-4.55**	D
No. of fruits / cluster	C <sub>1</sub>	3.96**	-18.30	136.01	3.54**	0.04	271.03	D
	C <sub>2</sub>	4.13**	-0.15**	3.02**	2.99**	0.05	-4.06**	D
No. of fruits / plant	C <sub>1</sub>	25.2**	-11.01*	46.61**	50.51**	-5.08	-75.95**	C
	C <sub>2</sub>	35.61**	-0.28	-630.00	27.10*	633.00	1260.00	C
Average fruit weight (gm)	C <sub>1</sub>	68.8**	5.99	25.95	21.60	2.61	-32.31	D
	C <sub>2</sub>	71.55**	9.02**	23.41*	18.10	3.81	-2.74	D
Total yield / plant (kg)	C <sub>1</sub>	1.44**	-0.18	4.78	5.35	-0.06	-8.18**	C
	C <sub>2</sub>	1.41**	-0.80**	3.21**	3.37**	0.42**	-4.86**	D
Estimated yield / ha	C <sub>1</sub>	35.5**	-3.78	43.91**	50.51**	-1.12	-74.4**	D
	C <sub>2</sub>	42.81**	-0.14**	15.01**	7.62	-6.05	-11.03	D

\* - Significant at 5% level    \*\* - Significant at 1% level    \* Cross 1 - Vybhav x Arka Alok    \* Cross 2 - Vybhav x Arka Abha

**Table 7: Estimates of additive dominance and interaction effects of quality characters of tomato**

Characters	Cross	m	d	h	i	j	l	Type of epistasis
No. of locules / fruit	C <sub>1</sub>	3.10**	-0.20	2.59**	2.90**	0.06	-4.22**	D
	C <sub>2</sub>	4.12**	-0.22**	0.52	-0.43	0.08	0.68	D
Pericarp thickness (mm)	C <sub>1</sub>	3.02**	-1.65**	7.53**	9.33**	-0.78**	-14.20**	D
	C <sub>2</sub>	5.27**	-1.00**	1.87**	1.36**	-0.46**	-1.57	D
TSS of fruit ( <sup>0</sup> Brix)	C <sub>1</sub>	4.17**	-0.15**	2.57**	2.35**	-0.02	-4.16**	D
	C <sub>2</sub>	3.22**	-0.73**	4.21**	4.43**	-0.53	-6.40	D

\* - Significant at 5% level

\* Cross 1 - Vybhav x Arka Alok \* Cross 2 - Vybhav x Arka Abha

\*\* - Significant at 1% level

#### 4.1.2.3 Number of fruits per cluster

Significant dominance effects (h) was noticed in cross-I. Highest mean was noticed in cross-II (4.58). Chi square test was significant in both the crosses.

#### 4.1.2.4 Number of fruits per plant

Both the additive (d) and dominance (h) effects were non significant in both the crosses. Highest mean was noticed in cross-II (38.37). Chi square test was significant in the cross-I.

#### 4.1.2.5 Average fruit weight (g)

Significant additive effects (d) were noticed in both the crosses. Highest magnitude of dominance was noticed in cross-II. Highest mean was noticed in cross-II (71.73).

#### 4.1.2.6 Total yield per plant (tonnes)

Additive (d) and dominance (h) effects were significant in cross-I. While in cross-II significant dominance effects (d) was noticed. The cross-II exhibited highest mean of 1.98. Significant chi square value was noticed in cross-I.

#### 4.1.2.7 Estimated yield per hectare

Significant dominance (d) effect was noticed in cross-I. While in cross – II both additive (d) and dominance (h) effects were significant. Highest mean was recorded n cross-I (46.70). Significant chi square value was recorded in cross – I.

#### 4.1.2.8 Number of locules per fruit

Both additive (d) and dominance (h) effects were significant in both crosses. Dominance effects (h) being higher in magnitude than additive (d) effect in both the crosses. The cross-I exhibited the highest mean of 3.59. Chi square test was significant in cross-I.



**Plate 4: Resistant F1 Vybhav x A.Alok**



**Plate 5: Resistant F1 Vybhav x A.Abha**

#### 4.1.2.9 Pericarp thickness

Both additive (d) and dominance (h) effects were significant in both the crosses. The magnitude of dominance (h) effect was higher than the additive (d) effect in both the crosses. The cross-I exhibited highest mean of 5.22. Chi square test was significant in cross – I.

#### 4.1.2.10 Total soluble solids

Additive (d) and dominance (h) effects were significant in cross-I, while in cross-II additive (d) effect was significant. Highest mean was noticed in cross-I (4.43). Chi- square test was significant in both the crosses.

#### 4.1.2.11 ToLCV disease Index

Additive (d) and dominance (h) effects were significant in cross – I and Cross-II. Highest mean was noticed in cross-II (1.845). Chi square test was significant in both the crosses. (Table-12)

Various gene effects *viz.*, additive (d), dominance (h), additive x additive (i), additive x dominance (j) and dominance x dominance (l) estimated from the observed means of six generations of two crosses (Vybhav x arka Alok (C<sub>1</sub>) and Vybhav x Arka Abha (C<sub>2</sub>) for developmental and reproductive characters, fruit quality attributes and leaf curl virus index are given in table 6 and 7 respectively. Under each character, only significant effects are considered for comparing their magnitude. Similarly, even to compare the magnitudes of different effects, the one's that were significant were considered therefore it means that the particular effects, which are left out, were not significant. However in knowing the type of epistasis, the crosses where in the signs of dominance (h) and dominance x dominance (l) were not significant were also considered at least to get an indication of type of epistasis .

Table 8: Per cent ToLCV incidence and disease scale for different generations in two crosses of tomato

Generation	Score	Per cent ToLCV incidence	
		Vybhav x Arka Alok	Vybhav x Arka Abha
P <sub>1</sub>	0	88	80
	1	12	20
	2	-	-
	3	-	-
	4	-	-
P <sub>2</sub>	0	-	-
	1	-	-
	2	89.16	98.64
	3	10.84	1.36
	4	-	-
F <sub>1</sub>	0	23.12	26.25
	1	76.88	73.75
	2	-	-
	3	-	-
	4	-	-
F <sub>2</sub>	0	73.25	76.88
	1	4.25	20.00
	2	22.00	3.12
	3	-	-
	4	-	-
B <sub>1</sub>	0	68.75	67.50
	1	10.93	12.92
	2	15.62	12.16
	3	3.125	5.17
	4	1.57	2.25
B <sub>2</sub>	0	86.25	82.50
	1	7.50	10.40
	2	2.50	2.90
	3	3.75	2.75
	4	-	1.45

Table 9: Co-efficient of infection and reaction of ToLCV infected plant of different generations in two crosses of tomato

Generations	Co-efficient infection	Reaction
Cross 1		
P <sub>1</sub>	3.5	Highly resistant
P <sub>2</sub>	62.5	Susceptible
F <sub>1</sub>	7.5	Resistant
F <sub>2</sub>	4.82	Resistant
B <sub>1</sub>	4.55	Resistant
B <sub>2</sub>	1.18	Highly resistant
Cross 2		
P <sub>1</sub>	3.5	Highly resistant
P <sub>2</sub>	74.7	Susceptible
F <sub>1</sub>	7.50	Resistant
F <sub>2</sub>	4.08	Resistant
B <sub>1</sub>	3.07	Resistant
B <sub>2</sub>	1.51	Highly resistant

\* Cross 1 - Vybhav x Arka Alok

\* Cross 2 - Vybhav x Arka Abha

Per cent ToLCV incidence, disease scale and reaction for different reactions in two crosses of tomato have been furnished in the table 8 and 9.

### 4.1.3 Estimation of gene effects

#### 4.1.3.1 Plant height

Additive genetic effect (d) was positive in cross-II while was positive in cross Vybhav x Arka Alok and Vybhav x Arka Abha. Additive x Additive effect (i) was positive in both the crosses, additive x dominance effect (j) was positive in cross-II and negative in cross - I. The sequence of genetic effects in the decreasing order of their magnitude was  $(h) > (i) > (d)$  in cross-II. The sign of (h) and (l) indicated the predominance of duplicate type of interaction in both crosses.

#### 4.1.3.2 Number of primary branches

Additive genetic effect (d) was positive in cross-I while negative in cross-II. Dominance effect (h) was positive in both the crosses. Additive x Additive (i) effect was positive in both the crosses. Additive x dominance effect (j) was positive in cross-II and negative in cross-I. Duplicate type of epistasis was noticed in both the crosses.

#### 4.1.3.3 Number of fruits per cluster

In cross-I additive x additive (i) effect was significantly positive, while in cross-II all the gene effects were highly significant except the additive x dominance (i) gene effect. Complementary type of epistasis was recorded in cross-I while duplicate type of epistasis was recorded in cross - II.

#### 4.1.3.4 Number of fruits per plant.

In cross-I additive (d) dominance (h), additive x additive (p), dominance x dominance (l) genetic effects were significant. While in cross-II, additive x

additive (i) genetic effect was positive and significant. Duplicate type of epistasis was recorded in both the crosses.

#### **4.1.3.5 Average fruit weight**

Additive (d) and dominance (h) genetic effects were positive and significant in cross-II. Duplicate type of epistasis was recorded in both the crosses.

#### **4.1.3.6 Total yield per plant**

Dominance x dominance (l) effect was significant in negative direction in case of Cross-I. While, in cross – II all type of gene effect were highly significant, dominance (h), additive x additive (i), were in positive direction and additive (d) additive x dominance (j) and dominance x dominance (l) were in negative direction. Duplicate type of epistasis was noticed in both the crosses.

#### **4.1.3.7 Estimated yield per hectare**

Dominance (h), additive x additive (i) were significant in positive direction while, dominance x dominance (l) was significant in negative direction in the cross-I. While in cross-II, additive (d) was significant in negative direction and dominance (h) was significant in positive direction. Duplicate type of epistasis was noticed in both the crosses.

#### **4.1.3.8 Number of locules per fruit**

In cross-I, dominance (h) and additive x additive (i) effects were significant in positive direction while, dominance x dominance (l) effect was significant in negative direction. In case of cross – II, significant additive (d) effect in negative direction was noticed. Duplicate type of epistasis recorded in cross-I while complementary type of epistasis was recorded in cross-II.

#### 4.1.3.9 Pericarp thickness

In cross-I, all the type of gene effects were highly significant, dominance (h), additive x additive (i), in positive direction while, dominance x dominance (l), additive x dominance (j) and dominance x dominance (l) were in negative direction.

As for as cross-II concerned, dominance (h), and additive x additive (i) were highly significant in positive direction and additive (d) and additive x dominance (j) were significant in negative direction. Duplicate type of epistasis was recorded in both the crosses.

#### 4.1.3.10 Total soluble solids

Significant and positive genetic effects were noticed in cross-I with respect to dominance (h) additive x additive (i) effects, while, in additive (d) and dominance x dominance (l) effects significant results in negative directions were noticed. In case of cross-II positive and significant results were noticed in dominance (h) and additive x additive (i) gene effects, while significant result in negative direction was registered in additive (d) gene effect. Duplicate type of epistasis was noticed in both the crosses.

#### 4.1.3.11 ToLCV disease

Significant and positive genetic effects were noticed in cross-I and cross-II with respect to additive (d), dominance (h), additive x additive (i), additive x dominance (j), and significant and negative results were noticed in dominance x dominance (l) gene effect. Duplicate type of epistasis was noticed in both the crosses (Table-11).

Table 10: Estimates of genetic parameters for different traits in two crosses of tomato

Characters	Cross	Heritability (Broad sense)	Genetic advance as % mean	Inbreeding depression	Heterosis (%)	
					MP	BP
Plant height (cm)	C <sub>1</sub>	87.00	6.81	4.81	1.77	3.78
	C <sub>2</sub>	86.00	7.15	4.3	-1.43	-1.08
Plant of primary branches	C <sub>1</sub>	86.00	16.81	4.32	-3.92	1.12
	C <sub>2</sub>	70.00	21.6	5.03	-3.31	3.13
No. of fruits / cluster	C <sub>1</sub>	49.00	67.51	35.91	13.58	13.85
	C <sub>2</sub>	47.00	74.51	0.49*	0.03	0.24
No. of fruits / plant	C <sub>1</sub>	89.00	89.58	0.70	-0.16	0.22
	C <sub>2</sub>	82.00	81.43	0.23	0.04	0.11
Average fruit weight (gm)	C <sub>1</sub>	91.00	84.66	4.88	4.28	7.66
	C <sub>2</sub>	88.00	55.53	4.86	5.32	10.53
Total yield / plant (kg)	C <sub>1</sub>	40.50	75.32	0.34**	-0.57*	-0.46*
	C <sub>2</sub>	47.00	85.15	0.39*	-0.16	0.22
Estimated yield / ha	C <sub>1</sub>	92.00	15.15	3.33	-6.6	-3.94
	C <sub>2</sub>	68.00	42.27	4.93*	7.38**	15.34**
No. of locules / fruit	C <sub>1</sub>	83.00	59.49	0.24	-0.31*	-0.17*
	C <sub>2</sub>	46.00	64.41	0.43**	0.96**	0.82**
Pericarp thickness (mm)	C <sub>1</sub>	92.00	17.69	0.22**	-1.8**	-0.91**
	C <sub>2</sub>	12.00	14.14	0.54**	0.51**	1.04**
TSS of fruit (°Brix)	C <sub>1</sub>	80.00	20.80	0.24**	0.21**	0.34**
	C <sub>2</sub>	64.00	18.70	0.51*	-0.21	-0.41
ToLCV disease index	C <sub>1</sub>	97.61	60.50	-0.12	-0.82	-0.77
	C <sub>2</sub>	97.81	60.40	0.78	-1.22	1.18

\* - Significant at 5% level \*\* - Significant at 1% level

#### 4.1.4 Estimation of heritability and genetic advances

Heritability, genetic advance as per cent mean, Heterosis over mid parent and over better parent and inbreeding depression were studied for all traits in two crosses. Results were summarized in table 10.

##### 4.1.4a Cross - I Vybhav x Arka Alok

Among the eleven character, broad sense heritability was ranged from 40.50 per cent total yield per plant) to 97.61 per cent (ToLCV disease index). The highest heritability was observed in ToLCV disease index (97.61%) followed by pericarp thickness (92.00%), estimated yield per hectare (92.00%). Average fruit weight (91.00%), number of fruits per plant (89.00%) plant height (87.00%). Number of locules per fruit (83.00) TSS of fruit 80.00%. Moderate heritability was noticed in number of fruits per cluster (49.00%) and total yield per plant (40.50%).

Genetic advance as per cent mean ranged from 15.15 per cent (estimated yield / ha) to 89.58 per cent (number of fruits / plant). High genetic advance was observed for number of fruits per plant (89.58%). Average fruit weight (84.66%). Total yield per plant (75.32%). Number of locules / fruit (59.49%) TSS of fruit (20.80%) and ToLCV disease index (60.50%). Moderate genetic advance was evident for number of primary branches (16.81%), estimated yield per hectare (15.15%), pericarp thickness (17.69%). Low genetic advance was registered for plant height (6.81%). (Table-10)

##### 4.1.4b Vybhav x Arka Abha

Broad sense heritability was ranged from 12.00 per cent (pericarp thickness) to 97.81 (ToLCV disease index). The highest heritability was observation in ToLCV index (97.81%) followed by average fruit weight (88.00%), plant height (86.00%) number of fruits per plant (82.00%), number of primary

branches (70.00%), estimated yield per hectare (68.00%), TSS of fruit (64.00%). Moderate heritability was noticed in total yield per plant (47.00%), number of fruit per cluster (47.00%), number of locules per fruit (46.00%) and low heritability was noticed in pericarp thickness (12.00%).

Genetic advance as per cent mean ranged from 7.15 per cent (plant height) to 85.15 (total yield per plant). High genetic advance as noticed for number of primary branches (21.60%), number of fruits / cluster (74.61%), number of fruits per plant (81.43%), average fruit weight (55.53%), total yield per plant (85.15%), number of locules per fruit (64.61%) and ToLCV disease index (60.40%). Moderate genetic advance was noticed for TSS of fruit (18.70%), and pericarp thickness (14.14%) and genetic advance as noticed for plant height (7.15%).

#### **4.1.5 Heterosis and inbreeding depression**

The estimates of heterosis over mid parent and better parent and inbreeding depression for eleven characters of two crosses are presented in table 10 and the same has been narrated below.

##### **4.1.5.1 Plant height**

The estimates of heterosis over mid parent was 1.77 per cent in case of cross Vybhav x Arka Alok. While, it was -1.43 per in case of Vybhav x Arka Abha. Heterosis percentage over the better parent was 3.78 in Vybhav x Arka Alok and -1.08 in Vybhav x Arka Abha. The inbreeding depression percentage was 4.81 in cross I and 4.3 in cross II in  $F_2$  generations.

##### **4.1.5.2 Number of primary branches**

The heterosis percentage over mid parent was -3.92 in cross I and -3.31 in cross II. The heterosis percentage over better parent was 1.12 in cross I and 3.13 in cross II. Inbreeding depression in  $F_2$  was 4.32 in cross I and 5.03 in cross II.

**Table 11: Estimates of additive, dominance and interaction effects of ToLCV disease index in tomato**

Characters	Cross	m	d	h	i	j	l	Type of epistasis
ToLCV disease index	C <sub>1</sub>	0.984**	0.249**	3.172**	1.58**	1.242**	-3.40**	D
	C <sub>2</sub>	0.745**	0.486**	1.695**	0.590**	0.80**	-3.59**	D

\* Cross 1 – Vybhv x Arka Alok

\* - Significant at 5% level

Cross 2 - Vybhv x Arka Abha

\*\* - Significant at 1% level

**Table 12: Joint scaling test for ToLCV disease index in tomato**

Characters	Cross	m	d	h	Chi square value
ToLCV disease index	C <sub>1</sub>	1.683**	1.173**	1.754**	72.48**
	C <sub>2</sub>	1.845**	1.375**	1.556**	477.86**

\* Cross 1 – Vybhv x Arka Alok

\* - Significant at 5% level

Cross 2 - Vybhv x Arka Abha

\*\* - Significant at 1% level

#### 4.1.5.3 Number of fruits per cluster

Heterosis over mid parent was 13.58 per cent in cross I and 0.03 in cross II. Heterosis percentage over better parent was 13.85 per cent in cross I and 0.24 per cent in cross II. Inbreeding depression in  $F_2$  was 35.91 per cent in cross I and 0.49 in cross II.

#### 4.1.5.4 Number of fruits per plant

The heterosis percentage over the mid parent was  $-0.16$  in cross I and  $0.04$  in cross-II. Heterosis percentage over the better parent was  $0.22$  in cross I and  $0.11$  in cross-II. The inbreeding depression in  $F_2$  was  $0.70$  and  $0.23$  per cent in cross I and cross- II respectively.

#### 4.1.5.5 Average fruit weight

The heterosis percentage over the mid parent was  $4.28$  in cross I and  $5.32$  in cross II. Heterosis percentage over better parent was  $7.66$  in cross I and  $10.53$  in cross II. The inbreeding depression in  $F_2$  was  $4.88$  per cent in cross I and  $4.86$  per cent cross II.

#### 4.1.5.6 Total yield per plant

Heterosis over mid parent was  $-0.57$  per cent in cross I and  $-0.16$  per cent in cross II. Heterosis over better parent was  $-0.46$  per cent in cross-I and  $0.22$  per cent in cross II. Cross I showed significant negative heterosis. The inbreeding depression in  $F_2$  was  $0.34$  per cent in cross I and  $0.39$  per cent in cross II.

#### 4.1.5.7 Estimated yield per hectare

The estimate of heterosis over mid parent was  $-6.60$  per cent in cross I and  $7.38$  per cent in cross II. The  $-3.94$  in cross I and  $15.34$  in cross II. Cross I showed significant positive heterosis. The inbreeding depression in  $F_2$  was  $3.33$  per cent in cross I and  $4.93$  in cross -II.

#### 4.1.5.8 Number of locules per fruit

Heterosis over mid parent was  $-0.31$  per cent in cross I and  $0.96$  per cent in cross II. Heterosis over better parent was  $-0.17$  per cent in cross I and  $0.82$  in cross II. Cross I showed significant negative heterosis while, cross II showed significant positive heterosis. Inbreeding depression in  $F_2$  was  $0.24$  in cross I and  $0.43$  in cross II.

#### 4.1.5.9 Pericarp thickness

Heterosis over mid parent was  $-1.8$  per cent in cross I and  $0.51$  per cent in cross II. Heterosis over better parent was  $-0.91$  per cent in cross I and  $1.04$  per cent in cross II. The crosses I and II showed significant negative and positive heterosis respectively. The inbreeding depression in  $F_2$  in cross I was  $0.22$  per cent and  $0.54$  per cent in cross- II.

#### 4.1.5.10 Total soluble solids

The heterosis percentage over the mid parent was  $0.21$  and  $-0.21$  in crosses I and II respectively. Heterosis percentage over better parent was  $0.34$  in cross I and  $0.41$  in cross II. Cross- I showed significant positive heterosis. The inbreeding depression in  $F_2$  was  $0.24$  per cent in cross I and  $0.51$  in cross- II.

#### 4.2 ToLCV disease index

The estimate of heterosis over mid parent was  $-0.82$  per cent in cross -I and  $-1.22$  per cent in cross II. The heterosis over better parent was  $-0.77$  per cent in cross I and  $-1.18$  per cent in cross II. The inbreeding depression in  $F_2$  in cross I was  $-0.12$  per cent and in cross II it was  $0.78$  per cent.

# DISCUSSION

## V. DISCUSSION

Tomato (*Solanum esculentum* L.) is one of the most ubiquitous vegetable crop, which has found acceptability in every hook and corner of the country and forms an important part of Indian cuisine though it is exotic in origin.

The extent of destruction by ToLCV is so severe that during summer months, it is virtually impossible to take up a crop with an economic yield. This is often attributed to high vector population (*Bemisia tabaci*), which in turn leads to high incidence of ToLCV. Attempts to limit this disease within economic threshold levels by way of limiting the vector population by chemical control, soil mulching, yellow polythene sheets, sticky traps or barrier crops have not given the effective results (Saikia and Muniyappa, 1989).

Consequently, host plant resistance is an attractive option to augment tomato yields. The development and cultivation of resistant varieties offers the most technically feasible, environmentally sound and economical means of disease control.

However, progress in this area seems to be modest. Several technical difficulties in evaluating resistance, meager understanding of basic mechanisms underlying ToLCV wilt resistance and genetic features which are not formally worked out pose a problem in evolving resistant cultivars for the disease.

Lot of work has been done to identify the sources of ToLCV resistant sources. So far identified sources are located in wild species. PI 127830, PI 27831 of *L. peruvianum* (Muniyappa *et al.*, 1991) LA 1921 of *L. pimpinellifolium* (Banerjee and Kalloo, 1989), PI 127085 A of *L. pimpinellifolium* (Villareal and Lai, 1978), Hawaii 7998 (Oliviera *et al.*, 1999) are identified for ToLCV and bacterial wilt resistance. As they are identified in wild species of *Lycopersicon* it is

difficult to transfer resistance to cultivated species, because of crossability barriers and unfavourable linkage.

The resistant source, Vybhav used in this study exhibited resistance for ToLCV. However yields were not of acceptable levels and so they were crossed with susceptible cultivars to ToLCV and having good marketable qualities to improve upon the traits in the hybrids.

Through plant breeding and genetic manipulation, striking differences have been developed between domestic tomato and its wild relatives. However changes in agricultural prices, biotic and abiotic environments and consumer preferences demand additional improvement at a faster rate. Efficient collection of genetic information and a rapid application of this information to breeding is clearly a priority. This is true of quantitative traits, which have genetic complexity and are subjected to environmental fluctuation.

Although some important traits in tomato are due to a single genetic factor, most of them are influenced by different genes, each having a small effect. Phenotypic selection is slow due to segregation at numerous loci and due to effects of environment on phenotype.

Hence, in order to probe into various gene effects involved in quantitative traits in tomato, six generation mean analysis (Hayman, 1958 and Jinks and Jones, 1958) was employed. Although various biometrical approaches were available to elucidate such information, generation mean analysis was used in the study because of its relative simplicity and statistical reliability since it is based on first order statistics. Further, detection, estimation and interpretation of non-allelic interaction has progressed much farther at the level of first degree of statistics because their effects are less confounded. Kinds of experiments required for their analysis are both smaller and simpler. Based on this, appropriate breeding methods

to be used for improvement of this crop for various quantitative traits have been proposed. The results obtained in present investigation are discussed here under.

## **5.1 Mean performance and variability**

### **5.1.1 Plant Height**

The mean values of  $F_1$  was intermediate to the parental mean in cross Vybhav x Arka Alok and suggesting incomplete dominance. The cross Vybhav x Arka Abha also shows intermediate to the parental mean suggesting that incomplete dominance.

The mean plant height of  $F_2$  population was found less in both the parents of the cross Vybhav x Arka Alok and Vybhav x Arka Abha. Which indicated the presence of more transgressive segregants. Mean plant height of  $B_1$  population and more than better parent in both the crosses, which indicated the presence of more transgressive segregants even under diseased conditions.

### **5.1.2 Number of primary branches**

Lesser number of primary branches than the better parent in the  $F_1$  of both the cross suggesting an over dominance nature for the trait in a negative direction. However, the mean of  $F_2$  population of both the cross was lesser than both the mid parent and better parent values which indicated the presence of large number of transgressive segregants that could be isolated for higher number of primary branches so, also, the  $B_1$  and  $B_2$  populations of the cross had higher number of primarily branches.

### **5.1.3 Number of fruits per cluster**

Number of clusters exhibited incomplete dominance in both the crosses, indicated by the trait that the  $F_1$  mean surpassed in both the parental means. The segregating generations exhibited mean values, which were on par with the mid

parent means in both the crosses. This gives an indication of lesser number of transgressive segregants being recovered for number of fruits per cluster. The  $B_1$  and  $B_2$  populations of this cross had high number of fruits per cluster.

#### **5.1.4 Number of fruits per plant**

This trait is very important as it plays an important role in deciding the final yield. The mean of resistant parents was not higher due to the fact that resistant parents were average bearers. However, a reduction in the mean number of fruits per plant was observed in segregating generations of the cross Vybhav x Arka Alok which indicated the presence of inbreeding depression. Increasing trend in means of the number of fruits per plant of  $B_2$  and Vybhav x Arka Abha indicated the presence of transgressive segregants. Higher variability in  $F_2$  was evidenced in both the crosses due to a wider range of fruits per plant.

#### **5.1.5 Average fruit weight**

The mean values of  $F_1$  in both the crosses, were intermediate to their parents, suggesting an incomplete dominance nature for the trait. The cross Vybhav x Arka Abha showed supplementing over the other cross with highest mean and variance being exhibited in  $F_2$  for this trait. It also suggested that more number of transgressive segregants could be isolated with average fruit weight in  $F_2$  population of this cross. However, the  $F_2$  of the cross Vybhav x Arka Abha also exhibited considerable variability.

#### **5.1.6 Number of locules per fruits**

Number of locules per fruits exhibited overdominance in the cross Vybhav x Arka Abha indicated by the fact that the  $F_1$  mean surpassed both the parental means. The cross Vybhav x Arka Alok segregating generation exhibited mean value, which was on par with the mid parent means in the cross. This gives an

indication of lesser number of transgressive segregants being recorded for number of locules per fruits.

### 5.1.6 Pericarp thickness

The pericarp thickness exhibited over dominance in the cross Vybhav x Arka Abha, indicated by the fact the  $F_1$  mean surpassed both the parental means. The cross Vybhav x Arka Alok exhibited the incomplete dominance where  $F_1$  mean less than the parental means. Hence, the cross is suitable for the hybrids with low pericarp thickness values lesser than  $F_1$  was obtained in segregating population hence, simple selection with less pericarp thickness and advance for further generations. However, in cross Vybhav x Arka Abha, the mean value of  $F_1$  was on par, there was an increasing trend in segregating populations. This indicated that making selection for lesser pericarp thickness would be difficult.

### 5.1.7 TSS of fruit ( $^{\circ}$ Brix)

In both the crosses, the mean values of  $F_1$  surpassed both the parents which indicated the presence of over dominance in a desirable direction as high TSS is preferred in processing industries. Higher mean and variance in  $F_2$  of cross Vybhav x Arka Alok, suggested predominance of transgressive segregants and selection could provide a genotype with higher TSS values. Similarly,  $B_2$  population of the cross Vybhav x Arka Alok exhibited maximum variance suggesting that higher number of transgressive segregants could be speculated in  $B_2$  population of this cross.

## 5.2 Scaling test and component of variance (Mather, 1949)

Persual of scaling test for development and reproductive traits, fruit quality attributes and ToLCV related parameters of two crosses indicates inadequacy of additive – dominance model for the expression of most of the traits, as evidenced

by significance of any one of the scaling test (A, B and C). The components of variances are also discussed below.

### 5.2.1 Plant height

Additive – dominance model failed to explain the inheritance of plant height as scaling tests were significant in both the crosses. The crosses Vybhav x Arka Alok and Vybhav x Arka Abha, significant differences were recorded in the estimates (h) and (i) and negative significant in (l) for both the crosses.

Variations for plant height were not explained adequately by a three parameter model in both the crosses. Therefore the model was extended to include epistatic effects. The higher magnitude of dominance and additive x additive was positive in both the crosses. The sequence of genetic effects in the decreasing order of their magnitude.

This indicated that the genes governing determinate type of plant growth of Vybhav x Arka Alok were more frequently dominant. Nevertheless, both additive and additive interactions were significant and positive but comparatively lesser than that of dominance effects. It may be possible to isolate a genotype with determinate plant growth in segregating generations. These findings are in confirmation with the works of Bhattacharjee (1999) and Bhushna (2000).

Plant height appeared to be controlled by dominance and additive x additive gene effects significantly in positive directions, in the cross. Hence simple selections would be recording in identifying genotypes with desirable plant height in segregating generations of this cross. These findings are in agreement with results of Ghosh and Syamal (1995) and Ramamohan (1988).

### 5.2.2 Number of primary branches

Significant scaling test indicted presence of digenic interactions dominance and additive x additive gene effects were found to be predominant and dominance x dominance interaction shows negative. Non-significance of dominance gene effects in cross-2 need not necessarily mean the absence of dominance. Because such results would be obtained due to cancellation of dominance gene effects and various loci.

The dominance gene effect was found to be predominant than that of additive gene effects. The results are in confirmation with Ghosh and Syamal (1955), Kanthaswamy (1988), Nagaraja (1995) and Ramamohan (1988).

Unbiased estimates of additive and dominance effects are not obtainable in presence of epistasis. However, the best approximation of these effects can be obtained form the additive dominance model (Hayman, 1958).

Both the additive and dominance gene effects in positive direction and dominance x dominance in negative direction. Therefore it could be suggested that the heterosis breeding be used for its exploitation.

The results were also in confirmation with the components of variance as outlined by Mather, 1949, Both 'D' and 'H' components were highly significant which indicated the additive, dominance and epistatic gene action were operating for the character. However, a great magnitude of 'D' indicated the provenance of additive gene effect.

### 5.2.3 Number of fruits per cluster

Significance of scaling tests necessitated the additive - additive Model to include digenic interactions for cross Vybhav x Arka Alok and cross Vybhav x Arka Abha shows duplicate type of epistasis. To improve the character number of

fruits per cluster, the mass selection is good method of breeding. Similar results of predominance of only additive and dominance effects were reported by Bhushana (2000), Kanthaswamy (1988), Nagaraja (1955) and Ramamohan (2000), Kanthaswamy (1988), Nagaraja (1955) and Ramamohan (1988). The estimates of components of variance also revealed the similar results in which 'D' and 'H' components were significant and indicated the predominance of additive and epistatic gene effects operating for the trait.

#### **5.2.4 Number of fruits per plant**

The cross Vybhav x Arka Alok expressed high magnitude of additive dominance and additive x additive interactions in a negative direction in former and positive direction in the latter suggested the complementary type of epistasis in inheritance of fruit numbers per plant.

#### **5.2.5 Average fruit weight (g)**

It appears that different genetic systems controls the character average fruit weight in the cross-2. A simple additive-dominance model adequately explained the data for cross Vybhav x Arka Abha where the additive gene effect was significantly predominant.

However, for the cross Vybhav x Arka Abha, three parameters model did not explain all the variation among the generation means. The model was extended to include digenic interactions. In the extended model, additive gene effect was significant with a high magnitude.

A predominance of additive and dominance gene effects were observed for inheritance of average fruit weight Vybhav x Arka Abha cross. Vybhav contains more number of genes with additive gene effects with increased mean weight of fruits. It suggests the effectiveness of simple selection even in early segregating generations in improving the trait. These results were in agreement with the

finding if Ghosh and Syamal (1995), Kanthaswamy (1990), Khattra *et al.* (1990), Natarajan (1992) and Ramamohan (1988).

### 5.2.6 Total yield per plant

Variation among the generation means for fruit yield per plant in both the cross was not sufficiently explained by additive dominance model. All types of gene effects were significant in cross Vybhav x Arka Abha with complementary epistasis which indicated that inheritance of fruit yield is ambiguous and a simple model could not be devised to study the inheritance of the trait. Singh *et al.* (1976) arrived at a similar conclusion after studying a progeny of diallel crosses. They concluded that fruit yield per plant was controlled by numerous genes with no clear major gene segregations. In the present case, all the types of gene effects were significant but the magnitude of interaction effect was comparatively higher than primary gene effects. Both intra and inter population selection methods would be effective in accumulating favourable gene combinations for improving the fruit yield. These results sustain the reports of Arunkumar and Shrivastava (1996), Ghosh and Syamal (1995), Khattra *et al.* (1990), Omara *et al.* (1988), Patil (1985) and Ramamohan (1988).

However, in cross Vyabhav x Arka Abha significance of only dominance x dominance interactions in a negative direction has indicated the importance of dominance based epistasis. Similar results were obtained by Bhattacharjee (1999), Bhushana (2000) and Ghosh and Syamal (1994a) Hence heterosis breeding would be the most important breeding tool to improve fruit yield per plant.

### 5.2.7 Estimated yield per hectare

The dominance and additive x dominance type of gene effects were significant in the positive direction and dominance x dominance in negative direction in the cross Vyabhav x Arka Alok with complementary epistasis which

indicated that inheritance of yield is ambiguous and a simple model could not be devised to study the inheritance of the trait. In the present case, the dominance type of gene effect were significant in both the cross. The intra and inter population selection method would be effective in accumulating favorable gene combinations for improving the fruit yield. These results sustain the reports of Arunkumar and Shrivastava (1996), Ghosh and Syamal (1995) Khattrra *et al.* (1990) Omara *et al.* (1983), Patil (1985) and Ramamohan (1988).

### 5.2.8 Number of locules per fruit

It appears that different genetic systems control number of locules per fruit in the two crosses. A simple additive- dominance model adequately explained the data for cross Vybhav x Arka Abha. Here the additive gene effect was negatively significant.

However, for the cross Vybhav x Arka Alok three parameter model did not explain all the variation among the generation means. The model was extended to include digenic interactions. In the extended model, dominant gene effect was significant and additive x additive with a higher magnitude. However, dominance x dominance interaction was also significant in negative direction.

A predominance of dominance and additive x additive gene effects were observed for inheritance of number of locules per fruit cross Vybhav x Arka Alok. Vybhav x Arka Alok were increasing parents, for this trait and the fact that additive and additive x additive gene effect were significant implies that Vybhav and Arka Alok contains more number of genes with additive gene effect with increased mean weight of fruits. It suggests the effectiveness of simple selection even in early segregating generations in improving the trait. These results were in agreement with the findings of Ghosh and Syamal (1995), Kanthaswamy (1990), Khattrra *et al.* (1990), Natarajan (1992) and Ramamohan (1988).

The prevalence of additivity was also supported by D, H and E components where in both the crosses, the predominance of significant additive components were noticed suggesting that simple selections in early generations would be rewarding.

### 5.2.9 Pericarp thickness (mm)

Inadequacy of additive-dominance model was evident by significant scaling test in the inheritance of pericarp thickness in both the crosses. Digenic interactions were estimated.

However in the cross Vybhav x Arka Alok, only dominance x dominance gene effect seemed to be predominant but in a negative direction. Duplicate type of epistasis was seen in both the crosses. This also suggests that cross Vybhav x Arka Alok could be relied more upon for selection than cross Vybhav x Arka Abha. The simple selection methods in early generations could isolate genotypes in a desirable direction. These results were in accordance with the works of Ghosh and Syamal (1994).

### 5.2.10 Total Soluble Solids

It appears that different genetic systems controls total soluble solids in the two crosses. A simple additive- dominance model adequately explained the data for gene interaction in total soluble solids in cross Vybhav x Arka Alok. Here the magnitude of additive gene effect being greater, revealed that additive gene action is controlling the inheritance of total soluble solids .It suggested that simple selections in earlier generations could be attempted in this cross to isolate genotypes with higher total soluble solids. These results were in accordance with Conti (1974), Khattra *et al.* (1992), Singh and Singh (1982) and Sonone *et al.* (1986).

However for the cross Vybhav x Arka Abha, the inadequacy of the additive-dominance model necessitated to include digenic interactions. In the extended model, the predominance of dominance and additive x dominance in a positive direction with a duplicate type of epistasis indicated the prevalence of dominance in inheriting the trait. Selections may not be rewarding, hence heterosis breeding could be attempted to isolate a genotype with higher total soluble solids. The similar results of dominance effects for inheritance of the trait was reported by Bhushana (2000), Chandrashekar and RamaRao (1989) and Ghosh and Syamal (1995). The estimates of D, H and E components suggest that dominance gene action governs the inheritance of the trait.

### **5.3 Genetic parameters**

The genetic parameters such as PCV, GCV, heritability, and genetic advance were studied and are discussed below.

#### **5.3.1 Plant height**

Much of the variation observed in  $F_2$  of both the crosses in respect of plant height was due to genotypic co-efficient of variation which indicated that there is little influence of environment on the expression of the character. The plant height also exhibited high heritability coupled with low genetic advance which indicated that selection for plant habit in advanced generations is ineffective. But high heritability alone indicates that though the character is least affected by environment, selection may not be useful because of operation of epistatic variances. These results were in agreement with results of Bhushana (2000), Nagaraja (1995), Rajjadhav and Kale (1985) and Reddy and Reddy (1992).

#### **5.3.2 Number of primary branches**

Wider differences between genotypic and phenotypic variation indicated a higher magnitude of environmental influence for the trait. But, both the crosses

registered high heritability and lower genetic advance. High heritability with low Genetic advance is an indication of non-additive gene action. The high heritability is being exhibited due to favourable influence of the environment rather than genotype and hence, selection for this trait may not be rewarding. This result is in confirmation with the result obtained by six parameter model scaling test (Hayman, 1958). Similar results of high heritability and low Genetic advance were reported by earlier workers *viz.*, Bhattacharjee (1999), Gadekar *et al.* (1992) and Singh *et al.* (1988).

### 5.3.3 Number of fruits per cluster

Existence of higher magnitude of variability in  $F_2$  of both the crosses was noticed due to high GCV and PCV estimates. However, a wide difference between GCV and PCV indicated a major role of environment in expression of the trait. This was supported by the significance of 'E' component of Mather discussed in earlier section. High interference of environment resulted in moderate genetic advance. However, low heritability was noticed gives an indication of epistasis occurring in inheritance of the trait. So selection for improvement of this character may not be useful. Higher estimates of GCV and PCV and high heritability coupled with moderate Genetic advance were reported by Ghosh and Syamal (1995), Kanthaswamy (1988), Kumar *et al.* (1980), Nagaraj (1995) and Ramamohan (1988).

### 5.3.4 Number of fruits per plant

Higher estimates of PCV and GCV with a wide difference in PCV and GCV indicated that contribution of environment towards variability was higher. However higher heritability was recorded due to a higher proportion of variance being contributed by genotype than environment. Genetic advance was moderate as evidenced by the role of environment. Hence, only a marginal improvement in advanced generations could be obtained upon selection. High PCV and GCV

coupled with moderate genetic advance was reported by Gadekar *et al.* (1992) and Padmalatha and Reddy (1990).

### 5.3.5 Average fruit weight

High estimates of both GCV and PCV were observed for this trait. A narrow difference between GCV and PCV indicated a lesser influence of environment for the trait average fruit weight per fruit. High heritability and high genetic advance in segregating generations ( $F_2$ ) of both the crosses indicated the promising nature of the two crosses in order to increase fruit weight through simple selections in further generations. The results were in confirmation with earlier reports of Bhattacharjee (1999) Bhushana (2000), Ghosh *et al.* (1995), Ghosh and Syamal (1994a), Jagadeesh (1998), Parthasarathy (1976), Reddy and Reddy (1992), Sahu and Mishra (1995).

### 5.3.6 Total yield per plant

High PCV and GCV coupled with high heritability and genetic advance was expressed by  $F_2$  generation of both the crosses. This shows a promising nature of the two crosses in order to increase yield through simple selection. The results were in confirmation with earlier reports of Bhattacharjee (1999), Bhushana (2000), Ghosh *et al.* (1995), Ghosh and Syamal (1994a), Jagadeesha (1998), Parthasarathy (1976), Reddy and Reddy (1992) and Sahu and Mishra (1995).

### 5.3.7 Estimated yield per hectare.

High PCV and GCV coupled with high heritability and low genetic advance was expressed by  $F_2$  generation of both the crosses. This shows a promising nature of the two crosses in order to increase yield through simple selection. The results were in confirmation with earlier reports of Bhattacharjee (1999), Bhushana (2000), Ghosh *et al.* (1995), Ghosh and Syamal (1994a),

Jagadeesha (1998), Parthasarathy (1976), Reddy and Reddy (1992) and Sahu and Mishra (1995).

### 5.3.8 Pericarp thickness

Higher estimates of PCV and GCV with a wide difference in PCV and GCV indicated that contribution of environment towards variability was higher. However, higher heritability was recorded due to a higher proportion of variance being contributed by genotype than environment. Genetic advance was moderate as evidenced by the role of environment. Hence, only a marginal improvement in advanced generations could be obtained upon selection. High PCV and GCV coupled with moderate genetic advance was reported by Gadekar *et al.* (1992) and Padmalatha and Reddy (1990).

### 5.3.9 Total Soluble Solids

Much of the variation observed in  $F_2$  of both the crosses in respect of total soluble solids was due to genotypic variation as evident from higher magnitude of variability, narrow difference between GCV and PCV and high heritability. Because of this expected genetic advance was also higher in both the crosses. Hence, it may be expected that simple selection would be highly effective in improving this trait. Pankaj Mittal (1996), Prasad and Prasad (1977) and Pujari *et al.* (1995) have reported high heritability coupled with high Genetic advance as per cent mean.

### 5.3.10 Days to ToLCV symptom expression

Both the crosses recorded high heritability coupled with high genetic advance for days to ToLCV symptom expression. Environmental influence on the trait was least as evidenced from the narrow difference between GCV and PCV. Therefore, simple selection based on phenotypic values in advanced generations would be remunerative.

### 5.3.11 Disease score for ToLCV

Much of the variation observed in  $F_2$  generation of both the crosses with respect to disease score was due to genotype and a minor role of environment could be appreciated in expression of this trait. Consequently, higher estimates of heritability and genetic advance was obtained which indicated that simple selection for lower disease scores in early generation would be effective.

## 5.4 Heterosis, Inbreeding depression and potence ratio

Exploitation of heterosis is a quick and convenient way of combining desirable characters. It is important in self-pollinated crops like tomato, as it may be an indicative of producing transgressive segregants for many quantitative characters in advanced generations. Heterosis in the present investigation was studied as confirmative evidence to various type of gene action operative for expression of the character.

### 5.4.1 Plant height

Significant positive mid parent and better parent heterosis was manifested in  $F_1$  of cross Vybhav x Arka Alok where as cross Vybhav x Arka Abha registered a negative mid parent and better parent heterosis which indicated the nature of dominance of tallness. In the previous studies Anbu *et al.* (1981), Bhattacharjee (1999), Bhushana (2000), Nagaraja (1995) and Ramamohan (1988) recorded positive heterosis for plant height. Scaling tests also revealed that the alleles for plant height seemed to be more frequent than that of parent Therefore, this cross may proved to be useful for obtaining plants with higher plant height but it is not desirable in tomato.

The inbreeding depression was of low order and non-significant in both the crosses. Any selection for improvement of this trait in the segregating generations may proved to be ineffective.

#### 5.4.2 Number of primary branches

Both the crosses, Vybhav x Arka Alok and Vybhav x Arka Abha, showed nonsignificant negative mid parent and positive better parent heterosis for number of primary branches.

Non-significance of  $F_1$  of both the crosses over midparent and better parent indicated that any selection in segregating generations for this trait would be ineffective. Sidhu *et al.* (1981), reported negative mid parent heterosis for trait while Bhushana (2000), Nagaraja (1995) and Ramamohan (1988), reported negative better parent heterosis for number of primary branches.

#### 5.4.3 Number of fruits per clusters

Both the mid parent and better parent heterosis was non-significant in both the crosses. The inbreeding depression was of high order and non-significant in the cross-1 and significant in cross-2. Any selection for improvement of this trait in the segregating generations may proved to be ineffective.

Manifestation of negative mid parent heterosis was reported by Ahmed *et al.* (1988), Dev (1994), Dharmatti (1995), Dhatt *et al.* (2001), Kurian *et al.* (2001), Nagaraja (1995), Prabhushankar (1990), Ramamohan (1988), Sanjay Chada (2002).

#### 5.4.4 Number of fruits per plant

Non-significance of  $F_1$  of both the crosses over midparent and better parent indicated that any selection in segregating generations for this trait would be ineffective. However, a negative heterosis was registered in cross 1. There was significant inbreeding depression cross 2, which indicated some of the transgressive segregants yielding higher number of fruits could be isolated. Some of the earlier reports also spread light upon the non-significance of midparent

heterosis by Ahmed *et al.* (1988), Dharmatti (1995), Dhatt *et al.* (2001), Kurian *et al.* (2001) and Sanjay Chada (2002).

#### 5.4.5 Average fruit weight

Non significant mid parent and better parent heterosis was observed in two crosses for this trait.

Inbreeding depression in both the cross indicated the scope of selection of more number of transgressive segregants in this cross with improved fruit size. Ahmed *et al.* (1988), Nagaraja (1995) and Ramamohan (1988) reported heterosis over both mid parent and better parent.

#### 5.4.6 Total yield per plant

Only Vybhav x Arka Alok exhibited significant and negative better parent heterosis which indicated partial to complete dominant nature for this trait. While the cross Vybhav x Arka Alok showed negative heterosis. Jalikop (1992) reported that high pollen sterility in  $F_1$ s, poor fruit set, reduced seed germination, seedling mortality, slow growth and late flowering in crosses involving *L. esculentum* to wild species of tomato results in decreased yield levels. Similar result for fruit yield was obtained by Kanthaswamy (1988) and Pujari and Kale (1994).

#### 5.4.7 No. of locules per fruit.

The crosses, Vybhav x Arka Alok, showed significant negative mid parent and better parent heterosis for number of locules per fruit. The cross Vybhav x Arka Abha showed positive significant mid parent and better parent heterosis.

Non-significance of  $F_1$  of both the crosses over mid parent and better parent indicated that any selection in segregating generations for this trait would be ineffective. Sidhu *et al.* (1981), reported negative mid parent heterosis for trait while

Bhushana (2000), Nagaraja (1995) and Ramamohan (1988), reported negative better parent heterosis for number of primary branches.

#### 5.4.8 Pericarp thickness

Both the mid parent and better parent heterosis was non-significant and negative direction in both the crosses. The inbreeding depression was of high order and non-significant in the cross- Vybhav x Arka Alok and significant in cross- Vybhav x Arka Abha. Any selection for improvement of this trait in the segregating generations may proved to be ineffective.

Manifestation of negative mid parent heterosis was reported by Ahmed *et al.* (1988), Dev (1994), Dharmatti (1995), Dhatt *et al.* (2001), Kurian *et al.* (2001), Nagaraja (1995), Prabhushankar (1990), Ramamohan (1988), Sanjay Chada (2002).

#### 5.4.9 Total soluble solids

Significant and positive heterosis over midparent and better parent was observed in cross Vybhav x Arka Alok, which indicated the over dominance was operating for this character.

A significant inbreeding depression was noticed as indicated by a decreasing trend in segregating generations.

### 5.5 Inheritance of ToLCV resistance

Moll and Stuber (1974), pointed out that from a plant breeder's point of view, heterosis estimates should indicate whether heterozygote represents the most ideal genotype. If heterosis above the higher parent (over dominance) is important, then the best genotype is a heterozygote with partial to complete dominance. The best genotype would be a homozygote when estimates of heritability of heterozygote fall above the high parent, it is tempting to conclude that this is due

to over dominance type of gene action. Heterosis estimates over high parent do not, however necessarily indicate over dominance. Moll and Stuber (1974) listed three possible genetic causes of heterosis. 1) Partial to complete dominance 2) over dominance and epistasis 3) Linkage between loci with complete dominance result in heterosis effects that may mimic effects of over dominance for several generations after a cross. In addition to possible genetic causes, apparent heterozygote advantage may be a result of genotype and environment interactions.

## SUMMARY



# SUMMARY

## VI. SUMMARY

The present investigation was conducted at the Division of Horticulture, Gandhi Krishi Vigyana Kendra, University of Agricultural Sciences Bangalore during 2006-07, involving different genotypes of tomato for their gene action for fruit yield and quality attributes inheritance of resistance to ToLCV, It was also intended to generate material for future breeding programmes that are to be used based on the knowledge regarding genetics of different characters.

The salient features of the present investigation are summarized here under:

Significant differences among the generations for fruit yield, quality attributes and ToLCV related parameters existed.

Higher estimates of phenotypic and genotypic coefficients of variability, heritability and genetic advance were observed for number of primary branches, number of fruits per plant, number of locules per fruit, average fruit weight, TSS of fruit symptom expression and disease score for ToLCV.

Six parameter model (Hayman, 1958) indicated that additive - dominance model was inadequate in explaining the expression of all the traits under study. Major contribution of dominance and dominance based interactions (additive x dominance, dominance x dominance) were observed for plant height, number of primary branches, number of fruits per plant, fruit yield and disease score for ToLCV.

Considerable magnitude of heterosis and inbreeding depression existed for plant height, fruit yield per plant and number of locules per fruit.

ToLCV disease resistance was governed by completely dominant genes in an inhibitory gene action for both the crosses ( Vybhav x Arka Alok and Vybhav x Arka Abha)

In the present investigation, Vybhav x Arka Alok and Vybhav x Arka Abha performed better for the reasons that no plants of  $F_1$  were susceptible till the end of the cropping period and there was enhanced fruit weight with reduced fruit yield. Further, this cross lead to identification of more number of transgressive segregants for fruit yield and resistance to ToLCV.

## REFERENCES

## VII. REFERENCES

- Ahmed, S. U., Saha, H. K. and Sharfuddin, A. F. M., 1988, Study of heterosis and correlation in tomato. *Thailand J. Agric. Sci.*, 21: 117-123.
- Anbu, S., Muthukrishnan, C. R. and Irulappan, I., 1981, Line x tester analysis in tomato. Part-II. Heterosis. *South Indian Hort.*, 29 : 277-313.
- Anonymous, 2000, *Horticultural Crop Statistics of Karnataka State at a Glance*. Statistical Wing, Directorate of Horticulture, Lalbagh, Bangalore. pp. 24.
- Anonymous, 2001, *FAO Production Year Book*, 56 : 25-26.
- Anonymous, 2002, *Agricultural Research Data Book*, pp: 125-126. Indian Agricultural Statistics Research Institute, New Delhi.
- Arunkumar and Shrivastava, 1996, Heterosis and inbreeding depression for some post harvest quality traits in tomato. *Madras Agric. J.*, 83 : 569-573.
- Ashwathappa, N., 1980, Genetic analysis of yield, yield components and resistance of root-knot nematode in tomato (*Lycopersicon esculentum* Mill.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore. 135pp.
- Banerjee, M.K. and Kalloo, 1987a, Sources and inheritance of resistance to leaf curl virus in *Lycopersicon*. *Theor. Appl. Genet.*, 73 : 707-710.
- Banerjee, M.K. and Kalloo, 1987b, Inheritance of tomato leaf curl virus resistance in *Lycopersicon hirsutum* f. *glabaratum*. *Euphytica*, 36 : 581-584.
- Banerjee, M.K. and Kalloo, 1989, The inheritance of earliness and fruit weight in crosses between cultivated tomatoes and two wild species of *Lycopersicon*. *Plant Breed.*, 102 : 148- 152.

- Bhattacharjee, I.J., 1999, Genetics of yield and its parameters and resistance to ToLCV in four crosses of tomato (*Lycopersicon esculentum* Mill.). *M.Sc (Agri.) Thesis*, Univ. Agric. Sci., Bangalore. 87pp.
- Bisht, S.R., Pawar, D.R., Joshi, M.S. and Borkar, P.G., 1990, Varietal reaction of tomato to early blight and leaf curl virus. *J. Trop. Agri.*, **28** : 55-56.
- Bhushana, H.O., 2000, Breeding for tomato leaf curl virus (ToLCV) resistance, enhanced fruit productivity, quality and ToLCV screening by squash blot technique in tomato (*Lycopersicon esculentum* Mill.). *Ph.D. Thesis*, Univ. Agric. Sci., Bangalore. 172pp.
- \*Butnaru, H., 1986, Inheritance of quantitative yield characters in tomatoes for processing. *Lucrari stiintifice Institutul Agronomic Timisoara Agronomie*, **21**: 65-68.
- \*Burton, G.W., 1952, Quantitative inheritance in grasses. *Proc. 6<sup>th</sup> Inter. Grassland Cong.* **1** : 227-283.
- Burton, G.W. and Devane, E.H., 1953, Estimating heritability in tall Fescue (*Festuca arundinaceae*) from replicated clonal material. *Agron. J.*, **45** : 478-481.
- Chandrashekar, A.C., 2000, Genetics of yield, yield attributes, tomato leaf curl virus (ToLCV) resistance and molecular diversity in *Lycopersicon* spp. *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore. 105pp.
- Chandrashekar, P. and Rama Rao, M., 1989, Studies on combining ability of certain characters in tomato. *South Indian Hort.*, **37** : 10-12.
- \*Conti, S., 1974, Research on the heterosis and components of phenotypic variance in long fruited tomato hybrids. *Rivista di Agronomia*. **8** : 383-391.

- Conti, S., Sanguineti, M.C., Toni, B. and Azzoni, A., 1988, Inheritance of quality traits in processing tomato. *Euphytica*, **37**:121-127.
- Dev, H., Rattan, R.S. and Thakur, M.C., 1994, Heterosis in tomato. *Indian J. Hort.*, **51**: 125-132.
- Dhaliwal, M.S., Singh, S. and Cheema, D.S., 2000, Estimating combining ability effects of the genetic male sterile lines of tomato for their use in hybrid breeding. *J. Genet. Breed.*, **54** : 199-205.
- Dharmatti, P.R., 1995, Investigations on summer tomatoes with special reference to tomato leaf curl virus (TLCV). *Ph.D. Thesis*, Univ. Agric. Sci., Dharwad. 184pp.
- Dhatt, A.S., Surjan Singh, Dhaliwal, M.S., Cheema, D.S and Singh, S., 2001, Genetic analysis of tomato hybrids incorporating nor, rin and als alleles for quality. *Crop. Improve.* **28** : 32-39.
- Dudi, B.S., Dixit, J. and Pratap, P.S., 1983, Components of variability, heritability and genetic advance studies in tomato. *Haryana Agric. Univ. J. Res.*, **13**: 135-139.
- Dudi, B.S., Kalloo and Pandita, M.I., 1979, Line x Tester analysis for the study of combining ability in tomato. *Haryana J. Hort. Sci.*, **8** : 117-123.
- Friedmann, M., Lapidot, M., Cohen, S. and Pilowsky, M., 1998, A novel source of resistance to tomato leaf curl virus exhibiting a symptomless reaction to viral infection. *J. American Soc. Hort. Sci.*, **123**: 1-4.

- Frimpong Adams and Oseisafo-Kantaka, 2002, Genetic studies on inheritance of disease resistance in tomato (*Lycopersicon esculentum* Mill). In: Abstracts of invited and contributed papers. International Conference on Vegetables, 50pp, November 11-14, held at Bangalore.
- Gadekar, D.A., Dhonukshe, B.L. and Patil, F.B., 1992, Studies on variability, heritability and genetic advance in tomato. *J. Maharashtra Agric. Univ.*, 17: 305-306.
- Ghosh, P.K. and Syamal, M.M., 1994a, Path analysis and correlation studies in tomato (*Lycopersicon esculentum* Miller). *The Orissa J. Hort.*, 22 : 41-45.
- Ghosh, P.K. and Syamal, M.M., 1994b, Diallel analysis for combining ability in tomato (*Lycopersicon esculentum* Miller). *South Indian Hort.*, 42:204-205.
- Ghosh, P.K. and Syamal, M.M., 1995, Study of components of variation and heritability in tomato (*Lycopersicon esculentum* Miller). *The Orissa J. Hort.*, 23 : 18-20.
- Ghosh, P.K., Syamal, M.M. and Joshi, A.K., 1996, Graphical analysis of gene effects in tomato. *Adv. Plant Sci.*, 9 : 55-59.
- Ghosh, P.K., Syamal, M.M., Rai, N. and Joshi, A.K., 1995, Improvement of hybrid tomatoes. *Adv. Plant. Sci.*, 8 : 207-213.
- Grace Sharon Arul Selvi, 2002, Studies on Heterosis and combining ability for yield , its attributes, resistance to tomato leaf curl virus (ToLCV) in tomato (*Lycopersicon esculentum* Mill.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore. 90pp.

- Hassan, A.A. and Abdel-ati-KEA., 1999, Genetics of TYLCV tolerance derived from *Lycopersicon pimpinellifolium* and *Lycopersicon penellii*. *Egyptian J. Hort.*, **26** : 323-338.
- Hassan, A.A., Mazayad, H.M., Moustafa, S.E., Nassar, S.H., Nakela, M.L. and Sims, W.L., 1984, Inheritance of resistance to tomato yellow leaf curl virus derived from *Lycopersicon penelli* and *Lycopersicon hirsutum*. *Hort. Sci.*, **19** : 574-575.
- Hayman, B.I., 1958, Separation of epistasis from additive and dominance variation in generation means. *Heredity*, **12** : 371-391.
- Jagadeesha, M., 1998, Genetical studies on leaf curl virus resistance in tomato (*Lycopersicon esculentum* Mill.) *Ph.D. Thesis*, Univ. Agric. Sci., Bangalore. 133pp.
- Jalikop, S.H., 1992, Study of genetics and some factors associated with leaf curl virus in *Lycopersicon*. *Ph.D. Thesis*, Univ. Agric. Sci., Bangalore. 187pp.
- Jinks, J.L. and Jones, R.M., 1958, Estimation of components of heterosis. *Genetics*, **43** : 223-224.
- Jinks, J.L., Perkins, J.M. and Breese, E.L., 1969, A general method of detecting additive, dominance and epistatic variation for metrical traits. II: Application to inbred lines. *Heredity*, **24** : 45-57.
- Johnson, H.W., Robinson, H.F. and Comstock, L.E., 1955, Genotypic and phenotypic correlations in soybeans and their implications in selections. *Agron. J.*, **47** : 477-483.

- Kaloo and Banerjee, M.K., 1990, Transfer of tomato leaf curl virus resistance from *Lycopersicon hirsutum f. glabratum* to *L. esculentum*. *Plant Breed.*, **105** : 156-158.
- Kaloo and Banerjee, M.K., 2000, H-24: moderately leaf curl resistant variety of tomato (*Lycopersicon esculentum* Mill.). *Veg. Sci.*, **25** : 117-120.
- Kanthaswamy, V., 1988, Genetic analysis of yield and yield components in tomato. *South Indian Hort.*, **36** : 214-217.
- Kanthaswamy, V. and Balakrishnan, R., 1989, Studies on hybrid vigour in F<sub>1</sub> and its retention in F<sub>2</sub> generation of tomato. *South Indian Hort.*, **37** : 77-83.
- Kasrawi, M.A., Suwan, M.A. and Mansour, M., 1988, Source of resistance to tomato yellow leaf curl virus (TYLCV) in *Lycopersicon* species. *Euphytica*, **37** : 198-110.
- Khattra, A.S., Nandapuri, K.S. and Thakur, J.C., 1990, Inheritance of some economic characters in tomato. *Indian J. Hort.*, **47** : 210-215.
- Khattra, A.S., Nandapuri, K.S. and Thakur, J.C., 1992, Genetics of some quality characters in tomato. *Haryana J. Hort. Sci.*, **21** : 227- 231.
- Kumar, N., Bisht, J.K. and Joshi, M.C., 1988, Genetic studies of quantitative traits in pear shaped tomato. *Prog. Hort.*, **20** : 234-240
- Kumar, T.P., Tewari, R.N. and Pachauri, D.C., 1997, Line x Tester analysis for processing characters in tomato. *Veg. Sci.*, **24** : 34-38.
- Kurian, A., Peter. K.V. and Rajan, S., 2001, Heterosis for yield components and fruit characters in tomato. *J. Trop. Agri.*, **39** : 5-8.

- \*Lush, J.L., 1949, Heritability of quantitative characters in farm animals. *Proc. 8<sup>th</sup> Cong. Genetics. Hereditas (Suppl)*, **35** :356-375.
- Mather, K., 1949, *Biometrical Genetics*, Methuen and Co. London (I edition). 248pp.
- Mittal, R.K. and Singh, H.N., 1978, Genetics of yield and yield components in tomato. *Indian J. Agric. Sci.*, **48** : 159-162.
- Moll, R.H. and Stuber, C.W., 1974, Quantitative genetics-empirical results relevant to plant breeding. *Adv. Agron.*, **26** : 277-313.
- Muniyappa, V., Jalikop, S.H., Saikia, A.K., Chennarayappa, Shivashankar, G., Ishwar Bhat, A. and Ramappa, H.K., 1991, Reaction of *Lycopersicon* cultivars and wild accessions to tomato leaf curl virus. *Euphytica*, **56**:37-41.
- Nagaraja, T.E., 1995, Studies on genetic architecture of fruit yield, its components and inheritance of leaf curl virus resistance in interspecific crosses of tomato (*Lycopersicon* sp.). *Ph.D. Thesis*, Univ. Agric. Sci., Bangalore.
- Nainar, P. and Pappiah, C.M., 2002, Inheritance of resistance to ToLCV disease in segregating generations of eight crosses of tomato (*Lycopersicon esculentum* Mill.). *South Indian Hort.*, **50**: 72-77.
- Natarajan, S., 1992, Inheritance of yield and its components in tomato under moisture stress. *Madras Agric. J.*, **81**: 311-312.
- \*Oliviera, W. F., Giordano, L. B. and Lopes, C. A., 1999, Inheritance of resistance to bacterial wilt in tomato. *Fitopatologia Brasileira*, **24** : 49-53.
- Omara, M.K., Younis, S.E.A., Sherrif, T.H.I., Hossein, M.Y. and El- Aref, H.M., 1988, A genetic analysis of yield and yield components in tomato (*Lycopersicon esculentum* Mill.). *Assuit J. Agric. Sci.*, **19** : 227-238.

- Padmalatha, B. and Reddy, E.N., 1990, Variability parameters in F<sub>2</sub> generation of tomato. *South Indian Hort.*, **38** : 11-14.
- Pankaj Mittal, 1996, Genetics of fruit characteristic in tomato. *Indian J. Agric. Sci.*, **66** : 109.
- Parthasarathy, V.A., Anand, N. and Irulappan, I., 1976, Genetic variability in tomato. *Indian J. Agric. Res.*, **10** : 133-135.
- Patil, A.A., 1985, Correlation, path analysis, genetic divergence, heterosis and combining ability in ten parental diallel cross of tomato. *Mysore J. agric. Sci.*, **19** : 48-49.
- Patil, A.A. and Bojappa, K.M., 1989, Combining ability for growth components in tomato. *Mysore J. agric.Sci.*, **23** : 199-202.
- Pilowsky, M and Cohen, S., 1974, Inheritance of resistance to tomato yellow leaf curl virus in tomatoes. *Phytopathology*, **64** : 632-635.
- Pilowsky, M. and Cohen, S., 1990, Tolerance to tomato yellow leaf curl virus derived from *Lycopersicon peruvianum*. *Plant Disease*, **74** : 248-250.
- Pradeep Kumar, T., Tewari, R.N. and Pachauri, D.C., 1997, Line x tester analysis for processing characters in tomato. *Veg. Sci.*, **24** : 34-38.
- Prasad, A. and Prasad, R., 1977, Variability and Correlation studies in tomato. *Indian J. Agric. Sci.*, **47** : 77-80.
- Pujari, C.V. and Kale, P.N., 1994, Heterosis studies in tomato. *J. Maharashtra Agric Univ.*, **19** : 83-85.

- Pujari, C.V., Wagh, R.S. and Kale, P.N., 1995, Genetic variability and heritability in tomato. *J. Maharashtra Agric. Univ.*, **20** : 15-17.
- Raghupathy, N., Thiruvudainambi, S. and Thamburaj, S., 1997, Reaction of tomato varieties to leaf curl virus. *South Indian Hort.*, **45** : 277-278.
- Raijadhav, S.B. and Kale, P.N., 1985, Combining ability of tomato lines resistant to root knot nematode. *J. Maharashtra Agric. Univ.*, **10** : 172-175.
- Ramachandran, C., Gopala Krishnan, P.K. and Peter, K.V., 1980, Evolving high yielding tomato varieties with resistance to bacterial wilt. *Annual Report, Kerala Agric. Univ.*, Trichur, Kerala.
- Ramamohan, 1988, Genetics of heat tolerance in tomato. *M.Sc.(Agri.) Thesis.* Univ. Agric. Sci., Bangalore. 114pp.
- Ramkishun, 1987, Loss in yield of tomato due to bacterial wilt caused by *Pseudomonas solanaceraum* E.F. Smith, *Indian Phytopath.*, **40** : 152-155.
- Reddy, P.V.V. and Reddy, K.V., 1992, Studies on variability in tomato. *South Indian Hort.*, **40** : 257-260.
- Robinson, H.F., Comstock, R.E and Harvey, P.H., 1949, Estimates of heritability and degree of dominance in Corn. *Agron. J.*, 41:353-359.
- Sadashiva, A.T., Madhavi Reddy, K., Krishna Reddy, M., Singh, T.H., Balaram, M.V., Narasimhaprasad, B.C. and Prasanna, K.M., 2002, Breeding tomato for combined resistance to bacterial wilt and ToLCV. In: *Inter. Conf. Vegetables*, pp: 14-16, November 11-14, held at Bangalore.
- Sahu, G.S. and Mishra, 1995, Genetic divergence in tomato. *Mysore J. agric. Sci.*, **29** : 5-8.

- Saikia, A.K. and Muniyappa, V., 1989, Epidemiology and control of tomato leaf curl virus in Southern India. *Trop. Agric. (Trinidad)*, **66** : 350-364.
- Sanjay Chada, Vidyasagar, Kumar, J. and Chada. S., 2002, Combining ability and gene action studies for some fruit characters in bacterial wilt resistant tomato lines. *South Indian Hort.*, **50** : 65-71.
- Shoba, N. and Arumugam, R., 1991, Association of leaf curl virus resistance in tomato. *South Indian Hort.*, **39** : 281-285.
- Shrivastava, J.P., Hamveer Singh, Srivastava, B.P., Verma, H.P.S and Singh, H., 1998, Heterosis in relation to combining ability in tomato. *Veg. Sci.*, **25** : 43-47.
- Sidhu, A.S, Dixit, J., Kalloo and Bhutani, R.D., 1981, Heterosis and combining ability in pearshaped tomato (*Lycopersicon esculentum* Mill.). *J. Res., (HAU)*, **11**: 1-7.
- Singh, R.K. and Chaudhary, B.D., 1985, *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani publishers, New Delhi. 260pp.
- Singh, A., Joshi, S. and Kumar, N., 1976, Heterosis and combining ability in tomato. *Veg.Sci.*, **3** : 91
- Singh, H.N. and Mittal, R.K., 1978, Combining ability in tomato. *Indian J. Genet.*, **38** : 348-351.
- Singh, R.R and Singh, H.N., 1980, Note on variance components in tomato. *Indian J. Agric. Sci.*, **50**: 361-363.
- Singh, R.R. and Singh, H.N., 1982, Note on genetic information and inheritance of T.S.S. in tomato. *Indian. J. Agric. Sci.*, **52** : 476-478.

- Singh, P.K., Singh, R.K., Sahu, B.C. and Kumar, R., 1988, Genetic variability in tomato (*Lycopersicon esculentum*). *Indian J. Agric. Sci.*, **58** : 718-720.
- Sivasubramaniam. S. and Menon, M., 1973, Heterosis and inbreeding depression in rice *Madras Agric. J.*, **60** : 1139-1141.
- Snedecor, G.W. and Cochran, W.G., 1967, *Statistical Methods* (6<sup>th</sup> edn.). Oxford and IBH pub. Co., Bombay. 350pp.
- Sonone, A.H., Yadav, M.D. and Thombre, M.V., 1986, Combining ability for yield and its components in tomato. *J. Maharashtra Agric. Univ.*, **11** : 288-290.
- Swamy, K.R.M. and Mathai, P.J., 1982, Note on combining ability in tomato. *Indian J. Agric. Sci.*, **52** : 193-196.
- Venkataram Reddy Patil, J., 2001, Studies on genetics of bacterial wilt resistance and heterosis for yield and quality attributes in tomato (*Lycopersicon esculentum* Mill.). *M.Sc. (Agri.) Thesis*, Univ. Agric. Sci., Bangalore. 90pp.
- Vidavsky, F. and Czosnek, H., 1984, Tomato breeding lines resistant and tolerant to tomato yellow leaf curl virus issued from *L. hirsutum*. *Phytopathology*, **74**: 170-179.
- Vidavsky, F., Leviatov, S., Milo, J., Rabionowitch, H.D., Kedar, N. and Czosnek, H., 1998, Response of tolerant breeding lines of tomato, *Lycopersicon esculentum*, originating from three different sources to early controlled inoculation by Tomato Yellow Leaf Curl Virus (TYLCV). *Plant Breed.*, **117** : 165-169.
- Vidyasagar, Chada, S. and Kumar, J., 1997, Heterosis in bacterial wilt resistant tomato lines. *Himachal J. Agric. Res.*, **23** : 40-44.

- Villareal, R.L. and Lai, S.H., 1978, Reaction of three tomato cultivars their F<sub>1</sub>s and three way crosses to two isolates of bacterial wilt. *Hort. Sci.*, **13** : 366.
- Webber, C.R. and Moorthy, B.R., 1952, Heritable and non-heritable relationships and variability of oil content and agronomic characters in the F<sub>2</sub> generations of soybean crosses. *Agron. J.*, **44** : 202-209.
- Wright, S., 1968, *Evolution and the Genetics of populations*. Vol. I. Genetic and Biometric foundations. The University of Chicago press, Chicago press, Chicago and London. 175pp.
- Yassin, A.M., 1984, Leaf curl epidemic in tomato and possible control strategies. *Acta Horticulturae*, **143** : 457-467.
- Yassin, T.E., 1987, Inheritance of resistance to leaf curl virus in tomato interspecific crosses. *J. Agric. Sci. Cambodia*, **107** : 813.
- Yassin, T.E., 1988, Inheritance of three agronomic characters in *Lycopersicon* interspecific crosses. *J. Agric. Sci.*, **110** : 471.
- Zakay, Y., Navot, N., Zeidan, M., Kedar, N., Czosnek, H. and Pleban, T., 1991, Screening of *Lycopersicon* accessions for resistance to ToLCV. *Theor. Appl. Genet.*, **77** :121-123.
- \* Zamir, D., Ekstein-Michelson, I., Zakay, Y., Navot, N., Zeidan, M., Sarfatii, M., Eshed, Y., Harel, E., Plean, T., Oss, H., Van, Kedar, N., Rabinowitch, H.D. and Czosnek, H., 1994, Mapping and introgression of a tomato yellow leaf curl virus tolerance gene TY-1. *Theor. Appl. Genet.*, **80** : 141-146.

---

\* Originals not seen.