INVESTIGATIONS ON SUMMER TOMATOES WITH SPECIAL REFERENCE TO TOMATO LEAF CURL VIRUS (TLCV)

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DECEMBER, 1995

INVESTIGATIONS ON SUMMER TOMATOES WITH SPECIAL REFERENCE TO TOMATO LEAF CURL VIRUS (TLCV)

Thesis Submitted to the
University of Agricultural Sciences, Dharwad
in partial fulfilment of the requirements for the
Degree of

DOCTOR OF PHILOSOPHY
IN
HORTICULTURE

BY

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CERTIFICATE

This is to certify that the thesis entitled **"INVESTIGATIONS ON SUMMER TOMATOES WITH SPECIAL REFERENCE TO TOMATO LEAF CURL VIRUS"** submitted by **Mr.P.R. DHARMATTI** for the degree of **DOCTOR OF PHILOSOPHY** in **HORTICULTURE**, to the University of Agricultural Sciences, Dharwad, is a record of bonafide research work done by him during the period of his study in this University, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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Affectionately dedicated

to my beloved

parents

ACKNOWLEDGEMENT

I express my deep sense of gratitude to **Dr. B.B. Madalageri**, Professor of Horticulture (Oleri), College of Agriculture, Dharwad and Chairman of my Advisory Committee for his valuable guidance.

I avail this opportunity to express my sincere thanks to members of my Advisory Committee, **Dr. U.G. Nalawadi**, D.I. (PGS), University of Agricultural Sciences, Dharwad, **Dr. S. Lingappa**, Professor and Head, Department of Agricultural Entomology, **Dr. Srikanth Kulkarni**, Associate Professor of Plant Pathology and **Dr. M.S. Kuruvinashetti**, Professor of Bio-technology, University of Agricultural Sciences, Dharwad for their valuable suggestions and constructive criticisms during the course of investigations.

I am deeply indebted to **Dr. G.S. Sulikeri**, Professor and Head, Division of Horticulture, **Dr. M.M. Rao**, Professor of Horticulture and **Dr. N.C. Hulmani**, D.I. (Hort.) KRCCH, Arabhavi, for their help and facilities provided during the course of the study.

I feel great pleasure in expressing my gratitude and sincere thanks to Dr. H.T. Channal, Mr. H.B. Babalad, Dr. B.D. Biradar, **Hanumaratti**, Shivakumar Shimpagere, M.B. Madalageri, V.S. Patil, **Girish Patil**, R.V. Patil and V.D. Gasti, UAS, Dharwad, for their kind help and co-operation during the entire course of study.

I am especially grateful to Dr. N.B.Kajjari, Retd. Chief Scientist (PS) and Ex-Board Member and Shri. Y.B. **Patil**, Board Member, UAS, Dharwad for their whole hearted help during the course of the study.

I remain ever grateful to my parents, brothers and wife Smt. **Girija** and daughters **Vijayalaxmi** and **Vinita** without whose love, affection and inspiration this work would not have been completed.

Dharwad
December, 1995

(P.R. Dharmatti)

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INTRODUCTION

I. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important and widely grown vegetable crops of both tropics and subtropics of the world belonging to the family Solanaceae. It is grown for its edible fruits, which can be consumed either fresh or cooked or in the form of various processed products like juice, ketchup, sauce, pickle, pastes, puree, whole canned fruits and also forms an important ingredient in the cocktail known as "Bloody Mary". Now-a-days cultivation of tomato is the focus of large horticultural industry in the world; because it supplies vitamin A and C and adds variety of colours and flavours to the foods. It is being grown in kitchen gardens, commercial fields and economically exploited in green houses or controlled environment conditions. In terms of total vitamins and minerals provided by the main vegetable crops, tomato stands first in the U.S. diet (Rick, 1978). Green tomatoes are also used for pickles and preserves. Large scale production of tomato is seen in U.S.A., Russia, China, Italy, Spain, Portugal and Turkey.

Tomato is a self pollinated crop and Peru-Equador region is considered to be the centre of origin of this plant (Rick, 1969). The crop is now cultivated over an area of 2.9 lakh ha in India with an annual production of 40.03 lakh tonnes

(Gill and Tomer, 1991). Karnataka contributes 10.9 per cent of total production from the estimated area of 25,133 ha (Anon., 1992). The average productivity of India (15.88 t/ha) compares poorly with productivity levels achieved in U.S.A., and in other developed countries (34 t/ha) (Anon., 1992). The per capita consumption of tomato products is 1.0 kg in India, 1.5 kg in Singapur, Philippines, Malaysia, Egypt and Mexico, 2 kg in Taiwan, 5-15 kgs in West African and East European countries and exceeds 25 kg in the U.S.A., Canada and Italy. For a long time, tomato was not consumed by human beings due to persistent superstitions of its poisonous nature. The Europeans (mostly Italians) consumed first and then Americans followed. The red fruited tomato might have been known in 1554. Since 1800, tomatoes are being used as a food (Boswell, 1949). Now, cultivation of tomato has become increasingly popular since mid-nineteenth century because of its varied climatic tolerance and high nutritive value. So, the efforts of many vegetable breeders have resulted in spectacular improvements in yield and quality characters. As a result of these efforts, hundreds of new cultivars have been developed since 50 years to meet the diverse needs; and varied situations and climates under which tomato is grown.

In India one of the major constraints in the cultivation and production of tomato is the occurrence of the leaf curl virus during summer in South India and autumn in North India (Banerjee and Kalloo, 1987a). This disease is presumed to be caused by a gemini virus. This virus disease has risen to alarming proportions in the plains of India and becoming a limiting factor in tomato cultivation. Infact, Saikia and Muniyappa (1989) reported cent per cent infection and fruit yield losses exceeding 90 per cent. Thus tomato cultivation is almost precluded during summer in south India and autumn in north India. Besides, disease intensity is increasing during the remaining period of the year also. Presence of many collateral hosts for the vector as well as virus ensures abundant inoculum in nature, resulting in fast spread of the disease. Thus, Indian tomato industry is in a desperate need of tomato varieties tolerant to leaf curl virus to stabilize tomato production.

Tomato leaf curl virus (TLCV) is known to be transmitted by the vector whitefly (*Bemisia tabaci* Genn.) and was first reported in India by Vasudeva and Sam Raj in 1948. The affected plants are severely stunted with reduced leaf let size and curled that show interveinal chlorosis and branches assuming erect position. Fruit set is greatly reduced and severely infected young plants almost fail to produce any marketable yield.

Many indirect approaches like checking the vector population by using trap crops and application of systemic insecticides may reduce the TLCV infection to certain levels. Some of the crops known as good hosts of the vector but non-hosts of the virus, eg., *Dolichas* (Lubia bean), maize (Anon., 1992) vegetable Cajanus, Cucumber (Yassin *et al.*, 1982), when interplanted with tomato in the field, might attract the vector and reduce the TLCV incidence. Besides, application of large amount of vector killing pesticides is not only uneconomical but also has environmental health hazards. Since, the host range of both virus and vector are quite diversified and widely distributed, it is impracticable to adopt crop health measures such as eradication of collateral or alternate hosts. Primary infection in any one field as are widely scattered and numerable with random pattern of spread, it is difficult to advocate roguing of infected plants. Added to this, there is no commercial tomato cultivar with inherent resistance against the disease, together with acceptable marketing quality. Therefore, it is imperative to concentrate on the development, of cultivars that are resistant to disease or disease escaping cultivars. The virus control and tomato production are very much linked as the disease has an important bearing on fruit yield. Hence, breeding for disease resistance has been one of the most important objectives of vegetable breeders in the last half of 20th century. Often, breeding for disease resistance has assumed greater importance than improvement for yield or quality. Host plant resistance, the most important disease control strategy, is environmentally sound with low running costs. As the virus solely banks upon the whitefly for its spread, use of vector resistant cultivars will help to break virus-vector-host transmission cycle. Therefore, breeding tomato cultivars possessing in built resistance either for virus or vector or both is an appropriate approach for the management of leaf curl virus.

For the development of a resistant variety, donors of resistance are the pre-requisite and should be identified by the well-established technique of the screening of germplasm and further assessment of the genetic material. To develop stable resistance in a variety, source of resistance with a broad genetic base would be imperative. The genetics of resistance helps in the formulation of the breeding method. A few scientists reported resistance for TLCV in accessions of certain *L. esculentum* (Yassin, 1984; Yassin and Nour, 1965) and wild relatives of *Lycopersicons* (Muniyappa *et al.*, 1991 and Banerjee and Kalloo, 1987a). In general, the wild species of genus *Lycopersicon* are well documented as rich reservoirs of several useful genes including disease resistance.

Resistance breeding is an integral part of the crop improvement programme and hence, it should not be alienated from the main stream of breeding efforts.

The resistant genotypes should also possess other desirable economic traits to make them viable at commercial level. Therefore, emphasis should be not only to understand the genetics of resistance, but also to understand the genetic regulation of architectural traits and fruit yield and their association with disease resistance in order to propose strategic methods of tomato improvement.No source of resistance was found among the numerous tomato cultivars that have been screened against the disease, as all of them were susceptible in varying degrees. It was, thus, imperative to seek source of resistance to the disease in the forms of *Lycopersicon esculentum.* For this purpose, and for achieving resistant tomato cultivars, the present investigation was under taken in tomato with the following objectives.

Objectives

1. To study genetic divergence in tomato for TLCV resistance
2. To study the genetics of TLCV
3. To estimate heterosis and combining ability for good horticultural traits including resistance to TLCV and
4. To develop management practices to control TLCV in summer by use of trap crop.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important Solanaceous vegetables grown worldwide under outdoor and indoor conditions. It has become an important commercial crop so far as the area, production, industrial values and its contribution to human nutrition. During the past few decades tremendous developments have contributed to the knowledge and understanding of various areas of crop production and voluminous literature has been generated. The main aim of any breeding programme is the improvement of both qualitative and quantitative characters of the plants. The information on genetic architecture of various quantitative traits, particularly of those that contribute to yield, disease resistance and quality would be most useful in planning the breeding programmes so as to make effective selections. The purpose of this section is to give a comprehensive up-to-date treatment to the various aspects of genetic improvement and use of trap crop in tomato with special reference to tomato leaf curl virus (TLCV) resistance.

2.1 GENETIC DIVERGENCE AND VARIABILITY

Planning and execution of a breeding programme for the improvement of quantitative attributes depends to a great extent, upon the magnitude of genetic variability and divergence existing in the material. It is reasonable to expect the genetic divergence to be associated with geographic diversity. This may be true for land races but in applied plant breeding where the origin of lines is not always known, selection of parents based on geographic diversity alone is not always relevant. The statistical techniques such as Mahalonobis's D^2, which quantify the differences among several quantitative traits is an efficient method to guage the extent of diversity among the genotypes. The concept of Mahalonobis's D^2 statistic is based on the technique of utilizing the measurement of potential parents under study with respect to aggregate of characters. Hence, the required information can be used while selecting parents in the hybridization programme. The D^2 statistic as a measurable genetic divergence was used for the first time in the field of plant breeding by Nair and Mukherjee (1960) in classifying teak. The importance of genetic divergence to yield improvement and heterosis in tomato has been emphasized by several workers.

The genus *Lycopersicon* possesses a wealth of genetic diversity. The complexity of forms in the genus *Lycopersicon* include several cultivated and wild progenitors. The phenomenon of introgression between species has further enriched the diversity. The progress made to derive such information on genetic divergence in tomato is reviewed below.

Sachan and Sharma (1971) while studying the multivariate analysis of genetic divergence in tomato reported its use in selecting genetically diverge parents for a successful hybridization programme out of the 20 varieties belonging to diverse genetic and geographical origins. The varieties were grouped into four clusters and also found that the maximum contribution to the total divergence was by stem length followed by number of branches, number of inflorescences and number of fruits per plant. Khanna and Misra (1977) grouped 50 varieties into ten clusters on the basis of intra and inter-cluster similarity with respect to plant height, fruit number per plant, number of branches, number of locules, number of days to flowering, total soluble solids and fruit yield in tomato, while TSS, locule number and fruit number per plant were the major determinants of D^2 values.

Bhattacharya *et al.* (1979) attempted to know the species differentiation in tomato based on the results of genetic divergence by D^2 statistics using 50 tomato genotypes including four wild collections. These genotypes were grouped into 16 clusters on the basis of the relative magnitude of D^2 values. The four wild collections of which three belonged to *Lycopersicon peruvianum* and one to *L. pimpinellifolium* Mill. were grouped into three distinct clusters which are highly diverse from all other clusters comprising only the common cultivars.

Singh and Singh (1980) studied 21 Indian and nine foreign varieties of tomato using Mahalonobis's D^2 statistics. Maximum divergence was noticed from number of fruits, fruit size and number of branches per plant and varieties were grouped into eight clusters. Patil (1984) studied the genetic divergence in 55 genotypes which were grouped into nine clusters. Among six characters, average fruit weight and plant height contributed 82.90 per cent to the total D^2 statistic.

Gadekar *et al.* (1992) reported that using the meteroglyph (scatter diagram) and index score analysis, 38 diverse geographic lines of tomato were grouped into eight complexes. Out of eight groups, two were solitary. Group-I consisted maximum number of lines for number of fruits and fruit yield per plant. Further with a same set of genotypes, they studied relative magnitude of D^2 values and were grouped into eight clusters irrespective of geographic divergence; indicating no parallelism between geographic and genetic diversity. The characters plant height, number of branches, fruit weight, number of fruits and fruit yield per plant played an important role in divergence between the populations.

Alice-Kurian and Peter (1994) reported that genetic diversity in a population of 64 tomato lines assessed using D^2 value indicated considerable diversity and were grouped into eight clusters. Maximum contribution to total genetic divergence was made by locules per fruit.

2.1.1 Variability

The genetic and environmental components of variation were discussed in the early part of this century by Johannson (1909) who attributed the variation in a segregating population to both heritable and non-heritable factors and the variation in a pure line to only environmental factors.

High phenotypic and genotypic variability were recorded by Parthasarathy *et al.* (1976), Kumar *et al.* (1980), Cuartero and Cubero (1982), Gadekar *et al.* (1992), Reddy and Reddy (1992) and Nagaraj (1995) for plant height. While Peter and Rai (1980) and Padmalatha and Reddy (1990) observed moderate PCV and GCV; Singh *et al.* (1988) showed moderate PCV and low GCV for plant height.

Parthasarathy *et al.* (1976), Kumar *et al.* (1980), Singh *et al.* (1988) and Gadekar *et al.* (1992), Prabhushankar (1990) and Nagaraj (1995) observed high PCV and GCV for number of branches, while moderate GCV and PCV were reported by Reddy and Reddy (1992).

High PCV and GCV were reported by Kumar *et al.* (1980) and Nagaraj (1995) for number of clusters per plant.

Parthasarathy *et al.* (1976), Kumar *et al.* (1980), Dudi *et al.* (1979), Prabhushankar (1990), Gadekar *et al.* (1992), Reddy and Reddy (1992), Naidu (1993) and Nagaraj (1995) observed high PCV and GCV for number fruits per plant.

High genotypic and phenotypic coefficient of variation recorded by Parthasarathy *et al.* (1976), Kumar *et al.* (1980), Prabhushankar (1990), Gadekar *et al.* (1992), Reddy and Reddy (1992), Naidu (1993) and Nagaraja (1995), while Padmalatha and Reddy (1990) observed moderate GCV and low PCV for average fruit weight.

Parthasarathy *et al.* (1976), Kumar *et al.*, (1980), Prabhushankar (1990), Reddy and Reddy (1992), Naidu (1993) and Nagaraja (1995) observed high PCV and GCV for fruit yield per plant, whereas Singh *et al.* (1988) and Padmalatha and Reddy (1990) reported moderate PCV and GCV.

2.2 HETEROSIS

Heterosis is defined as general biological phenomenon observed in F_1 generation which manifests itself by greater viability, rapid growth and development, higher productivity, resistance, adaption and uniform maturity, in which are combined a number of other valuable economic characters too in the quickest possible time. The term "heterosis" was first coined by Shull (1910) and at the beginning of 20th century, Hedrick and Booth (1908) first observed the phenomenon of vigour in tomato by way of increase in yield. Subsequently several researchers confirmed these findings (Powers, 1945 and Griffing, 1952). A comprehensive characterwise review of literature on heterosis is presented in this chapter.

2.2.1 Plant height

For outdoor large scale production, determinate types with negative heterosis or no heterosis would be appreciated. Heterosis for plant height in tomato was reported by Powers (1945), Dokic (1954), Tayal *et al.* (1959), Usik (1970), Khanna and Misra (1977), Kalloo *et al.* (1974), Khanna and Chaudhary (1974), Ramamohan (1988), Anbu *et al.* (1981), Sidhu *et al.* (1981), Patil (1984), Ahmed *et al.* (1988), Kanthaswamy and Balakrishnan (1989), Prabhushankar (1990), Dundi (1991), Jalikop (1992), Naidu (1993), Tendulkar (1994) and Nagaraja (1995).

2.2.2 Number of branches per plant

Significant positive heterosis for number of branches per plant was observed by Misra and Khanna (1977), Sidhu *et al.* (1981), Patil (1984), Kanthaswamy and Balakrishnan (1989), Prabhushankar (1990), Dundi (1991) and Nagaraj (1995). However, Ashwathappa (1980) reported significant negative heterosis for this trait over better parent.

2.2.3 Number of clusters per plant

Positive heterosis for clusters per plant has significant effect on yield. Ahmed and Petrescu (1983), Kanthaswamy and Balkrirshnan (1989), Prabhushankar (1990), Dundi (1991) and Nagaraj (1995) reported positive heterosis for this trait.

2.2.4 Number of fruits per cluster

The tendency in hybrids to show higher values than parents for this character was observed by Ashwathappa (1980), Cuaratero and Cubero (1982), Patil (1984) and Kanthaswamy and Balakrishnan (1989). Prabhushankar (1990) reported that heterosis for this character over the best parent and the commercial check was 43.28 per cent and 111.11 per cent respectively. Dundi (1991), Tendulkar (1994) and Nagaraja (1995) reported significant heterosis for this character.

2.2.5 Number of fruits per plant

Number of fruits per plant is considered as an important component of yield. Manifestation of heterosis for fruits per plant has been reported by Usik (1971), Chaudhary and Khanna (1972), Zubeldia and Nuez (1974), Cavicchi and Silvetti (1976), Rajanna *et al.* (1977), Babu (1978), Singh *et al.* (1978), Reddy and Mathai (1979), Dixit *et al.* (1980), Anbu *et al.* (1981), Sidhu *et al.* (1981), Sonone *et al.* (1981), Govindarasu *et al.* (1982), Legon Martin *et al.* (1984), Patil (1984), Valicek and Obeidat (1987), Ahmed *et al.* (1988), Ramamohan (1988), Kanthaswamy and Balakrishnan (1989), Yadav *et al.* (1989), Prabhushankar (1990), Dundi (1991), Naidu (1993), Tendulkar (1994) and Nagaraj (1995).

2.2.6 Average fruit weight

This trait is also an important component of yield and heterosis for this has been reported by workers like Reddy and Mathai (1979), Dixit *et al.* (1980), Anbu *et al.* (1981) Sidhu *et al.* (1981), Patil (1984), Ahmed *et al.* (1988), Prabhushankar (1990), Dundi (1991) and Naidu (1993).

Tendulkar (1994) observed the extent of heterosis exhibited by the F_1's over their respective mid, better and best parents ranging from -9.63 to 51.40, -6.71 to 33.24 and -6.64 to 4.36 per cent respectively. However, Usik (1971) and Babu (1978) observed poor or no heterosis in majority of hybrids.

2.2.7 Yield per plant

An over view of work on heterosis in tomato for fruit yield per plant revealed a wide range of both midparental heterosis and heterobeltiosis followed by the work of Hederick and Booth (1908), Rattan and Saini (1976), Singh *et al.* (1976), Yogananda (1978), Dixit *et al.* (1980), Raijadhav and Kale (1985), Bhuiyan *et al.* (1986), Ahmed *et al.* (1988), Prabhushankar (1990), Dundi (1991), Mandal *et al.* (1992), Naidu (1993), Pujari and Kale (1994) and Tendulkar (1994).

2.2.8 Locules per fruit

Tesi *et al.* (1970) and Nandapuri and Tyagi (1976) have reported that the hybrids were intermediate between their parents in respect of number of locules per fruit. Anbu *et al.* (1981) has observed a heterosis of 20.90 per cent over the best parent and 77.05 per cent over the mid parent. The reduced tendency in hybrids to show lower values than their parents for this character was noticed by Gowda (1979), Sidhu *et al.* (1981) and Prabhushankar (1990). However, Hoser (1965) and Dundi (1991) obtained positive heterosis for this trait. Tendulkar (1994) reported significant negative heterosis in 29 crosses over mid and better parents and 18 crosses were also exhibited significant negative heterosis over check with *per se* value of 3.13 locules per fruit.

2.2.9 Total soluble solids

High total soluble solids in the fruit is desirable character as it is useful in processing industry. The positive heterosis for soluble solids was reported by Chaudhary and Khanna (1973), Gowda (1979), Sonone *et al.* (1981), Patil and Patil (1988), Dundi (1991), Naidu (1993), Tendulkar (1994) and Nagaraja (1995). However, Sidhu *et al.* (1981) observed non significant differences for this trait. Ashwathappa (1980), Kanthaswamy and Balakrishnan (1989), Prabhushankar (1990) and Khattra *et al.* (1992) observed negative heterosis for this trait. Valick and Obeidat (1987) noticed three hybrids being intermediate between their parent in content of TSS.

2.3 COMBINING ABILITY

The genetic values of parents are expressed in terms of combining abilities. Sprague and Tatum (1942) defined general combining ability (gca) as the average performance of the progeny of an individual when it is mated to a number of other individuals in a population. Specific combining ability (sca) which is a term that refers to the average performance of the progeny of a cross between two specific parents that are different from what would be expected on the basis of their general combining abilities alone. Estimation of combining abilities provides quite relevant and vital information that is of direct utility to plant breeding programmes. Hybridization is one of the means of obtaining increased yield and choice of parents in such a programme is difficult owing to the differential behaviour of the inbreds in relation to combining ability. A measure of general and specific combining ability of the parents in terms of additive and non-additive portions of genetic variance would be of immense value in the choice of parents and for effective crosses for plant improvement.

Genetically, general combining ability is associated with genes which are additive in their effects, while specific combining ability is attributed to deviation from the additive scheme caused by dominance and epistasis. General combining ability involves both additive effects as well as additive X additive, additive X dominance and dominance X dominance type of interactions (Griffing, 1956).

The extent of hybrid vigour is dependent on the combining ability of the varieties used as parents. If a variety with an outstanding combining ability could be found, it might be used as a common parent for obtaining superior combinations. Generally, `top crossing', `Line X tester analysis' and `diallel crossing technique' are employed for this purpose. Following review presents the genetic information on combining ability for different characters in tomato.

2.3.1 Plant height

Kalloo *et al.* (1974), Singh and Mittal (1978), Peter and Rai (1980), Sidhu *et al.* (1981), Patil (1984), Dundi (1991), Jalikop (1992) and Nagaraja (1995) have reported significant gca and sca for this trait. Govindarasu *et al.* (1981) observed higher specific combining ability variances than general combining ability variances. Sonone *et al.* (1986) views that non-additive effects were important for height. With regard to gca and sca effects, Chandrashekar and Ramrao (1989) and Prabhushankar (1990) were of the opinion that both the effects were important. However, Svanosio and Vandoni (1974) while reporting the sca effects being significant, Misra and

Khanna (1977), Dhillon *et al.* (1979) and Dundi (1991) have observed gca to be significant for plant height.

2.3.2 Number of branches per plant

Higher general combining ability for number of branches was reported by Singh and Nandapuri (1974), Dudi *et al.* (1979), Supe and Kale (1992) and Nagaraja(1995). Contrary to it Kalloo *et al.* (1974) reported the variance component of branches was due to sca indicating non-additive gene action. Singh and Mittal (1978), Sidhu *et al.* (1981), Patil (1984) and Dundi (1991) observed both significant GCA and SCA variances.

2.3.3 Number of clusters per plant

Singh *et al.* (1976) noticed significant gca effects for number of clusters per plant and out of 15 F_1 hybrids four crosses gave significant positive sca effect for this trait. Dholaria and Quadri (1983) reported that small and medium fruited cultivars were good general combiners for this trait and also out of 15 crosses three hybrids showed significant positive sca effects. Tendulkar (1994) recorded significant gca and sca effects for parents and six crosses respectively.

2.3.4 Number of fruits per cluster

Singh and Mittal (1978) observed significant GCA variances for fruit number per bunch. Dudi *et al.* (1979), Peter and Rai (1980), Dundi (1991), Dholoria and Qadri (1983) and

Patil (1984) have reported both GCA and SCA variances to be significant. Prabhushankar (1990) observed only one parent (AVRDC) out of eight having significant positive gca effect and seven crosses out of 28 showing significant sca effects.

2.3.5 Number of fruits per plant

Significant general combining ability and specific combining ability effects were observed for this character by several workers like Avarado and Cortazar (1972), singh *et al.* (1972), Nandapuri *et al.* (1975), Trinklein and Lambeth (1974), Dhillon *et al.* (1979), Dudi *et al.* (1979), Dixit *et al.* (1980), Borikar *et al.* (1982), Swamy and Mathai (1982), Dholoria and Quadri (1983), Chandrashekar and Ramrao (1989), Dundi (1991) and Tendulkar (1994).

2.3.6 Average fruit weight

The high gca values for average fruit weight were reported by Avarado and Cortazar (1972), Kaul *et al.* (1972), Singh *et al.* (1972), Singh and Nandpuri (1974), Milkova (1975), Trinklein and Lambeth (1974) and Khalaf-Allah *et al.* (1985); whereas Singh and Mittal (1978), Dixit *et al.* (1980), Das *et al.* (1988), Prabhushankar (1990), Dundi (1991), Tendulkar (1994) observed both GCA and SCA variances being highly significant.

2.3.7 Yield per plant

Dudi *et al.* (1979), Dixit *et al.* (1980), Govindarasu *et al.* (1981), Sidhu *et al.* (1981), Swamy and Mathai (1982), Moya *et al.* (1986), Patil and Bojappa (1986), Das *et al.* (1988), Dundi (1991) and Tendulkar (1994) have recorded SCA and GCA variances significant for this trait. However, Raijadhav and Kale (1985), Lonkar and Borikar (1988) and Omara *et al.* (1988) reported only high general combining ability values for this trait. Chandrashekhar and Ramrao (1989) and Singh *et al.* (1989) recorded significant sca effects for fruit yield.

2.3.8 Total soluble solids (TSS)

Singh *et al.* (1980) reported significant gca and sca differences among male parents, female parents and crosses for this trait. Singh and Singh (1982) found that the additive genetic effects predominated over non-additive effects for this character. Patil and Bojappa (1986) observed significant SCA and GCA variances for TSS. Positive significant gca was observed in DWD-2 and CA-1 by Dundi (1991), whereas Tendulkar (1994) observed significant positive gca effects for L-15 and DWD-1 and sca for 26 out of 45 crosses.

2.3.9 Locules per fruit

Anbu *et al.* (1980) and Kalloo *et al.* (1974) have reported higher SCA variances for locule number per fruit.

Singh and Mittal (1978), Singh *et al.* (1980), Tarrera and Nuez (1983), Sidhu *et al.* (1981), and Dundi (1991) have found significant differences for GCA and SCA variances for this trait. Tendulkar (1994) also observed significant gca and sca effects for this trait and cross combination of UC-204B x 003 was the best for least number of locules.

2.4 TOMATO LEAF CURL VIRUS DISEASE

Tomato leaf curl virus disease is the most serious disease of tomato in many parts of India (Pruthi and Samuel, 1939; Butter and Rataul, 1973; Shaheen, 1983; Muniyappa and Veeresh, 1984; Sastry and Singh, 1973; Davino *et al.*, 1992 and Gomez and Alarze, 1992). In Karnataka state its incidence ranged from 17 to 53 per cent in tomato crops sown in July to November, to 90 to 100 per cent, in those transplanted in February to May and losses of fruit yield exceeded to 90 per cent when infection occurred within four weeks of transplanting into the field (Saikia and Muniyappa, 1989).

2.4.1 Symptomatology

The TLCV affected plants have been described by Vasudeva and Sam Raj (1948), Sastry and Singh (1973), Saklani and Mathai (1977), Raychaudhuri and Nariani (1977), Seetharam Reddy (1978), Capoor (1981), Muniyappa (1980), Muniyappa and Veeresh (1984), Ioannov and Iordanov (1985), Zaher (1986) and

Cohen and Kern (1988). The infected plants exhibited vein clearing, reduction in leaf size and stunted growth. The reduction in leaf size was more pronounced in the successive leaves accompanied by shortening of the internodes resulting in curling and crowding of leaves. The leaflets were deformed and their margins curling inward or outward. The leaflets showed a tendency to become stiff and crinkled with their tips. Coiled or twisted in the form of cork-screw. The younger leaves were pale in colour with light green and dark green areas. Puckering of the leaflets was a characteristic symptom and the plants had a greater tendency to produce stunted lateral branches imparting a bushy appearance. The plants infected in young age seldom attained height of not more than 25 to 37 cms. The disease induced non-fruitfulness due to deformed floral structure. The infected plants usually developed purple patches especially on the older leaves.

Many crop plants and weeds form source of this virus. Pruthi and Samuel (1939) and Muniyappa and Veeresh (1984) recorded TLCV on a few host plants. Hassan *et al.*,(1993) reported that curling, bushy growth, shoe string fern leaf, Chlorosis, Shoot proliferation, decrease of fruit yield and fruit weight was reduced by 22 per cent and fruit number by between 15 and 79 per cent, plant height by 26 per cent.

2.4.3 Vector

Bemisia tabaci Genn. (white fly) is implicated as the sole vector responsible for TLCV transmission (Vasudeva and Sam Raj, 1948; Varma, 1959; Butter and Rataul, 1973; Castellani *et al.*, 1981; Shaheen, 1983; Haydar, *et al.*, 1990; Ioannov, 1992; Nucifera, 1992; Chermiti *et al.*, 1993; Berlinger *et al.*, 1993; Kisha, 1984; Yano, 1988; Channarayappa *et al.*, 1992 and Nagaraja, 1995).

Out of ten species of white flies, *Bemisia tabaci* is the most important and it transmits over 25 different viruses (Pimpale and Summanawar, 1983). It has piercing and sucking type of mouth parts and carry plant viruses on their styles and belongs to the family Aleyrodidae in the order Homoptera. Nitzany (1975) reported that females transmit 32 and males less than 5 percentage of TLCV. The efficiency of females was about six fold that of males. Fifteen whiteflies per plant are needed to ensure 100% transmission. However, transmission to more than 80% of the plant can occur when only three white flies are present (Shaheen 1983). The acquisition threshold period of one hour TLCV persist in its vector, but not for the full life span of the insect and this virus is not transmitted to progeny of insect vector. White flies require a longer feeding period to infect the plant than to acquire the virus. Two white fly species may become limiting factor in Summer tomato production; the tobacco whitefly *Bemisia tabaci* primarily as vector of plant viruses in warm countries and the green house whitefly (*Trialeurodes vaporariorum*) which damages the green house tomatoes in temperate zones. Berlinger and Dahan (1988) reported four hours of inoculation feeding to introduce the virus into a healthy tomato plant. Virus symptom appear after a three week inoculation time. Whitefly is reported from numerous localities throughout the warm temperate and tropical areas of the world. The life cycle lasts for 17-32 days during August to March & the longest life cycle noticed was 39 days during December and the shortest being the 11 days in April. The longevity of the whitefly adults is prolonged during winter and reduced during summer season. There is rapid multiplication of white fly during April to October when the average maximum temperature ranges from 12 to 35°C (Butter *et al.*, 1983).

2.4.4 Host Range of TLCV

Many crop plants and weeds form source of this virus. Pruthi and Samuel (1939) and Muniyappa and Veeresh (1984) recorded TLCV on a few host plants. While Saikia and Muniyappa (1989), Seetharam Reddy (1978), Nitzany (1975) and Pimpale and Summanwar (1983) reported that *Bemisia tabaci* can transmit this virus to 23, 32, 2 and 99 host plants respectively.

2.4.5 Disease intensity and crop loss

Sastry *et al.* (1978) demonstrated that tomato planted in Karnataka during December to May experience low rainfall, humidity and high temperature which favoured the build up of whitefly population resulting in increased incidence of leaf curl. The studies of Saikia and Muniyappa (1989) revealed that in sequential transplantings, 90 to 100 per cent of plants were infected in plants transplanted between February and the end of May.

The stage of the plant at which the infection occurs has an important bearing on disease severity and subsequent yield loss. In plants infected within 20 days after transplanting the yield loss was 92.3 per cent. Infection after 35 and 50 days resulted in 74 and 28.9 per cent loss respectively. According to Saikia (1985) the plants which are affected 2, 4 and 6 weeks after planting were severely stunted and yield loss was 94.94, 90.02 and 78.00 per cent respectively. However, when the plants were infected 10 weeks after planting, the crop loss was low (10.18%). Similar results were reported from Lebanon and Sudan by Makkouk and Shehab (1978) and Yassin and Nour (1965). Mazyard *et al.* (1979) reported that in tomato growing area of Saudi Arabia, TLCV caused severe epidemics in summer & early autumn, owing to optimum conditions and an abundance of the vector. Winter planting showed only low infection with mild symptoms.

Maramorosch (1975) reported the lowest population of white flies in the months of winter. When temperatures were low, a large part of the pest population was unable to complete development before ageing and deterioration of the food plants. On early transplanted tomatoes some of the white flies developed to the adult stage, while on the late transplanted tomatoes very few completed their development. Shaheen (1983) reported infestation of TLCV during April and yield loss was noticed to 40 per cent.

2.4.6 Disease Management

2.4.6.1 Insecticides

Several researchers tried application of number of insecticides and partially reduced the leaf curl in tomato crop by controlling the vector population (Varma, 1959; Vasudeva, 1959, Sastry and Singh, 1971; Singh *et al.*, 1973; Thirumalachar *et al.*, 1973, Sastry *et al.*, 1976; Rataul and Butter, 1975 and 1976; Mote, 1976; Saklani and Mathai, 1978; Yassin 1983; Mishra, 1984; Berlinger *et al.*, 1986; Fadal and Burgstaller, 1986; Saikia and Muniyappa, 1989; Haydar *et al.*, 1990; Servian and Matsui, 1992; Peralata and Hilje, 1993; Guevara, 1993 and Singh and Reddy, 1995).

2.4.6.2 Cultural and Physical Control

The residual effect of the chemicals and the possibility of white flies developing resistance to them make the chemical control a stop-gap arrangement. Fresh crop mulch like wheat straw, when placed near young tomato seedlings, was found to reduce the leaf curl incidence significantly in Israel (Cohen *et al.*, 1974). Shaheen (1983) recommended late planting to reduce disease incidence. Ponti *et al.*, (1983), Hussey (1983) and Veire *et al* (1984) reported the use of combined yellow sticky plates and *Encarsia formosa* parasites for control of vector. Quinlan (1983) noticed reduced vector population by use of *verticillium lecanii* fungus. Sharaf *et al* (1984) recorded the lower population of *B. tabaci* and the incidence of disease in drip irrigation than furrow irrigation. Tripp *et al.* (1992) reported a fewer whiteflies on CO_2 enriched green house tomatoes with high C:N ratio with 1000 ml CO_2 per litre of air. Rui and Zheng (1990) observed that by use of insecticides along with yellow sticky plates reduced the vector population. Ioannov (1987), Ali and Said (1987) and Saikia and Muniyappa (1989) suggested the covering of nursery seedlings by nylon net combined with 2-3 sprays of monocrotophos after transplanting seedlings to keep the disease incidence under check. Zaher (1986) reported that spray applications of B, Mn and Zn reduced the symptom severity of TLCV. Suwwan *et al.* (1988) observed that silver (aluminium), white and black plastic mulches have significantly increased the yield as well as reduced the TLCV infection.

2.4.6.3 Use of Trap crop

Yassin (1984) postulated that crops known as good hosts of the vector but non hosts of the virus as in *Dolichos* (Lubia bean) when inter planted with tomato in the field reduced the TLCV incidence. Al-Musa (1982) noticed cucumber as the better host for white flies than the egg plant and maize. Yassin *et al.* (1982) and El-Serwiy *et al.* (1987) suggested pigeonpea and cucumber as inter plants reduced the incidence of TLCV. Rao and Willey (1980) and Gravena *et al.* (1984) observed that growing sorghum around the tomato crop and spraying 0.8 kg carboryl per ha reduced the incidence of whitefly. Sastry *et al.* (1977) reported that intercropping with 6 rows of maize or *Crotalaria juncea* (sunhemp) planted as border crop and sprayed with Dimethoate at 0.05 per cent at 15 days interval reduced the disease incidence. However, Gautam and Niraula (1990) from Nepal reported that when tomato cultivars Pusa Ruby and Roma were intercropped with maize recorded higher yield compare to control. Hilje (1993) suggested a combination of interference (physical barriers, like mulches and sprinkler irrigation), repellents (oils and botanical and synthetic pesticides), distraction (trap crops) and mortality (insecticides and natural enemies) for control of *Bemisia tabaci* on tomatoes. However, it was opined that since difficulties in managing *B. tabaci* are enormous (Maramorosch, 1975), the most feasible approach was to breed resistant varieties for whiteflies/TLCV.

2.4.6.4 Use of resistant/disease escaping cultivars

So far there is no TLCV resistant or tolerant commercial variety reported in tomato (Banerjee and Kalloo, 1987a; Kalloo and Banerjee, 1990a and Muniyappa *et al.*, 1991). When resistance is not available within the crop species, breeder is constrained to look beyond. Hence, several workers resorted to examine related species of *L. esculentum*, for source of TLCV resistance.

Both cultivated (*L. esculentum*) and wild species embrace an unusually vast amount of genetic variation (Rick, 1987). So immense is the genetic potential that despite continuing best efforts by several researchers, as yet a tiny fraction is realised. Presently, sexual hybridization and contemporary tools of molecular biology provide an opportunity for exploiting the vast reservoir of traits in *Lycopersicon* . A number of useful traits that have been detected in wild species of *Lycopersicon* includes; resistance to several diseases and pests (Rick, 1987). Wild species can also add significantly to the cause of variation in many useful quantitative traits by means of transgressive and other novel variation in the segregating progenies of interspecific crosses (Rick, 1982). But it is difficult task for the breeder to transfer the resistant genes from wild species to cultivated forms, because of crossability barriers. Hence,it is advisable to search resistant genes from the cultivated types. However, Yassin and Nour (1965) pointed out a short maturing disease escaping tomato cultivars under Sudan conditions. Cultivars such as, Heinz, Pearson and 'FAO' series of cultivars, might give relatively high fruit yield despite their susceptibility to TLCV disease (Yassin, 1983 & 1984 and Yassin *et al.*, 1982). Rowell *et al.* (1989) reported CL 1131 - 0.0-43-8-1 to record resistance against TLCV in Cambodia. VL-81 and VL-82 were reported as most resistant varieties for TLCV in Taiwan (Anon., 1988). Nassar (1984) reported that VC-97-3 and VC-204-9 were recommended for summer season in Egypt.

Fadl and Burgstaller (1986) observed that EC-104 and EC-395; Indian cultivars performed well in Sudan and recorded lower incidence of TLCV. Hassan *et al.* (1993) reported that VF-145-B-7879 had less incidence of TLCV. Nourai (1986) also recorded less incidence of TLCV in San Marzano variety. Davino *et al.* (1992) found M-46, M-47 and M-48 to be resistant to TLCV in Italy. Gomez and Alarze (1992) recorded an 'F_1' hybrid Nema 512 as tolerant to TLCV.

2.4.6.5 Assessment of symptom severity

To assess the resistance of a given genotype, Banerjee and Kalloo (1987a) and Ahmed (1984) quantified the disease severity by working out coefficient of infection which was obtained by multiplying the per cent disease (% plant infected) by response value. Symptom severity grades designated with numerical values 0-4, have been given on the basis of visual inspection (Som and Choudhary, 1976; Banerjee and Kalloo, 1987a and Kalloo and Banerjee, 1990a). Likewise four grades were adopted by Hassan *et al.* (1993) and Muniyappa *et al.* (1991) and Nagaraj (1995). Reaction of test genotypes were scored by Yassin (1985) and Pilowsky and Cohen (1990) as diseased and healthy.

2.4.6.6 Source of resistance

Vasudev and Sam Raj (1948) screened more than sixty varieties of tomato and reported all of them to be susceptible to TLCV. Subsequently Nariani and Vasudeva (1963) tested 98 varieties of tomato and *Lycopersicon* sps. including lines of *L. pimpinellifolium, L. hirsutum* and *L. peruvianum* but did not find resistant genotypes. Joshi and Chaudhary (1981) studied TLCV reaction in 166 cultivars and among them three lines (B2247, Silvestra and 65537) exhibited a fair level of tolerance. Banerjee and Kalloo (1987a) screened 122 varieties, lines and wild accessions of *Lycopersicon* and recorded that *L. hirsutum, f. typicum* (A 1904) and *L. peruvianum* possessed resistance to TLCV and observed no disease symptoms in *L. pimpinellifolium* (A 1921) till 90 days of age. Moustafa and Nakhla (1990) reported that 6 lines of *Lycopersicon cheesmani, L. peruvianum* and *L. pimpinellifolium* showed resistance to TLCV; and among them 2 lines (44 and 53) produced satisfactory yields with good horticultural characteristics under natural infection conditions. Davino *et al.* (1992) observed resistance in M-46, M-47 and M-48 to TLCV from Israel and in cherry type tomato variety Rs.9020. Bas *et al.* (1992) reported resistance to TLCV in *L. hirsutum, f. glabratum* and the whitefly survival on it was lowest. Channarayappa *et al.* (1992) screened more than 1200 varieties, breeding lines and wild species of *Lycopersicon* and reported that all tomato (*L. esculentum*) accession were susceptible to TLCV and three lines of *L. hirsutum* and one line of *L. peruvianum* showed apparent resistance to TLCV.

Pilowsky and Cohen (1990) reported that *L.peruvianum* is a good source of resistance to TLCV. Banerjee and Kalloo (1989) observed that two lines viz.,A-1921 (*L.pimpinellifolium*) and B-6013 (*L. hirsutum, f. glabratum*) were resistant for TLCV. Further, Kalloo and Banerjee (1990a, 1990b) revealed that five breeding lines (LCP-22, LCP-2, LCP-3, LCP-9 and LCP-15) of *L.pimpinellifolium* and H-2, H-11, H-17, H-23, H-24 and H-36 of *L. hirsutum, f. glabratum* were resistant to TLCV. According to Ioannov (1992), MV-RNA (*L. peruvianum*) and Hirsute (*L.pimpinellifolium*); and LA-1969 of (*L. chilense*) (Zamir *et al.*, 1994) were resistant to TLCV.

Moustafa and Hassan (1993) screened 17 true breeding lines of tomato and reported resistance in four hybrids (Typhoon, Ty-20 and BB-234 and BB-235). Kheyr *et al.* (1994)

found LA 1969 (*L. chilense*) and LC-177 (*L. hirsutum*) to contain resistance for TLCV. However, among *L. esculentum* accessions LE-812 and LE-376 and AVRDC lines were found carrying field resistance for TLCV (Shoba and Armugaum, 1991). Rowell *et al.* (1989), Anon., (1988), Nassar (1984), Fadal and Burgstaller (1986), Hassan *et al.* (1993) and Nourai (1986 were of the opinion that some *L. esculentum* genotypes showed field resistance for TLCV.

2.5 BREEDING FOR RESISTANCE TO TLCV

Once resistance source is located, then hybridization, a means of gene transfer, gains importance.

L. esculentum can be crossed with eight other tomato species with varying degrees of success, and the resultant hybrids are sufficiently fertile to yield required progenies (Rick, 1982). *L. pimpinellifolium* crosses most freely with cultivated species producing fertile progenies (Rick and Butler, 1956). Rick (1979) updated the status of interspecific crossability relations in *Lycopersicon* species. However, Nucifera (1992) reported that Rita F_1 was receptive to *B. tabaci* and more resistant to TLCV infection than Arletta F_1 in the greenhouse conditions. Kandeel (1991) reported that the cross between Clivia x Aurgia was recorded TLCV resistance. Shoba and Armugaum (1991) recorded less incidence of TLCV on F_1 hybrids of cultivated tomatoes. Moustafa and Hassan (1993) reported that four tomato hybrids (Typhoon, Ty-20, BB-234 and BB-235) had better resistance for TLCV. Gomez and Alrze (1992) reported that Nema 512 F_1 hybrid was resistant to TLCV. However, in interspecific hybridization F_1 were significantly resistant to TLCV (Channarayappa *et al.*, 1992; Zamir *et al.*, 1994; Kalloo and Banerjee, 1990b; Pilowsky and Cohen., 1989; Banerjee and Kalloo, 1989a and Nagaraja 1995).

2.5.1 Genetics of TLCV resistance

Som and Choudhary (1976) reported that the resistance for TLCV in *L. pimpinellifolium* was incompletely dominant and governed by polygenes. While screening for virus resistance these workers relied upon natural occurrence of the disease and visual ratings. However, Banerjee and Kalloo (1987a) tested the reaction for local (Hissar) strain of TLCV using viruliferous whitefly and found that the resistance of *L.pimpinellifolium* (A-1921) was due to single incompletely dominant gene. They designated this gene as "TLC". Same workers (1987b) studied the inheritance of resistance to TLCV in the progenies derived from *L.esculentum* (5 cultivars) and *L.hirsutum, f. glabratum* (line B 6013) and showed that the resistance derived from this species is based on 2 epistatic genes, one from the wild and the other from the crop species, resulting in a 13:3 segregation in the F_2 generation. The work carried out in Oman by Yassin (1985) indicated that *L.pimpinellifolium* (LA1582) carried a dominant factor for TLCV resistance. Pilowasky and Cohen (1990) reported that in F_1 hybrid Ty-20 the tolerance trait, which was derived from *Lycopersicon peruvianum* is recessive and controlled polygenically. Shoba and Armugaum (1991) reported that in 6 F_2 crosses of tomato TLCV incidence was positively correlated with yield, number of fruits per plant and showed high environmental and positive phenotypic correlation with yield. Jalikop (1992) revealed the tolerance of *L. pimpinellifolium* indicated that TLCV score had pre-dominance of additive effect in the crosses involving *L. pimpinellifolium*. The inheritance studies of Pilowsky and Cohen (1990) suggested that tolerance to TLCV of *L. peruvianum* was through five recessive genetic factors. Zamir *et al.* (1994) reported that tolerance of *L. chilense* to TLCV was due to partial dominance gene. As yet no study directed towards working out relative virus concentration in the plant in relation to TLCV symptom severity. Such a study on threshold limits may be more appropriate especially when incomplete gene dominance or recessive resistance is involved.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The study on "Investigations on summer tomatoes with special reference to tomato leaf curl virus (TLCV)" was undertaken during the year 1992-95 at the Division of Horticulture, University of Agricultural Sciences, Dharwad. The details of the material used for the investigation, development of F_1s and their evaluation, use of trap crop, experimental designs adopted and statistical procedures followed are outlined in this chapter.

3.1 EXPERIMENTAL SITE

The experiments were conducted in the red clay soils (Inceptisols) of the Olericulture block of the Division of Horticulture. The physical and chemical properties of the soil are furnished in Appendix-I.

3.2 LOCATION AND CLIMATE

Geographically, the Main Research Station (MRS), Dharwad is situated in the transitional belt of Karnataka State at 15° 26' N latitude, 75° 07' E longitude over an altitude of 678 metres above the mean sea level.

The maximum temperature ranges from 26.4°C (August) to 37.1°C (April). The minimum temperature ranges from 13.7°C (January) to 21.3°C (May). The average rainfall for the year

1993, 1994 and 1995 were 799.3, 779.8 and 582.3 mm (for nine months) respectively. The details of weather data are given in Appendix-II.

The zone is characterized by two assured crops : one in *kharif* and the other in *rabi* under rainfed conditions. During *kharif* (June-October)sorghum, groundnut, maize, soybean, cotton, chilli, okra, tomato, potato, brinjal, curcubits, beans, leafy vegetables and onion are the main crops followed by *rabi* sorghum, bengalgram, wheat, maize, tomato, brinjal, chilli, curcubits, onion, beans and cole crops during winter. This sequence forms a congenial atmosphere for survival and build-up of whiteflies to the subsequent summer crop of tomato to cause TLCV.

3.3 EXPERIMENT-I : EVALUATION OF TOMATO GENOTYPES FOR SUMMER PRODUCTION

The material consisted of 402 (Appendix-III) cultures of *Lycopersicon esculentum* including *L. pimpinellifolium* maintained in the germplasm collection at the Division of Horticulture, UAS, Dharwad. The material represents major tomato growing regions of the world.

The seeds of different genotypes were sown on the sterilized beds during 1st week of December, 1992. The seedlings were raised by following regular nursery practices except use of any insecticides. The seedlings of 30 days old were transplanted to the main field under epiphytotic conditions at the spacing of 60 cm X 60 cm. Entries planted in a single row per consisted of 25 seedlings per row in two replications. A susceptible check was inter-planted after every 5 genotypes to ensure proper spread of inoculum. Recommended package of practices were followed to raise the crop without any plant protection measures so as to encourage enough population build up of whitefly and transmission of TLCV disease. The observations on symptom development of TLCV were recorded 60 days after transplanting.

3.4 EXPERIMENT-II : DEVELOPMENT AND UTILIZATION OF TOMATO HYBRIDS FOR SUMMER

The material for Experiment-II was selected on the basis of the results of Experiment-I. This material comprised of 5 lines viz., 20/2 Alcobasa, 20/4 Alcobasa, 20/5 Alcobasa, 20/6 Alcobasa and AVRDC Alcobasa, which exhibited tolerance/ resistance to TLCV and 10 testers viz., N-229 8MF$_6$, 79B-1390, CA-1, UC-204B, DWD-2, DWD-1, L-15, Marikrit, LE-79 and L-58 with desirable agronomic characters to constitute a line X tester design of mating to produce 50 F$_1$s. Besides, 5 check varieties/hybrids viz., Ratna, Rupali, Vaishali, Cross-B and Punjab Chuhara were also included in the study to form a total of 70 entries i.e., 5 lines, 10 testers, 50 F$_1$s and 5 checks. The salient features of the parental lines are presented in Table-1.

Table 1. Salient features of the parents

Sl. No.	Parent	Origin	Remarks
I. LINES			
1.	20/4 Alcobasa	AVRDC Taiwan	Small round fruits having slight beak. Fruit colour is pink and leaves are like potato leaf type. Fruit weight is 25 (g). Number of fruits per plant is 8-10 and found resistant to TLCV in Experiment-I.
2.	20/6 Alcobasa	AVRDC Taiwan	Medium size pink fruits having no beak, fruits are firm, weigh 45 g locules 6 and potato leaf type. Found resistant to TLCV.
3.	20/5 Alcobasa	AVRDC Taiwan	Round small pink fruit. Beak is absent. Fruit weigh 38-40 g, locules 4, T.S.S. 2.5, leaves are small and potato leaf type, tolerant/resistant to TLCV.
4.	20/2 Alcobasa	AVRDC Taiwan	Fruits are big (90 g) pink colour with slight ridges, T.S.S. 3.0, locules 4, leaves small, potato leaf type found resistant to TLCV.
5.	AVRDC Alcobasa	AVRDC Taiwan	Fruits small in clusters (10) with prominant beak, pink colour, potato leaf type, resistant to TLCV
II. TESTERS			
6.	N-229 8MF6	UC-Davis, USA	Medium size firm, flat red fruits, No beak, slight oval shape, fruit weights 65 g and very attractive, heavy bearing, plants are very vigorous and determinate type.
7.	79B 1390	USDA,Beltsville Lab.	Dwarf and determinate stature, small and ribbed fruits, light green leaves
8.	CA-1	UC-Davis, USA	Indeterminate type, medium size ribbed fruits and suitable for processing
9.	UC-204B	UC-Davis, USA	Firm and medium sized fruits with good agronomic base and processing type
10.	DWD-2	Breeding line of UAS, Dharwad	Pear shaped fruits, firm, long storage and green shoulder
11.	DWD-1	Breeding line of UAS, Dharwad	Large size firm fruits, jointless and determinate type
12.	L-15	UAS, Dharwad	Medium size fruits, long storage life, large leaves, multiple disease reistant and determinate type
13.	Marikrit	Philippines	Medium to small fruits with wilt resistance
14.	L-58	Breeding line of UAS, Dharwad	Medium oval shape fruits with slight beak and very firm. Leaves are wrinkled and determinate type.
15.	LE-79	Kerala	Medium to big fruits, good keeping quality, resistant to bacterial wilt and salt tolerant

3.4.1 Hybridization programme

The parental seeds were sown during winter (October) 1993 in the nursery beds. The healthy four week old seedlings were transplanted in a crossing block at a spacing of 90 X 60 cm on second of November 1993.

Healthy flower buds in a cyme preferably of the first flush which were expected to open the next day were selected for emasculation. Emasculation was carried out between 4 and 6 p.m. The emasculated flowers (1-2 per cyme) were covered with butter paper bags and pollinated next day with the pollen of desired male parents between 10.00 a.m. and 12 noon. The ripe fruits were harvested and the seeds were extracted by fermentation method. Simultaneously, some flowers in each of these genotypes were selfed by covering the flowers with butter paper bags and the selfed fruits were collected and seeds extracted.

3.4.2 Evaluation of F_1 hybrids in summer

3.4.2.1 Nursery raising

Raised nursery beds of size 3.0 m X 1.2 m and 15 cm in height were prepared and sterilized. Each bed was applied with 500 g of 15:15:15 NPK complex fertilizer and was mixed thoroughly. The seeds of 15 parents, 50 hybrids and 5 checks were sown in rows spaced at 10 cm apart during first week of January, 1994. The beds were watered regularly. No plant protection measures were taken to create epiphytotic situation for TLCV. The seedlings were ready for transplanting in 35 days. The seedlings were transplanted on 13-2-1994 in the experimental block with 70 entries in randomized block design with three replications. Each entry was represented by a single row of 15 plants spaced at 60 cm apart in a row, which were kept apart at 60 cm. The susceptible check (Pusa Ruby) was inter planted at every 5th row to ensure inoculum build-up and spread of disease. The plants were fertilized with 115 kg of N, 100 kg of P_2O_5 and 60 kg of K_2O per hectare and were grown under irrigation. No plant protection measures were taken.

3.5 EXPERIMENT-III : STUDY OF F_2 POPULATIONS IN SUMMER

The material for the study consisted of two F_1s (20/6 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF$_6$), their F_2s and four parents viz., 20/6 Alcobasa, 20/5 Alcobasa, L-58 and N-229 8MF$_6$ and a susceptible check, Pusa Ruby. These populations were used because of the involvement of disease resistant parents like 20/6 Alcobasa and 20/5 Alcobasa for TLCV in the crosses; so that, recombinants for disease resistance could be selected.

The seeds of two F1s, F2s, parents and check were sown in raised nursery beds during January, 1995. Sufficient F2 seeds were sown to get maximum population. The seedlings were transplanted after four weeks on 18-2-1995. The seedlings were transplanted in the epiphytotic conditions in the main field at a spacing of 60 cm X 60 cm. Separate blocks were made for parents, F1s and for F2s. The F2 population consisted of 252 plants for 20/6 Alcobasa X L-58 and 246 for 20/5 Alcobasa X N-229 8MF6. Parents, checks and F1s had each a population of 15 plants. Recommended package of practices were followed for raising the crop. The plant protection measures were not taken.

3.6 EXPERIMENT-IV : MANAGEMENT OF SUMMER TOMATOES BY USE OF TRAP CROP

To mitigate TLCV effect during summer in tomato cv. Megha (L-15), maize crop was interplanted as indicated below.

Details of the experiments

Trap crop : Maize Cv. Deccan 101
Tomato : Cv. L-15 (Megha)
Design : Split plot
Replications : 3
Plot size : 7.2 X 7.2 m
Spacing of trap crop : 60 X 30 cm
Spacing for tomato : 60 X 60 cm
Number of treatments : 14

Factor-I : Row directions (D)

D_1 - South-North
D_2 - East-West

Factor-II : Intercrop with row proportions (R)

R_1 - 1 row of maize : 1 row of tomato
R_2 - 1 row of maize : 2 rows of tomato
R_3 - 1 row of maize : 3 rows of tomato
R_4 - 2 rows of maize : 1 row of tomato
R_5 - 2 rows of maize : 2 rows of tomato
R_6 - 2 rows of maize : 3 rows of tomato
R_7 - Control (only tomato)

During January, 1994 maize seeds were sown in the experimental block. The seeds of tomato were simultaneously sown in the nursery beds to coincide that by the time seedlings are ready for transplanting, there would be a substantial height of maize crop in the field to trap movement of whiteflies. Plant protection measures were avoided. After one month of maize sowing, the tomato seedlings were transplanted between the rows of maize on 20-2-1994 (As per the treatments). Recommended package of practices were followed for both the crops.

The experiment was repeated during the following year with certain modifications based on the experience of previous experiment.

Details of experiment

Design	:	Split plot
Replications	:	4
Plot size	:	3.6 X 3.6 m
Spacing of trap crop	:	60 X 30 cm
Variety of trap crop	:	Maize (Deccan-101)
Spacing for tomato	:	60 X 60 cm
Variety of tomato	:	L-15 (Megha)
Number of treatments	:	8

Factor-I : Nursery practices (N)

N_0 - Normal practice of raising tomato nursery

N_1 - Tomato nursery surrounded by maize as trap crop

Factor-II : Population density of trap crop (D)

D_1 - 1 row of maize : 1 row of tomato (100 % maize population)

D_2 - 1 row of maize : 1 row of tomato (75 % maize population)

D_3 - 1 row of maize : 1 row of tomato (50 % maize population)

D_4 - Control (only tomato)

Tomato seeds were sown in two separate nursery beds in the third week of December, 1994. Maize was planted around one nursery bed to trap the movement of whiteflies. In the main experimental block maize was sown in the first week of January 1995. The tomato seedlings were transplanted in the main experimental block on 20-1-1995 as per the treatments. Recommended package of practices were followed to raise both the crops. No plant protection measures were takenup during the experimentation.

3.7 EXPERIMENT-IV : VECTOR INOCULATION AND TEST OF CONFIRMITY

In order to ensure the validity of results obtained under field conditions, vector inoculation of TLCV was done in the glass house. The whitefly (*B. tabaci*) was employed for transferring the local TLCV isolate from the infected *L. esculentum* (L-15 and Pusa Ruby) to the genotypes and hybrids under test. Thirty vectors that had undergone 24 h acquisition period were released for 24 h inoculation on 10 days old seedlings of test entries.

3.7.1 Collection of vectors

The white flies were collected (Plate-1) from the TLCV infected tomato plants by using an aspirator after gently turning of leaves upwards. Aspirator consisted of a glass tube (25 cm length and 0.5 cm diameter) fitted to two transparent plastic tubes, both separated by a piece of muslin cloth that enabled to gather the flies in the glass tube upon sucking.

Plate 1. Acquisition of whitefiles for TLCV inoculation

Plate 2. Artificial inoculation of test genotypes for TLCV

3.7.2 Acquisition access

Whiteflies were made viruliferous by allowing an acquisition access period of 24 h in a tube containing a TLCV infected tomato leaves. After the acquisition, viruliferous whiteflies were used for inoculation.

3.7.3 Inoculation of seedlings

A muslin cloth cage (60 cm X 60 cm size) (Plate-2) was used to enclose the young seedlings of the genotypes/ hybrids 20/4 Alcobasa, 20/6 Alcobasa, 20/5 Alcobasa, 20/2 Alcobasa and AVRDC Alcobasa, L-58, LE-79, N-229 8MF6, Pusa Ruby (susceptible check), 20/6 Alcobasa X L-58 and AVRDC Alcobasa X N-229 8MF6 planted in a seed pan. About 30 viruliferous *B. tabaci* were introduced into the cage through the side hole allowing 24 hours inoculation.

3.8 OBSERVATIONS RECORDED

The following observations were recorded on three random plants from each entry and the average from these three plants was worked out for the purpose of statistical computation. The details of observations recorded in each experiments and techniques adopted for recording the observations were as follows.

3.8.1 Plant height

Plant height was measured in centimeters from the ground level to the tip of the plant 60 day after transplanting.

3.8.2 Number of branches

Number of branches per plant was counted on 70th day after transplanting.

3.8.3 Fruit cluster per plant

Number of fruiting clusters on each reference plant was counted on 70th day after transplanting.

3.8.4 Number of fruits per cluster

Before first picking, 3 fruit bunches were chosen at random in each of reference plant to calculate the average number of fruits per cyme.

3.8.5 Number of fruits per plant

Total number of fruits harvested from all the pickings were pooled and average number of fruits per plant was calculated.

3.8.6 Average fruit weight

Average fruit weight in grams was computed by using following formula.

$$\text{Avg. fruit wt.(g)} = \frac{\text{Total fruit weight from all the pickings}}{\text{Total No. of fruits from all the pickings}}$$

3.8.7 Fruit yield per plant

Fruit yield was determined by adding the total fruit weight over all the pickings from each reference plant and it was expressed in grams.

3.8.8 Locules per fruit

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

3.8.9 Total soluble solids (TSS)

A drop of tomato juice from each reference entry was placed on the prism of Brix hand refractometer and reading was recorded. Necessary temperature corrections were made to room temperature (25°C) as per the procedure followed by Ranganna (1977) and expressed in percentage.

3.8.10 Number of whiteflies per plant

The number of whiteflies on the plant were counted from lower, middle and top portions of the plant at weekly intervals for three times after 60 days of transplanting. The average number of whiteflies per plant was computed from three readings.

3.8.11 Per cent of TLCV infection

The incidence of TLCV infection was recorded on 90th day after transplanting. The number of plants infected in each entry was recorded and computed for calculating percentage TLCV by using following formula.

$$\text{Percentage of TLCV infection} = \frac{\text{Total No. of plants infected with TLCV}}{\text{Total number of plants}} \times 100$$

3.8.12 TLCV symptom severity in F2 population

Disease severity was visually graded as given below as per the scale suggested by Som and Chaudhary (1977).

Class	Score	Symptom severity and description
Resistant	0	No symptoms
Moderately resistant	Upto 25 %	Light yellowing along the leaf margins and mild vein-clearing
Tolerant	26-50 %	Yellowing of leaves and slight curling. Growth, flowering and yield not greatly effected.
Susceptible	51-75 %	Pronounced leaf curling, yellowing, stunting and reduced fruiting.
Highly susceptible	> 75%	Very severe curling puckering, stunting and reduction in leaf size. No fruit formation.

Based on this scale, the plants were classified tolerance and susceptible.

3.8.13 Light intensity

Light intensity at tomato crop canopy in the experiment on trap crop was recorded by Lux meter at 9.30 a.m., 12.30 and 3.30 p.m. and the average was calculated.

3.9 STATISTICAL ANALYSIS OF DATA

3.9.1 Mahalonobis D^2 analysis

Mahalonobis (1936) D^2 statistic was used for assessing the genetic divergence between populations comprising 402 genotypes used in Experiment-I. The generalized distance between any two populations is given by formula.

$$D^2 = \Sigma\ \Sigma\ \ ^{ij}\ \delta_i\ \delta_j$$

Where,

D^2 = Square of generalized distances.

^{ij} = Reciprocal of the common dispersal matrix

$\delta_i = (\mu_{i1} - \mu_{i2})$

$\delta_j = (\mu_{i1} - \mu_{i2})$

μ = General mean

Since the formula for computation requires inversion of higher order determinant transformation of the original, correlated unstandardized character means (X_s) to standardized uncorrelated variables (Y_s) was done to simplify the computational procedures.

The D^2 values were obtained as the sum of squares of the differences between the pairs of corresponding uncorrelated (Y_s) values of any two genotypes

3.9.1.1 Clustering of the genotypes

Clustering can be done by utilizing "Dendrogram technique" described by Sneath and Sokal (1962). Utilizing the $(d^2)^{1/2}$ values the dissimilarity coefficient values. Dissimilarity coefficients between the genotypes can be arranged into a reasonable hierarchial system, and the diagrams called dendrograms representing the trees that connect the most similar entries were constructed.

By the above procedure objectively delimited groups were obtained, of which some are of higher rank than the others. A horizontal line drawn across a dendrogram at a given level of dissimilarity indicates the groups of a given rank. The horizontal line must be drawn straight and parallel to the abscissa, so that a given rank is equivalent any where within any one study. Using this technique, by drawing a horizontal line at a desired level of dissimilarity, various groups of genotypes can be obtained.

3.9.1.2 Canonical variate analysis

This analysis was made to represent the number of correlated variables by lesser number of canonical variates, which are obtained as a linear combinations of a number of correlated variables. The vectors or canonical roots were calculated to represent the genotypes in two dimensional graphs (Rao & Wildey, 1980) The canonical roots ($\lambda_1, \lambda_2, \lambda_3$ ..... λ_p) were obtained by solving the equation,

$$C\ (A - \lambda_1) = 0$$

Where, C = The coefficient vector

λ = Eigen root of the matrix A

I = Common dispersion matrix.

The correlated unstandardized means were transformed into uncorrelated standardized variables. From these transformed variables (Y_1, Y_2 .... Y_p), sum of squares and sum of products from each character and character combination were computed to obtain the matrix of variances and co-variances (Matrix A). Matrix $(A)^P$ was then derived from matrix A, where P is the number of characters. The first approximation trial vector was obtained by first getting the column totals of matrix $(A)^P$ and then by dividing each of the column totals by the highest quantity among them. Determination of canonical vectors was done by iteration. The vectors were then standardized by dividing them by corrected sum of squares of these vectors. The first root λ_1 was calculated as the P^{th} root of the highest column total of the last approximation. For getting the second root, λ_2, the original $(A)^P$ matrix was transformed and represented as $(B)^P$. Each ix, j^{th} element of $(B)^P$ was calculated as $(i,j)^{th}$ element of $(A)^P - j\ x_i^{th}$ element x_j^{th} element of the first vector. The procedure followed in the case of matrix A was repeated to obtain the second canonical root. From the values, Y_1, Y_2 ..... Y_{11} the mean values of Z_i were calculated as :

$$Z_i = (C') (Y_i)$$

Where,

C' = Canonical vector

Y_i = Vector of transformed variables

Z = Values were computed for each genotype corresponding to λ_1, λ_2 .... respectively using their corresponding vectors. These Z values were plotted on two dimensional graph. The percentage contribution for each of the canonical root was calculated, to estimate the percentage of variability explained by each of the total variations traced in the dispersion matrix from each root.

$$\text{Percentage contribution from each canonical root} = \frac{\lambda_1}{\Sigma_i^p \lambda_i}$$

The clusters are formed arbitrarily based on the nearness to each other.

3.9.1.3 Inter-cluster distance

The inter-cluster distances were calculated by the formula described by Singh and Choudhary (1977).

$$\text{Square of inter cluster distance} = \frac{\Sigma D_i^2}{n_i \; n_j}$$

Where,

ΣD_i^2 is the sum of distances between all possible combination (n_i n_j) of the entries included in the cluster study (i and j).

n_i = Number of entries in cluster i

n_j = Number of entries in cluster j

3.9.2 Analysis of variance

Data were analyzed by the methods outlined by Singh and Choudhary (1977) using the mean value in each treatment over replications,, and the variance, due to different sources were estimated.

The model of analysis of variance table adopted is given below :

Model of ANOVA for Parents and Hybrids

Source	Degree of freedom	Mean sum of squares
Replication	(r-1)	
Treatments	(t-1)	
Parents	(P-1)	
Parents Vs hybrids	1	
Hybrids	(Mf-1)	
Lines	(f-1)	M_1
Testers	(M-1)	M_2
Line X testers	(M-1) (f-1)	M_3
Error	(t-1) (r-1)	M_4
Total	(Mfr-1)	

Where,

r = number of replications

M = number of male parents (testers)

f = number of female parents (lines)

t = number of treatments

p = total number of parents

Significance of treatments was tested at 5 and 1 per cent probability.

3.9.3 Estimation of heterosis

The magnitude of heterosis in relation to mid parent, better parent, best parent and check values was worked out. These were calculated as percentage increase or decrease of F1s over the mid parent (MP), better parent (BRP), best parent (BSP) and check (CK) values following the methods of Turner (1953) and Hays et al. (1955).

a. Heterosis over mid parent (MP)

$$\text{Mid parent heterosis (\%)} = \frac{\bar{F}1 - \overline{MP}}{\overline{MP}} \times 100$$

The significance of heterosis was tested by calculating S.E. in following manner.

$$S.E. = ?\sqrt{\frac{3/2 \times Ems}{r}}$$

b. Heterosis over better parent (BRP)

$$\text{Better parent heterosis (\%)} = \frac{\bar{F}1 - \overline{BRP}}{\overline{BRP}} \times 100$$

$$\text{S.E.} = ?\sqrt{\frac{2 \times \text{Ems}}{r}}$$

c. Heterosis over best parent (BSP)

$$\text{Best parent heterosis (\%)} = \frac{\bar{F}1 - \overline{BSP}}{\overline{BSP}} \times 100$$

$$\text{S.E.} = ?\sqrt{\frac{2 \times \text{Ems}}{r}}$$

d. Heterosis over check (CK)

$$\text{Check parent heterosis (\%)} = \frac{\bar{F}1 - \overline{\text{Check}}}{\overline{\text{Check}}} \times 100$$

$$\text{S.E.} = ?\sqrt{\frac{2 \times \text{Ems}}{r}}$$

Where,

EMS = Error mean square

$\bar{F_1}$ = Mean of F_1

$\overline{MP}$ = Mean of two parents

$\overline{BRP}$ = Mean of better parent

$\overline{BSP}$ = Mean of best parent

$\overline{\text{Check}}$ = Mean of check used

Mid parental value (MP)

For each character, the arithmetic average value of two parents involved in each cross was taken.

Better parental value (BRP)

For each character, the superior value between the parents in each cross was taken.

Best parental value (BSP)

For each character, the best value among 15 parents involved in the crossing programme was taken.

Check value (CK)

For each character the best two checks involved in evaluation was taken. (i.e., Vaishali hybrid and Punjab Chuhara variety).

The significance of F_1 heterosis was tested by comparing the mean deviation with CD values obtained separately form MP, BRP, BSP and CK by using the following formula.

CD for heterosis over MP

$$\sqrt{3/2 \text{ X } Ems/r} \text{ X t-values}$$

CD for heterosis over BRP, BSP AND CK

$$\sqrt{2 \text{ X } Ems/r} \text{ X t-values}$$

3.9.4 Combining ability analysis

The variation among the hybrids was further partitioned into genetic components attributable to general (GCA) and specific (SCA) combining ability following the method suggested by Kempthorne (1957).

The analysis was based on the following mathematical model.

$$Y_{ijk} = \mu + m_i + f_j + s_{ij} + e_{ijk}$$

Where,

μ = Population mean

m_i = gca effect of i^{th} (male) parent

f_j = gca effect of j^{th} (female) parent

s_{ij} = sca effect of $(ixj)^{th}$ cross

e_{ijk} = random error effect associated with $(ijk)^{th}$ observation in k^{th} replication.

The RBD analysis of crosses involved in line X tester analysis was carried out separately including parents.

ANOVA for combining ability

Source	D.F.	MSS	Expected means sum of squares
Replication	(r-1)	---	---
Hybrids	(lt-1)	---	---
Lines	(f-1)	M_1	e^2+r Cov. (FS)-2Cov. (HS) + Mr Cov (HS)
Tester	(rt-1)	M_2	e^2+r Cov. (FS)-2Cov. (HS) + Fr Cov (HS)
Line X tester	(f-1)(rt-1)	M_3	e^2+r Cov. (FS)-2Cov.
Error	(r-1) (rlt-1)	M_4	e^2

Where,

r = number of replications

m = number of male parents (testers)

f = number of female parents (lines)

Cov.(FS) = Covariance of full sib

Cov.(HS) = Covariance of half sib

Estimates of variances : The GCA and SCA variances were expressed in terms of covariances of full sibs (Fs) and half sibs (Hs) as indicated below.

$$\text{Covariance (HS)} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r\ (m + f)}$$

$$\text{Covariance (FS)} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3r} + \frac{6r\ \text{Cov(HS)} - r\ (f+m)\ \text{Cov(HS)}}{3r}$$

After estimating Cov. (HS) and Cov(FS) the GCA variance of lines and testers and SCA variance for the hybrids were estimated as shown below.

$$1^2 = \frac{(M_1 - M_3)}{rm}$$

Cov.(HS) due to tester

$$t^2 = \frac{(M_2 - M_4)}{rf}$$

GCA variance

$$\text{GCA} = \text{Cov HS}$$

SCA variance

$$SCA = \frac{(M_3 - M_4)}{r}$$

Where,

M_1 = Mean sum of squares due to line (female)

M_2 = Mean sum of squares due to tester (male)

M_3 = Mean sum of squares due to line X tester

M_4 = Mean sum of squares due to error

Estimation of combining ability effects :

The model used to estimate gca and sca effects of ijk observation was :

$$X_{ij} = \mu + g_i + g_j + S_{ij} = e_{ijk}$$

Where,

μ = population mean

g_i = gca effects of i^{th} female parent

g_j = gca effects of j^{th} male parent

s_{ij} = gca effects of ij^{th} combination

i = number of the female parent involved

j = number of male parent involved

k = number of replications

e_{ijk} = error associated with observation X_{ijk}.

The individual effects were estimated as follows.

General combining ability (gca effects)

a. Lines

$$g_i = \frac{x_{i..}}{mr} - \frac{x_{..}}{mfr}$$

Where,

X_i = total of i^th female parent over all male parents and replications.

b. Testers

$$g_i = \frac{x_{j..}}{fr} - \frac{x_{..}}{mfr}$$

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

Specific combining ability (sca) effects

$$S_{ij} = \frac{X_{ij}}{r} - \frac{X_i}{mr} - \frac{X_j}{fr} + \frac{X_{..}}{mrf}$$

Where,

X_{ij} = ij^th combination total over all replications.

The standard errors of the effects

The standard error (SE) pertaining to gca effects of male and females and sca effects of different combinations were calculated as follows :

$$\text{S.E. (gca for females)} = \sqrt{\frac{\text{Error variance}}{mr}}$$

$$\text{SE (gca for males)} = \sqrt{\frac{\text{Error variance}}{fr}}$$

$$\text{SE (sca for hybrids)} = \sqrt{\frac{\text{Error variance}}{r}}$$

The critical differences were calculated by multiplying the standard errors with table 't' value at 5 per cent and 1 per cent levels of probability for error degrees of freedom.

Least significant differences between estimates

To test the significant differences of two estimates, the least significant difference were calculated by the values of 't' at appropriate degrees of freedom for error and the standard error of the differences of the two estimates. The standard errors of differences were obtained as follows :

$$\text{S.E. } (g_i - g_j) \text{ lines} = \left[\frac{2M_4}{mr}\right]^{1/2}$$

$$\text{S.E. } (g_i - g_j) \text{ testers} = \left[\frac{2M_4}{fr} \right]^{1/2}$$

$$\text{S.E. } (s_{ij} - s_{kj}) \text{ crosses} = \left[\frac{2M_4}{r} \right]^{1/2}$$

Proportional contribution of lines, testers and their interactions

$$\text{Contribution of lines} = \frac{\text{SS (lines)}}{\text{SS (crosses)}} \times 100$$

$$\text{Contribution of testers} = \frac{\text{SS (testers)}}{\text{SS (crosses)}} \times 100$$

$$\text{Contribution of L X T} = \frac{\text{SS (L X T)}}{\text{SS (crosses)}} \times 100$$

3.9.3 Chi-square test

Chi-square test was employed for the data obtained from Experiment-III to test the segregation ratio for disease incidence. This statistic was computed by using the formula.

$$\chi^2 = [(\text{Observed Mean}) - (\text{Expected Mean})]^2 \times \text{Weight}$$

The Chi-square value was compared with table χ^2 at (5-3) degrees of freedom for the significance. Non-significance of Chi-square value indicated the adequacy of additive dominance model.

3.9.4 Statistical analysis for split plot design

Fisher's method of analysis of variance was applied for the analysis and interpretation of the data as given by Panse and Sukhatme (1967). The level of significance used in 'F' test was P = 0.05 and 0.01 critical difference values were calculated wherever, the 'F' test was significant.

The data on TLCV percentage was transformed into Arcsin root percentages and transformed data was used for statistical analysis (Snedecor and Cochron, 1967).

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The investigations on screening of tomato germplasm for resistance/tolerance to leaf curl virus (TLCV); selection and use of divergent parents for production of F_1 hybrids and their evaluation under epiphytotic condition, study of combining ability and genetics of TLCV were carried out. The results obtained from each of these studies are presented in this chapter.

4.1 EXPERIMENT-I : EVALUATION OF TOMATO GENOTYPES

The data obtained from evaluation of 402 tomato genotypes were used for testing divergence among genotypes through different methods.

4.1.1 Canonical roots and the extent of variability extracted by them

The canonical variate analysis was employed to get the spatial positioning of all the 402 genotypes on a graph. The first two canonical vectors derived in the decreasing order of magnitude are given in Table-2. It could be seen from the first vector that variables : yield per plant, number of white flies per plant and fruit weight have contributed more for divergence in the discriminating entries. But the second vector, indicated that the variables like incidence of TLCV

Table 2. Contributing variables towards divergence

Sl. No.	Characters	Vector-1	Vector-2
1.	Yield per plant	0.700	0.027
2.	Number of whiteflies per plant	0.700	0.027
3.	Fruit weight	0.120	0.279
4.	Number of fruits per plant	0.020	-0.034
5.	Number of branches	0.006	-0.011
6.	Plant height	-0.024	0.132
7.	Per cent of TLCV infection	-0.071	0.950

contributed the highest value (0.950) followed by fruit weight and plant height for divergence. Considering overall position TLCV, number of white flies and yield per plant contributed great deal for the divergence in the order of merit. Further, Table-3 presents that the highest per cent (92.684 %) of the total variability was absorbed by canonical root-1, while the second root absorbed 4.324 per cent of the total variability. The first two roots thus accounted for 97.007 per cent of the total variability produced by all the characters under study. The remaining four vectors absorbed only 2.99 per cent of the variability, so they were not considered important.

4.1.2 Canonical graph

The canonical variables were derived for 402 tomato genotypes using the first two principal components and plotted on the graph (Fig-1). The Z_1 axis refers to the first vector and Z_2-axis to the second vector. Most of the genotypes were scattered towards the right side of Z_2 axis having positive values. However, a few genotypes migrated to the negative side. In general, the entries showed a wider distribution on the graph. The accession 229 (AVRDC Alcobasa), 238 (20/6 Alcobasa) and 133 (20/2 Alcobasa) were at the extreme right of the first vector. The remaining genotypes were distributed within the extremes.

Table 3. Canonical roots and variability extracted by them

Canonical roots	Variability extracted	Percentage of variability	Cumulative % of variability extracted
1.	1868120.229	92.684	92.684
2.	87150.623	4.324	97.007
3.	47947.275	2.379	99.386
4.	12127.588	0.602	99.988
5.	192.946	0.010	99.997
6.	52.480	0.003	100.000

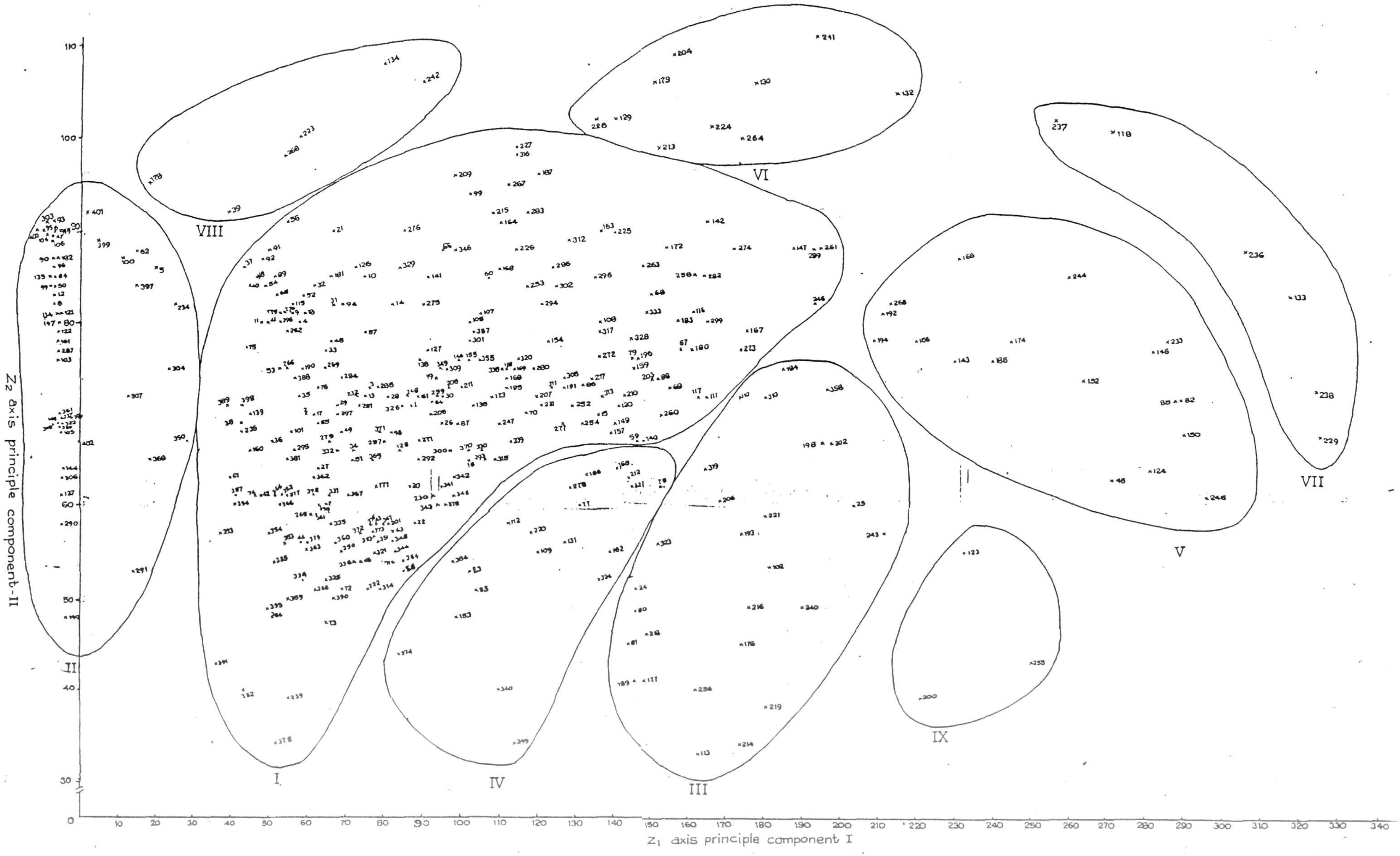

FIG.1. DISTRIBUTION OF TOMATO GENOTYPES IN DIFFERENT CLUSTERS ON CANONICAL GRAPH.

4.1.3 Clustering of genotypes by using canonical graph

Four hundred and two genotypes were arbitarily grouped into nine clusters as shown in Fig-1 and the entries included in them are given in Table-4. Among nine clusters, Cluster-I was the biggest with 261 entries followed by cluster-II (51 entries). The remaining clusters viz., III, IV, V, VI, VII, VIII and IX had respectively 27, 20, 18, 10, 6, 6 and 3 genotypes.

The genotypes having 'potato leaf' character along with Alcobasa fruit colour were generally clustered in VII and IX cluster, whereas the typical cultivated types were mostly clustered in I and II clusters.

4.1.4 D^2 analysis

The square of the distance (D^2 values) between two entries, calculated as the sum of the squares of the differences between the mean values of all the 7 transformed variables were used for final grouping of the entries (Table-5). Since each entry produced 401 combinations a total of 1149053.820 D^2 values were obtained for 402 genotypes (Appendix-III).

4.1.5 Clustering of entries

Using the dendrogram technique, four clusters were formed by drawing a horizontal line at 1071.939 dissimilarity

Table 4. Distribution of tomato genotypes in different clusters on canonical graph

Cluster No.	No. of genotypes	Accessions
I.	261	378,239,382,391,73,386,395,359,393,385,334,288,325,390,72,222,314,354,353,44,379,363,360,250,336,45,61,387,394,74,42, 356,352,366,377,365,251,392,298,331,7,335,367,372,376,43,347,201,373,383,351,321,63,345,344,71,364,58,22,171,362,27,381,160,389,398,139,38,235,36,101,295,279,49,332,34,51,369,20,230,341,342,343,375,348,75,53,266,388,190,35,76,2,17,55,29,297,257,371,98,128,271,292,300,370,16,330,293,315,37,40,318,54,89,65,92,91,56,11,41,175,270,115,52,32,396,9,262,4,180,181,31,94,57,48,33,269,284,232,281,13,3,285,28,326,248,1,151,64,205,26,87,247,339,21,126,10,14,138,127,19,349,309,259,30,208,211,136,275,329,141,276,66,346,164,215,97,209,267,283,187,316,227,146,155,355,301,357,105,107,294,253,168,60,226,286,302,296,312,163,225,173,195,166,338,188,169,320,280,154,70,231,207,311,191,308,277,252,86,217,254,313,15,120,210,149,157,59,140,260,108,317,272,328,79,196,159,203,88,69,117,111,263,68,333,183,116,299,67,180,273,167,172,258,282,246,274,142,147,289,261
II.	51	199,291,368,350,307,304,234,397,5,62,100,399,401,119,93,303,6,95,47,170,104,106,400,182,90,96,84,135,50,99,12,8,121,114,197,122,161,287,103,361,148,337,305,322,380,125,402,144,306,137,290
III.	27	113,214,219,256,177,189,81,218,80,24,323,176,216,240,102,193,206,319,221,243,25,202,198,310,110,184,358
IV.	20	249,340,374,153,83,23,384,112,220,109,131,324,162,77,278,186,158,212,327,78
V.	18	245,124,46,150,82,85,145,233,152,244,174,185,143,156,194,192,265,165
VI.	10	132,241,264,130,224,213,228,129,179,204
VII.	6	229,238,133,236,118,237
VIII.	6	178,39,268,223,134,242
IX.	3	200,255,123

Table 5. The D^2 clusters and the entries included in them

Cluster No.	No. of genotypes	Accessions
I.	217	1,127,276,329,66,87,300,136,230,326,60,168,107,97,209,187,227,316,134,242,14,141,275,19,26,208,211,105,155,357,146,309,64,259,205,138,151,271,128,292,248,30,349,301,355,346,16,342,341,348,343,375,112,293,315,330,370,23,384,153,83,70,188,195,247,166,169,338,173,207,280,320,339,77,131,278,109,220,249,340,2,29,34,257,369,281,332,367,284,17,269,18,266,76,388,190,295,354,356,366,377,381,3,285,232,98,371,13,28,27,55,297,49,279,51,10,57,126,21,181,94,31,32,33,48,4,52,65,89,92,9,11,41,37,39,40,91,56,115,270,223,268,53,262,175,396,54,318,75,7,392,44,251,363,379,298,362,365,331,335,72,73,390,250,360,288,334,325,239,378,359,386,395,382,391,35,36,101,42,74,352,353,385,38,387,394,139,160,235,389,398,61,393,350,20,364,22,58,344,314,321,222,374,336,372,347,376,383,43,63,71,45,351,171,373,201,345
II.	51	5,234,100,304,307,62,178,397,399,401,6,104,119,400,170,47,96,106,90,182,93,303,95,8,121,103,161,287,197,12,50,84,99,135,114,122,125,322,361,148,337,380,305,144,137,306,290,402,199,291,368
III	99	15,86,252,277,311,308,154,191,231,294,79,196,108,272,317,296,217,254,313,59,140,327,78,323,120,210,159,328,203,333,149,157,158,212,186,162,324,129,228,163,225,164,215,253,226,267,283,286,302,312,24,80,81,218,189,113,256,177,102,221,184,198,202,176,216,214,219,240,67,111,260,69,88,116,183,117,258,299,282,110,273,167,310,193,206,319,68,263,172,180,142,274,264,130,224,241,179,204,213
IV	35	25,243,200,123,255,143,185,165,156,265,132,147,261,289,192,194,246,358,46,152,82,124,150,245,85,233,145,118,174,244,237,133,236,229,238

corresponding to the significant D^2 value. Cluster I was the biggest having 217 entries, followed by cluster-III with 99 entries. Cluster II and IV were having 51 and 35 entries, respectively.

4.1.6 Dissimilarity coefficients between different characters

The dissimilarity coefficient values between the different clusters are given in Table-6. It is clear from the table that cluster-II was the most divergent and was far from all the other clusters. Cluster III was nearer to cluster IV compared to its divergence with cluster I. Cluster II and IV were more divergent compared to II and III.

Based on the dissimilarity coefficients between the clusters, two major divergent groups can be formed. Cluster II, which is far from the other clusters formed the first divergent group. Clusters I, III and IV which were nearer to each other but were far from cluster II formed the second divergent group. While cluster III and IV which were nearer to each other but far from other clusters formed the third divergent group.

4.2 EXPERIMENT-II : EVALUATION OF F_1 HYBRIDS FOR SUMMER

4.2.1 Analysis of variance

The analysis of variance for 11 characters are presented in Table-7. It is clear from the table that all the entries comprising parents and crosses showed significant

Table 6. Dissimilarity coefficients between different D^2 cluster

Cluster No.	II	III	IV
I	213.37	127.36	74.91
II	--	85.96	138.41
III		--	52.45
IV			--

Table 7. Analysis of variance (mean sum of squares) for 11 characters in tomato

Source of variation	D.F.	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of fruits/ cluster	No. of fruits/ plant	Avg.fruit weight (g)	Yield/ plant (g)	T.S.S.	No. of locules/ fruit	No. of whiteflies/ plant	Per cent of TLCV infection
Replication	2	3.71	0.72	2.99	2.64**	22.54	526.00**	16995.12	0.45**	0.09	1.46*	11.73
Treatments (Parents + Hybrids)	64	218.82**	3.75**	13.98**	4.16**	129.67**	1333.19**	536294.35**	6.03**	4.74**	6.52**	1318.99**
Parent	14	60.24**	1.88**	4.34*	5.20**	73.79**	211.58	911830.20**	1.04**	5.47**	2.58**	225.31**
Females	4	24.61	0.31	5.44*	1.74**	15.73	98.40	35207.92	0.06	12.86**	0.06	26.41
Males	9	28.79	0.95	3.94*	1.38**	31.87*	251.79	50250.83	0.63**	1.82**	1.83**	124.17**
Female Vs Male	1	485.80**	16.55**	3.48	53.36**	683.38**	302.50	683473.90**	8.64**	8.71**	19.50**	1931.15**
Crosses	49	251.44**	4.32**	15.15**	2.76**	148.00**	1677.17**	663087.30**	7.48**	4.32**	7.47**	1589.23**
Parents Vs Crosses	1	839.96**	1.89	92.35**	41.53**	13.44	180.80	554995.00**	4.40**	14.82**	14.91**	3385.46**
Error	128	21.25	0.50	2.02	0.41	14.11	156.05	47017.30	0.04	0.08	0.37	27.42

* and ** indicates significant at 5 and 1 per cent level, respectively.

differences for all the characters except average fruit weight. Among the parents, females exhibited significant differences for number of cluster, number of fruits per plant and number of locules per fruit. But male parents varied significantly for all the characters except for plant height, number of branches, fruit weight and yield per plant. The contribution of female Vs male showed highly significant variation for all the characters except clusters per plant and fruit weight. The variance for the hybrids were highly significant for all the characters. But, variance for parents Vs Hybrids were highly significant for all the characters except number of branches, number of fruits per plant and average fruit weight.

4.2.2 Magnitude of heterosis

The mean *per se* values of the parents and hybrids, and magnitude of heterosis over mid-parent better parent, best parent and check-1 and 2 are presented separately for each character in (Table-8 to 18).

4.2.2.1 Plant height (Table-8)

A range of variation for plant height was observed among the females with 20/2 Alcobasa showing the lowest (25.00 cm) and 20/4 Alcobasa the highest (31.97 cm) *per se* values. The males ranged from 15.03 cm (DWD-1) to 23.80 cm(UC-204B). Among the F_1's, the lowest mean value (12.00 cm) was recorded in

Table 8. Mean performance of parents and hybrids, and magnitude of heterosis for average plant height (cm)

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	31.97	19.67	42.17	25.82	63.33**	31.90**	31.90**	37.67**	148.05**
20/4 Alcobasa X 79B 1390	31.97	23.77	29.77	27.87	6.82	-6.88	-6.88	-2.81	75.12**
20/4 Alcobasa X CA-1	31.97	16.70	35.73	24.33	46.85**	11.76	11.76	16.66	110.18**
20/4 Alcobasa X UC-204B	31.97	23.80	29.50	27.88	5.80	-7.72	-7.72	-3.69	73.53**
20/4 Alcobasa X DWD-2	31.97	21.13	27.50	26.55	3.58	-13.98	-13.98	-10.22	61.76**
20/4 Alcobasa X DWD-1	31.97	15.03	25.23	23.50	7.38	-21.08	-21.08	-17.63	48.41*
20/4 Alcobasa X L-15	31.97	22.80	15.67	27.38	-42.79**	-50.98**	-50.98**	-48.84**	-7.82
20/4 Alcobasa X Marikrit	31.97	19.83	36.33	25.90	40.28**	13.64	13.94	18.61	113.70**
20/4 Alcobasa X L-58	31.97	16.57	40.00	24.27	64.84**	25.12*	25.12*	30.59*	135.29**
20/4 Alcobasa X LE-79	31.97	21.07	21.37	26.52	-19.42	-33.16**	-33.16**	-30.23*	25.70
20/6 Alcobasa X N-229 8MF6	26.80	19.67	17.67	23.23	-23.96	-34.07*	-44.73**	-42.31**	3.94
20/6 Alcobasa X 79B 1390	26.80	23.77	12.60	25.28	-50.16**	-52.98**	-60.59**	-58.82**	-25.88
20/6 Alcobasa X CA-1	26.80	16.70	37.30	21.75	71.49**	39.18**	16.67	21.78	119.41**
20/6 Alcobasa X UC-204B	26.80	23.80	13.87	25.30	-45.19**	-48.25**	-56.61**	-54.72**	-18.41
20/6 Alcobasa X DWD-2	26.80	21.13	19.23	23.97	-19.75	-28.25*	-39.85**	-37.22**	13.12
20/6 Alcobasa X DWD-1	26.80	15.03	24.43	20.91	16.81	-8.84	-23.58*	-20.24	43.70
20/6 Alcobasa X L-15	26.80	22.80	33.07	24.80	33.33*	23.39	3.44	7.97	94.53**
20/6 Alcobasa X Marikrit	26.80	19.83	42.27	23.31	81.27**	57.72**	32.22**	38.00**	148.64**
20/6 Alcobasa X L-58	26.80	16.57	35.23	21.68	62.49**	31.45*	10.20	15.02	107.23**
20/6 Alcobasa X LE-79	26.80	21.07	32.63	23.93	36.35*	21.75	2.06	6.53	91.94**
20/5 Alcobasa X N-229 8MF6	26.07	19.67	40.60	22.87	77.55**	55.73**	26.99*	32.55**	138.82**
20/5 Alcobasa X 79B 1390	26.07	23.77	41.83	24.92	67.89**	60.45**	30.84**	36.57**	146.06**
20/5 Alcobasa X CA-1	26.07	16.70	30.43	21.38	42.32**	16.72	-4.82	-0.65	79.00**
20/5 Alcobasa X UC-204B	26.07	23.80	15.73	24.93	-36.90**	-39.66**	-50.80**	-48.64**	-7.47
20/5 Alcobasa X DWD-2	26.07	21.13	14.17	23.60	-39.97**	-45.65**	-55.68**	-53.74**	-16.65
20/5 Alcobasa X DWD-1	26.07	15.03	14.87	20.55	-27.66	-42.96**	-53.48**	-51.45**	-12.53
20/5 Alcobasa X L-15	26.07	22.80	24.27	24.43	-0.68	-6.90	-24.08	-20.76	42.76
20/5 Alcobasa X Marikrit	26.07	19.83	37.37	22.95	62.82**	43.34**	16.89	22.00	119.82**
20/5 Alcobasa X L-58	26.07	16.57	39.67	21.32	86.08**	52.17**	24.08	29.51*	133.35**
20/5 Alcobasa X LE-79	26.07	21.07	35.73	23.57	51.63**	37.05**	11.76	16.65	110.18**
20/2 Alcobasa X N-229 8MF6	25.00	19.67	33.93	22.33	51.94**	35.72*	6.13	10.77	99.59**
20/2 Alcobasa X 79B 1390	25.00	23.77	32.33	24.38	32.60*	29.32	1.13	5.55	90.18**
20/2 Alcobasa X CA-1	25.00	16.70	25.27	20.85	21.18	1.08	-20.96	-17.50	48.65*
20/2 Alcobasa X UC-204B	25.00	23.80	17.23	24.40	-29.37*	-31.08*	-46.10**	-43.75**	1.35
20/2 Alcobasa X DWD-2	25.00	21.13	27.00	23.06	17.05	8.00	-15.54	-11.85	58.82**
20/2 Alcobasa X DWD-1	25.00	15.03	20.90	20.01	4.41	-16.40	-34.63**	-31.77**	22.94
20/2 Alcobasa X L-15	25.00	22.80	34.80	23.90	45.61**	39.20	8.85	13.61	104.70**
20/2 Alcobasa X Marikrit	25.00	19.83	25.30	22.41	12.86	1.20**	-20.86	-17.40	48.82*
20/2 Alcobasa X L-58	25.00	16.57	34.40	20.78	-65.52**	37.60*	7.60	12.31	102.35**
20/2 Alcobasa X LE-79	25.00	21.07	35.77	23.03	55.28**	43.08**	11.89	16.78	110.41**
AVRDC Alcobasa X N-229 8MF6	25.20	19.67	35.43	22.43	57.95**	40.59**	10.82	15.67	108.41**
AVRDC Alcobasa X 79B 1390	25.20	23.77	15.00	24.49	-38.73**	-40.48**	-53.08**	-51.03**	-11.76
AVRDC Alcobasa X CA-1	25.20	16.70	15.70	20.95	-25.06	-37.70*	-50.89**	-48.74**	-7.64
AVRDC Alcobasa X UC-204B	25.20	23.80	25.00	24.50	2.04	-0.79	-21.80	-18.38	47.06*
AVRDC Alcobasa X DWD-2	25.20	21.13	21.70	23.16	-6.33	-13.89	-32.12**	-29.15*	27.64
AVRDC Alcobasa X DWD-1	25.20	15.03	21.93	20.11	9.03	-12.98	-31.40**	-28.40*	29.00
AVRDC Alcobasa X L-15	25.20	22.80	12.00	24.00	-50.00**	-52.38**	-62.46**	-60.82**	-29.41
AVRDC Alcobasa X Marikrit	25.20	19.83	23.67	22.51	5.11	-6.07	-25.96	-22.72	39.23
AVRDC Alcobasa X L-58	25.20	16.57	17.03	20.89	-18.44	-32.42*	-46.73**	-44.40**	0.17
AVRDC Alcobasa X LE-79	25.20	21.07	23.67	23.13	2.31	-6.07	-25.96	-22.72	39.23
S.E.±					3.26	3.76	3.76	3.76	3.76

Punjab Chuhara Check-1 (30.63)   Vaishali Check-2 (17.00)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

AVRDC Alcobasa x L-15 and the highest (42.27 cm) in 20/6 Alcobasa X Marikrit.

The heterosis over mid parent ranged between -0.68 per cent (20/5 Alcobasa X L-15) to 86.08 per cent (20/5 Alcobasa X L-58). As many as 20 crosses showed significant mid-parent heterosis in the positive direction, while nine crosses exhibited significant heterosis in the negative direction. The range of better parent heterosis was from -0.79 (AVRDC Alcobasa X UC-204B) to 57.72 per cent (20/6 Alcobasa X Marikrit). With respect to heterosis over best parent, five crosses were significant in positive direction, while 18 crosses exhibited negative significant heterosis. The maximum heterosis over Check-1 and 2 was manifested by the cross 20/6 Alcobasa X Marikrit.

4.2.2.2 Number of branches per plant (Table-9)

The highest number of branches in female was observed with 20/2 Alcobasa (4.07) and the lowest was 20/4 Alcobasa (3.27). The males had a range of variation from 1.37 (CA-1) to 3.20 (L-58). Among the hybrids, 20/5 Alcobasa X LE-79 and 20/5 Alcobasa X DWD-2 were observed to have maximum (5.40) and minimum (0.67) number of branches per plant respectively.

The range of mid-parent heterosis varied from -1.12 per cent (20/5 Alcobasa X 79B 1390) to 96.36 per cent (20/5 Alcobasa X LE-79). Out of 50 hybrids, 13 showed significant

Table 9. Mean performance of parents and hybrids, and magnitude of heterosis for average number of branches per plant

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	3.27	2.13	4.07	2.70	50.62**	24.46	0.00	45.36*	149.69**
20/4 Alcobasa X 79B 1390	3.27	2.60	2.60	2.93	-11.36	-20.49	-36.12*	-7.14	59.51
20/4 Alcobasa X CA-1	3.27	1.37	4.00	2.32	72.66**	22.32	-1.72	42.86*	145.40**
20/4 Alcobasa X UC-204B	3.27	1.93	3.07	2.60	17.95	-6.12	-24.57*	9.64	88.34*
20/4 Alcobasa X DWD-2	3.27	2.97	2.40	3.12	-22.99	-26.60	-41.03**	-14.28	47.24
20/4 Alcobasa X DWD-1	3.27	1.60	2.00	2.43	-17.81	-38.83*	-50.86**	-28.57	22.70
20/4 Alcobasa X L-15	3.27	2.20	1.97	2.73	-28.05	-39.75*	-51.60**	-29.64	20.86
20/4 Alcobasa X Marikrit	3.27	2.23	4.13	2.75	50.30**	26.30	1.47	47.50*	153.37**
20/4 Alcobasa X L-58	3.27	3.20	4.70	3.23	45.36**	43.73*	15.48	67.85**	188.34**
20/4 Alcobasa X LE-79	3.27	2.17	2.77	2.72	1.84	-15.29	-31.94*	-1.07	69.94*
20/6 Alcobasa X N-229 8MF6	3.57	2.13	1.50	2.85	-47.37**	-57.98**	-63.14**	-46.43*	-7.97
20/6 Alcobasa X 79B 1390	3.57	2.60	1.67	3.08	-45.95**	-53.22**	-58.97**	-40.35	2.45
20/6 Alcobasa X CA-1	3.57	1.37	3.50	2.47	41.89*	-1.96	-14.00	25.00	114.72**
20/6 Alcobasa X UC-204B	3.57	1.93	2.33	2.75	-15.15	-34.73*	-42.75**	-16.78	87.70
20/6 Alcobasa X DWD-2	3.57	2.97	2.73	3.27	-16.33	-23.53	-32.92*	-2.50	67.48
20/6 Alcobasa X DWD-1	3.57	1.60	2.13	2.59	-17.42	-40.34**	-47.66**	-23.93	30.67
20/6 Alcobasa X L-15	3.57	2.20	3.43	2.89	19.08	-3.92	-15.72	-22.50	110.43**
20/6 Alcobasa X Marikrit	3.57	2.23	4.87	2.90	67.82**	36.41*	19.66	73.93**	198.77**
20/6 Alcobasa X L-58	3.57	3.20	3.83	3.39	13.30	7.28	-5.90	36.79	134.97**
20/6 Alcobasa X LE-79	3.57	2.17	3.43	2.87	19.77	-3.92	-15.72	22.50	110.43**
20/5 Alcobasa X N-229 8MF6	3.33	2.13	3.53	2.73	29.27	6.01	-13.27	26.07	116.56**
20/5 Alcobasa X 79B 1390	3.33	2.60	2.93	2.96	-1.12	-12.01	-28.00*	4.64	79.75*
20/5 Alcobasa X CA-1	3.33	1.37	3.53	2.35	50.35*	6.01	-13.27	26.09	116.56**
20/5 Alcobasa X UC-204B	3.33	1.93	1.00	2.63	-62.03**	-69.97**	-75.43**	-64.28**	-38.65
20/5 Alcobasa X DWD-2	3.33	2.97	0.67	3.15	-78.84**	-79.88**	-83.54**	-76.07**	-58.89
20/5 Alcobasa X DWD-1	3.33	1.60	1.53	2.47	-37.84	-54.05**	-62.41**	-45.35*	-6.13
20/5 Alcobasa X L-15	3.33	2.20	1.77	2.77	-36.14	-46.84**	-56.51**	-36.78	8.59
20/5 Alcobasa X Marikrit	3.33	2.23	5.10	2.78	83.23**	53.15**	25.31	82.14**	212.88**
20/5 Alcobasa X L-58	3.33	3.20	4.93	3.26	51.02**	48.04**	21.13	76.07**	202.45**
20/5 Alcobasa X LE-79	3.33	2.17	5.40	2.75	96.36**	62.16**	32.68*	92.86**	231.29**
20/2 Alcobasa X N-229 8MF6	4.07	2.13	4.27	3.10	37.63*	4.91	4.91	52.50*	161.96**
20/2 Alcobasa X 79B 1390	4.07	2.60	3.57	3.33	7.00	-12.28	-12.28	27.50	119.02**
20/2 Alcobasa X CA-1	4.07	1.37	3.17	2.72	16.56	-22.11	-22.11	13.21	94.48**
20/2 Alcobasa X UC-204B	4.07	1.93	1.23	3.00	-58.89**	-69.78**	-69.78**	-56.07**	-24.54
20/2 Alcobasa X DWD-2	4.07	2.97	3.47	3.52	-1.42	-14.74	-14.74	23.93	112.88**
20/2 Alcobasa X DWD-1	4.07	1.60	2.50	2.83	-11.76	-38.57**	-38.57**	-10.71	53.37
20/2 Alcobasa X L-15	4.07	2.20	3.33	3.13	6.38	-18.18	-18.18	18.93	104.29**
20/2 Alcobasa X Marikrit	4.07	2.23	2.53	3.15	-19.58	-37.83**	-37.83**	-9.64	55.21
20/2 Alcobasa X L-58	4.07	3.20	4.00	3.63	10.09	-1.72	-1.72	42.86	145.40**
20/2 Alcobasa X LE-79	4.07	2.17	4.33	3.12	39.04*	6.39	6.33	54.64**	165.64**
AVRDC Alcobasa X N-229 8MF6	3.40	2.13	4.10	2.76	48.19**	20.59	0.74	46.43*	151.53**
AVRDC Alcobasa X 79B 1390	3.40	2.60	1.30	3.00	-56.67**	-61.76**	-68.06**	-53.57**	-20.24
AVRDC Alcobasa X CA-1	3.40	1.37	1.67	2.39	-30.07	-50.89**	-58.97**	-40.36	2.45
AVRDC Alcobasa X UC-204B	3.40	1.93	2.67	2.67	0.00	-21.47	-34.40*	4.64	63.80
AVRDC Alcobasa X DWD-2	3.40	2.97	1.70	3.19	-46.60**	-50.00**	-58.23**	-39.28	4.29
AVRDC Alcobasa X DWD-1	3.40	1.60	1.77	2.50	-29.33	-47.94**	-56.51**	-36.79	8.59
AVRDC Alcobasa X L-15	3.40	2.20	0.90	2.80	-67.86**	-73.53**	-77.89**	-67.86**	-44.78
AVRDC Alcobasa X Marikrit	3.40	2.23	3.17	2.81	12.43	-6.76	-22.11	13.21	94.48**
AVRDC Alcobasa X L-58	3.40	3.20	1.83	3.30	-44.44**	-46.18**	-55.04**	-34.64	12.27
AVRDC Alcobasa X LE-79	3.40	2.17	2.10	2.79	-24.55	-38.23*	-48.40**	-25.00	28.83
S.E.±					0.50	0.58	0.58	0.58	0.58

Punjab Chuhara Check-1 (2.80) Vaishali Check-2 (1.63)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

positive heterosis, while nine had negative heterosis for this trait. Heterosis in F_1s over their better parents ranged from -1.72 (20/2 Alcobasa X L-58) to 62.16 per cent (20/5 Alcobasa X LE-79). Five and 20 crosses displayed significant positive and negative heterosis over better parent respectively. Only one cross (20/5 Alcobasa X LE-79) was found to have significant heterosis (at 1 per cent level) over best parent. Among the 50 hybrids, 11 and 26 hybrids recorded significant positive heterosis over Check-1 and 2 respectively. The maximum heterosis over two checks was observed by the hybrid 20/5 Alcobasa X LE-79.

4.2.2.3 Number of clusters per plant (Table-10)

The differences among the males varied from 1.6 (DWD-1) to 5.33 (DWD-2). The range in females was from 2.40 (AVRDC Alcobasa) to 5.73 (20/6 Alcobasa). The hybrids ranged from 0.83 (20/4 Alcobasa X L-15) to 13.33 (20/5 Alcobasa X LE-79). Of checks, Punjab Chuhara had the highest number of clusters per plant (5.67) than Vaishali.

Heterosis over mid parent exhibited by the F_1s for number of cluster per plant extended from -3.05 (20/4 Alcobasa X DWD-2) to 390.80 per cent (20/5 Alcobasa X LE-79). Significant positive and negative heterosis was observed in 22 and 7 crosses respectively over mid parent. Per cent heterosis over better parental values in case of hybrids varied from

Table 10. Mean performance of parents and hybrids, and magnitude of heterosis for average number of clusters per plant

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	4.50	3.33	7.00	3.91	78.72**	55.55*	22.16	23.45	183.40**
20/4 Alcobasa X 79B 1390	4.50	3.67	6.17	4.08	51.02*	37.11	7.67	8.82	149.79**
20/4 Alcobasa X CA-1	4.50	2.67	7.67	3.58	113.95**	70.44**	33.86	35.27	210.53**
20/4 Alcobasa X UC-204B	4.50	4.33	3.83	4.42	-13.21	-14.89	-33.16	-32.45	55.06
20/4 Alcobasa X DWD-2	4.50	5.33	4.77	4.91	-3.05	-10.51	-16.75	-15.87	93.12*
20/4 Alcobasa X DWD-1	4.50	1.60	1.03	3.05	-66.12*	-77.11*	-82.02**	-81.83**	-58.30
20/4 Alcobasa X L-15	4.50	3.83	0.83	4.17	-80.00**	-81.56**	-85.51**	-85.36**	-66.40
20/4 Alcobasa X Marikrit	4.50	2.17	3.93	3.34	18.00	-12.67	-31.41	-30.68	59.11
20/4 Alcobasa X L-58	4.50	2.40	6.17	3.45	78.74**	37.11	7.68	8.82	149.80**
20/4 Alcobasa X LE-79	4.50	2.30	5.33	3.40	53.86	18.44	-6.98	-6.00	115.79*
20/6 Alcobasa X N-229 8MF6	5.73	3.33	6.33	4.53	39.71	10.47	10.47	11.64	156.27**
20/6 Alcobasa X 79B 1390	5.73	3.67	2.23	4.70	-52.48**	-61.08**	-61.08**	-60.67**	-9.72
20/6 Alcobasa X CA-1	5.73	2.67	5.17	4.20	23.02	-9.77	-9.77	-8.82	109.31*
20/6 Alcobasa X UC-204B	5.73	4.33	1.77	5.03	-64.90**	-69.11**	-69.11**	-68.78**	-28.34
20/6 Alcobasa X DWD-2	5.73	5.33	3.17	5.53	-42.77*	-44.68*	-44.68*	-44.09*	28.34
20/6 Alcobasa X DWD-1	5.73	1.60	4.83	3.67	31.82	-15.71	-15.71	-14.81	95.55*
20/6 Alcobasa X L-15	5.73	3.83	6.00	4.78	25.44	4.71	4.71	5.82	142.91**
20/6 Alcobasa X Marikrit	5.73	2.17	6.00	3.95	51.90*	4.71	4.71	5.82	142.91**
20/6 Alcobasa X L-58	5.73	2.40	4.67	4.07	14.75	-18.50	-18.50	-17.63	89.07*
20/6 Alcobasa X LE-79	5.73	2.30	4.33	4.01	7.88	-24.43	-24.43	-23.63	75.30
20/5 Alcobasa X N-229 8MF6	3.13	3.33	8.33	3.23	157.73**	150.15**	45.37*	46.91*	237.25**
20/5 Alcobasa X 79B 1390	3.13	3.67	5.77	3.40	69.61*	57.22*	0.70	1.76	133.60**
20/5 Alcobasa X CA-1	3.13	2.67	6.00	2.90	106.90**	91.69*	4.71	5.82	142.91**
20/5 Alcobasa X UC-204B	3.13	4.33	1.23	3.73	-66.96*	-71.59**	-78.53**	-78.31**	-50.20
20/5 Alcobasa X DWD-2	3.13	5.33	1.70	4.23	-59.84*	-68.10**	-70.33**	-70.01**	-31.17
20/5 Alcobasa X DWD-1	3.13	1.60	1.70	2.37	-28.17	-45.68	-70.33**	-70.01**	-31.17
20/5 Alcobasa X L-15	3.13	3.83	4.27	3.48	22.49	11.49	-25.48	-2.45	72.87
20/5 Alcobasa X Marikrit	3.13	2.17	5.33	2.65	101.26**	70.28*	-7.00	-6.00	115.79*
20/5 Alcobasa X L-58	3.13	2.40	6.00	2.77	116.87**	91.69*	4.71	5.82	142.91**
20/5 Alcobasa X LE-79	3.13	2.30	13.33	2.71	390.80**	325.88**	132.63**	135.10**	439.68**
20/2 Alcobasa X N-229 8MF6	3.00	3.33	4.67	3.16	47.37	40.24	-18.50	-17.63	89.07
20/2 Alcobasa X 79B 1390	3.00	3.67	5.50	3.33	65.00*	49.86	-4.01	-3.00	122.67**
20/2 Alcobasa X CA-1	3.00	2.67	5.00	2.83	76.47*	66.67	-12.74	-11.82	102.43*
20/2 Alcobasa X UC-204B	3.00	4.33	3.07	3.67	-16.36	-29.09	-46.42**	-45.85*	24.29
20/2 Alcobasa X DWD-2	3.00	5.33	5.90	4.17	41.60	10.69	2.97	4.06	138.87**
20/2 Alcobasa X DWD-1	3.00	1.60	3.10	2.30	34.78	3.33	-45.90*	-45.32*	25.51
20/2 Alcobasa X L-15	3.00	3.83	7.67	3.41	124.39**	100.26**	33.85	35.27	210.53**
20/2 Alcobasa X Marikrit	3.00	2.17	4.77	2.59	84.52*	59.00	-16.75	-15.87	93.12
20/2 Alcobasa X L-58	3.00	2.40	7.33	2.70	171.60**	144.33**	27.92	29.28	196.76**
20/2 Alcobasa X LE-79	3.00	2.30	8.73	2.65	229.56**	191.00**	52.35**	53.97**	253.44**
AVRDC Alcobasa X N-229 8MF6	2.40	3.33	6.83	2.87	138.37**	105.10	19.20	20.46	176.52**
AVRDC Alcobasa X 79B 1390	2.40	3.67	4.10	3.03	35.16	11.72	-28.45	-27.69	65.99
AVRDC Alcobasa X CA-1	2.40	2.67	3.10	2.53	22.37	16.10**	-45.90*	-45.33*	25.51
AVRDC Alcobasa X UC-204B	2.40	4.33	6.50	3.37	93.07**	50.11	13.44	14.64	163.16**
AVRDC Alcobasa X DWD-2	2.40	5.33	3.67	3.87	-5.17	-31.14	-35.95	-35.27	48.58
AVRDC Alcobasa X DWD-1	2.40	1.60	6.33	2.00	216.67**	163.75**	10.47	11.64	156.27**
AVRDC Alcobasa X L-15	2.40	3.83	4.33	3.11	39.04	13.05	-24.43	-23.63	75.30
AVRDC Alcobasa X Marikrit	2.40	2.17	6.07	2.29	165.69**	152.92**	5.93	7.05	145.75**
AVRDC Alcobasa X L-58	2.40	2.40	3.77	2.40	56.94*	57.08	-34.20	-33.51	52.63
AVRDC Alcobasa X LE-79	2.40	2.30	4.33	2.35	84.40	80.04	-24.43	-23.63	75.30
S.E.±					1.00	1.16	1.16	1.16	1.16

Punjab Chuhara Check-1 (5.67) Vaishali Check-2 (2.47)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

-9.77 (20/6 Alcobasa X CA-1) to 325.88 per cent (20/5 Alcobasa X LE-79). As many as 14 and 7 crosses displayed significant positive and negative heterosis respectively over better parent. Only three crosses viz., 20/5 Alcobasa X N-229 8MF6, 20/5 Alcobasa X LE-79 and 20/2 Alcobasa X LE-79 showed significant positive heterosis over best parent (20/6 Alcobasa). The cross 20/5 Alcobasa X LE-79 recorded highly significant positive heterosis over check-1 (135.10 %) and 2 (439.68 %).

4.2.2.4 Number of fruits per cluster (Table-11)

The mean values for this trait indicated that the females varied from 3.03 (20/6 Alcobasa) to 5.07 (AVRDC Alcobasa).Among the males, L-58 had the highest (3.40) and CA-1 the lowest (1.23) number of fruits per cluster. The mean value of hybrids was in the range of 0.00 to 3.67. The checks (Punjab Chuhara and Vaishali) recorded 1.13 and 0.97 fruits per cluster respectively.

Out of 50 cross combinations, none of the crosses exhibited positive significant heterosis over mid-parent values.The range was from -1.96 (20/6 Alcobasa X L-15) to 40.62 (20/6 Alcobasa X CA-1) per cent. None of the hybrids showed significant heterosis over better parent and the best parent (AVRDC Alcobasa) in positive direction. Although, many crosses

Table 11. Mean performance of parents and hybrids, and magnitude of heterosis for average number of fruits per cluster

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X W-229 8MF6	4.23	1.37	2.40	2.80	-14.29	-43.26**	-52.66**	112.39**	147.42**
20/4 Alcobasa X 79B 1390	4.23	2.67	2.73	3.45	-20.77	-35.46**	-46.15**	141.59**	181.44**
20/4 Alcobasa X CA-1	4.23	1.23	1.50	2.73	-45.12**	-64.54**	-70.41**	32.74	54.64
20/4 Alcobasa X UC-204B	4.23	1.63	2.73	2.93	-6.82	-35.46**	-46.15**	141.59**	181.44**
20/4 Alcobasa X DWD-2	4.23	2.40	1.93	3.31	-41.71**	-54.37**	-61.93**	70.80	98.97
20/4 Alcobasa X DWD-1	4.23	1.50	1.27	2.87	-55.81**	-69.98**	-74.95**	12.39*	30.93
20/4 Alcobasa X L-15	4.23	2.07	0.77	3.15	-75.66**	-81.80**	-84.81**	-31.86	-20.62
20/4 Alcobasa X Marikrit	4.23	1.97	2.40	3.10	-22.58	-43.26**	-52.66**	112.39	147.42**
20/4 Alcobasa X L-58	4.23	3.40	2.83	3.81	-25.76*	-33.10**	-44.18**	150.44**	191.75**
20/4 Alcobasa X LE-79	4.23	1.53	1.50	2.88	-47.98**	-64.54**	-70.41**	32.74	54.64
20/6 Alcobasa X W-229 8MF6	3.03	1.37	0.83	2.20	-62.12**	-72.61**	-83.63**	-26.55	-14.43
20/6 Alcobasa X 79B 1390	3.03	2.67	1.23	2.85	-56.73**	-59.40**	-75.74**	8.85	26.80
20/6 Alcobasa X CA-1	3.03	1.23	3.00	2.13	40.62	-0.99	-40.83**	165.49**	209.28**
20/6 Alcobasa X UC-204B	3.03	1.63	0.00	2.33	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
20/6 Alcobasa X DWD-2	3.03	2.40	0.60	2.71	-77.91**	-80.20**	-88.16**	-46.90	-38.14
20/6 Alcobasa X DWD-1	3.03	1.50	0.00	2.27	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
20/6 Alcobasa X L-15	3.03	2.07	2.50	2.55	-1.96**	-17.49	-50.69**	121.24**	157.73**
20/6 Alcobasa X Marikrit	3.03	1.97	3.17	2.50	26.67	4.62	-37.47**	180.53**	226.80**
20/6 Alcobasa X L-58	3.03	3.40	3.67	3.21	13.99	7.94	-27.61**	224.78**	278.35**
20/6 Alcobasa X LE-79	3.03	1.53	2.07	2.28	-9.49	-31.68	-59.12**	83.18	113.40*
20/5 Alcobasa X W-229 8MF6	4.57	1.37	2.53	2.97	-14.61	-44.64**	-50.10**	123.89**	160.82**
20/5 Alcobasa X 79B 1390	4.57	2.67	2.03	3.62	-43.78**	-55.58**	-60.00**	79.65	109.28*
20/5 Alcobasa X CA-1	4.57	1.23	1.73	2.90	-40.23**	-62.14**	-65.88**	53.10	78.35
20/5 Alcobasa X UC-204B	4.57	1.63	0.00	3.20	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
20/5 Alcobasa X DWD-2	4.57	2.40	0.00	3.49	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
20/5 Alcobasa X DWD-1	4.57	1.50	0.00	3.03	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
20/5 Alcobasa X L-15	4.57	2.07	1.07	3.32	-67.84**	-76.59**	-78.90**	-5.31	10.31
20/5 Alcobasa X Marikrit	4.57	1.97	1.37	3.27	-58.16**	-70.02**	-72.98**	21.24	41.34
20/5 Alcobasa X L-58	4.57	3.40	3.00	3.99	-24.69*	-34.35**	-40.82**	165.49**	209.28**
20/5 Alcobasa X LE-79	4.57	1.53	1.43	3.05	-53.01**	-68.71**	-71.80**	26.55	47.42
20/2 Alcobasa X W-229 8MF6	4.53	1.37	2.20	2.95	-25.42	-51.43**	-56.60**	94.69**	126.80*
20/2 Alcobasa X 79B 1390	4.53	2.67	1.77	3.20	-50.93**	-60.93**	-65.09**	56.64	82.47
20/2 Alcobasa X CA-1	4.53	1.23	1.57	2.88	-45.66**	-65.34**	-69.03**	38.93	61.85
20/2 Alcobasa X UC-204B	4.53	1.63	0.00	3.08	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
20/2 Alcobasa X DWD-2	4.53	2.40	2.07	3.47	-40.38**	-54.30**	-59.17**	83.18	113.40*
20/2 Alcobasa X DWD-1	4.53	1.50	1.00	3.01	-66.85**	-77.92**	-80.28**	-11.50	3.09
20/2 Alcobasa X L-15	4.53	2.07	2.40	3.30	-27.27*	-47.02**	-52.66**	112.38**	147.42**
20/2 Alcobasa X Marikrit	4.53	1.97	2.07	3.25	-36.41**	-54.30**	-59.17**	83.18	113.40*
20/2 Alcobasa X L-58	4.53	3.40	2.63	3.97	-33.61**	-41.94**	-48.13**	132.74**	171.13**
20/2 Alcobasa X LE-79	4.53	1.53	2.13	3.03	-29.67*	-52.98**	-58.00**	88.49	119.58*
AVRDC Alcobasa X W-229 8MF6	5.07	1.37	2.50	3.22	-22.28	-50.69**	-50.69**	121.24**	157.73**
AVRDC Alcobasa X 79B 1390	5.07	2.67	1.37	3.87	-64.66**	-72.98**	-72.98**	21.24	41.23
AVRDC Alcobasa X CA-1	5.07	1.23	0.80	3.15	-74.60**	-84.22**	-84.22**	-29.20	-17.52
AVRDC Alcobasa X UC-204B	5.07	1.63	1.77	3.35	-47.26**	-65.09**	-65.09**	56.63	82.47
AVRDC Alcobasa X DWD-2	5.07	2.40	1.27	3.73	-66.07**	-74.95**	-74.95**	12.39	30.93
AVRDC Alcobasa X DWD-1	5.07	1.50	1.40	3.28	-57.36**	-72.39**	-72.39**	23.89	44.33
AVRDC Alcobasa X L-15	5.07	2.07	0.00	3.57	-100.00**	-100.00**	-100.00**	-100.00*	-100.00
AVRDC Alcobasa X Marikrit	5.07	1.97	2.10	3.52	-40.28**	-58.58**	-58.58**	85.84	116.49*
AVRDC Alcobasa X L-58	5.07	3.40	0.90	4.23	-78.74**	-82.25**	-82.25**	-20.35	-7.22
AVRDC Alcobasa X LE-79	5.07	1.53	2.33	3.30	-29.29*	-54.04*	-54.04**	106.19*	140.21**
S.E.±					0.45	0.53	0.53	0.53	0.53

Punjab Chuhara Check-1 (1.13) Vaishali Check-2 (0.97)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

showed significant positive heterosis over checks, the cross 20/6 Alcobasa X L-58 had recorded the highest heterotic values over them.

4.2.2.5 Number of fruits per plant (Table-12)

Among the parents, the maximum number fruits (18.00) per plant was registered by female parent 20/4 Alcobasa. The two testers 79B1390 and DWD-2 recorded the mean number of 10.00 and 12.00 fruits respectively. The cross 20/6 Alcobasa X L-58 recorded the highest number (24.67) of fruits per plant. It was interesting to note that 7 crosses did not set fruits. The performance of checks (Punjab Chuhara and Vaishali) was of the order of 4.33 and 2.00 number of fruits per plant respectively.

The magnitude of heterosis over mid, better and best parent ranged from -1.89 (20/2 Alcobasa X Marikrit) to 142.62 (20/6 Alcobasa X L-58), -7.89 (AVRDC Alcobasa X Marikrit) to 94.74 (20/6 Alcobasa X L-58) and -1.83 (20/2 Alcobasa X L-15 and AVRDC Alcobasa X N-229 8MF6) to 37.05 (20/6 Alcobasa X L-58) per cent, respectively. Out of 50 hybrids, 12, two and one hybrids exhibited significant heterosis in positive direction, while 18, 25 and 36 crosses showed significant negative heterosis over mid, better and best parents respectively. The maximum heterosis (469.74) over check-1 and (1133.50) over check-2 was manifested by cross 20/6 Alcobasa X L-58.

Table 12. Mean performance of parents and hybrids, and magnitude of heterosis for number of fruits per plant

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	18.00	5.00	14.10	11.50	22.61	-21.67	-21.67	225.63**	605.00**
20/4 Alcobasa X 79B 1390	18.00	10.00	21.33	14.00	52.38**	18.50	18.50	392.61**	966.50**
20/4 Alcobasa X CA-1	18.00	3.00	11.67	10.50	11.11	-35.17*	-35.17*	169.51*	483.50**
20/4 Alcobasa X UC-204B	18.00	6.67	10.33	12.33	-16.22	-42.61*	-42.61*	138.57*	416.50**
20/4 Alcobasa X DWD-2	18.00	12.00	7.83	15.00	-47.78**	-56.50**	-56.50**	80.83	291.50
20/4 Alcobasa X DWD-1	18.00	2.00	3.00	10.00	-70.00**	-83.33**	-83.33**	-30.71	50.00
20/4 Alcobasa X L-15	18.00	7.67	3.00	12.83	-76.62**	-83.33**	-83.33**	-30.71	50.00
20/4 Alcobasa X Marikrit	18.00	4.33	10.00	11.17	-10.45**	-44.44**	-44.44**	130.95	400.00**
20/4 Alcobasa X L-58	18.00	7.67	22.00	12.83	71.45	22.22	22.22	408.08*	1000.00**
20/4 Alcobasa X LE-79	18.00	3.00	3.67	10.50	-65.08**	-79.63**	-79.63**	-15.24	83.50
20/6 Alcobasa X N-229 8MF6	12.67	5.00	6.33	8.83	-28.30	-50.04*	-64.83**	46.19	216.50
20/6 Alcobasa X 79B 1390	12.67	10.00	3.00	11.33	-73.53**	-76.32**	-83.33**	-30.71	50.00
20/6 Alcobasa X CA-1	12.67	3.00	15.33	7.83	95.74**	21.05	-14.83	254.04**	666.50**
20/6 Alcobasa X UC-204B	12.67	6.67	0.00	9.67	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/6 Alcobasa X DWD-2	12.67	12.00	1.67	12.33	-86.49**	-86.82**	-90.72**	-61.43	-16.50
20/6 Alcobasa X DWD-1	12.67	2.00	0.00	7.33	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/6 Alcobasa X L-15	12.67	7.67	16.67	10.17	63.93*	31.58	-7.39	284.99**	733.50**
20/6 Alcobasa X Marikrit	12.67	4.33	16.67	8.50	96.08**	31.58	-7.39	284.99**	733.50**
20/6 Alcobasa X L-58	12.67	7.67	24.67	10.17	142.62**	94.74**	37.05*	469.74**	1133.50**
20/6 Alcobasa X LE-79	12.67	3.00	10.00	7.83	27.66	-21.05	-44.44**	130.95	400.00**
20/5 Alcobasa X N-229 8MF6	15.33	5.00	20.67	10.17	103.28**	34.83	14.83	377.37**	933.50**
20/5 Alcobasa X 79B 1390	15.33	10.00	11.33	12.67	-10.53	-26.09	-37.05*	161.66*	466.50**
20/5 Alcobasa X CA-1	15.33	3.00	12.00	9.17	30.91	-21.74	-33.33*	177.14*	500.00**
20/5 Alcobasa X UC-204B	15.33	6.67	0.00	11.00	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/5 Alcobasa X DWD-2	15.33	12.00	0.00	13.67	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/5 Alcobasa X DWD-1	15.33	2.00	0.00	8.67	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/5 Alcobasa X L-15	15.33	7.67	5.33	11.50	-53.62*	-65.22**	-70.39**	23.09	166.50
20/5 Alcobasa X Marikrit	15.33	4.33	7.33	9.83	-25.42	-52.18**	-59.28**	69.28	266.50
20/5 Alcobasa X L-58	15.33	7.67	20.33	11.50	76.81**	32.61	12.94	369.51**	916.50**
20/5 Alcobasa X LE-79	15.33	3.00	17.00	9.17	85.45**	10.87	-5.55	292.61**	750.00**
20/2 Alcobasa X N-229 8MF6	13.33	5.00	10.33	9.17	12.73	-22.50	-42.61**	138.57*	416.50**
20/2 Alcobasa X 79B 1390	13.33	10.00	10.00	11.67	-14.29	-24.98	-44.44**	130.95	400.00**
20/2 Alcobasa X CA-1	13.33	3.00	8.33	8.17	2.04	-37.50	-53.72**	92.38	316.50*
20/2 Alcobasa X UC-204B	13.33	6.67	0.00	10.00	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/2 Alcobasa X DWD-2	13.33	12.00	11.67	12.67	-7.89	-12.50	-35.17*	169.51*	483.50**
20/2 Alcobasa X DWD-1	13.33	2.00	2.67	7.67	-65.22	-80.00**	-85.17**	-38.34	33.50
20/2 Alcobasa X L-15	13.33	7.67	17.67	10.50	68.25**	32.55	-1.83**	308.08**	783.50**
20/2 Alcobasa X Marikrit	13.33	4.33	8.67	8.83	-1.89	-35.00	-51.83	100.23	333.50*
20/2 Alcobasa X L-58	13.33	7.67	19.33	10.50	84.13**	45.01*	7.39	346.42**	866.50**
20/2 Alcobasa X LE-79	13.33	3.00	19.00	8.17	132.65**	42.50	5.55	338.80**	850.00**
AVRDC Alcobasa X N-229 8MF6	12.67	5.00	17.67	8.83	100.00**	39.47	-1.83	308.08**	783.50**
AVRDC Alcobasa X 79B 1390	12.67	10.00	5.67	11.33	-50.00*	-55.25*	-68.50**	30.95	183.50
AVRDC Alcobasa X CA-1	12.67	3.00	2.33	7.83	-70.21*	-81.58**	-87.05**	-46.19	16.50
AVRDC Alcobasa X UC-204B	12.67	6.67	10.33	9.67	6.90	-18.42	-42.61*	138.57*	416.50**
AVRDC Alcobasa X DWD-2	12.67	12.00	5.00	12.33	-59.46**	-60.53**	-72.22**	15.47	150.00
AVRDC Alcobasa X DWD-1	12.67	2.00	5.33	7.33	-27.27	-57.89*	-70.39**	23.09	166.50
AVRDC Alcobasa X L-15	12.67	7.67	0.00	10.17	-100.00**	-100.00**	-100.00**	-100.00	-100.00
AVRDC Alcobasa X Marikrit	12.67	4.33	11.67	8.50	37.25	-7.89	-35.17*	169.51*	483.50**
AVRDC Alcobasa X L-58	12.67	7.67	3.00	10.17	-70.49**	-76.32**	-83.33**	-30.71	50.00
AVRDC Alcobasa X LE-79	12.67	3.00	11.67	7.83	48.94	-7.89	-35.17*	169.51*	483.50**
S.E.±					2.65	3.07	3.07	3.07	3.07

Punjab Chuhara Check-1 (4.33) Vaishali Check-2 (2.00)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

4.2.2.6 Average fruit weight (Table-13)

The magnitude of variation among the parents with respect to fruit weight was considerable (31.33 g in 20/4 Alcobasa to 61.67 g in N-229 8MF6). The cross 20/6 Alcobasa X L-58 recorded a highest mean value of 87.27 g, while 7 crosses did not set fruits.

Mid parent heterosis exhibited by the F_1s for fruit weight varied from -8.65 (AVRDC Alcobasa X 79B1390) to 106.14 (20/6 Alcobasa X L-58) per cent. The cross 20/6 Alcobasa X L-58 recorded the highest and significant positive heterosis over better and best parent; and checks. Out of 50 hybrids 12, 9 and one crosses had significant heterosis in positive direction over mid, better and best parent respectively. A total of 16, 18 and 25 crosses have shown negative significant heterosis over mid, better and best parent respectively. Other hybrids which had positive heterosis (though non-significant) over best parent were 20/6 Alcobasa X Marikrit, 20/5 Alcobasa X N 229 8 MF6, 20/5 Alcobasa X LE-79, 20/2 Alcobasa X 79B 1390, 20/2 Alcobasa X CA-1 and 20/2 Alcobasa X L-15. There were as many as 23 and 19 hybrids showing significant positive heterosis over Check-1 and Check-2, respectively.

4.2.2.7 Yield per plant (Table-14)

Among the parents, females generally tended to be high yielders than the males and also showed a range of

Table 13. Mean performance of parents and hybrids, and magnitude of heterosis for average fruit weight (g)

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X W-229 8MF6	31.33	61.67	39.67	46.50	-14.70	-35.67*	-35.67*	63.05	32.33
20/4 Alcobasa X 79B 1390	31.33	37.67	44.90	34.50	30.14	19.19	-27.19	84.54*	49.67
20/4 Alcobasa X CA-1	31.33	50.00	53.33	40.67	31.15	6.67	-13.52	119.19**	77.78
20/4 Alcobasa X UC-204B	31.33	35.67	46.67	33.50	39.30	30.84	-24.32	91.82*	55.57
20/4 Alcobasa X DWD-2	31.33	42.33	24.83	36.83	-32.58	-41.34	-59.74**	2.06	-17.23
20/4 Alcobasa X DWD-1	31.33	43.33	8.33	37.33	-77.68*	-80.78**	-86.50**	-65.76	-72.23*
20/4 Alcobasa X L-15	31.33	36.00	13.33	33.67	-60.40*	-62.97*	-78.38**	-45.21	-55.57
20/4 Alcobasa X Marikrit	31.33	31.67	40.83	31.50	29.63	28.92	-33.79*	67.82*	36.10
20/4 Alcobasa X L-58	31.33	42.33	61.67	36.83	67.42*	45.69*	0.00	153.47**	105.57**
20/4 Alcobasa X LE-79	31.33	31.67	50.00	31.50	58.73*	57.89	-18.92	105.50*	66.67*
20/6 Alcobasa X W-229 8MF6	42.33	61.67	14.83	52.00	-71.47**	-75.95**	-75.95**	-39.05	-50.57
20/6 Alcobasa X 79B 1390	42.33	37.67	16.50	40.00	-58.75**	-61.02*	-73.24**	-32.18	-45.00
20/6 Alcobasa X CA-1	42.33	50.00	14.33	46.17	-68.95**	-71.34**	-76.76**	-41.10	-52.23
20/6 Alcobasa X UC-204B	42.33	35.67	0.00	39.00	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
20/6 Alcobasa X DWD-2	42.33	42.33	10.00	42.33	-76.38**	-76.38**	-83.78**	-58.90	-66.67*
20/6 Alcobasa X DWD-1	42.33	43.33	0.00	42.83	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
20/6 Alcobasa X L-15	42.33	36.00	50.23	39.17	28.26	18.66	-18.55	106.45*	67.43*
20/6 Alcobasa X Marikrit	42.33	31.67	67.50	37.00	82.43**	59.46**	9.45	177.43**	125.00**
20/6 Alcobasa X L-58	42.33	42.33	87.27	42.33	106.14**	106.16**	41.51*	258.69**	190.90**
20/6 Alcobasa X LE-79	42.33	31.67	51.33	37.00	38.74	21.26	-16.77	110.97**	71.10*
20/5 Alcobasa X W-229 8MF6	41.67	61.67	64.67	51.67	25.16	4.86	4.86	165.80**	115.57**
20/5 Alcobasa X 79B 1390	41.67	37.67	40.00	39.67	0.84	-4.00	-35.14*	64.40	33.33
20/5 Alcobasa X CA-1	41.67	50.00	54.00	45.83	17.82	8.00	-12.44	121.95**	80.00*
20/5 Alcobasa X UC-204B	41.67	35.67	0.00	38.67	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
20/5 Alcobasa X DWD-2	41.67	42.33	0.00	42.00	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
20/5 Alcobasa X DWD-1	41.67	43.33	0.00	42.50	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
20/5 Alcobasa X L-15	41.67	36.00	27.67	38.83	-28.76	-33.59	-55.13**	13.73	-7.78
20/5 Alcobasa X Marikrit	41.67	31.67	30.33	36.67	-17.27	-27.21	-50.82**	24.66	3.37
20/5 Alcobasa X L-58	41.67	42.33	55.43	42.00	31.98	30.95	-10.12	127.82**	84.78*
20/5 Alcobasa X LE-79	41.67	31.67	67.67	36.67	84.55**	62.40*	9.73	178.13**	125.57**
20/2 Alcobasa X W-229 8MF6	31.67	61.67	39.33	46.67	-15.71	-36.22*	-36.22*	61.65	31.10
20/2 Alcobasa X 79B 1390	31.67	37.67	68.33	34.67	97.12**	81.39**	10.80	180.85**	127.78**
20/2 Alcobasa X CA-1	31.67	50.00	62.50	40.83	53.06*	25.00	1.34	156.88**	108.33**
20/2 Alcobasa X UC-204B	31.67	35.67	0.00	33.67	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
20/2 Alcobasa X DWD-2	31.67	42.33	50.33	37.00	36.04	18.90	-18.39	106.86*	67.78
20/2 Alcobasa X DWD-1	31.67	43.33	12.33	37.50	-67.11**	-71.54**	-80.00**	-49.32	-58.90
20/2 Alcobasa X L-15	31.67	36.00	67.67	33.83	100.00**	87.97**	9.73	178.13**	125.57**
20/2 Alcobasa X Marikrit	31.67	31.67	52.33	31.67	65.26*	65.23*	-15.14	115.08**	74.43*
20/2 Alcobasa X L-58	31.67	42.33	55.00	37.00	48.65*	29.93	-10.81	126.06**	83.33*
20/2 Alcobasa X LE-79	31.67	31.67	50.33	31.67	58.95*	58.92	-18.39	106.86*	67.78*
AVRDC Alcobasa X W-229 8MF6	31.67	61.67	59.57	46.67	27.94	-3.40	-3.40	144.84**	98.57**
AVRDC Alcobasa X 79B 1390	31.67	37.67	31.67	34.67	-8.65	-15.93	-48.65**	30.17	5.57
AVRDC Alcobasa X CA-1	31.67	50.00	12.33	40.83	-69.80**	-75.34**	-80.00**	-49.32	-58.90
AVRDC Alcobasa X UC-204B	31.67	35.67	56.00	33.67	66.34*	56.00*	-9.19	130.17**	86.67*
AVRDC Alcobasa X DWD-2	31.67	42.33	41.67	37.00	12.61	-1.56	-32.43*	71.27	38.90
AVRDC Alcobasa X DWD-1	31.67	43.33	42.00	37.50	12.00	-3.07	-31.90	72.63	40.00
AVRDC Alcobasa X L-15	31.67	36.00	0.00	33.83	-100.00**	-100.00**	-100.00**	-100.00*	-100.00**
AVRDC Alcobasa X Marikrit	31.67	31.67	60.00	31.67	89.47	89.45**	-2.70	146.60**	100.00**
AVRDC Alcobasa X L-58	31.67	42.33	17.33	37.00	-53.15*	-59.06*	-71.90**	-28.77	-42.23
AVRDC Alcobasa X LE-79	31.67	31.67	41.67	31.67	31.58	31.58	-32.43	71.27	38.90
S.E.±					8.83	10.19	10.19	10.19	10.19

Punjab Chuhara Check-1 (24.33) Vaishali Check-2 (30.00)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

Table 14. Mean performance of parents and hybrids, and magnitude of heterosis for total fruit weight per plant

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	564.00	310.00	518.67	437.00	-18.69	-8.04	-20.81	351.00*	727.62**
20/4 Alcobasa X 79B 1390	564.00	369.67	974.33	466.83	108.71**	72.75*	48.75	747.24**	1454.70**
20/4 Alcobasa X CA-1	564.00	153.33	580.00	358.67	61.71	2.84	-11.45	404.34**	825.48**
20/4 Alcobasa X UC-204B	564.00	242.32	371.67	403.17	-7.81	-34.10	-43.27	223.19	493.06
20/4 Alcobasa X DWD-2	564.00	506.00	130.00	535.00	-75.70**	-76.95*	-80.15**	13.04	107.43
20/4 Alcobasa X DWD-1	564.00	86.67	31.67	325.33	-90.27	-94.39**	-95.16**	-72.46	-49.46
20/4 Alcobasa X L-15	564.00	285.33	29.00	424.67	-93.17**	-94.86**	-95.57**	-74.78	-53.72
20/4 Alcobasa X Marikrit	564.00	131.67	366.67	347.83	5.41	-34.99	-44.02	218.84	485.08
20/4 Alcobasa X L-58	564.00	313.33	1358.33	438.67	209.65**	140.84**	107.38**	1081.16	2067.43**
20/4 Alcobasa X LE-79	564.00	140.00	213.33	352.00	-39.39	-62.17*	-67.43*	85.50	240.40
20/6 Alcobasa X N-229 8MF6	545.67	310.00	95.00	427.83	-77.80**	-82.59*	-85.50**	-17.39	51.58
20/6 Alcobasa X 79B 1390	545.67	369.67	41.67	457.67	-90.90**	-92.36**	-93.64**	-63.76	-33.51
20/6 Alcobasa X CA-1	545.67	153.33	211.67	349.50	-39.44	-61.21*	-67.68*	84.06**	237.75
20/6 Alcobasa X UC-204B	545.67	242.32	0.00	394.00	-100.00*	-100.00**	-100.00**	-100.00	-100.00
20/6 Alcobasa X DWD-2	545.67	506.00	15.67	525.83	-97.02**	-97.13**	-97.61**	-86.37	-75.00
20/6 Alcobasa X DWD-1	545.67	86.67	0.00	316.17	-100.00*	-100.00**	-100.00**	-100.00	-100.00
20/6 Alcobasa X L-15	545.67	285.33	664.67	415.50	59.97	21.18	1.48	477.97**	960.59**
20/6 Alcobasa X Marikrit	545.67	131.67	1073.33	338.67	216.93**	96.70**	63.87*	833.33**	1612.67**
20/6 Alcobasa X L-58	545.67	313.33	2087.67	429.50	386.07**	282.59**	218.73**	1715.36**	3231.21**
20/6 Alcobasa X LE-79	545.67	140.00	516.69	342.83	50.70	-5.31	-21.12	349.28*	724.43
20/5 Alcobasa X N-229 8MF6	655.00	310.00	1311.33	482.50	171.78**	100.20**	100.20**	1040.29**	1992.44**
20/5 Alcobasa X 79B 1390	655.00	369.67	448.33	512.33	-12.49	-31.55	-31.55	289.85	615.38*
20/5 Alcobasa X CA-1	655.00	153.33	628.00	404.17	53.38	-4.12	-4.12	446.09**	902.07**
20/5 Alcobasa X UC-204B	655.00	242.32	0.00	448.67	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/5 Alcobasa X DWD-2	655.00	506.00	0.00	580.50	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/5 Alcobasa X DWD-1	655.00	86.67	0.00	370.83	-100.00**	-100.00**	-100.00**	-100.00	-100.00
20/5 Alcobasa X L-15	655.00	285.33	120.00	470.17	-74.48*	-81.68**	-81.68**	4.35	91.48
20/5 Alcobasa X Marikrit	655.00	131.67	215.33	393.33	-45.25	-67.12*	-67.12*	87.24	243.60
20/5 Alcobasa X L-58	655.00	313.33	1096.00	484.17	126.37**	67.33*	67.33*	853.04**	1648.84**
20/5 Alcobasa X LE-79	655.00	140.00	1149.33	397.50	189.14**	75.47**	75.47**	899.42**	1733.94**
20/2 Alcobasa X N-229 8MF6	415.00	310.00	396.67	362.50	9.43	-4.42	-39.44	244.93	532.95
20/2 Alcobasa X 79B 1390	415.00	369.67	673.33	392.33	71.62	62.25	2.80	485.50**	974.40**
20/2 Alcobasa X CA-1	415.00	153.33	517.67	284.17	82.17	24.74	-20.97	350.15*	726.02**
20/2 Alcobasa X UC-204B	415.00	242.32	0.00	328.67	-100.00*	-100.00*	-100.00**	-100.00	-100.00
20/2 Alcobasa X DWD-2	415.00	506.00	618.33	460.50	34.27	22.20	-5.60	437.68**	886.64**
20/2 Alcobasa X DWD-1	415.00	86.67	30.33	250.83	-87.91	-92.69*	-95.37**	-73.63	-51.60
20/2 Alcobasa X L-15	415.00	285.33	1187.67	350.17	239.17**	186.18**	81.32**	932.76**	1795.12**
20/2 Alcobasa X Marikrit	415.00	131.67	401.00	273.33	46.71	-3.37	-38.78	248.70	539.86
20/2 Alcobasa X L-58	415.00	313.33	911.67	364.17	150.34**	119.68**	39.19	692.75**	1354.71**
20/2 Alcobasa X LE-79	415.00	140.00	944.33	277.50	240.30**	127.55**	44.17	721.16**	1406.83**
AVRDC Alcobasa X N-229 8MF6	396.67	310.00	1088.67	353.33	208.11**	174.45**	66.21*	846.67**	1637.15**
AVRDC Alcobasa X 79B 1390	396.67	369.67	178.33	383.17	-53.46	-55.04	-72.77**	55.07	184.55
AVRDC Alcobasa X CA-1	396.67	153.33	29.67	275.05	-89.21	-92.52*	-95.47**	-74.20	-52.66
AVRDC Alcobasa X UC-204B	396.67	242.32	563.67	319.50	76.42	42.10	-91.33	390.15*	799.42**
AVRDC Alcobasa X DWD-2	396.67	506.00	211.67	451.33	-53.10	-58.17	-67.68	84.06	237.75
AVRDC Alcobasa X DWD-1	396.67	86.67	200.67	241.67	-16.97	-49.41	-69.36*	74.50	220.20
AVRDC Alcobasa X L-15	396.67	285.33	0.00	341.00	-100.00*	-100.00*	-100.00**	-100.00	-100.00
AVRDC Alcobasa X Marikrit	396.67	131.67	703.33	264.17	166.25**	77.31	7.38	511.59**	1022.27**
AVRDC Alcobasa X L-58	396.67	313.33	51.33	355.00	-85.54*	-87.06	-92.16**	-55.36	-18.09
AVRDC Alcobasa X LE-79	396.67	140.00	423.33	268.33	57.76	6.72	-35.37	268.11	575.50*
S.E.±					153.32	177.04	177.04	177.04	177.04

Punjab Chuhara Check-1 (115.00) Vaishali Check-2 (62.67)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

variation from 396.67 g (AVRDC Alcobasa) to 655.0 g (20/5 Alcobasa) per plant. The higher mean value of 506.00 g was recorded by the male parent DWD-2. Among the hybrids, the highest yield of 2087.67g was recorded for 20/6 Alcobasa X L-58 (Plate-3) followed by 20/4 Alcobasa X L-58 (1358.33 g), 20/5 Alcobasa X N-229 8MF6 (1311.33) (Plate-4), 20/2 Alcobasa X L-15 (1187.67 g) and 20/5 Alcobasa X LE-79 (1149.33 g). AS many as 7 crosses were very sensitive to summer conditions and did not yield any thing. Cultivar Punjab Chuhara (Check-1) and the commercial hybrid Vaishali (Check-2) had hardly 115 and 62.67 g per plant respectively.

Mid parent heterosis for total fruit weight per plant ranged from -7.81 (20/4 Alcobasa X UC-204B) to 386.07 per cent (20/6 Alcobasa X L-58). There were 26 hybrids each showing positive and negative heterosis over mid parent. In all there were 12, 11 and 8 crosses with significant positive heterosis over mid, better and best parent respectively. The crosses exhibiting positive significant heterosis over best parent were 20/4 Alcobasa X L-58, 20/6 Alcobasa X Marikrit, 20/5 Alcobasa X N-229 8MF6, 20/5 Alcobasa X L-58, 20/5 Alcobasa X LE-79, 20/2 Alcobasa X L-15 and AVRDC Alcobasa X N-229 8MF6 in that order. There were as many as 21 and 22 crosses respectively showing significant positive heterosis over check-1 and 2.

Plate 3. Best cross combination (20/6 Alcobasa X L-58) for summer

Plate 4. Best cross combination (20/5 Alcobasa X N-229 $8MF_6$) for summer

4.2.2.8 Total soluble solids (Table-15)

The testers ranged from 2.90 (L-58) to 4.07 (CA-1), while that of lines from 2.50 (20/5 Alcobasa) to 2.87 (20/6 Alcobasa). The F_1s showed wider range of variation from 2.80 (20/2 Alcobasa X Marikrit) to 5.43 (20/5 Alcobasa X L-58). The checks recorded 4.33 (Punjab Chuhara) and 3.23 (Vaishali) per cent of total soluble solids.

It can be seen from the Table-15 that 17 crosses had exhibited significant positive heterosis over best parent (CA-1). Two crosses namely 20/5 Alcobasa X L-58 (33.41 %) and 20/4 Alcobasa X L-58 (30.96 %) exhibited the highest positive heterotic value. The number of crosses recording significant positive heterosis over mid and better parents were 38 and 29 respectively. The range of heterosis over check 1 and 2 was from -0.69 (20/4 Alcobasa X UC-204B) to 25.40 (20/5 Alcobasa X L-58) per cent, from -7.12 (20/6 Alcobasa X DWD-2) to 68.11 (20/5 Alcobasa X L-58) per cent respectively.

4.2.2.9 Locules per fruit (Table-16)

The locule number has direct influence on shelf life of tomato and those with a few number of locules keep better. A greater range of variation was observed among females (2.00 to 6.33) compared to males (2.00 to 5.00). Hybrids, ranged from 2.00 to 4.10. The checks Punjab Chuhara and Vaishali had 2.00 and 3.00 locules per fruit respectively. Range of heterosis

Table 15. Mean performance of parents and hybrids, and magnitude of heterosis for total soluble solids

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	2.67	3.70	4.03	3.18	26.70**	8.92	-0.98	-6.93*	24.77**
20/4 Alcobasa X 79B 1390	2.67	3.40	4.33	3.04	42.86**	27.35**	6.39	0.00	34.05**
20/4 Alcobasa X CA-1	2.67	4.07	3.50	3.37	3.96	-14.00**	-14.00**	-19.17**	8.36
20/4 Alcobasa X UC-204B	2.67	2.97	4.30	2.82	52.66**	44.78**	5.65	-0.69	33.13**
20/4 Alcobasa X DWD-2	2.67	4.07	4.13	3.37	22.77**	1.47	1.47	-4.62	27.86**
20/4 Alcobasa X DWD-1	2.67	3.90	3.47	3.29	5.58	-11.02**	-14.74**	-19.86**	7.43
20/4 Alcobasa X L-15	2.67	3.97	4.13	3.32	24.62**	4.20	1.47	-4.62	27.86**
20/4 Alcobasa X Marikrit	2.67	3.83	4.20	3.25	29.23**	9.57**	3.19	-3.00	30.03**
20/4 Alcobasa X L-58	2.67	2.90	5.33	2.79	91.62**	83.80**	30.96**	23.09**	65.01**
20/4 Alcobasa X LE-79	2.67	3.10	5.23	2.89	81.50**	68.82**	28.50**	20.78**	61.92**
20/6 Alcobasa X N-229 8MF6	2.87	3.70	4.90	3.29	49.24**	32.43**	20.39**	13.16**	51.70**
20/6 Alcobasa X 79B 1390	2.87	3.40	4.73	3.13	51.06**	39.22**	16.22**	9.24**	46.44**
20/6 Alcobasa X CA-1	2.87	4.07	4.03	3.47	16.35**	-0.82	-0.82	-6.93*	24.77**
20/6 Alcobasa X UC-204B	2.87	2.97	0.00	2.92	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/6 Alcobasa X DWD-2	2.87	4.07	3.00	3.47	-13.46**	-26.28**	-26.28**	-30.72**	-7.12
20/6 Alcobasa X DWD-1	2.87	3.90	0.00	3.38	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/6 Alcobasa X L-15	2.87	3.97	3.80	3.42	11.22**	-4.20	-6.63	-12.24**	17.65**
20/6 Alcobasa X Marikrit	2.87	3.83	4.23	3.35	26.37**	10.43**	3.93	-2.31	30.96**
20/6 Alcobasa X L-58	2.87	2.90	4.60	2.89	59.54**	58.62**	13.02**	6.23	42.41**
20/6 Alcobasa X LE-79	2.87	3.10	5.00	2.99	67.60**	61.29**	22.85**	15.47**	54.80**
20/5 Alcobasa X N-229 8MF6	2.50	3.70	4.90	3.10	58.06**	32.43**	20.39**	13.16**	51.70**
20/5 Alcobasa X 79B 1390	2.50	3.40	4.00	2.95	35.59**	17.65**	-1.72	-7.62**	23.84**
20/5 Alcobasa X CA-1	2.50	4.07	4.63	3.29	41.12**	13.93**	13.93**	6.93*	43.34**
20/5 Alcobasa X UC-204B	2.50	2.97	0.00	2.74	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/5 Alcobasa X DWD-2	2.50	4.07	0.00	3.29	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/5 Alcobasa X DWD-1	2.50	3.90	0.00	3.20	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/5 Alcobasa X L-15	2.50	3.97	4.27	3.23	31.96**	7.56	4.91	-1.38	32.20**
20/5 Alcobasa X Marikrit	2.50	3.83	4.37	3.17	37.89**	13.91**	7.38*	0.92	35.29**
20/5 Alcobasa X L-58	2.50	2.90	5.43	2.70	101.23**	87.36**	33.41**	25.40**	68.11**
20/5 Alcobasa X LE-79	2.50	3.10	3.93	2.80	40.48**	26.88**	-3.44	-9.24**	21.67**
20/2 Alcobasa X N-229 8MF6	2.57	3.70	4.30	3.13	37.23**	16.22**	5.65	-0.69	33.13**
20/2 Alcobasa X 79B 1390	2.57	3.40	4.40	2.99	47.49**	29.41**	8.11**	1.62	36.22**
20/2 Alcobasa X CA-1	2.57	4.07	4.73	3.32	42.71**	16.29**	16.29**	9.24**	46.44**
20/2 Alcobasa X UC-204B	2.57	2.97	0.00	2.77	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/2 Alcobasa X DWD-2	2.57	4.07	5.30	3.32	51.76**	23.77**	23.77**	16.17**	55.73**
20/2 Alcobasa X DWD-1	2.57	3.90	3.53	3.23	9.28*	-9.48	-13.27**	-18.48**	9.29**
20/2 Alcobasa X L-15	2.57	3.97	4.37	3.27	33.67**	10.08**	7.37*	0.92	35.29**
20/2 Alcobasa X Marikrit	2.57	3.83	2.80	3.20	-12.50**	-26.96**	-31.20**	-35.33**	-13.31**
20/2 Alcobasa X L-58	2.57	2.90	4.20	2.73	53.66**	44.83**	3.19	-3.00	30.03**
20/2 Alcobasa X LE-79	2.57	3.10	4.37	2.73	54.12**	40.96**	7.37*	0.92	35.29**
AVRDC Alcobasa X N-229 8MF6	2.70	3.70	4.10	3.20	28.12**	10.81**	0.74	-5.31	26.93**
AVRDC Alcobasa X 79B 1390	2.70	3.40	3.97	3.05	30.05**	16.67**	-2.46	-8.31*	22.91**
AVRDC Alcobasa X CA-1	2.70	4.07	4.77	3.39	40.89**	17.20**	17.20**	10.16**	47.68**
AVRDC Alcobasa X UC-204B	2.70	2.97	3.63	2.83	28.24**	22.47**	-10.81**	-16.17**	12.38**
AVRDC Alcobasa X DWD-2	2.70	4.07	4.13	3.39	22.17**	-1.47	1.47	-4.62	27.86**
AVRDC Alcobasa X DWD-1	2.70	3.90	3.57	3.30	8.08*	-8.55*	-12.28**	-17.55**	10.52*
AVRDC Alcobasa X L-15	2.70	3.97	0.00	3.33	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
AVRDC Alcobasa X Marikrit	2.70	3.83	3.37	3.27	3.06	-12.17**	-17.20**	-22.17**	4.33
AVRDC Alcobasa X L-58	2.70	2.90	3.60	2.80	28.57**	24.14**	-11.55**	-16.86**	11.45*
AVRDC Alcobasa X LE-79	2.70	3.10	4.47	2.90	54.02**	44.19**	9.83*	-3.23	38.39**
S.E.±					0.13	0.15	0.15	0.15	0.15

Punjab Chuhara Check-1 (4.33) Vaishali Check-2 (3.23)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively
Note : Zero values are taken for the purpose of statistical analysis.

Table 16. Mean performance of parents and hybrids, and magnitude of heterosis for average number of locules per fruit

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	2.00	3.00	4.07	2.50	62.67**	103.50**	103.50**	103.50**	35.67**
20/4 Alcobasa X 79B 1390	2.00	2.60	3.93	2.30	71.01**	96.50**	96.50**	96.50**	31.00**
20/4 Alcobasa X CA-1	2.00	2.60	2.93	2.30	27.54**	46.50**	46.50**	46.50**	-2.33
20/4 Alcobasa X UC-204B	2.00	3.00	3.00	2.50	20.00**	50.00**	50.00**	50.00**	0.00
20/4 Alcobasa X DWD-2	2.00	2.60	2.77	2.30	20.29*	38.50**	38.50**	38.50**	-7.67
20/4 Alcobasa X DWD-1	2.00	2.93	3.43	2.47	39.19**	71.50**	71.50**	71.50**	14.33
20/4 Alcobasa X L-15	2.00	3.00	3.00	2.50	20.00*	50.00**	50.00**	50.00**	0.00
20/4 Alcobasa X Marikrit	2.00	2.00	3.00	2.00	50.00**	50.00**	50.00**	50.00**	0.00
20/4 Alcobasa X L-58	2.00	5.00	3.00	3.50	-14.29*	50.00**	50.00**	50.00**	0.00
20/4 Alcobasa X LE-79	2.00	3.00	3.77	2.50	50.67**	88.50**	88.50**	88.50**	25.67**
20/6 Alcobasa X N-229 8MF6	5.93	3.00	2.27	4.47	-49.25**	-36.50**	13.50	13.50	-24.33**
20/6 Alcobasa X 79B 1390	5.93	2.60	2.00	4.27	-53.12**	30.00**	0.00	0.00	-33.33**
20/6 Alcobasa X CA-1	5.93	2.60	3.27	4.27	-23.44**	33.50**	63.50**	63.50**	9.00
20/6 Alcobasa X UC-204B	5.93	3.00	0.00	4.47	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/6 Alcobasa X DWD-2	5.93	2.60	2.73	4.27	-35.94**	6.50	36.50**	36.50**	-9.00**
20/6 Alcobasa X DWD-1	5.93	2.93	0.00	4.43	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/6 Alcobasa X L-15	5.93	3.00	2.00	4.47	-55.22**	-33.35**	0.00	0.00	-33.33**
20/6 Alcobasa X Marikrit	5.93	2.00	3.00	3.97	-24.37**	50.00**	50.00**	50.00**	0.00
20/6 Alcobasa X L-58	5.93	5.00	2.13	5.47	-60.98**	-57.40**	6.50	6.50	-29.00**
20/6 Alcobasa X LE-79	5.93	3.00	2.60	4.47	-41.79**	-13.33	30.00**	30.00**	-13.33
20/5 Alcobasa X N-229 8MF6	2.27	3.00	2.00	2.63	-24.05**	-11.89	0.00	0.00	-33.33**
20/5 Alcobasa X 79B 1390	2.27	2.60	3.80	2.43	56.16**	67.40**	90.00**	90.00**	26.67**
20/5 Alcobasa X CA-1	2.27	2.60	3.43	2.43	41.10**	51.10**	71.50**	71.50**	14.53
20/5 Alcobasa X UC-204B	2.27	3.00	0.00	2.63	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/5 Alcobasa X DWD-2	2.27	2.60	0.00	2.43	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/5 Alcobasa X DWD-1	2.27	2.93	0.00	2.60	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/5 Alcobasa X L-15	2.27	3.00	3.10	2.63	17.72**	36.56**	55.00**	55.00**	3.33
20/5 Alcobasa X Marikrit	2.27	2.00	3.00	2.13	40.63**	50.00**	50.00**	50.00**	0.00
20/5 Alcobasa X L-58	2.27	5.00	3.00	3.63	-17.43**	32.16**	50.00**	50.00**	0.00
20/5 Alcobasa X LE-79	2.27	3.00	3.77	2.63	43.04**	66.07**	88.50**	88.50**	25.67**
20/2 Alcobasa X N-229 8MF6	3.00	3.00	3.60	3.00	20.00**	20.00**	80.00**	80.00**	20.00*
20/2 Alcobasa X 79B 1390	3.00	2.60	3.60	2.80	28.57**	38.46**	80.00**	80.00**	20.00
20/2 Alcobasa X CA-1	3.00	2.60	3.00	2.80	7.14	15.38**	50.00**	50.00**	0.00
20/2 Alcobasa X UC-204B	3.00	3.00	0.00	3.00	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
20/2 Alcobasa X DWD-2	3.00	2.60	2.77	2.80	-1.19	6.53	38.50**	38.50**	-7.67
20/2 Alcobasa X DWD-1	3.00	2.93	3.00	2.97	1.12	2.39	50.00**	50.00**	0.00
20/2 Alcobasa X L-15	3.00	3.00	2.77	3.00	-7.78	-7.67	38.50**	38.50**	25.67**
20/2 Alcobasa X Marikrit	3.00	2.00	3.00	2.50	20.00*	50.60**	50.00**	50.00**	0.00
20/2 Alcobasa X L-58	3.00	5.00	4.00	4.00	0.00	33.33**	100.00**	100.00**	33.33**
20/2 Alcobasa X LE-79	3.00	3.00	2.00	3.00	-33.33**	-33.33**	0.00	0.00	-33.33**
AVRDC Alcobasa X N-229 8MF6	6.33	3.00	4.10	4.67	-12.14**	36.67**	105.00**	105.00**	36.67**
AVRDC Alcobasa X 79B 1390	6.33	2.60	2.93	4.47	-34.33**	12.69	46.50**	46.50**	-2.33
AVRDC Alcobasa X CA-1	6.33	2.60	3.93	4.47	-11.94**	51.15**	96.50**	96.50**	31.00**
AVRDC Alcobasa X UC-204B	6.33	3.00	3.43	4.67	-26.43**	14.33	71.50**	71.50**	14.33
AVRDC Alcobasa X DWD-2	6.33	2.60	3.00	4.47	-32.84**	15.38	50.00**	50.00**	0.00
AVRDC Alcobasa X DWD-1	6.33	2.93	3.17	4.63	-31.65**	8.19	58.50**	58.50**	5.67
AVRDC Alcobasa X L-15	6.33	3.00	0.00	4.67	-100.00**	-100.00**	-100.00**	-100.00**	-100.00**
AVRDC Alcobasa X Marikrit	6.33	2.00	2.93	4.17	-29.60**	46.50**	46.50**	46.50**	31.00**
AVRDC Alcobasa X L-58	6.33	5.00	3.00	5.67	-47.06**	40.00**	50.00**	50.00**	0.00
AVRDC Alcobasa X LE-79	6.33	3.00	2.27	4.67	-51.43**	-24.33**	13.50	13.50	-24.33**
S.E.±					0.20	0.23	0.23	0.23	0.23

Punjab Chuhara Check-1 (2.00) Vaishali Check-2 (3.00)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively
Note : Zero values are taken for the purpose of statistical analysis.

over mid parental values was of considerable magnitude (-1.19 to 71.01). Out of 50 hybrids 17 showed significant heterosis in positive direction, and 28 were in negative direction. Seven hybrids had showed non significant heterosis for locules over best parent with 2.00 locules per fruit. The crosses 20/6 Alcobasa X 79B1390, 20/6 Alcobasa X L-15, 20/5 Alcobasa X N-229 8MF6 and 20/2 Alcobasa X LE-79 had absolute heterosis over best parent. The significant negative heterosis over better and best parent has been observed in 12 and 7 crosses respectively. However, as many as 28 and 36 crosses had shown significant positive heterosis over better and best parent respectively. Seven and 24 crosses had shown non significant differences over check-1 and 2 respectively.

4.2.2.10 Number of white flies per plant (Table-17)

Production of tomato in summer is rediculed because of TLCV and it is transmitted through whiteflies. These have been known to be attracted by some but not all genotypes. Therefore, it is presumed that resistance to TLCV could be due to non attraction of whiteflies and their relative harbouring. A greater range of variation was observed among the parents.The lines exhibited less number of (1.50 to 1.83) whiteflies compared to testers (2.10 to 4.50). The F_1s recorded a range of variation from 1.13 (20/5 Alcobasa X N-229 8MF6) to 6.83 (AVRDC Alcobasa X L-15) number of whiteflies per plant. The

Table 17. Mean performance of parents and hybrids, and magnitude of heterosis for average number of whiteflies per plant

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	1.77	2.10	2.07	1.93	6.90	16.95	38.00	-56.60**	-58.01**
20/4 Alcobasa X 79B 1390	1.77	3.10	1.83	2.43	-24.66	3.39	22.00	-61.63**	-62.88**
20/4 Alcobasa X CA-1	1.77	2.93	1.47	2.35	-37.59*	-16.95	-2.00	-69.18**	-70.18**
20/4 Alcobasa X UC-204B	1.77	4.10	3.67	2.93	25.00	107.34**	144.67**	-23.06*	-25.56**
20/4 Alcobasa X DWD-2	1.77	4.50	3.13	3.13	0.00	76.84**	108.67**	-34.38**	-36.51**
20/4 Alcobasa X DWD-1	1.77	2.60	3.13	2.18	43.51*	76.84**	108.67**	-34.38**	-36.51**
20/4 Alcobasa X L-15	1.77	3.27	4.30	2.52	70.86**	142.94**	186.67**	-9.85	-12.78
20/4 Alcobasa X Marikrit	1.77	3.43	1.50	2.60	-42.31**	-15.25	0.00	-68.55**	-69.57**
20/4 Alcobasa X L-58	1.77	2.77	1.90	2.27	-16.18	7.34	26.67	-60.17**	-61.46**
20/4 Alcobasa X LE-79	1.77	2.10	3.30	1.93	70.69**	86.44**	120.00**	-30.82**	-33.06**
20/6 Alcobasa X N-229 8MF6	1.60	2.10	5.20	1.85	181.08**	2.25**	246.67**	9.01	5.48
20/6 Alcobasa X 79B 1390	1.60	3.10	3.40	2.35	44.68**	1.12**	126.67**	-28.72**	-31.03**
20/6 Alcobasa X CA-1	1.60	2.93	1.43	2.27	-36.76	-10.63	-7.00	-70.02**	-70.99**
20/6 Alcobasa X UC-204B	1.60	4.10	4.53	2.85	59.06**	183.12**	202.00**	-5.03	-8.11
20/6 Alcobasa X DWD-2	1.60	4.50	6.13	3.05	101.09**	283.12**	308.67**	28.51**	24.34*
20/6 Alcobasa X DWD-1	1.60	2.60	5.40	2.10	157.14**	237.50**	260.00**	13.21	9.53
20/6 Alcobasa X L-15	1.60	3.27	2.27	2.43	-6.85	41.88	51.33	-52.41**	-53.95**
20/6 Alcobasa X Marikrit	1.60	3.43	1.60	2.51	-36.42*	0.00	6.67	-66.46**	-67.54**
20/6 Alcobasa X L-58	1.60	2.77	1.77	2.18	-19.08	10.62	18.00	-62.89**	-64.10**
20/6 Alcobasa X LE-79	1.60	2.10	2.80	1.85	51.35*	75.00	86.67**	-41.30**	-43.20**
20/5 Alcobasa X N-229 8MF6	1.83	2.10	1.13	1.97	-42.37	-38.25	-24.67	76.31**	-77.08**
20/5 Alcobasa X 79B 1390	1.83	3.10	2.57	2.47	4.05	40.44	71.33*	-46.12**	-47.87**
20/5 Alcobasa X CA-1	1.83	2.93	3.33	2.38	39.86*	81.97**	122.00**	-30.19**	-32.45**
20/5 Alcobasa X UC-204B	1.83	4.10	5.37	2.97	80.90**	193.44**	258.00**	12.58	8.92
20/5 Alcobasa X DWD-2	1.83	4.50	5.27	3.17	66.32**	187.78**	251.33**	10.48	6.89
20/5 Alcobasa X DWD-1	1.83	2.60	5.67	2.21	155.64**	209.84**	278.00**	18.88	15.01
20/5 Alcobasa X L-15	1.83	3.27	3.03	2.55	18.95	65.57**	102.00**	-36.48**	-38.54**
20/5 Alcobasa X Marikrit	1.83	3.43	2.80	2.63	6.33	53.05	86.67**	-41.30**	-43.20**
20/5 Alcobasa X L-58	1.83	2.77	1.77	2.30	-23.19	-3.28	18.00	-62.89**	-64.10**
20/5 Alcobasa X LE-79	1.83	2.10	1.70	1.97	-13.56	-7.10	13.33	-64.36**	-65.52**
20/2 Alcobasa X N-229 8MF6	1.77	2.10	1.63	1.93	-15.52	-7.91	8.67	-65.83**	-66.94**
20/2 Alcobasa X 79B 1390	1.77	3.10	1.97	2.43	-19.18	11.30	31.33	-58.70**	-60.04**
20/2 Alcobasa X CA-1	1.77	2.93	1.87	2.35	-20.57	5.65	24.66	-60.80**	-62.07**
20/2 Alcobasa X UC-204B	1.77	4.10	5.23	2.93	78.41**	195.48**	248.67**	9.64	6.08
20/2 Alcobasa X DWD-2	1.77	4.50	3.47	3.13	10.64	96.04**	131.33**	-27.25**	-29.61**
20/2 Alcobasa X DWD-1	1.77	2.60	5.50	2.19	151.91**	210.73**	266.67**	15.30	11.56
20/2 Alcobasa X L-15	1.77	3.27	1.93	2.52	-23.18	9.04	28.67	-59.54**	-60.85**
20/2 Alcobasa X Marikrit	1.77	3.43	2.07	2.60	-20.51	16.95	38.00	-56.60**	-58.01**
20/2 Alcobasa X L-58	1.77	2.77	1.53	2.27	-32.35	-13.56	2.00	-67.92**	-68.97**
20/2 Alcobasa X LE-79	1.77	2.10	1.53	1.93	-20.69	-13.56	2.00	-67.92**	-68.97**
AVRDC Alcobasa X N-229 8MF6	1.50	2.10	1.80	1.80	0.00	20.00	20.00	-62.26**	-63.49**
AVRDC Alcobasa X 79B 1390	1.50	3.10	5.00	2.30	117.39**	233.33**	233.33**	4.82	1.42
AVRDC Alcobasa X CA-1	1.50	2.93	5.37	2.21	142.11**	258.00**	258.00**	12.58	8.92
AVRDC Alcobasa X UC-204B	1.50	4.10	3.50	2.80	25.00	133.33**	133.33**	-26.62*	-29.01**
AVRDC Alcobasa X DWD-2	1.50	4.50	5.33	3.00	77.78**	255.33**	255.33**	11.74	8.11
AVRDC Alcobasa X DWD-1	1.50	2.60	4.03	2.05	96.75**	168.67**	168.67**	-15.51	-18.25
AVRDC Alcobasa X L-15	1.50	3.27	6.83	2.39	186.71**	355.33**	355.33**	43.19**	38.54**
AVRDC Alcobasa X Marikrit	1.50	3.43	3.83	2.47	55.41**	155.33**	155.33**	-19.71	-22.31*
AVRDC Alcobasa X L-58	1.50	2.77	5.47	2.13	156.25**	264.67**	264.67**	14.68	10.95
AVRDC Alcobasa X LE-79	1.50	2.10	2.67	1.80	48.15*	78.00	78.00*	-44.02**	-45.84**
S.E.±					0.43	0.50	0.50	0.50	0.50

Punjab Chuhara Check-1 (4.77) Vaishali Check-2 (4.93)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively

checks harboured higher number 4.77 (Punjab Chuhara) and 4.93 (Vaishali) compared to lines or testers.

The heterosis over mid-parent ranged from 0.00 (20/4 Alcobasa X DWD-2 and AVRDC Alcobasa X N-229 8MF6) to 186.71 (AVRDC Alcobasa X L-15) per cent. While 24 crosses showed non significant heterosis, three exhibited significant negative heterosis over mid parent. Two crosses namely 20/6 Alcobasa X Marikrit and 20/4 Alcobasa X Marikrit recorded zero heterosis respectively over better and best parent. None of the hybrids exhibited the significant negative heterosis over better and best parents.

4.2.2.11 Percentage of TLCV infection (Table-18)

Per cent infection of TLCV ranged from 29.43 to 36.60 per cent among the females, while a greater magnitude was noticed in the males (38.57 to 57.30 %). The F_1s exhibited quite a remarkable performance for TLCV. The range of variation was from 25.30 per cent (20/6 Alcobasa X L-58) to 90 per cent (in 7 crosses). The checks were of the order of 52.73 and 58.73 per cent TLCV by Punjab Chuhara and Vaishali, respectively. Significant negative heterosis over mid-parent was observed in 12 crosses and the range was from -0.72 (20/4 Alcobasa X UC-204B) to 146.91 per cent (20/6 Alcobasa X N-229 $8MF_6$). However, only two hybrids (20/5 Alcobasa X N-229 8MF6, 20/4 Alcobasa X L-58) exhibited significant negative heterosis over better

Table 18. Mean performance of parents and hybrids, and magnitude of heterosis for per cent of TLCV infection

Crosses	Mean values				Per cent heterosis				
	Female	Male	F_1	MP	MP	BRP	BSP	CK-1	CK-2
20/4 Alcobasa X N-229 8MF6	36.60	40.80	33.13	38.70	-14.38	-9.48	12.57	-37.17**	-43.59**
20/4 Alcobasa X 79B 1390	36.60	46.03	32.50	41.31	-21.34*	-11.20	10.43	-38.36**	-44.66**
20/4 Alcobasa X CA-1	36.60	47.30	29.37	41.95	-30.00**	-19.75	-0.20	-44.30**	-49.99**
20/4 Alcobasa X UC-204B	36.60	55.53	45.73	46.06	-0.72	24.94*	55.38**	-13.28	-22.13**
20/4 Alcobasa X DWD-2	36.60	57.30	51.67	46.95	10.05	41.17**	75.57**	-2.01	-12.02
20/4 Alcobasa X DWD-1	36.60	41.43	52.37	39.01	34.22**	43.08**	77.95**	-0.68	-10.83
20/4 Alcobasa X L-15	36.60	50.50	71.60	43.55	64.41**	95.63**	143.29**	35.79**	21.91**
20/4 Alcobasa X Marikrit	36.60	51.10	29.63	43.85	-32.42**	-19.04	0.68	-43.81**	-49.55**
20/4 Alcobasa X L-58	36.60	42.20	27.00	39.40	-31.47**	-26.23*	-8.26	-48.80**	-54.03**
20/4 Alcobasa X LE-79	36.60	38.57	49.83	37.58	32.59**	36.15**	69.32**	-5.50	-15.15*
20/6 Alcobasa X N-229 8MF6	32.10	40.80	90.00	36.45	146.91**	180.37**	205.81**	70.68**	53.24**
20/6 Alcobasa X 79B 1390	32.10	46.03	68.10	39.07	74.32**	112.15**	131.40**	29.15**	15.95**
20/6 Alcobasa X CA-1	32.10	47.30	31.07	39.71	-21.75*	-3.21	5.57	-41.08**	-47.09**
20/6 Alcobasa X UC-204B	32.10	55.53	90.00	43.81	105.40**	180.37**	205.81**	70.68**	53.24**
20/6 Alcobasa X DWD-2	32.10	57.30	81.17	44.70	81.58**	152.87**	175.81**	53.93**	38.21**
20/6 Alcobasa X DWD-1	32.10	41.43	90.00	36.76	144.79**	180.37**	205.81**	70.68**	53.24**
20/6 Alcobasa X L-15	32.10	50.50	36.23	41.30	-12.27	12.87	23.10	-31.29**	-38.31**
20/6 Alcobasa X Marikrit	32.10	51.10	32.40	41.60	-22.12*	0.93	10.09	-38.55**	-44.83**
20/6 Alcobasa X L-58	32.10	42.20	25.30	37.15	-31.90**	-21.18	-14.03	-52.02**	-56.92**
20/6 Alcobasa X LE-79	32.10	38.57	45.03	35.33	27.45**	40.28**	53.07**	-14.60	-23.33**
20/5 Alcobasa X N-229 8MF6	35.80	40.80	26.47	38.30	-30.90**	-26.06*	-10.06	-49.80**	-54.93**
20/5 Alcobasa X 79B 1390	35.80	46.03	39.43	40.91	-3.63	10.13	33.98*	-25.22**	-32.86**
20/5 Alcobasa X CA-1	35.80	47.30	50.17	41.55	20.74*	40.14**	70.47**	-4.85	-14.58**
20/5 Alcobasa X UC-204B	35.80	55.53	90.00	45.67	97.08**	151.40**	205.81**	70.68**	53.24**
20/5 Alcobasa X DWD-2	35.80	57.30	90.00	46.55	93.34**	151.40**	205.81**	70.68**	53.24**
20/5 Alcobasa X DWD-1	35.80	41.43	90.00	38.61	133.06**	151.40**	205.81**	70.68**	53.24**
20/5 Alcobasa X L-15	35.80	50.50	62.33	43.15	44.46**	74.11**	111.79**	18.20*	6.13
20/5 Alcobasa X Marikrit	35.80	51.10	45.83	43.45	5.49	28.02*	55.72**	-13.08	-21.96**
20/5 Alcobasa X L-58	35.80	42.20	26.73	39.00	-31.45**	-25.33	-9.17	-49.31**	-54.49**
20/5 Alcobasa X LE-79	35.80	38.57	29.37	37.19	-21.02**	-17.96	-2.04	-44.30**	-49.99**
20/2 Alcobasa X N-229 8MF6	29.43	40.80	30.33	35.11	-13.62	3.06	3.06	-42.48**	-48.35**
20/2 Alcobasa X 79B 1390	29.43	46.03	34.73	37.73	-7.95	18.01	18.00	-34.14**	-40.86**
20/2 Alcobasa X CA-1	29.43	47.30	33.77	38.37	-11.99	14.75	14.75	-35.96**	-42.50**
20/2 Alcobasa X UC-204B	29.43	55.53	90.00	42.48	111.85**	205.81**	205.81**	70.68**	53.24**
20/2 Alcobasa X DWD-2	29.43	57.30	44.83	43.37	3.38	52.33**	52.33**	-14.98	-23.67**
20/2 Alcobasa X DWD-1	29.43	41.43	77.80	35.43	119.57**	164.36**	164.36**	47.54**	32.47**
20/2 Alcobasa X L-15	29.43	50.50	35.57	39.70	-11.01	20.86	20.86	-32.54**	-39.43**
20/2 Alcobasa X Marikrit	29.43	51.10	42.30	40.27	5.05	43.73**	43.73**	-19.78*	-27.98**
20/2 Alcobasa X L-58	29.43	42.20	27.83	35.81	-22.29*	-5.44	-5.44	-47.22**	-52.61**
20/2 Alcobasa X LE-79	29.43	38.57	28.97	34.00	-14.80	-1.56	-1.56	-45.06**	-50.67**
AVRDC Alcobasa X N-229 8MF6	31.97	40.80	26.50	36.39	-27.16**	-17.11	-9.95	-49.74**	-54.88**
AVRDC Alcobasa X 79B 1390	31.97	46.03	72.67	39.00	86.32**	127.31**	146.92**	37.81**	23.73**
AVRDC Alcobasa X CA-1	31.97	47.30	79.33	39.63	100.17**	148.14**	169.55**	50.44**	35.07**
AVRDC Alcobasa X UC-204B	31.97	55.53	53.43	43.75	22.13**	67.12**	81.55**	1.33	-9.02
AVRDC Alcobasa X DWD-2	31.97	57.30	79.30	44.63	77.67**	148.04**	169.45**	50.39**	35.02**
AVRDC Alcobasa X DWD-1	31.97	41.43	51.90	36.70	41.42**	62.34**	76.35**	-1.57	-11.63
AVRDC Alcobasa X L-15	31.97	50.50	87.67	41.23	122.61**	174.22**	197.89**	66.26**	49.28**
AVRDC Alcobasa X Marikrit	31.97	51.10	40.77	41.53	-1.85	27.52*	38.53**	-22.68**	-30.58**
AVRDC Alcobasa X L-58	31.97	42.20	76.40	37.09	106.02**	138.98**	159.60**	44.89**	30.09**
AVRDC Alcobasa X LE-79	31.97	38.57	40.13	35.27	13.80	25.52	36.36*	-23.89**	-31.67**
S.E.±					3.70	4.27	4.27	4.27	4.27

Punjab Chuhara Check-1 (52.73) Vaishali Check-2 (58.73)

Underlined figures indicate best parent value
BRP indicates better parent
BSP indicates best parent
CK indicates check parent
* and ** - indicate significant at 5 and 1 per cent level, respectively.

parent and none over the best parent. With regard to standard heterosis for TLCV over check 1 and 2, there were as many as 23 and 29 crosses indicating significant negative heterosis.

4.2.3 Combining ability studies

4.2.3.1 Analysis of variance

Analysis of variance for combining ability in respect of 11 characters is presented in Table-19. Mean square due to hybrids, females, males and between female vs. male were significant for all the characters. The maximum variance for hybrids was noticed for fruit yield per plant followed by average fruit weight, whereas the least were for number of branches per plant and number of locules per fruit. A similar trend was noticed for females, males and female vs. male. The estimates of SCA variances were greater than corresponding GCA variances for all the characters. The ratio of GCA to SCA variances was less than unity in all the cases.

Testers contributed more than the lines for all the characters. Contribution of line X testers was of higher magnitude compared to either female or male contribution.

4.2.3.2 Combining ability effects

Estimates of general combining ability (gca) and specific combining ability (sca) effects for all the characters are presented in Table-20 and 21, respectively.

Table 19. Analysis of variance (mean sum of squares) for combining ability in respect of 11 characters in tomato (L X T)

Source of variation	D.F.	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of fruits/ cluster	No. of fruits/ plant	Avg.fruit weight (g)	Yield/ plant (g)	T.S.S.	No. of locules/ fruit	No. of whiteflies/ plant	Per cent of TLCV infection
Replication	2	4.23	0.87	3.66	1.32*	41.68	653.83*	30091.09	0.60**	0.07	0.79	12.62
Hybrids	49	251.44**	4.32**	15.15**	2.76**	148.00**	1677.17**	663087.30**	7.48**	4.32**	7.47**	1589.23**
Females	4	407.17**	6.14**	6.61*	2.26**	60.22**	921.17**	195623.90**	5.23**	8.18**	15.29**	2124.43**
Males	9	409.54**	9.39**	25.29**	5.42**	333.65**	3056.06**	1371052.00**	17.13**	6.99**	15.26**	3362.22**
Female Vs Male	36	194.62**	2.86**	13.56**	2.15**	111.35**	1416.40**	538036.60**	5.33**	3.23**	4.65**	1086.52**
Error	98	23.21	0.57	2.12	0.40	15.81	170.23	55527.04	0.03	0.05	0.44	29.85
Estimates of variance components												
GCA		0.84	0.02	0.02	0.01	0.54	3.85	1848.41	0.03	0.02	0.04	7.43
SCA		57.79	0.78	3.85	0.76	32.41	420.11	163673.00	1.76	4.20	1.43	353.04
GCA/SCA		0.01	0.02	0.01	0.01	0.02	0.01	0.01	0.02	0.01	0.03	0.02
Cont. % of Female		13.22	11.58	3.56	8.70	3.32	4.48	2.40	5.70	15.42	16.70	10.91
Cont. % of male		29.92	39.86	30.67	21.06	41.40	33.46	37.98	42.01	29.67	37.50	38.86
Cont. % of Female X Male		56.86	48.55	65.76	70.22	55.27	62.05	59.61	52.28	54.91	45.80	50.23

* and ** indicates significant at 5 and 1 per cent level, respectively.

Table 20. Estimates of gca effects of parents for 11 characters in tomato (L X T)

Parent	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of fruits/ cluster	No. of fruits/ plant	Avg. fruit weight (g)	Yield/ plant (g)	T.S.S.	No. of locules/ fruit	No. of whiteflies/ plant	Per cent of TLCV infection
I. LINES											
20/4 Alcobasa	3.04**	0.27*	-0.32	0.36**	1.18*	1.24	-10.23	0.63**	0.66**	-0.65**	-10.05**
20/6 Alcobasa	-0.46	0.04	-0.54*	0.06	-0.08	-5.91**	3.03	-0.21**	-0.63**	0.17	6.60**
20/5 Alcobasa	2.18**	0.14	0.37	-0.33**	-0.11	-3.14	29.23	-0.48**	-0.42**	-0.02	2.70**
20/2 Alcobasa	1.41*	0.34**	0.58**	0.13	1.25*	8.70**	100.50**	0.14**	0.14**	-0.61**	-7.72**
AVRDC Alcobasa	-6.17**	-0.78**	-0.09	-0.21*	-2.25**	-0.89	-122.53**	-0.08**	0.25**	1.10**	8.48**
S.E.±	0.69	0.11	0.21	0.09	0.57	1.87	33.75	0.03	0.03	0.10	0.78
II. TESTER											
N-229 8MF6	6.67**	0.59**	1.64**	0.44**	4.31**	6.50*	214.47**	0.81**	0.58**	-0.91**	-11.05**
79B1390	-0.98	-0.49**	-0.24	0.18	0.75	3.17	-4.40	0.65**	0.62**	-0.33*	-2.85*
CA-1	1.60	0.27	0.39	0.07	0.42	2.19	-74.20	0.70**	0.68**	-0.59**	-7.59**
UC-204B	-7.02**	-0.84**	-1.71**	-0.75**	-5.38**	-16.58**	-280.53**	-2.05**	-1.34**	1.18**	21.50**
DWD-2	-5.37**	-0.71**	-1.15**	-0.48**	-4.28**	-11.75**	-272.47**	-0.38**	-0.38**	1.39**	17.06**
DWD-1	-5.81**	-0.92**	-1.59**	-0.92**	-7.31**	-24.58**	-415.07**	-1.52**	-0.71**	1.47**	20.08**
L-15	-3.33**	-0.62**	-0.37	-0.30*	-0.98	-5.33	-67.33	-0.32**	-0.46**	0.39**	6.35**
Marikrit	5.70**	1.06**	0.23	0.57**	1.35	13.09**	84.33	0.16**	0.36**	-0.92**	-14.15**
L-58	5.98**	0.96**	0.59	0.96**	8.35**	18.23**	633.40**	1.00**	0.40**	-0.79**	-15.68**
LE-79	2.55*	0.70**	2.22**	0.24	2.75**	15.09**	181.80**	0.96**	0.25**	-0.88**	-13.67**
S.E.±	1.04	0.16	0.31	0.14	0.85	2.80	50.62	0.04	0.05	0.14	1.17

* and ** indicates significant at 5 and 1 per cent level, respectively.

4.2.3.2.1 Plant height

The lines which contributed significant positive gca effects were 20/4 Alcobasa, 20/5 Alcobasa and 20/2 Alcobasa, while the testers N-229 8MF6, Marikrit, L-58 and LE-79 had positive gca effects. The testers 79B1390 and CA-1 did not show significant effect. The remaining parents were indicating significant negative gca effect.

The cross 20/5 Alcobasa X 79B1390 exhibited the highest positive significant sca effect (13.35). Of the 50 crosses, 30 have recorded significant sca effects, of which 15 showed significant negative sca effects. The cross with highest significant negative sca effect was 20/6 Alcobasa X N-229 8 MF6.

4.2.3.2.2 Number of branches per plant

All the parents except 20/6 Alcobasa, 20/5 Alcobasa and CA-1 had significant gca effects. Marikrit, L-58, LE-79, N-229 8MF6, 20/4 Alcobasa and 20/2 Alcobasa have showed significant positive gca effects and were in that order of merit.

The sca effects were significant for 22 crosses, of which 11 crosses showed significant positive sca effects. The cross 20/5 Alcobasa X LE-79 attained the highest significant positive value (1.66) and was considered to be the best combination for this trait.

Table 21. Estimates of specific combining ability effect for 11 characters in tomato (L X T) hybrids

Crosses	Plant height (cm)	No. of branches/ plant	No. of clusters/ plant	No. of fruits/ cluster	No. of fruits/ plant	Avg. fruit weight (g)	Yield/ plant (g)	T.S.S.	No. of locules/ fruit	No. of whiteflies/ plant	Per cent of TLCV infection
1	2	3	4	5	6	7	8	9	10	11	12
20/4 Alcobasa X N-229 8MF6	5.17*	0.31	0.69	-0.05	-0.90	-5.19	-153.17	-1.04**	0.20*	0.35	1.90
20/4 Alcobasa X 79B 1390	0.42	-0.08	1.73**	0.55*	9.89**	3.38	521.37**	-0.58**	0.02	-0.47	-6.94**
20/4 Alcobasa X CA-1	3.80	0.56	2.60**	-0.58*	0.55	12.79*	196.83	-1.46**	-1.04**	-0.58*	-5.32**
20/4 Alcobasa X UC-204B	6.19**	0.74*	0.87	-1.48**	5.02**	24.89**	194.83	2.08**	1.05**	-0.14	-18.05**
20/4 Alcobasa X DWD-2	2.54	-0.06	1.25*	0.40	1.42	-1.78	-54.90	0.24**	-0.15	-0.88**	-7.68**
20/4 Alcobasa X DWD-1	0.72	-0.25	-2.05**	0.18	-0.38	-5.44	-10.63	0.72**	0.85**	-0.96**	-10.00**
20/4 Alcobasa X L-15	-11.33**	-0.58	-3.47**	-0.94**	-6.71**	-19.69**	-361.03**	0.19*	0.17	1.28**	22.97**
20/4 Alcobasa X Marikrit	0.31	-0.09	-0.97	-0.18	-2.05	-10.61	-175.03	-0.22**	-0.65**	-0.21	1.50
20/4 Alcobasa X L-58	3.69	0.57	0.90	-0.13	2.95	5.08	267.57**	0.07	-0.69**	0.06	0.40
20/4 Alcobasa X LE-79	-11.51**	-1.11**	-1.56**	-0.75**	-9.78**	-3.44	-425.83**	0.00	0.23*	1.55**	21.22**
20/6 Alcobasa X N-229 8MF6	-15.84**	-2.03**	0.24	-1.32**	-7.41**	-22.87**	-590.10**	0.66**	-0.31**	2.66**	42.12**
20/6 Alcobasa X 79B 1390	-13.25**	-0.79*	-1.98**	-0.65*	-7.19**	-17.87**	-424.57**	0.65**	-0.62**	0.27	12.02**
20/6 Alcobasa X CA-1	8.87**	0.29	0.32	1.22**	5.48**	-19.05**	-184.77	-0.09	0.58**	-1.43**	-20.27**
20/6 Alcobasa X UC-204B	-5.94**	0.23	-0.97	-0.96**	-4.05*	-14.62*	-190.10	-1.38**	-0.66**	-0.10	9.57**
20/6 Alcobasa X DWD-2	-2.23	0.50	-0.13	-0.63*	-3.49*	-9.45	-182.50	-0.05	1.11**	1.29**	5.18*
20/6 Alcobasa X DWD-1	3.42	0.11	1.98**	-0.79**	-2.12	-6.62	-55.57	-1.91**	-1.29**	0.48	10.99**
20/6 Alcobasa X L-15	9.56**	1.11**	1.92**	1.10**	8.21**	24.37**	261.37*	0.69**	0.46**	-1.58**	-29.04**
20/6 Alcobasa X Marikrit	9.74**	0.87**	1.32*	0.89**	5.88**	23.21**	518.37**	0.65**	0.64**	-0.93**	-12.38**
20/6 Alcobasa X L-58	2.42	-0.07	-0.38	1.00**	6.88**	37.84**	983.63**	0.17*	-0.26**	-0.89**	-17.95**
20/6 Alcobasa X LE-79	3.26	-0.21	-2.34**	0.12	-2.19	5.05	-135.77	0.61**	0.35**	0.23	-0.23
20/5 Alcobasa X N-229 8MF6	4.46*	-0.10	1.33*	0.77**	6.96**	24.19**	600.03**	0.94**	-0.79**	-1.22**	-17.52**
20/5 Alcobasa X 79B 1390	13.35**	0.38	0.64	0.54*	1.18	2.86	-44.10	0.20**	0.97**	-0.37	-12.75**
20/5 Alcobasa X CA-1	-0.63	0.22	0.24	0.35	2.18	17.84**	205.37*	0.78**	0.54**	0.66*	2.73
20/5 Alcobasa X UC-204B	-6.71**	-1.20**	-2.42**	-0.57*	-4.02*	-17.40**	-216.30*	-1.10**	-0.87**	0.92**	13.47**

Contd. ......

Contd. ......

1	2	3	4	5	6	7	8	9	10	11	12
20/5 Alcobasa X DWD-2	-9.93**	-1.66**	-2.51**	-0.84**	-5.12**	-22.23**	-224.37*	-2.78**	-1.83**	0.62*	17.91**
20/5 Alcobasa X DWD-1	-8.79**	-0.59	-2.07**	-0.40	-2.09	-9.40	-81.77	-1.63**	-1.50**	0.94**	14.89**
20/5 Alcobasa X L-15	-1.87	-0.65*	-0.73	0.05	-3.09	-0.98	-309.50**	1.44**	1.35**	-0.62*	0.95
20/5 Alcobasa X Marikrit	2.20	1.00**	-0.26	-0.52	-3.42*	-16.73**	-365.83**	1.06**	0.43**	0.46	4.95*
20/5 Alcobasa X L-58	4.22*	0.94**	0.04	0.73**	2.58	3.23	-34.23	1.28**	0.39**	-0.70*	-12.62**
20/5 Alcobasa X LE-79	3.72	1.66**	5.75**	-0.13	4.85**	18.60**	470.70**	-0.18*	1.31**	-0.68*	-12.00**
20/2 Alcobasa X W-229 8MF6	-1.43	0.44	2.55**	-0.03	-4.74**	-12.98*	-385.90**	-0.28**	0.25*	-0.13	-3.23
20/2 Alcobasa X 79B 1390	4.62*	0.82*	0.17	-0.19	-1.52	19.35**	109.63	-0.02	0.20*	-0.38	-7.03**
20/2 Alcobasa X CA-1	-5.03*	-0.34	-0.97	-0.29	-2.85	14.50*	23.77	0.26**	-0.46**	-0.22	-3.25
20/2 Alcobasa X UC-204B	-4.44*	-1.16**	-0.79	-1.03**	-5.39**	-29.24**	-287.57**	-1.72**	-1.43**	1.38**	23.89**
20/2 Alcobasa X DWD-2	3.67	0.94**	1.48*	0.76**	5.18**	16.26**	322.70**	1.64**	0.37**	-0.59*	-16.84**
20/2 Alcobasa X DWD-1	-1.98	0.18	-0.88	0.13	-0.79	-8.90	-122.70	1.28**	0.94**	1.36**	13.11**
20/2 Alcobasa X L-15	9.43**	0.72*	2.47**	0.92**	7.88**	27.18**	686.90**	0.92**	0.45**	-1.13**	-15.39**
20/2 Alcobasa X Marikrit	-9.09**	-1.76**	-1.03	-0.29	-3.45*	-6.57	-251.43*	-1.13**	-0.13	0.31	11.89**
20/2 Alcobasa X L-58	-0.27	-0.20	1.17	-0.11	0.21	-9.04	-289.83**	-0.57**	0.83**	-0.35	-1.10
20/2 Alcobasa X LE-79	4.53*	0.39	0.94	0.11	5.48**	-10.57	194.43	-0.37**	-1.02**	-0.26	-1.98
AVRDC Alcobasa X W-229 8MF6	7.65**	1.39**	0.29	0.61*	6.09**	16.84**	529.13**	-0.27**	0.65**	-1.67**	-23.26**
AVRDC Alcobasa X 79B 1390	-5.13*	-0.33	-0.56	-0.25	-2.35	-7.72	-162.33	-0.24**	-0.57**	0.94**	14.70**
AVRDC Alcobasa X CA-1	-7.01**	-0.72*	-2.20**	-0.71**	-5.35**	-26.08**	-241.20	0.51**	0.37**	1.57**	26.12**
AVRDC Alcobasa X UC-204B	10.91**	1.39**	3.31**	1.07**	8.45**	36.36**	499.13**	2.12**	1.90**	-2.06**	-28.88**
AVRDC Alcobasa X DWD-2	5.95**	0.29	-0.08	0.30	2.01	17.19**	139.07	0.95**	0.50**	-0.44	1.43
AVRDC Alcobasa X DWD-1	6.63**	0.56	3.02**	0.87**	5.38**	30.36**	270.67**	1.53**	1.00**	-1.82**	-28.99**
AVRDC Alcobasa X L-15	-5.79**	-0.60	-0.20	-1.14**	-6.29**	-30.89**	-277.73**	-3.24**	-2.42**	2.06**	20.51**
AVRDC Alcobasa X Marikrit	-3.15	-0.01	0.94	0.09	3.05	10.69	273.93**	-0.35**	-0.30**	0.37	-5.90*
AVRDC Alcobasa X L-58	-10.06**	-1.24**	-1.73**	-1.50**	-12.62**	-37.12**	-927.13**	-0.96**	-0.27**	1.88**	31.27**
AVRDC Alcobasa X LE-79	0.01	-0.72*	-2.79**	0.65*	1.65	-9.64	-103.53	-0.06	-0.86**	-0.84**	-7.01**
S.E.±	2.07	0.32	0.63	0.27	1.71	5.61	101.25	0.08	0.10	0.29	2.35

* - Significant at 5 per cent level.

** - Significicnat at 1 per cent level.

4.2.3.2.3 Number of clusters per plant

Among the females 20/2 Alcobasa and 20/6 Alcobasa showed significant positive and negative gca effects respectively. Out of 10 male parents, two were significant in positive direction and N-229 8MF6 (1.64) and LE-79 (2.22) were found to be superior general combiners.UC-204B, DWD-2 and DWD-1 showed significant negative gca effects.

Twenty four crosses showed significant sca effects. Only two crosses viz., 20/5 Alcobasa X LE-79 (5.75) and AVRDC Alcobasa X UC-204B (3.31) recorded comparatively high positive values. 20/4 Alcobasa X L-15 was a poor combination for number of cluster per plant.

4.2.3.2.4 Number of fruits per cluster

The parents, 20/4 Alcobasa, N-229 8MF6, Marikrit and L-58 were found to be significantly superior general combiners for higher number of fruits per cluster.

Only 14 crosses have exhibited positive significant sca effect for fruit number per cluster. The maximum sca effects were recorded in 20/6 Alcobasa X CA-1. A total of 15 crosses showed significant negative sca effects. The poorest cross combination was AVRDC Alcobasa X L-58.

4.2.3.2.5 Number of fruits per plant

Significant positive general combining ability effects were observed in five parents namely L-58 (8.35), N-229 8MF6 (4.31), LE-79 (2.75), 20/2 Alcobasa (1.25) and 20/4 Alcobasa (1.18). The parent DWD-1 had the highest (-7.31) significant negative gca effect.

Out of 50 crosses, 29 showed significant sca effects of which 14 were in positive direction. The best cross with highest sca effect was 20/4 Alcobasa X 79B1390 (9.89) followed by AVRDC Alcobasa X UC-204B and 20/6 Alcobasa X L-15; and the poorest combination was AVRDC Alcobasa X L-58 (-12.62).

4.2.3.2.6 Average fruit weight

Only one female 20/2 Alcobasa exhibited positive significant gca effect. Out of 10 males, 4 showed significant positive gca effects and the highest gca value was recorded in L-58 (18.23) followed by LE-79 (15.09).The male parents DWD-1, DWD-2 and UC-204B exhibited poor general combining ability for this trait.

Estimates of sca effects were significant for 29 crosses of which 16 were in positive direction.The crosses 20/6 Alcobasa X L-58 (37.84) and AVRDC Alcobasa X L-58 (-37.12) were the best and poorest combinations respectively.

4.2.3.2.7 Fruit yield per plant

Among the 15 parents, only 4 have shown significant positive gca effects. They were 20/2 Alcobasa, N-229 8MF6, L-58 and LE-79. The genotypes AVRDC Alcobasa, UC-204B, DWD-2 and DWD-1 exhibited significant negative gca effect for this character.

Twenty eight crosses manifested significant sca effects of which half were positive and the other half were in negative direction. The cross 20/6 Alcobasa X L-58 (983.63) was the best combination followed by 20/2 Alcobasa X L-15 (686-90), 20/5 Alcobasa X N-229 8MF6 (600.03), AVRDC Alcobasa X N-229 8MF6 (529.13), 20/4 Alcobasa X 79B1390 (521.37) and 20/6 Alcobasa X Marikrit (518.37).

4.2.3.2.8 Total soluble solids

All the 15 parents recorded significant gca effect. The parent L-58 and LE-79 were the best general combiners, while UC-204B was the poor combiner.

Except 6 crosses, all have recorded significant sca effects, of which 20 were negative and 24 in positive direction. The cross with the highest positive sca effect was AVRDC Alcobasa X UC-204B (2.12) followed by 20/4 Alcobasa X UC-204B (2.08) and AVRDC Alcobasa X L-15 had the lowest (-3.24) sca effects.

4.2.3.2.9 Number of locules per fruit

It could be seen from Tables 20 and 21 that all the parents have shown significant general combining ability effects. However, significant negative gca effects that represent for few locules per fruit were observed in six parents namely, 20/6 Alcobasa, UC-204B, DWD-1, DWD-2, L-15 and 20/5 Alcobasa which appeared to be of importance.

All the crosses exhibited significant sca effects (except 4) of which 20 crosses were in negative direction. The cross AVRDC Alcobasa X L-15 with sca effect of -2.42 was the best combination for least number of locules per fruit.

4.2.3.2.10 Number of white flies per plant

The significant gca effect was observed for all the parents except 20/6 Alcobasa and 20/5 Alcobasa. Among the females, 20/4 Alcobasa and 20/2 Alcobasa had significant negative gca effects; whereas among testers, N-229 8MF6, 79B1390, CA-1, Marikrit, L-58 and LE-79 have exhibited significant negative gca effect.

Out of 50 crosses, significant sca effects were noticed for 31 crosses. Seventeen hybrids showed significant negative sca effects. The highest negative sca (-2.06) effect was observed in the cross AVRDC Alcobasa X UC-204B.

4.2.3.11 Per cent of TLCV infection

Both male and female parents recorded significant gca effects. However, 20/4 Alcobasa and 20/2 Alcobasa among females and N-229 8MF6, 79B1390, CA-1, Marikrit, L-58 and LE-79 among males have shown significant negative gca effects.

Thirty nine crosses have shown significant sca effect of which 21 and 18 crosses exhibited significant negative and positive sca effect respectively. The highest negative sca effect was recorded in the cross combination 20/6 Alcobasa X L-15 followed by AVRDC Alcobasa X DWD-1 and AVRDC Alcobasa X UC-204B.

4.3 EXPERIMENT-III : MANAGEMENT OF SUMMER TOMATOES BY USE OF TRAP CROP

The results on plant height, number of branches per plant, number of white flies and per cent TLCV on tomato inter planted with maize are presented in Table-22 and 23.

4.3.1 Plant height

The row direction of trap crop (maize) and tomato had no significant effect on plant height of tomato. However, slightly taller tomato plants (39.50 cm) were observed when interplanted in maize in North South direction as compared to East-West direction (36.54 cm).

Table 22. Influence of trap crop (maize) on growth parameters of summer tomato

Directions	ROW PROPORTIONS															
	Plant height (cm)								Average number of branches per plant							
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean
North-South (D_1)	57.97	38.40	30.87	57.40	41.33	28.63	21.93	39.50	1.67	2.40	3.17	1.33	2.70	3.13	4.43	2.70
East-West (D_2)	47.43	42.67	31.03	48.10	39.13	26.87	20.53	36.54	1.77	2.33	4.07	1.57	3.23	4.33	4.77	3.15
Mean	52.70	40.54	30.95	52.75	40.23	27.75	21.23	38.02	1.72	2.37	3.62	1.45	2.97	3.73	4.60	2.93
Comparison of			S.E.±		C.D. at 5%						S.E.±		C.D. at 5%			
Directions (D)			1.38		NS						0.12		NS			
Row proportions (R)			1.63		4.75						0.25		0.73			
Interactions (D X R)			2.54		7.40						0.35		1.02			

Table 23. Influence of trap crop (maize) on incidence of TLCV in summer tomato

Directions	ROW PROPORTIONS															
	Percentage of TLCV								Average number of whiteflies per plant							
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean
North-South (D_1)	9.23	63.37	83.07	9.59	60.48	90.00	90.00	57.96	0.33	1.93	3.00	0.33	2.43	3.67	4.33	2.29
East-West (D_2)	12.75	73.91	90.00	11.57	46.77	87.43	90.00	58.92	0.67	2.73	3.93	0.33	2.23	4.23	4.60	2.67
Mean	10.99	68.64	86.54	10.58	53.63	88.72	90.00	58.44	0.50	2.33	3.47	0.33	2.33	3.95	4.47	2.48
Comparison of			S.E.±		C.D. at 5%						S.E.±		C.D. at 5%			
Directions (D)			0.29		NS						0.17		NS			
Row proportions (R)			1.74		5.07						0.24		0.70			
Interactions (D X R)			2.29		6.69						0.35		NS			

Among the row proportions, sowing of maize and transplanting of tomato in 2:1 row proportions (R_4) resulted in tallest plants (52.75 cm) of tomato followed by 1:1 row proportions (52.70 cm). The tomato plants as sole crop had the least height (21.23 cm).

Interaction between row direction and row proportions of maize had significant effect on tomato plant height. At the ratio of 1:1 and 2:1 in North-South direction influenced significantly taller growth of tomato over other treatment combinations. However, sole tomato planting in either directions were found on par in their plant growth (height).

4.3.2 Number of branches

Planting pattern had no significant effect on number of branches of tomato.

Among the intercropping treatments, maize + tomato at 2:3 row proportions has recorded significantly higher (3.73) number of branches per plant of tomato and was found on par with 1:3 row proportion.

Interaction effects were non-significant.

4.3.3 Per cent TLCV infection

The direction of maize planting had no influence on infection of tomato leaf curl virus.

Row proportion exerted significant influence on TLCV infection. The least per cent (10.58 %) of TLCV incidence was in the treatment 2:1 (maize : tomato) row proportion. The higher incidence of TLCV (90.00 %) was recorded in tomatoes planted without maize as inter crop.

Interaction effect was significant. Sowing of maize + transplanting of tomato in North-South direction at 1:1 row proportion has recorded the least (9.23 %) TLCV in tomato followed by North-South direction of maize with 2:1 proportion and East-West direction at same (1:1 and 2:1) row proportions.

4.3.4 Number of whiteflies per plant

Planting of maize in either directions had no significant influence on white flies on tomato.

A highly significant influence of maize intercropping with tomato was observed on number of whiteflies on tomato plant. Among the row proportions, maize + tomato at 2:1 ratio had the least count (0.33) of whiteflies and was on par with 1:1 row proportions. The higher number of white flies (4.47) per plant were observed on tomato without a trap crop.

It may be interesting to note here that inspite of low incidence of TLCV on tomatoes interplanted with maize, such plants did not bear any fruits, probably because of heavy shading. The incoming radiation on tomato crop canopy was examined.

4.3.5 Crop canopy radiation

The data on light intensity (Lux) at tomato canopy under different levels of row proportions and direction of maize as trap crop are presented in Table-24a and 24b.

The row direction had significant effect on light interception on tomato canopy. East-West rows had higher lux readings (233.1 lux) on tomato canopy compared to North-South rows of trap crop when recorded at 9.30 am.

Among the different intercropping treatments, tomato received significantly higher lux (286.2 and 280.3 lux respectively) at 9.30 a.m. when proportioned at 2:3 and 1:3 with maize. The row proportion of 2:1 (maize : tomato) significantly obstructed the light (117.3 lux), while the sole crop of tomato had the highest lux (334.8 lux).

The interaction between the direction and row proportion was significant. The highest light was received on tomato as sole crop irrespective of row direction. Among the intercropping treatments, maize + tomato at 1:3 and 2:3 row proportions with East-West direction of planting have recorded higher light interception (296.3 and 300 lux light intensity respectively), where as 2:1 and 2:2 row proportions with North-South direction has recorded significantly lower light intensity (97.3 and 121.3 lux respectively).

Table 24a. Influence of trap crop (maize) on interception of light on tomato

Directions	ROW PROPORTIONS															
	LUX meter reading at 9.30 a.m.								LUX meter reading at 12.30 p.m.							
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean
North-South (D_1)	144.0	188.0	264.3	97.3	121.3	272.3	329.0	202.3	275.0	311.3	334.3	203.3	254.7	356.3	329.0	294.9
East-West (D_2)	180.0	224.0	296.3	137.3	153.0	300.0	340.7	233.1	298.0	346.3	350.3	282.7	291.0	365.3	373.7	329.6
Mean	162.0	206.0	280.3	117.3	137.2	286.2	334.8	217.7	286.5	328.8	342.3	243.0	272.8	360.8	351.3	312.2
Comparison of			S.E.±		C.D. at 5%						S.E.±		C.D. at 5%			
Directions (D)			0.85		5.17						3.32		20.18			
Row proportions (R)			2.23		6.52						6.52		19.03			
Interactions (D X R)			3.04		8.89						9.16		26.73			

Table 24b. Influence of trap crop (maize) on interception of light on tomato

Directions	ROW PROPORTIONS															
	LUX meter reading at 3.30 p.m.								Average of three readings							
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean	R_1	R_2	R_3	R_4	R_5	R_6	R_7	Mean
North-South (D_1)	311.0	341.7	359.3	181.7	201.0	361.7	367.7	303.4	243.3	259.3	320.0	160.7	192.5	330.1	350.7	265.2
East-West (D_2)	257.0	297.7	306.0	213.0	234.7	353.7	365.3	289.6	245.0	289.3	317.2	211.0	226.2	339.7	359.9	284.1
Mean	284.0	319.7	332.7	197.3	217.8	357.7	366.5	296.5	244.2	274.3	318.6	185.9	209.4	334.9	355.3	274.6
Comparison of			S.E.±		C.D. at 5%						S.E.±		C.D. at 5%			
Directions (D)			1.26		7.67						2.40		14.63			
Row proportions (R)			2.31		6.73						4.42		12.90			
Interactions (D X R)			3.27		9.55						6.27		18.29			

Almost similar trend of treatments on light interception was recorded at other times (12.30 pm and 3.30 pm) except that the amount of incoming radiation changed with the time; the highest being at 12.30 pm. Even the mean data over different timings followed a similar pattern.

In view of the fact that maize intercropping at appropriate population certainly reduced TLCV incidence but came in the way of light interception and thus hindered yielding ability of tomatoes. Therefore, the experiment was modified for the subsequent season to examine whether making provision for balanced interception of light through decreasing the trap crop population could reduce TLCV incidence and could enable tomato plant to bear fruits. The results on Table-25 suggest that neither nursery practices nor its interaction with population density of maize had any significant effect on tomato plant morphology (height and number of branches), incidence of TLCV and or white flies. However, density of maize as intercrop with tomato exerted significant effect on all the above characters under observation. The height of tomato increased with increase in the density of maize. The sole crop of tomato after 90 days of planting had just 28.17 cm height, while those under 100 per cent density of maize grew to a height of 49.88 cm. On the other hand, there was a progressive decrease in the number of branches of tomato with increase in the density of maize population (highest number of branches of 4.47 in control as against 1.82 in 100 per cent density).

able 25. Influence of nursery practices and population density of trap crop (maize) on summer tomato

Nursery practices	POPULATION DENSITY (MAIZE)																			
	Plant height (cm)					Average number of branches/plant					Percentage of TLCV					Avg. No. of whiteflies/plant				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
ormal nursery (N_0)	49.43	43.73	34.93	28.10	39.05	1.60	2.97	3.57	4.27	3.10	22.10	63.65	87.65	90.00	65.85	1.77	2.27	3.93	4.07	3.01
ursery with Maize border (N_1)	50.33	46.83	31.90	28.23	39.32	2.03	3.93	4.37	4.67	3.75	11.57	67.65	80.70	83.96	60.97	0.97	3.10	3.83	4.17	3.02
ean	49.88	45.28	33.42	28.17	39.19	1.82	3.45	3.97	4.47	3.43	16.83	65.65	84.18	86.98	63.41	1.37	2.69	3.88	4.12	3.02
omparison of			S.E.±		C.D. at 5%			S.E.±		C.D. at 5%			S.E.±		C.D. at 5%			S.E.±		C.D. at 5%
ursery practices (N)			0.77		NS			0.12		NS			1.17		NS			0.10		NS
opulation density (D)			1.54		4.74			0.19		0.59			2.12		6.55			0.21		0.65
nteractions (N X D)			2.03		NS			0.27		NS			2.85		NS			0.28		NS

With regard to the per cent incidence of TLCV, the least incidence (16.83 %) was recorded on tomatoes interplanted with maize at 100 per cent density. Progressive decrease in the density of maize population gave room to tremendous increase of TLCV; and the maximum incidence (86.98 %) was on sole crop of tomato. With regard to the whitefly count, a similar trend as that of TLCV was recorded. The least number (1.37) of whitefly on tomato were noticed when interplanted with 100 per cent density of maize, while the highest (4.12) number of whiteflies per plant were observed on the sole crop of tomato.

Inspite of the modification of the experiment to manage TLCV on summer tomatoes, there was hardly any advantage on productivity (yield) of tomato plant. Tomatoes under 100 per cent density of maize suffered for want of light, while those with sparse density of maize or sole crop were affected severely by TLCV. Thus tomatoes under both the situations suffered from one reason or the other and hence did not yield.

4.4 TEST OF TLCV RESISTANCE BY ARTIFICIAL INOCULATION

On the basis of the information obtained from experiments conducted under epiphytotic conditions, certain parents which showed field resistance/tolerance to TLCV were put to test under artificial inoculation in green house conditions along with susceptible entries and the hybrids involving the parents of tolerance and susceptibility. The results on TLCV infection and the survival of whitefly on each of these test entries are presented in Table-26.

It can be observed from the table that all the entries developed symptoms of TLCV 30 days after inoculating with viruliferous whiteflies in the cage. However, there was difference in the per cent infection among entries. The check entry Pusa Ruby had 100 per cent infection; whereas, 20/6 Alcobasa had only 50.00 per cent infection followed by 20/5 Alcobasa. Corresponding to TLCV infection the survival count of whitefly was maximum on Pusa Ruby, while was least on 20/6 Alcobasa and 20/5 Alcobasa.

4.5 INCIDENCE OF TLCV ON F_2 POPULATION OF SUMMER TOMATO

The scoring for incidence of TLCV on two F_2 populations of 20/6 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6 constituting a total population of 252 and 246 plants respectively, suggested that it was not possible to make distinct classes as indicated in material and methods. However plants were distinguished as affected and unaffected groups depending upon the symptoms and the yields obtained out of them.

From the Table-27 it can be noted that F2 population of 20/6 Alcobasa X L-58, there were 179 and 72 plants respectively under the group viz., unaffected and affected,

Table 26. Per cent of TLCV incidence in selected genotypes under artificial inoculation

Sl. No.	Genotypes/F_1	No. of whiteflies per cage	No. of whiteflies alive after 20 days	Percentage of TLCV infection after 30 days
1.	20/4 Alcobasa	30	28	79.50
2.	20/6 Alcobasa	30	23	50.00
3.	20/5 Alcobasa	30	23	55.40
4.	20/2 Alcobasa	30	27	83.00
5.	AVRDC Alcobasa	30	24	60.00
6.	L-58	30	28	86.70
7.	LE-79	30	25	66.20
8.	N-2298MF$_6$	30	25	76.50
9.	Pusa Ruby (Check)	30	30	100.00
10.	20/6 Alcobasa X L-58	30	29	61.70
11.	20/5 Alcobasa X N-2298MF$_6$	30	28	65.50

Table 27. Segregation in F_2 population for incidence of TLCV in summer tomatoes

Sl. No.	Crosses	Observed		Ratio	Expected		χ^2	Probability (P)
		Unaffected	Affected		Unaffected	Affected		
1.	20/6 Alcobasa X L-58	179	72	3:1	188.25	62.75	0.225	0.7 to 0.5
2.	20/5 Alcobasa X N-2298MF_6	146	100	9:7	138.375	107.625	0.960	0.5 to 0.3

thereby fitting to a monogenic ratio of 3:1 (tolerance : susceptible). The expected frequencies were 188.25 and 62.75 respectively. But such a situation could not be observed in the segregating population of 20/5 Alcobasa X N-229 8MF6. A digenic ratio of 9:7 (tolerance : susceptible) was fitting to chi-square test suggesting a complementary gene interaction for TLCV resistance.

DISCUSSION

V. DISCUSSION

Cultivation of tomato, has been endangered by tomato leaf curl virus (TLCV) to the extent that most vegetable growers avoid taking the crop especially in summer (January-May) when population of *Bemisia tabaci*, the vector, of gemini virus becomes dense and at times results in abandoning of whole fields prior to harvest. Since the host range of both virus and vector are diverse and widely distributed, it is impracticable to adopt crop health measures such as eradication of collateral hosts. The primary infection in any one field is widely scattered with a random pattern of spread, thus making it difficult to advocate roguing of infected plants. The two important yield components, fruit number and average fruit weight are drastically influenced in TLCV affected plants resulting in sharp decline in total yields.

Attempts to reduce the disease incidence by chemical control of vector population, soil mulching with yellow polyethylene sheets to attract and kill the whiteflies and physical barriers like netting often were ineffective (Saikia and Muniyappa, 1989). Oil sprays like mineral oils have recently been of relatively wide use in the control of many diseases caused by fungi and viruses (Russel, 1978). Singh *et al.* (1973) in India and Yassin *et al.* (1982) in Sudan were the first to apply mineral oil, cotton seed oil, sesame and groundnut oil sprays against TLCV. But promising results were not obtained, as regards to the disease control, as well as increase in tomato fruit yield. Further, the use of *Lablab vulgaris* L. (lubia bean) and maize as trap crops to reduce the TLCV incidence (Yassin, 1984) was not encouraging. Consequently, host resistance was thought to be 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. But development of TLCV resistant cultivars is still awaited despite the fact that the disease was reported more than four decades ago by Vasudeva and Sam Raj (1948). Therefore, without question, built-in host plant resistance is by far the most important disease control strategy. This is more necessary in case of TLCV disease as nothing parallel to fungicide is available for field use to check TLCV. Once a sensitive variety has become infected in the field by TLCV, there is little that can be done to control. Besides, application of chemicals for the control of vector often has a low efficacy in checking the TLCV spread.

Host plant resistance for disease is a rule and not an exception. Resistance breeding essentially involves (i) identification of resistant source and (ii) its successful introgression into commercial variety. The full potential of available sources of resistance can only be realized if the genetics of disease resistance is understood.

The principal concern of the present investigation was (i) whether tomato can be grown successfully by use of trap crop in summer with existing variety and (ii) if not, to assess the possibility of to developing a variety/hybrid through identification of resistant/tolerance source and gene transfer to cultivated types.

5.1 USE OF TRAP CROP IN SUMMER TOMATOES

The cultivation of tomato in summer is a lucrative business, inspite of low yields due to TLCV, because of very high market prices. In the absence of resistant variety/hybrid the cultivators use available variety and try to grow the crop. In recent years, cv. Megha released by University of Agricultural Sciences, Dharwad, has become very popular because of its multiple disease resistance to major diseases viz., leaf spot diseases and bacterial wilt but not to TLCV. This variety was chosen for this study and was interplanted with varying plant densities and row proportion of maize as trap crop. Maize being a good host for the vector, it was thought that it would attract the vector and hence reduce the incidence and spread of TLCV.

It was evident from the studies that intercropping tomato with maize at row proportions of 1:1 and 2:1 (maize : tomato) restricted the movement of whiteflies and reduced the incidence of TLCV considerably compared to sole crop of tomato.

Row direction on their own did not exert any influence but interacted with row proportions of maize. The rows in North-South direction with 1:1 ratio (Maize : Tomato) had a least incidence (9.23 %) of TLCV on tomato. But then; such tomatoes too didnot yield anything under dense shade. The sole crop of tomato was completely infected with TLCV and remained unfruitful. Although tomatoes under trap crop were less infective, they were deprived of sunlight to an extent of 52 per cent of total incoming radiation thus grew lanky (59.7 % taller than control) and hardly flowered and fruited. Therefore an ultimate aim of cultivating summer tomatoes was nullified. Eventhough the previous workers (Yassin, 1984; Rao and Willey, 1980 and Sastry and Singh, 1971) also recorded low incidence of TLCV by interplanting with maize and tomato yields were too low to merit adoption of the practice.

These experiences led to the modification of the experiment. It was thought that whether trapping the whiteflies in the nursery stage itself would reduce the population of the vectors and also facilitate reduction of the density of trap crop to allow sufficient sunlight to the main crop. The results of this experiment also led to the conclusions that even the nursery protected seedlings with trap crop when planted open was as bad as unprotected seedlings when planted as a sole tomatoes. However,it can be inferred that tomatoes interplanted with 100 per cent population of intercrop (maize) could significantly reduce the incidence of TLCV (16.83 %), but unfortunately remained unfruitful. In view to increase incidental light on tomato canopy through reducing the maize population by 75 or 50 per cent, progressively increased the incidence of TLCV, thus bringing out no advantage to tomato crop. Therefore, under circumstances existing it is not possible to raise economic tomatoes in summer with varieties on hand by use of trap crop like maize. An alternative could be to go in for a variety/hybrid that could tolerate or resist TLCV. As on today, there are no references to show that there is any resistant hybrid/variety with in-built-resistance to TLCV. However, it was clear that screening of varieties, hybrids and populations of tomatoes for resistance to TLCV could be done reliably in the summer season under Dharwad condition.

5.2 SOURCE OF RESISTANCE TO TLCV AND GENETIC DIVERGENCE

Any breeding programme, including one that involves host plant resistance to pathogens or their vectors, must begin with extensive screening of germplasm. Success in locating resistance to TLCV breeding is directly related to the availability of diversity in germplasm for resistance either to TLCV or its vector. The genes for resistance to TLCV have been reported in wild species like *L. hirsutum, f. typicum, L. peruvianum, L. pimpinellifolium* (Banerjee and Kalloo, 1989b; Rick, 1987 and Pilowsky and Cohen, 1990); *L. cheesmani*

(Moustafa and Nakhla, 1990) and *L. chilense* (Kheyr *et al.*, 1994). But transfer of these genes to cultivated species was found very difficult, because of barriers to gene exchange. Although there are stray cases of success in transferring TLCV resistance from wild relatives, the progenies inherited many features of wild species along with genes of TLCV resistance. This necessitated the search for genes in related subspecies of *L. esculentum* itself. In view of that, an attempt was made to screen 402 genotypes/breeding lines belonging to diverse origin. The reaction of genotypes to TLCV under epiphytotic conditions in the summer season has an interesting pattern. In general, the potato leaf types belonging to *L. esculentum* Var. *grandiflorum* were carrying less load of whiteflies and in turn with none or less symptoms of TLCV (Plate-5). They had good fruit set and development. On the other hand, the cultivated types *L. esculentum* were affected severely (Plate-6) (40-100 %), indicating a distinct diversity among the genotypes. This was confirmed from the data on D^2 values that distinguished genotypes into 4 clusters. The resistant/tolerant group of potato leaf types were congregated in cluster-II and the of commercial types in cluster-I with a dissimilarity coefficient between the two clusters being as high as 213.37. Further, the study on canonical variate analysis amply proved that the population contributed the highest divergence (0.950) for the character TLCV resistance /tolerance followed by population of

Plate 5. Potato leaf type for TLCV tolerance and fruiting

Plate 6. A commercial tomato variety with 100 per cent infestation of TLCV

whitefly and fruit yield per plant. The canonical graph (Fig.1) gave a clear idea of distribution of genotypes wherein all the Alcobasa types which had shown tolerance/resistance to TLCV, were located at the farthest end of the graph, implying their distinctive characters. These findings are fairly valid because of high (97.007 %) total variability covered by the two canonical roots. It was noted by Sachan and Sharma (1971) and Gadekar *et al.* (1992) that it is essential to have at least 95 per cent of the variability to be contributed by a maximum of two canonical roots to accept the real variability. Thus, it would be sound enough to select donor parents for resistance to TLCV from Cluster-II and IV of D^2 which corresponds to cluster-VII and IX of canonical graph (Fig.1). The genotypes included were 20/1 Alcobasa,20/2 Alcobasa, 20/4 Alcobasa, 20/5 Alcobasa, 20/6 Alcobasa and AVRDC Alcobasa. All these genotypes are potato leaf types and such genotypes having potato leaf character were found tolerant/resistant to TLCV by Shoba and Armugaum (1991) also.

These genotypes could be utilized in resistance breeding programme either to develop hybrids or varieties incorporating the genes of these types into commercial varieties.

5.3 BREEDING FOR RESISTANCE TO TLCV COMBINED WITH ECONOMIC TRAITS

An ideotype of summer tomato is expected to have built in resistance/tolerance of TLCV with a capacity to yield 30 t/ha (around 1 kg/plant) of each fruit weighing about 60-80 g of red fruits. The genetic behaviour of various breeding lines, cultivars and *Lycopersicon* sp., showing various levels of resistance reaction to TLCV under field conditions, suggested that the reaction of tomato plants to the disease is an inherited character. The resistance source for TLCV was found in economically less important Alcobasa types. Therefore, transferring resistance from Alcobasa type to good horticultural types through breeding programme is essential. Thus, the work on hybridization between selected Alcobasa types (Potato leaf type) and genotypes having desired horticultural traits, but susceptible to TLCV, was undertaken. The results of this study are discussed here under.

5.3.1 Performance of Hybrids (Heterosis breeding)

The term heterosis is synonymous with increased vegetative growth and high fruit production. The utilization of hybrid vigour as a means of maximizing the yield of horticultural crops has become one of the most important techniques in vegetable breeding. The advent of tomato hybrids in India had great impact as it resulted in quantum jump in tomato production. However, the hybrids released so far, have not made much impact on increasing summer tomato production due to TLCV. In view of this, it is essential to identify the parents that give desirable F_1 hybrids suitable for summer. With this objective in view female lines having TLCV tolerance/resistance were selected from one diverse group of tomatoes under the spp. *L. esculentum* var. *grandiflorum*, while males from other diverse group of spp. *L. esculentum* (commercial) to develop F_1's and tested under epiphytotic conditions (summer).

It was evident from the results that there was a considerable degree of heterosis for fruit yield and its component characters (number of fruits and average fruit weight) along with tolerance/resistance to TLCV. A few of the most promising cross combinations with high *per se* values for the yield were; 20/6 Alcobasa X L-58, 20/4 Alcobasa X L-58, 20/5 Alcobasa X N-229 8MF6, 20/2 Alcobasa X L-15, 20/5 Alcobasa X LE-79 and AVRDC Alcobasa X N-229 8MF6; which also had highly significant positive heterosis over the best parent and the commercial checks. Considering the other component characters like number fruits per plant, average fruit weight and tolerance to TLCV (less than 30 %), only three of the above cross combinations viz., 20/6 Alcobasa X L-58, 20/4 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6 qualify to be of commercial value (Table-28). The validity of their performance was

Table 28. The best cross combination for economic characters

Sl. No.	Characters	Cross combination
1.	Yield per plant (More than 1 kg)	20/6 Alcobasa X L-58 (2087.67), 20/4 Alcobasa X L-58 (1358.33), 20/5 Alcobasa X N-229 8MF6 (1311.33), 20/2 Alcobasa X L-15 (1187.67), 20/5 Alcobasa X LE-79, (1149.33) and AVRDC Alcobasa X N-229 8MF6 (1088.67)
2.	Number of fruits/plant (More than 15/plant)	20/6 Alcobasa X L-58 (24.67), 20/4 Alcobasa X L-58 (22.00), 20/4 Alcobasa X 79B 1390 (21.33), 20/5 Alcobasa X N-229 8MF6 (17-67), 20/2 Alcobasa X L-58 (19.33), 20/2 Alcobasa X LE-79 (19.00), 20/5 Alcobasa X LE-79 (17.00)
3.	Avg. fruit weight (More than 60 g)	20/6 Alcobasa X L-58 (87.27), 20/5 Alcobasa X LE-79 (67.67), 20/2 Alcobasa X 79B 1390 (68.33), 20/2 Alcobasa X L-15 (67.67), 20/6 Alcobasa X Marikrit (67.50) 20/5 Alcobasa X N-229 8MF6 (64.67), 20/4 Alcobasa X L-58 (61.67), 20/2 Alcobasa X CA-1 (62.50), AVRDC Alcobasa X N-229 8MF6 (59.57)
4.	TLCV infection (< 30 %)	20/6 Alcobasa X L-58 (25.30), 20/5 Alcobasa X N-229 8MF6 (26.47), 20/5 Alcobasa X L-58 (26.73), AVRDC Alcobasa X N-229 8MF6 (26.50), 20/4 Alcobasa X L-58 (27.00), 20/2 Alcobasa X L-58 (27.83), 20/2 Alcobasa X LE-79 (28.97)

confirmed from the results obtained during similar epiphytotic conditions of 1995 (Table-29). Obviously these three hybrids had significantly high positive sca effects for yield and their component characters and significant negative sca effects for TLCV infection and number of whiteflies. The parental contribution (gca effect) for yield and their component characters came from males rather than females in these crosses. Therefore, the above facts reveal that the crosses carried predominantly non-additive than the additive gene effects for all the economic characters, including TLCV tolerance. Similar study under epiphytotic conditions for TLCV tolerance using potato leaf types by Shoba and Armugaum (1991) also indicated non-additive gene action for TLCV tolerance and yield. Further, the findings of Banerjee and Kalloo (1989b) and Nagaraja(1995) support these facts. However, Channarayappa *et al.* (1992) and Rick (1987) observed both additive and non-additive gene effects for these traits using *L. esculentum* X *L.pimpinellifolium* (non-additive gene effect) and *L. esculentum* X *L. hirsutum* (additive gene effect).

Thus the foregoing discussion reveals that heterosis breeding for development of tomatoes through exploitation of non-additive gene action is the most practicable approach for developing cultivars for summer season. The best combinations therefore, could be 20/6 Alcobasa X L-58, 20/4 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6. Not only these are high

Table 29. Performance of F_1 hybrids for the year 1994 and 1995

Sl. No.	Crosses	Yield/plant (g)		Percentage of TLCV
		1994	1995	1994
1.	20/6 Alcobasa X L-58	2087.67	1950.50	25.30
2.	20/4 Alcobasa X L-58	1358.33	1230.00	27.00
3.	20/5 Alcobasa X N-229 8MF6	1311.33	1110.00	26.47
4.	20/5 Alcobasa X LE-79	1149.33	1235.40	29.37
5.	20/2 Alcobasa X L-15	1187.67	--	35.57
6.	AVRDC Alcobasa X N-229 8MF6	1088.67	1135.00	26.50
7.	20/2 Alcobasa X L-58	944.30	1050.00	27.83
8.	20/5 Alcobasa X L-58	1096.30	1330.50	26.73

yielding under heavy epiphytotic conditions but also have good quality parameters like attractive red fruits, desirable range of TSS and a few locules. A breeder can rely on *per se* performance of crosses while selecting best hybrids as there were strong relationships between *per se* performance of crosses vs. heterosis and sca (Table-30).

5.4 TEST OF TLCV RESISTANCE BY ARTIFICIAL INOCULATION

The genotypes which were identified as field tolerant to TLCV and some of their F_1s, commercial cultivars/hybrids along with a susceptible check (Pusa Ruby) were subjected to artificial inoculation through viruliferous whiteflies under controlled green house conditions.

The difference in per cent TLCV infection in reference genotypes and the susceptible check (Pusa Ruby) under similar inoculum load clearly indicated a degree of tolerance, though not complete resistance; in Alcobasa types. Infact total resistance in potato leaf types (*L.esculentum* Var.*grandiflorum*) cannot be expected as they belong to *L. esculentum* as was noticed in some accessions of wild species like *L. hirsutum*. However, the genotypes (Alcobasa 20/6) with low level of infection even under artificial inoculation appeared to have inherited their tolerance to their progeny (F_1), which also had comparatively low infection rate than Pusa Ruby (100%). Hence, it would be possible to accumulate the genes for resistance/

Table 30. Correlation for yield with different components

Sl. No.	Characters	'r' value
1.	Crosses *per se* yield Vs Heterosis	0.97**
2.	Crosses per se yield Vs SCA	0.7376**
3.	Heterosis Vs SCA	0.7376**
4.	GCA Vs yield (Parent per se)	0.0592

* and ** = Significant at 5 and 1 per cent level of probability, respectively.

tolerance in a genotype, although developing totally an inbuilt resistance is a far-reaching task. Shoba and Armugaum (1991) also opined that potato leaf types cannot be considered as genotypes with inbuilt resistance. similar conclusions were drawn by Vasudeva and Samraj (1959), Kasrawi *et al.* (1988) and Joshi and Choudhary (1981).

5.5 INHERITANCE OF TLCV

A degree of tolerance in F_1 arising out of the cross between totally susceptible commercial variety and a tolerant 'potato leaf type' indicate partial dominance of genes for TLCV resistance. The tolerant F_1s of two crosses 20/6 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6 were selfed to study inheritance of TLCV in F_2. The segregating population of both crosses have shown a range of reaction from tolerance to susceptible. The chi-square test revealed a good fit for monogenic inheritance (3:1) in F_2 of 20/6 Alcobasa X L-58, while it was digenic inheritance (9:7) in 20/5 Alcobasa X N-229 8MF6. There are also reports of dominant polygenic inheritance (Som and Chaudhary, 1976) in *L. pimpinellifolium* and other sources. This indicates that different sources of resistance inherit resistance in their own fashion and have to be utilized accordingly by adopting appropriate breeding methods. An interesting observation in segregating population was that a few F_2 plants (Plate-7 and 8) went on producing flowers and

Plate 7. Promising F_2 segregants of the cross 20/6 Alcobasa X L-58

Plate 8. Promising F_2 segregants of the cross 20/5 Alcobasa X N-229 $8MF_6$

fruits of desirable weight inspite of TLCV infection until late maturity (Fig.2 and 3). Therefore, by adopting comprehensive selection strategies it may be feasible to evolve genotypes that can mature early, express symptoms late and react weakly to TLCV and produce normal fruit yields. This approach appear to be better suited for determinate type of tomato cultivars, where cropping period is limited.

Overall, it can be inferred that the genotypes with potato leaf type (Alcobasa fruit colour) are a diverse group that carry genes for field resistance/tolerance to TLCV. A few of them like 20/6 Alcobasa (Plate-9) 20/5 Alcobasa and 20/4 Alcobasa, can be used as donors in a hybrid breeding programme (Plate-10) with selected commercial types like L-58 and N-229 8MF6. Specific combinations like 20/6 Alcobasa X L-58, 20/5 Alcobasa X N-229 8MF6 and 20/4 Alcobasa X L-58 can be commercially exploited as summer hybrids as they showed heterosis for yield and yield components and low incidence of TLCV. Though, the genotypes with complete resistance were not found among the potato leaf types, they were far superior to the susceptible check variety (Pusa Ruby). Monogenic or digenic inheritance for TLCV tolerance in F_2 of the selected crosses was an indication of possible utility of promising populations derived from crosses between potato leaf types and desirable cultivars.

Plate 9. A best female combiner 20/6 Alcobasa

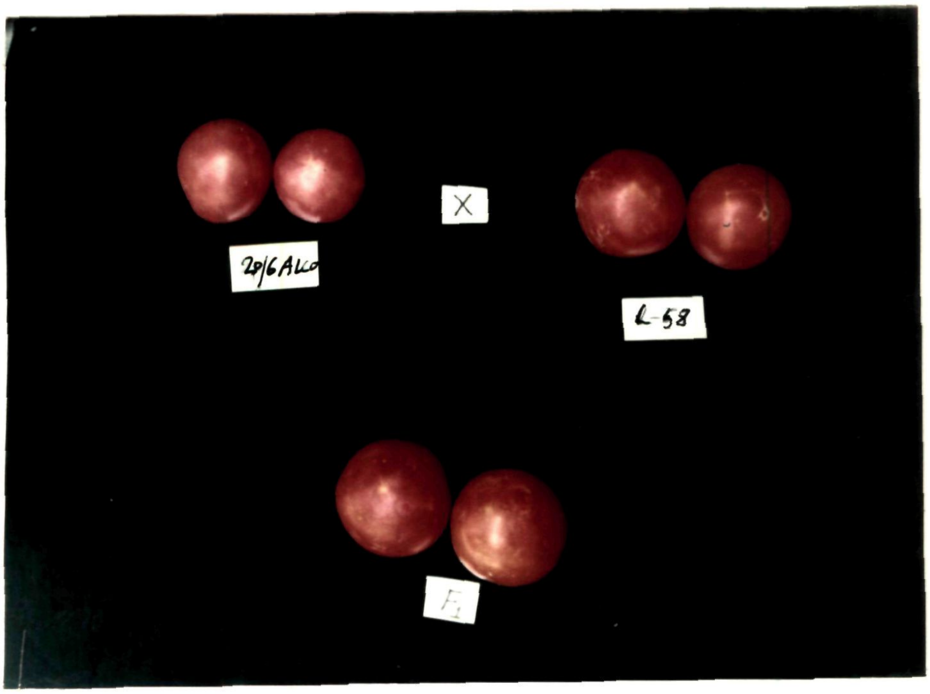

Plate 10. The F_1 fruits of 20/6 Alcobasa X L-58

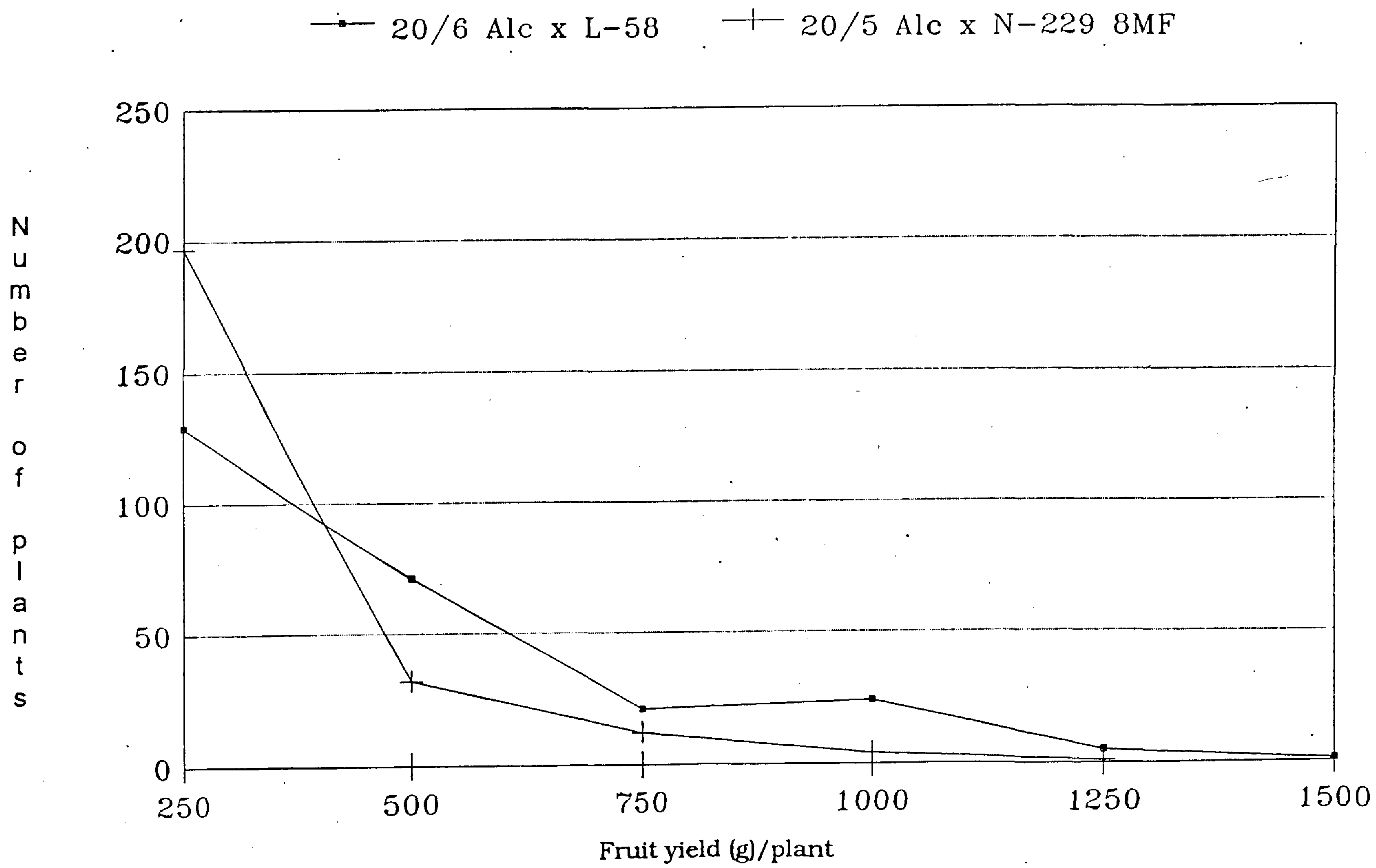

Fig. 2. Frequency distribution of F_2 populations for fruit yield (g)/plant

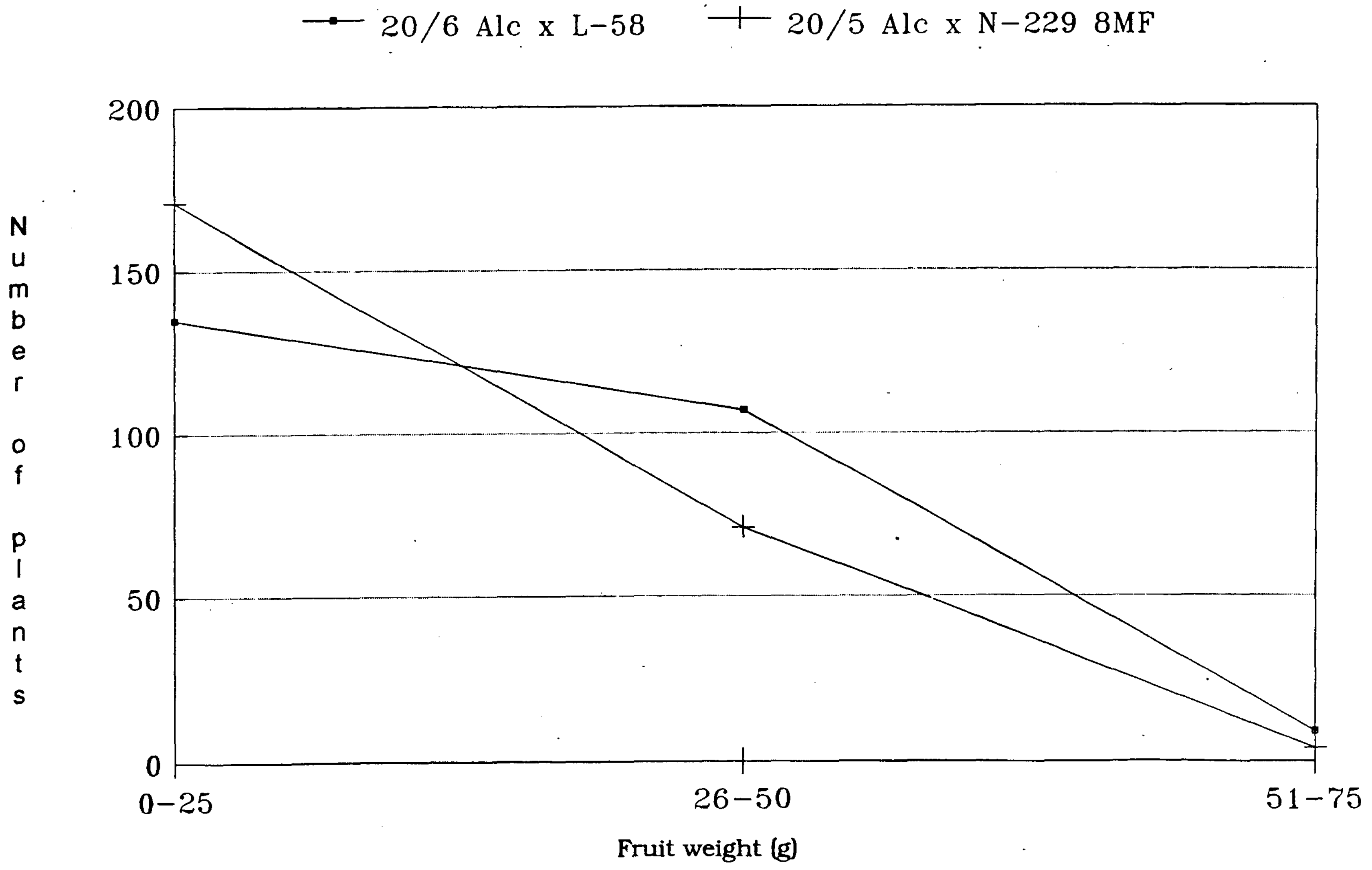

Fig. 3. Frequency distribution of F_2 populations for average fruit weight (g/fruit)

5.6 FUTURE LINE OF WORK

1. Use of wild species as donor parents for TLCV resistance need careful scrutiny.

2. Identification of strains of TLCV and sources of resistance to different strains.

3. Detailed studies are needed to identify independent sources of resistance to TLCV among potato leaf types and introduce them in cultivated types.

4. TLCV resistance needs to be visualised from the point of both colonization of plants by the vector and the virus infection and disease development. A systematic search for source of resistance to both vector and the TLCV needs to be done. Study of inheritance pattern would help in breeding for resistance to TLCV.

SUMMARY

VI. SUMMARY

The "Investigations on summer tomatoes with special reference to tomato leaf curl virus" (TLCV) were undertaken during 1993 to 1995 in the experimental plots of the Division of Horticulture, University of Agricultural Sciences, Dharwad. The study was mainly envisaged to findout the right donor for TLCV resistance/tolerance, utility of the donors in development of F1 hybrids for summer, to understand genetics of TLCV resistance and to know the utility of trap crop in control of TLCV on tomatoes during summer.

A large number (402) genotypes were evaluated under TLCV epiphytotic conditions to assess the magnitude of genetic diversity for TLCV and economic characters. The genotypes were grouped under 4 distinct clusters on the basis of D^2 values, which consisted of 217, 51, 99 and 35 genotypes respectively in I, II, III and IV clusters. The cluster-II and IV were the most divergent consisting of genotypes with potato leaf types (Alcobasa fruits), which exhibited field tolerance to TLCV, while cluster-I consisted of commercial, susceptible types. The canonical variate analysis also revealed maximum divergence for TLCV, fruit yield and number of whiteflies. The genotypes congregated in 9 clusters on the graph, with TLCV tolerant groups in cluster-VII and IX, while those of commercial types were in cluster-I.

Based on divergence, the following female parents having tolerance to TLCV (Potato leaf types); Alcobasa 20/2, Alcobasa 20/4, Alcobasa 20/5, Alcobasa 20/6 and AVRDC Alcobasa and males that are susceptible but had commercial qualities : CA-1, 79B 1390, UC-204B, L-15, N-229 8MF6, Marikrit, LE-79, L-58, DWD-1 and DWD-2 were used in crossing programme following Line X Tester format. All the 50 F1s, parents (15) and commercial hybrid/varieties (Vaishali and Punjab Chuhara) were evaluated in summer for tolerance to TLCV and economic characters. Heterosis was found to be significant for most of the characters. It was found that 20/6 Alcobasa X L-58, 20/5 Alcobasa X N-229 8MF6 and 20/4 Alcobasa X L-58 having positive significant heterosis for yield, fruit number and average fruit weight, with negative heterosis for TLCV and whitefly count were the most promising hybrids with high *per se* yield during both years. They also possessed good quality attributes like red fruit colour, acceptable range of TSS and a few locules.

Combining ability analysis revealed that majority of the characters were under the control of non-additive genes as SCA variances were at least two times greater than GCA variances. Among the lines, 20/2 Alcobasa showed good general combining ability for most of the economic characters. The testers, N-229 8MF6, L-58 and LE-79 were good general combiners for yield and yield components and for TLCV resistance. The best cross combinations with highly significant sca effects for yield, yield components and low TLCV incidence were 20/6

Alcobasa X L-58, 20/4 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6.

Study of segregating population of 20/6 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6 indicated two distinct group of plants namely those that were affected severely by TLCV with no fruits and those with tolerance to TLCV with a capacity to produce normal flowers and fruits. The F_2 segregants of 20/6 Alcobasa X L-58 indicated simple dominance for TLCV resistance (3:1 ratio) but in 20/5 Alcobasa X N-229 8MF6 it was complementary type of gene action (9:7) involving two pairs of genes.

Test of resistance/tolerance of selected genotypes and their hybrids to TLCV under artificial inoculation revealed that the resistant parents viz., 20/6 Alcobasa, 20/5 Alcobasa and 20/4 AVRDC Alcobasa recorded low incidence of 50.00-55.50 per cent of TLCV and high mortality of whiteflies compared to susceptible check (Pusa Ruby) with 100 per cent TLCV infection. The two hybrids 20/6 Alcobasa X L-58 and 20/5 Alcobasa X N-229 8MF6 had comparatively low (61.7 and 65.50 per cent) incidence of TLCV infection than susceptible check.

Trap crop (maize) interplanted with tomato at the row proportion of 1:1 and 2:1 (maize:tomato) in either direction (North-South or East-West) reduced TLCV incidence but heavy shading resulted in unfruitfulness. On the contrary progressive reduction of maize population from normal increased TLCV incidence.

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* - Original not seen.

APPENDICES

Appendix-I. Physical and chemical properties of the soils of the experimental site

Properties	Characterization		Methods employed
	(0-30 cm)	(30-60 cm)	
I. **Physical properties**			
Clay	35.20	---	Hydrometer method (Piper, 1950)
SCH (%)	7.60	---	Hydrometer method (Piper, 1950)
Fine sand (%)	29.20	---	Hydrometer method (Piper, 1950)
Coarse sand (%)	27.10	---	Hydrometer method (Piper, 1950)
II. **Chemical properties**			
Organic carbon (%)	0.46	---	Walkley and Black (1934) Raped titration
Available nitrogen (kg/ha)	233.00	220.00	Modified Kjeldahal's method (Jackson, 1967)
Available phosphous (kg/ha)	31.00	25.40	Bray's extraction method
Available potassium (kg/ha)	296.00	248.00	Flame photometer method (Muhr *et al.*, 1966)
III. pH (1:2.5 - 5 Soil:Water)	6.70	---	pH meter (Piper, 1950)

APPENDIX-II. Monthly meteorological data for the cropping season and (1993-95) of the Main Research Station, UAS, Dharwad

Months	Rainfall (mm)			Temperature (°C)						Relative humidity		
				Mean maximum			Mean minimum					
	1993	1994	1995	1993	1994	1995	1993	1994	1995	1993	1994	1995
January	0.0	8.0	5.2	30.1	29.3	27.3	13.7	14.5	13.7	80	81	83
February	0.0	0.0	0.0	31.7	31.9	32.6	14.8	16.2	16.7	76	76	73
March	0.0	0.0	0.0	34.5	36.1	35.1	18.8	20.0	19.1	70	68	68
April	16.2	55.6	20.6	37.1	34.9	36.8	20.5	20.6	21.3	66	70	66
May	101.7	28.0	56.6	36.2	36.5	33.8	21.3	21.3	21.3	67	65	68
June	88.5	86.0	143.4	30.2	28.1	31.4	21.3	20.9	22.1	79	84	75
July	166.0	296.1	184.4	26.6	25.0	27.1	21.0	20.6	21.0	89	93	87
August	68.1	89.3	50.5	26.4	25.6	28.1	20.5	20.6	20.7	89	91	86
September	44.6	52.6	121.6	28.1	27.5	28.3	20.1	19.2	20.6	86	86	82
October	266.2	164.2	--	29.0	29.0	--	20.3	20.1	--	84	83	--
November	8.4	0.0	--	29.0	28.0	--	17.4	16.4	--	82	85	--
December	39.6	0.0	--	26.7	28.0	--	13.8	12.4	--	86	84	--

Appendix-III. Weighted pair group average method for cluster formation and mean values of economic characters for 402 genotypes

Sl. No.	GENOTYPES/ ADVANCED BREEDING LINES	Percentage of TLCV	No.of fruits per plant	Average fruit weight (g)	Yield per plant (g)	Node	Inter cluster dissimila- rities	No. of objects in fused group
1	2	3	4	5	6	7	8	9
1	LE-79 X Marikrit (F2)	68.35	1.65	38.00	62.50	1	0.002	2
2	DWD-1 X DWD-2 (F2)	75.00	2.00	22.90	44.90	2	0.163	2
3	CA-1 X Marikrit (F2)	79.45	2.50	24.10	55.60	3	0.170	3
4	CA-1 X UC-204B (F2)	83.75	1.15	36.90	42.50	4	0.180	2
5	DWD-3 X Marikrit (F2)	94.45	0.35	23.80	16.65	5	0.196	2
6	Vaishali	100.00	0.00	0.00	0.00	6	0.230	3
7	CA-1 X 79B 1390 (F2)	62.50	3.35	14.40	48.15	7	0.302	2
8	DWD-1 X Bush (F2)	95.00	0.00	0.00	0.00	8	0.406	2
9	DWD-2 X CA-1 (F2)	89.90	1.80	21.95	38.70	9	0.477	2
10	L-15 X DWD-3 (F2)	90.00	2.65	21.50	55.85	10	0.668	5
11	Marikrit X 79B 13(F2)	87.85	1.50	24.30	36.60	11	0.964	4
12	79 B 1390 X CA-1 (F2)	96.15	0.00	0.00	0.00	12	1.069	6
13	DWD-1 X Marikrit (F2)	79.80	3.20	17.70	55.60	13	1.512	3
14	LE-79 X UC-204B (F2)	87.05	2.00	32.20	60.00	14	1.683	2
15	DWD-2 X DWD-3 (F2)	69.60	1.65	27.20	98.30	15	2.194	3
16	L-15 X DWD-2 (F2)	65.70	4.00	18.90	75.00	16	2.221	2
17	L-15 X Bush (F2)	71.25	1.35	33.90	44.85	17	2.436	2
18	Marikrit X UC-204 B (F2)	86.65	1.30	33.20	43.15	18	2.591	2
19	L-15 X Marikrit (F2)	75.00	2.35	29.20	67.50	19	2.737	3
20	L-15 X UC-204 B (F2)	62.10	3.35	19.45	63.30	20	3.075	2
21	DWD-1 X Marikrit (F2)	93.75	1.65	31.20	49.80	21	3.150	7
22	DWD-2 X 79 B 1390 (F2)	50.20	2.35	27.35	63.30	22	3.170	3
23	DWD-1 X LE-79 (F2)	45.00	3.35	21.00	73.35	23	3.370	2
24	DWD-2 X CA-1 (F2)	36.40	4.85	21.70	105.00	24	3.510	2
25	L-15 X DWD-1 (F2)	42.70	4.20	34.80	144.30	25	3.587	2
26	L-15 X CA-1 (F2)	70.45	2.85	24.00	69.15	26	3.778	
27	79B 1390 X Bush (F2)	71.40	2.80	16.40	46.65	27	4.180	2
28	DWD-2 X LE-79 (F2)	78.55	3.50	17.25	60.00	28	4.765	2
29	DWD-2 X UC-204 B (F2)	76.20	2.80	18.36	50.80	29	0.038	2
30	DWD-3 X CA-1 (F2)	81.25	4.00	17.50	69.80	30	5.046	2
31	L-15 X LE-79 (F2)	87.50	2.65	19.35	50.65	31	5.282	2
32	DWD-2 X Marikrit (F2)	90.00	2.35	20.60	49.00	32	5.303	5
33	LE-79 X Marikrit (F2)	86.35	2.30	21.65	48.35	33	5.647	2
34	DWD-2 X Bush (F2)	70.00	3.15	17.25	53.15	34	6.106	2
35	DWD-1 X UC-204 B (F2)	83.30	3.85	11.50	44.35	35	6.354	2
36	LE-79 X 79 B 1390 (F2)	77.35	3.50	11.50	39.15	36	6.463	2
37	L-3	94.40	2.50	14.05	34.35	37	6.463	2
38	Rupali	78.35	3.50	10.25	35.50	38	6.584	2
39	UC-204B X 79B 1390 (F2)	96.88	1.50	22.10	30.85	39	6.691	2
40	L-15 X 79B 1390 (F2)	90.00	1.35	25.55	34.15	40	6.350	2
41	CA-1 X LE-79 (F2)	87.25	1.35	28.20	37.50	41	6.819	2
42	DWD-1 X 79B 1390 (F2)	67.50	2.35	15.30	35.65	42	7.138	2
43	DWD-1 X DWD-2 (R) (F2)	60.25	4.00	14.45	52.50	43	7.175	3
44	DWD-1 X CA-1 (F2)	57.30	3.00	14.70	43.35	44	7.644	2
45	L-18	52.50	3.50	15.60	54.15	45	7.960	2
46	L-20	43.75	5.35	36.35	193.35	46	7.975	2
47	L-5	100.00	0.00	0.00	0.00	47	8.230	2
48	L-13	88.30	2.65	18.75	49.20	48	8.329	2
49	L-4	72.15	2.20	24.00	50.75	49	8:895	2
50	L-12	97.05	0.00	0.00	0.00	50	8.906	2

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1	2	3	4	5	6	7	8	9
51	L-17	67.50	2.35	22.65	52.75	51	9.667	3
52	L-15 X 89/BF (F3)	87.85	1.35	33.75	43.00	52	9.777	2
53	L-15 X DWD-2 (F3)	87.80	3.00	13.50	40.90	53	9.873	2
54	L-15 X 004 (F3)	93.00	2.65	14.50	38.35	54	10.110	2
55	L-15 X T-1 (F3)	77.70	3.35	13.95	47.50	55	10.405	3
56	L-15 X 008 (F3)	95.00	1.30	32.50	40.65	56	10.613	2
57	L-15 X 005 (F3)	87.65	2.35	23.70	55.65	57	10.944	2
58	L-15 X 004 (F3)	42.85	2.35	28.25	61.00	58	10.992	2
59	L-15 X 003 (F3)	58.50	3.00	34.85	104.15	59	11.305	2
60	L-15 X 002 (F3)	84.40	1.65	47.40	76.50	60	11.523	3
61	L-15 X 001 (F3)	64.75	1.15	25.85	29.15	61	11.590	2
62	L-15 X Marikrit (F3)	95.45	0.35	19.25	13.50	62	11.643	2
63	L-15 X LE-79 (F3)	57.10	3.65	16.80	60.65	63	12.056	7
64	L-15 X CA-1 (F3)	72.00	2.80	24.80	67.65	64	12.599	2
65	L-15 X 79B 1390 (F3)	87.25	1.00	43.60	38.40	65	12.606	2
66	DWD-1 X 006 (F3)	87.25	1.15	58.35	67.25	66	12.635	2
67	DWD-1 X 007 (F3)	77.50	3.35	34.70	112.50	67	12.640	2
68	DWD-1 X 89/BF (F3)	82.30	2.65	41.25	166.80	68	12.880	2
69	DWD-1 X 79B 1390 (F3)	68.00	2.65	41.60	109.65	69	12.908	2
70	DWD-1 X TI (F3)	72.65	3.65	23.40	84.85	70	13.070	2
71	DWD-1 X 88/BF (F3)	52.85	4.15	14.75	60.85	71	13.222	2
72	DWD-1 X 006 (R) (F3)	45.30	2.80	15.70	30.00	72	13.521	2
73	DWD-1 X 004 (F3)	41.00	3.00	15.70	47.15	73	14.126	2
74	DWD-1 X 003 (F3)	70.00	3.35	10.75	36.00	74	14.257	2
75	DWD-1 X 002 (F3)	83.35	2.35	15.50	34.35	75	14.470	2
76	DWD-1 X 001 (F3)	79.45	1.85	25.50	46.65	76	14.535	2
77	DWD-1 X Marikrit (F3)	46.65	2.50	37.30	93.00	77	14.765	2
78	DWS-1 X LE-79 (F3)	48.90	2.65	41.30	107.50	78	14.992	2
79	DWD-1 X CA-1 (WR)(F3)	74.45	3.20	33.15	104.15	79	15.232	2
80	UC-204 B X DWD-2 (F3)	36.60	5.65	18.80	104.50	80	15.381	2
81	UC-204B X LE-79 (F3)	29.00	5.65	18.25	103.15	81	15.454	2
82	UC-204B X Marikrit (F3)	55.00	4.65	44.15	205.85	82	15.598	2
83	UC-204B X 001 (F3)	38.75	2.85	23.70	65.85	83	15.670	2
84	UC-204B X 003 (F3)	97.85	0.00	0.00	0.00	84	15.775	2
85	UC-204B X 004 (F3)	63.35	6.65	30.95	206.00	85	16.212	2
86	UC-204B X 005 (F3)	74.35	1.85	28.75	95.85	86	16.335	2
87	UC-204B X 89/BF (F3)	67.75	2.20	33.15	71.15	87	16.433	3
88	UC-204B X 79 B 1390(F3)	69.30	2.65	43.05	107.50	88	16.684	2
89	UC-204B X CA-1 (F3)	90.25	1.15	33.70	38.35	89	16.710	2
90	UC-204B X 002 (F3)	99.25	0.00	0.00	0.00	90	16.962	3
91	UC-204B X 006 (F3)	94.30	1.65	23.10	38.00	91	17.050	2
92	UC-204B X T-1 (F3)	92.50	1.00	36.35	35.85	92	17.184	3
93	UC-204B X 008 (F3)	100.00	0.00	0.00	0.00	93	17.488	3
94	L-87/41	88.45	2.00	25.81	51.35	94	18.063	2
95	007	100.00	0.00	0.00	0.00	95	18.095	2
96	001	99.25	0.00	0.00	0.00	96	18.100	5
97	L-36	92.50	1.35	42.90	73.35	97	18.226	2
98	L-40	74.25	3.15	19.20	60.35	98	18.567	2
99	L-60	97.50	0.00	0.00	0.00	99	18.627	8
100	22/10	95.25	0.50	23.85	10.50	100	18.901	2
101	20/3	77.80	2.65	16.60	42.15	101	18.916	2
102	005	41.90	6.80	19.20	130.00	102	18.985	2
103	008	92.50	0.00	0.00	0.00	103	19.029	2
104	20/3	100.00	0.00	0.00	0.00	104	19.330	2
105	87/23	83.75	2.15	34.60	73.85	105	19.364	2
106	L-43	100.00	0.00	0.00	0.00	106	19.652	2
107	87/F-6-17-4-20-1	82.00	1.80	42.90	75.00	107	19.869	2

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1	2	3	4	5	6	7	8	9
108	VC-11-1	79.75	2.65	37.25	97.50	108	20.058	2
109	CA-1 X 6 X 6	46.50	3.50	25.00	86.35	109	20.495	2
110	L-42	62.80	2.80	45.30	122.50	110	20.561	3
111	Pusa Ruby	70.25	3.65	32.40	117.50	111	21.150	2
112	L-54	54.25	3.65	22.70	80.85	112	21.161	2
113	AVRDC	11.90	5.80	20.01	116.35	113	21.446	2
114	86/F-4-2-2	95.00	0.00	0.00	0.00	114	21.610	2
115	L-54-1	91.25	1.65	26.35	42.00	115	21.681	3
116	87/F-6-17-4-20-3	85.71	4.65	26.85	116.30	116	22.163	2
117	L-15/4	75.00	5.35	22.05	117.50	117	22.184	2
118	L-15/6	97.50	6.65	29.30	195.00	118	22.244	3
119	L-3/2	100.00	0.00	0.00	0.00	119	22.286	2
120	L-15/5	70.84	3.35	29.05	101.50	120	22.431	3
121	87/47 Pimento	96.50	0.00	0.00	0.00	121	22.471	2
122	S-22	95.55	0.00	0.00	0.00	122	22.691	3
123	88/Alco/BF	31.32	4.65	35.65	165.20	123	22.735	2
124	L-5/4	47.50	6.50	30.80	200.65	124	22.935	2
125	89/Bush	84.17	0.00	0.00	0.00	125	23.087	4
126	88/T-1	95.00	4.15	13.50	55.00	126	23.211	3
127	88/Petoproc/5	74.50	1.50	43.80	65.00	127	23.399	3
128	89/BF/JL/SL	68.60	2.65	23.50	61.30	128	24.082	2
129	88/L-15/DT-5	99.25	2.85	35.60	101.35	129	24.591	2
130	88/BF/Thick F/J/F	100.00	3.80	34.10	128.35	130	24.650	4
131	L-39	45.95	3.35	27.30	90.80	131	25.708	6
132	88/Alt. Res.	100.00	4.85	31.85	154.50	132	26.131	3
133	20/2 Alcobasa	17.90	4.85	46.50	225.60	133	26.273	3
134	19/1	100.00	1.15	51.15	58.00	134	26.363	3
135	Flocenta	97.75	0.00	0.00	0.00	135	26.713	2
136	88/L-15	65.35	1.65	43.05	73.35	136	26.880	3
137	N-229-8MF6	73.00	0.00	0.00	0.00	137	27.276	2
138	88/Firm/ BF	83.00	2.50	26.80	65.00	138	27.430	3
139	88/SF/V.Firm/Uni.m	73.59	1.15	28.80	32.80	139	27.514	4
140	87/f-4-17-3-4	59.76	3.20	33.42	105.50	140	28.742	2
141	88/Petoproc/S	89.50	2.35	28.75	66.60	141	29.238	3
142	8/L-15/Uni M	85.00	2.00	57.90	115.90	142	29.318	4
143	88/Small/Ind/AVRC	73.34	6.00	27.75	165.00	143	29.516	2
144	90-7/8	76.50	0.00	0.00	0.00	144	29.793	2
145	CA-1 X 6	72.75	7.00	29.00	201.65	145	29.900	3
146	86/F3-1-15	78.25	2.15	33.40	71.65	146	30.023	2
147	86/F3-4-6	86.25	5.50	24.75	136.00	147	30.829	3
148	L-78	85.25	0.00	0.00	0.00	148	30.874	5
149	L-82	73.25	5.15	19.75	101.70	149	30.891	2
150	86/F3-1	56.00	8.00	25.95	207.65	150	31.078	2
151	86/VC-F	79.55	3.15	20.70	65.25	151	32.125	3
152	86-F4-2-2-11	69.95	7.15	26.45	189.15	152	33.075	3
153	86/AVRDC	36.25	3.20	22.40	70.85	153	33.173	2
154	86-F3-4-10	79.50	2.00	32.40	88.65	154	33.181	3
155	LE-79 X 7 X 7	80.25	2.65	29.00	74.15	155	33.405	2
156	88/L-15/DT-11	76.05	5.15	30.60	157.50	156	34.337	3
157	88/L-15/DT-10	68.20	4.35	23.25	100.60	157	35.127	2
158	88/L-15/W-11	65.35	5.85	17.50	102.50	158	35.510	2
159	88/L-15/DT-7	81.00	4.80	21.70	105.65	159	36.630	2
160	88/L-15/DT-12	69.75	1.50	22.90	33.85	160	36.633	4
161	88/L-15/DT-15	94.25	0.00	0.00	0.00	161	36.740	2
162	88/L-15/DT-3	49.38	5.35	18.85	100.50	162	37.278	2
163	88/L-15/DT-8	89.25	3.35	29.80	99.15	163	37.415	3
164	88/L-15/W-10	95.75	3.65	22.75	81.50	164	37.740	2

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1	2	3	4	5	6	7	8	9
165	88/L-15/DT-9	82.25	6.15	26.95	165.80	165	38.115	2
166	88/L-15/DT-13	76.25	2.85	28.60	81.30	166	38.165	2
167	88/L-15/DT-14	75.00	3.80	33.30	125.80	167	38.176	2
168	88/L-15/W-6	84.25	1.85	47.55	79.20	168	38.316	2
169	88/L-15/DT-1	75.35	2.80	29.75	82.50	169	38.862	2
170	88/L-15/DT-2	100.00	0.00	0.00	0.00	170	39.039	2
171	88/L-15/W-7	65.00	3.35	17.70	57.50	171	39.141	4
172	88/L-15/W-12	85.35	2.35	47.40	109.30	172	39.228	4
173	88/L-15/W-29	71.00	2.50	31.70	78.15	173	39.379	4
174	UC-204 B	70.25	4.65	37.60	174.20	174	40.379	5
175	Marikrit	93.00	3.00	13.60	40.80	175	40.790	3
176	L-59	26.35	5.65	22.00	124.20	176	40.970	3
177	Alcobasa	14.25	2.85	36.60	104.20	177	41.150	3
178	L-152	100.00	1.00	16.35	16.35	178	41.762	3
179	22-3(B)	97.25	1.15	91.45	104.15	179	42.279	2
180	UC-204B (R)	63.25	1.85	60.75	112.50	180	42.472	2
181	79B 1390	86.75	1.65	29.80	49.00	181	42.492	3
182	L-15	99.30	0.00	0.00	0.00	182	42.605	4
183	T-19	87.00	5.35	21.25	113.50	183	44.053	6
184	AVRDC	76.75	6.35	21.10	133.65	184	44.144	2
185	L-50	76.25	7.80	22.15	172.50	185	44.790	3
186	AVRDC-S	64.50	5.65	17.15	96.65	186	45.391	2
187	L-54	89.50	1.85	53.25	85.80	187	45.717	3
188	L-15 X DWD-1	80.50	3.80	21.60	81.65	188	46.284	4
189	20/1	22.90	5.15	20.20	104.20	189	47.641	2
190	S-22 (L)	79.25	2.15	21.75	44.35	190	48.164	3
191	88/L-15/DT-6	70.95	2.65	34.60	90.85	191	48.904	7
192	88/L-15/DT-4	70.45	2.80	54.75	148.70	192	51.864	2
193	79B 1390 X CA-1	42.65	4.45	27.95	124.35	193	52.157	4
194	79B 1390 X L-15	72.35	3.65	39.45	148.35	194	52.319	2
195	S-22-R	76.50	3.15	25.80	81.30	195	52.765	3
196	L-15-10	70.05	2.50	42.50	103.35	196	52.818	4
197	DWD-3-R	92.85	0.00	0.00	0.00	197	53.732	8
198	85/3-GKVK	62.65	5.65	24.80	140.00	198	54.025	5
199	DWD-1-J	49.65	0.00	0.00	0.00	199	54.974	2
200	CO-3	57.50	7.85	20.05	157.65	200	55.035	3
201	20/6 Alco	17.50	3.10	19.15	59.25	201	55.119	3
202	T-50	62.05	6.00	23.65	141.70	202	56.222	4
203	87/F-6-17-1-22-3	74.55	4.15	26.40	109.65	203	57.812	2
204	L-T-43	95.05	1.30	83.10	108.00	204	57.893	3
205	L-58	73.35	2.50	26.70	66.65	205	58.140	2
206	L-15-B	54.10	5.15	23.50	120.85	206	59.379	2
207	L-9519	60.00	1.65	52.15	84.15	207	60.071	3
208	L-48	75.35	2.85	24.65	70.80	208	60.773	4
209	Bangalore X KH	96.25	2.00	35.80	71.65	209	62.099	2
210	14/195	73.75	4.00	25.90	103.35	210	62.154	5
211	L-54	76.65	2.85	25.55	72.75	211	63.032	3
212	Roma	60.25	4.50	23.10	103.85	212	65.155	4
213	L-23-1	85.00	1.15	91.55	104.25	213	67.899	2
214	L-57	95.00	5.85	21.20	124.25	214	68.718	2
215	DWD-2-DT	11.25	2.85	27.60	79.15	215	68.733	3
216	N-229 8MF6-J	44.10	3.00	25.00	125.85	216	69.237	3
217	L-15/7	65.00	2.15	44.25	95.00	217	70.569	3
218	DWD-1-SF	31.50	5.65	18.95	106.65	218	71.727	5
219	*88/BF/JL/F1*	*17.00*	*6.50*	*19.85*	*128.65*	*219*	72.644	2
220	L-SF	44.50	2.65	32.20	84.15	220	72.720	3
221	20/4 Alco	15.10	8.50	15.25	130.00	221	72.753	2

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1	2	3	4	5	6	7	8	9
222	21/4 Alco	24.20	3.65	15.15	55.80	222	75.781	2
223	L-12	100.00	1.50	29.90	44.15	223	75.847	6
224	Arka Sourab	99.25	3.80	31.90	120.00	224	76.454	3
225	L-43	92.25	3.00	35.15	101.65	225	76.998	2
226	L-15-9	85.000	2.35	35.50	82.50	226	77.297	9
227	L-15	94.75	1.65	49.60	82.00	227	78.292	5
228	L-23	100.00	3.85	25.70	99.15	228	79.181	4
229	AVRDC Alcobasa	17.00	5.85	40.40	231.65	229	80.391	2
230	DWD-4	47.75	1.50	46.65	65.00	230	80.688	2
231	21/AVRDC	18.00	3.00	30.25	87.50	231	82.409	3
232	L-51	80.00	2.50	22.67	54.25	232	83.546	3
233	LE-79-1	70.00	5.65	39.10	203.35	233	85.071	3
234	SF/Bush	90.00	1.00	20.50	20.50	234	86.412	3
235	SF/Al. Tol.	76.25	1.65	20.05	32.50	235	87.799	3
236	L-78	79.75	4.65	47.40	217.50	236	88.287	4
237	L-15-30	94.50	3.15	57.40	180.65	237	89.235	5
238	20/6 Alcobasa	14.80	5.35	43.35	230.85	238	89.727	13
239	L-57-8	24.10	2.00	21.45	39.15	239	90.325	4
240	87/37	26.95	7.00	33.56	135.00	240	91.164	13
241	L-26	99.25	2.15	64.06	137.50	241	92.382	6
242	L-15/8	100.00	1.65	48.05	65.00	242	93.366	4
243	L-26/BL-SEL-1	45.25	6.65	22.90	151.35	243	94.320	2
244	F3-6-8	79.85	4.50	41.45	185.00	244	95.721	3
245	88/J/BF	40.00	7.35	28.80	211.70	245	96.951	2
246	L-15-3	80.00	3.85	37.05	138.35	246	98.446	5
247	L-15-1	70.50	3.20	25.25	80.00	247	98.871	5
248	CA-1-2	75.00	2.20	29.30	62.50	248	99.935	5
249	88/BF/Firm	55.00	3.65	22.30	80.85	249	101.226	3
250	20/5 Alco	13.85	3.50	14.80	50.65	250	106.127	2
251	L-53	61.25	3.00	15.25	45.85	251	107.481	2
252	LE-79-R	73.35	3.85	24.90	93.30	252	107.814	5
253	AVRDC Alco	22.00	3.85	22.30	85.80	253	109.626	2
254	79 B 1390/S	62.85	2.65	35.85	94.15	254	111.152	5
255	H-229 8MF6/JT	16.55	6.85	26.25	178.35	255	111.390	5
256	19/AVRDC	19.10	4.50	25.70	115.00	256	111.923	7
257	UC-204B-DT	66.80	2.00	28.85	57.75	257	114.429	3
258	22/AVRDC	88.35	3.80	31.00	116.75	258	117.417	8
259	86/F5-15-1-3	76.95	2.95	21.20	68.35	259	119.416	5
260	86/F5-18-5	66.05	3.65	30.80	109.35	260	120.427	3
261	86/F-15-20-2	84.25	4.85	28.90	140.00	261	120.668	3
262	L-24	82.00	2.50	16.85	42.00	262	120.937	4
263	L-52	85.25	2.50	45.20	104.80	263	122.138	7
264	F3-12-12	95.00	2.15	47.65	124.20	264	122.492	4
265	F3-2-8	82.50	5.13	29.60	152.25	265	126.744	3
266	L-13	80.00	1.35	30.50	40.80	266	128.823	6
267	AVRDC Alco-2	95.00	2.35	36.55	81.65	267	134.041	6
268	L-15 X 79B 1390 (F3)	100.00	1.65	26.05	41.35	268	135.998	3
269	L-15 X 79B 1390-9-14 (F3)	80.25	1.50	32.00	47.50	269	136.601	4
270	AVRDC/9	85.00	1.83	22.05	40.80	270	137.449	5
271	L-15 X 79B 1390-14-13 (F3)	72.75	3.65	18.15	65.00	271	137.703	6
272	UC-204B X 79B 1390 (F3)	75.00	3.00	34.05	97.50	272	138.293	2
273	L-15 X 79B 1390 - SP (F2)	70.00	2.85	43.40	123.35	273	141.019	2
274	UC-204 B X 79 B 1390/7-20 (F2)	85.00	2.65	48.00	121.65	274	141.417	3
275	UC-204 B X 79 B 1390/7-23 (F2)	87.50	2.20	31.12	65.85	275	148.232	6
276	L-5/2	9.40	1.35	47.45	60.85	276	149.744	3
277	L-6/21	68.35	3.65	25.25	911.70	277	150.280	9
278	L-16/7	54.25	3.15	29.40	92.50	278	150.329	7

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1	2	3	4	5	6	7	8	9
279	L-19/7	70.00	2.15	22.50	48.35	279	150.681	9
280	L-3/10	75.00	1.65	53.08	83.85	280	152.734	6
281	L-4/22	71.90	1.80	31.00	53.35	281	163.789	7
282	L-15/7	86.25	3.20	37.25	117.50	282	166.466	2
283	L-2/12	95.00	2.15	39.50	84.70	283	166.601	6
284	DWD-1 X DWD-2/15/7 (F3)	70.00	1.35	38.10	49.65	284	168.949	5
285	DWD-1 X DWD-2/2/12 (F3)	80.00	2.35	24.70	57.50	285	170.359	5
286	DWD-1 X DWD-2/3/14 (F3)	87.50	3.65	25.35	90.80	286	171.530	3
287	L-1/1	93.85	0.00	0.00	0.00	287	176.458	11
288	L-1/7	45.25	2.15	21.45	45.00	288	176.815	4
289	L-8/7	89.60	5.65	25.15	140.00	289	180.885	3
290	L-6/4	68.35	0.00	0.00	0.00	290	183.504	8
291	L-2/7	56.65	1.00	6.25	12.50	291	187.198	4
292	L-9/7	65.00	2.65	25.60	64.65	292	191.226	7
293	L-6/14	65.00	3.50	22.45	76.70	293	191.696	6
294	L-11/7	82.50	2.15	40.55	86.65	294	199.407	11
295	L-20/3	60.00	1.00	41.85	40.00	295	206.281	4
296	L-21/3	85.00	2.35	41.60	96.65	296	218.502	8
297	L-24/3	79.25	3.50	14.65	50.85	297	222.113	5
298	L-6/12	60.00	2.15	23.00	46.15	298	222.643	2
299	L-3/1	80.00	3.80	32.15	118.30	299	225.578	10
300	L-7/3	60.25	1.85	37.90	68.80	300	226.498	5
301	L-3/21	85.00	3.35	22.80	75.00	301	230.085	4
302	L-5/17	90.00	3.70	26.30	90.85	302	230.797	7
303	L-1/10	100.00	0.00	0.00	0.00	303	234.155	5
304	L-7/9	83.35	1.65	6.05	20.00	304	238.641	5
305	L-2/11	85.00	0.00	0.00	0.00	305	243.297	4
306	L-2/4	76.25	0.00	0.00	0.00	306	245.242	9
307	L-10/13	86.00	0.85	13.40	11.65	307	250.945	8
308	L-4/19	79.25	4.65	20.10	92.50	308	258.158	5
309	L-1/17	75.00	2.15	31.95	69.70	309	264.812	19
310	L-4/11	62.50	3.35	38.80	128.35	310	272.210	8
311	L-3/15	76.50	3.65	24.95	90.00	311	279.020	2
312	L-1/9	89.25	3.15	29.85	92.85	312	279.977	4
313	L-2/3	65.50	2.50	39.15	97.50	313	291.096	6
314	L-1/15	39.25	2.20	26.70	56.65	314	294.756	5
315	Cross B	71.50	3.35	23.65	79.15	315	301.096	5
316	18-T1	95.00	1.65	51.00	81.65	316	308.879	14
317	L-20/8	81.75	3.35	30.50	98.65	317	312.114	7
318	L-15-M	95.00	2.50	15.30	36.65	318	313.486	11
319	Punjab chahura	57.10	4.35	27.50	118.00	319	314.579	5
320	LIHB-176	71.75	2.00	43.65	81.70	320	315.887	6
321	LIHB-124	45.55	2.00	28.10	55.85	321	334.580	7
322	LIHB-145	85.00	0.00	0.00	0.00	322	337.075	5
323	RFS-2	40.25	2.85	37.65	107.50	323	362.221	7
324	RFS-1	42.75	5.00	19.80	98.00	324	366.014	11
325	CA-1-R	47.50	2.50	19.50	47.50	325	376.260	13
326	UC-204B-J	65.00	1.35	46.25	60.00	326	392.937	9
327	001	49.40	2.85	36.25	103.35	327	393.124	3
328	006	82.45	4.20	25.25	104.20	328	394.889	5
329	008	86.00	1.35	46.95	60.00	329	396.078	3
330	002	62.45	2.65	29.90	76.65	330	413.492	4
331	Marikrit-DT	60.00	2.15	24.00	48.35	331	416.726	10
332	L-2/12	65.00	1.85	29.20	49.15	332	419.250	12
333	L-2/13	85.45	4.35	24.80	107.65	333	429.796	5
334	L-2/16	48.25	2.35	19.10	43.35	334	433.723	15
335	L-1/2	55.00	2.15	22.35	48.00	335	442.962	9

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1	2	3	4	5	6	7	8	9
336	L-2/4	49.25	2.65	20.80	53.30	336	448.802	4
337	L-2/5	85.00	0.00	0.00	0.00	337	479.972	8
338	L-2/6	75.00	2.65	31.65	80.80	338	522.418	13
339	L-2/7	60.00	2.15	41.20	80.00	339	564.058	8
340	L-2/9	22.75	3.50	22.50	78.35	340	565.296	9
341	L-2/10	47.50	2.50	27.55	67.65	341	571.493	7
342	L-1/13	65.00	4.65	15.55	71.65	342	598.745	16
343	004	60.00	3.20	21.45	68.35	343	600.018	4
344	002-1	47.80	2.35	26.65	60.00	344	604.328	23
345	007	55.00	3.50	17.50	60.85	345	606.785	10
346	003	95.00	4.20	17.35	72.50	346	612.837	9
347	L-1/9	55.00	2.65	22.50	58.70	347	620.115	26
348	L-2/15	56.25	2.50	27.40	70.85	348	640.950	11
349	L-2/17	85.00	4.65	15.00	70.00	349	662.622	7
350	L-3/6	75.00	1.00	22.25	21.70	350	699.552	13
351	L-3/7	55.25	4.15	14.10	57.65	351	749.778	21
352	L-3/8	65.25	2.35	17.80	40.00	352	772.784	10
353	L-3/16	56.70	2.85	14.25	40.35	353	776.600	4
354	L-3/12	55.00	1.65	24.25	36.35	354	812.957	26
355	005	84.05	3.50	22.40	76.70	355	836.013	16
356	LE-79-1	55.00	1.15	32.50	37.50	356	857.788	19
357	L-3/4	82.75	2.65	29.55	74.70	357	885.109	3
358	L-1/4	65.00	3.65	38.45	139.65	358	923.126	7
359	L-1/5	45.00	2.50	16.50	40.00	359	1018.231	15
360	L-1/6	55.00	2.85	17.90	50.00	360	1097.210	19
361	L-1/7	85.75	0.00	0.00	0.00	361	1119.306	23
362	L-1/14	63.75	2.00	24.35	45.00	362	1198.621	8
363	L-1/18	54.10	2.50	18.35	44.65	363	1249.180	12
364	L-1/10	48.25	3.35	18.50	61.65	364	1251.600	5
365	L-40	60.00	2.20	21.00	45.00	365	1316.352	10
366	CA-1-P	55.00	1.15	33.00	38.00	366	1320.170	18
367	BF-179	55.00	1.65	33.40	50.85	367	1381.692	22
368	L-7-1	70.00	0.50	15.00	15.00	368	1432.331	13
369	88/J/BF	64.25	2.15	27.65	55.85	369	1467.483	18
370	Sunog	65.00	3.00	26.05	70.15	370	1648.069	10
371	Perfecto	54.25	3.00	26.15	58.30	371	1893.460	24
372	86/F5-3-1	62.50	2.65	20.30	53.85	372	1928.747	10
373	L-3-5	60.00	3.50	16.45	57.35	373	1980.008	26
374	L-10/5	55.00	3.80	16.00	60.80	374	2168.563	19
375	L-10/6	58.00	3.65	19.45	70.00	375	2409.242	37
376	L-5/8	21.10	2.35	24.25	56.35	376	2422.324	10
377	L-2/5	55.00	1.35	29.60	38.85	377	2442.779	34
378	L-1/6	85.00	3.35	11.30	37.70	378	2858.653	20
379	L-1/5	64.10	2.85	15.65	44.65	379	3105.818	28
380	L-6/9	91.90	0.00	0.00	0.00	380	3285.999	45
381	F5-4-7	55.00	1.35	31.10	39.85	381	3345.759	13
382	F3-4-1	45.00	3.15	9.95	31.30	382	3773.633	45
383	F2-8-2	65.00	3.00	19.15	56.65	383	4810.454	18
384	F3-6-9	56.25	3.00	24.25	70.80	384	4875.026	46
385	F3-6-10	43.25	3.85	10.00	38.35	385	512.452	41
386	F3-10-5	65.00	3.00	12.65	38.00	386	5375.835	51
387	F3-3-1	80.00	2.00	15.80	31.50	387	5561.525	18
388	F3-6-8	78.75	1.65	26.65	42.50	388	5783.555	17
389	F3-7-8	43.50	1.35	23.00	29.65	389	6011.612	50
390	F3-5-8	37.35	3.20	15.50	49.15	390	6519.362	69
391	L-4/10	65.00	2.65	10.45	27.20	391	8360.346	31
392	L-4/11	55.00	3.85	12.50	46.65	392	9359.311	80

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1	2	3	4	5	6	7	8	9
393	L-4/18	64.25	1.00	27.10	26.65	393	10836.415	68
394	L-22/5	46.25	2.15	16.10	31.35	394	12915.525	137
395	L-6/14	86.25	3.15	12.10	38.00	395	15672.274	49
396	F3-10-21	95.00	2.50	16.20	40.50	396	25371.349	99
397	88/TF/J	80.00	1.20	11.80	14.15	397	44830.065	35
398	26/DWD-SL	99.25	2.15	17.95	33.00	398	82164.408	217
399	21/DWD-1	100.00	0.35	10.70	7.50	399	255660.386	134
400	Marikrit-W	100.00	0.00	0.00	0.00	400	267300.824	268
401	L-10-8	98.75	0.85	6.85	6.00	401	1149053.820	402
402	L. pimpinellifolium	78.50	0.80	8.35	6.35			