INVESTIGATIONS ON BACTERIAL WILT RESISTANCE IN TOMATO

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By

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CERTIFICATE

This is to certify that the thesis entitled "**INVESTIGATIONS ON BACTERIAL WILT RESISTANCE IN TOMATO**" submitted by **Mr. GURURAJ P. KULKARNI** for the degree of **DOCTOR OF PHILOSOPHY** in **HORTICULTURE** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis for the award of any other degree, diploma, associateship, fellowship or other similar titles.

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Affectionately
Dedicated

To

Beloved Parents
Smt. Indira P. Kulkarni
Shri. Pralhadrao J. Kulkarni

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No scientific endeavour is a result of an individual's efforts.

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Introduction

I. INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) once considered inedible, has become one of the most popular and extensively consumed vegetable. It's self-pollinated crop belonging to family Solanaceae. Tomato occupies a distinct place in the realm of vegetables because of its high nutritive value and large-scale utilisation. The fruits are consumed either fresh or cooked or in the form of various processed products like juice, ketchup, sauce, puree, whole canned fruits and also forms an important ingredient in the cocktail known as "Bloody Mary'. In fact tomato tops the list of the processed vegetables and is a very good source of vitamin A and C. In the present days it is gaining more medicinal importance because of the antioxidant property of ascorbic acid and lycopene content. The lycopene captures electrically charged oxygen molecules that can damage tissue. This also reduces the amount of so called 'bad' cholesterol and therefore may also lower the risk of heart diseases (Anon., 2002a). Annual world production of tomato during 2001 amounted to 98.62 million tonnes. India's contribution estimated to be 5.5 million tonnes from an area of 0.36 million hectares with a productivity of 15.06 t ha^{-1} (Anon., 2001). Within India, Karnataka has an area of 0.039 million hectares with production of 0.082 million tonnes (Anon, 2000b).

The productivity of India is very low compared to 79.29, 66.57 and 50.00 t ha^{-1} of Canada, USA and Australia respectively. In the face of mounting pressure, sustainable advance in tomato productivity and production is perhaps salutary to realise nutritional security particularly when India is facing demographic watershed. Without regular infusion of genetic variability available in tomato through hybridization, it is not feasible to make advances in productivity and production.

Now a days in India the cultivation of tomato is hindered by bacterial wilt incidence caused by *Ralstonia solanacearum* (Yabuuchi *et al.,* 1995). The disease is causing great threat to tomato production in plains of India and becoming a limiting factor in tomato production. The yield loss due to this disease is upto 90.62 per cent (Ramkishun, 1987). Thus tomato cultivation is greatly affected by bacterial wilt incidence. It is not known how long it can remain in the soil. Therefore, tomato industry in India is in a desperate need of tomato varieties/hybrids resistant to bacterial wilt. Race 1 of *Ralstonia solanacearum* infects tomato, eggplant and other solanaceous crops. Unfortunately, varietal resistance is known to fluctuate both geographically and over time caused by genetic variability of strains of the pathogen as well as with local environmental and climatic conditions (Prior *et al.,* 1990). *R. solanacearum* is an aerobic gram negative rod measuring approximately 0.5-0.7 x 1.5 – 2.5 μm. Virulent forms are mainly non-flagellated and non motile. Avirulent forms usually bear 1-4 flagella and highly motile (Kelman and Hruschka, 1973).

Various strategies have been developed for controlling bacterial wilt like application of chemicals, cultural practices and biological control, but none of them proved as effective as cultivation of resistant cultivar. So, there is an urgent need to approach the disease management through host plant resistance. For the development of a resistant variety/hybrids donors of resistance are the pre-requisite and should be identified by the well established technique of screening 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. However, in order to evolve tomato hybrid/variety resistant to bacterial wilt with more genetic diversity, the investigations with respect to various mechanisms of resistance *viz.*, genetical, histopathological, nutritional and their association with other traits, is very much essential. The utilisation of effective genetic resource and the efficient breeding and selection methods to recombine the desired type of resistance for getting higher and economical yield is necessary.

Considering the spectrum of aforesaid requirement in tomato, the present investigations were taken up with the following objectives.

1. To screen the tomato genotypes against *Ralstonia solanacearum*.
2. To develop bacterial wilt resistant tomato hybrids with higher yield.
3. To estimate the heterosis and combining ability effects for growth, yield and quality parameters.
4. To study the inheritance of bacterial wilt resistance and isolation of transgressive segregants with bacterial wilt resistance.
5. To manage the bacterial wilt of tomato through soil amendment.
6. To study the histopathology of resistant and susceptible tomato genotypes and
7. To know the effect of crop rotation with non-hosts on bacterial wilt incidence in tomato.

Review of Literature

II. REVIEW OF LITERATURE

Tomato (*Lycopersicon esculentum* Mill.) having unfounded superstitions (as a safety food) that persisted widely, to a level of dietary staple is because of the chain of events initiated by tomato growers. The tomato breeders have exploited the phenomenon of heterosis to their best level. Because of this, over the past few decades, the area under this crop, increased considerably in India and other parts of the world. The increased area and continuous growing of this crop round the year has exposed it to many biotic and abiotic stresses. One of the biotic stresses which hampers the cultivation of tomato in tropical, sub-tropical and humid regions of the world is bacterial wilt, incited by *Ralstonia solanacearum* (Yabuuchi *et al.*, 1995). So, there is an urgent need to identify resistance source and to understand the mechanisms of bacterial wilt resistance which helps in developing bacterial wilt resistant hybrid / variety with good horticultural traits and in effective management of disease. Thus the tomato production can be boosted in bacterial wilt endemic areas. Moving in this direction, the chapter has been penned in order to capitalize on the literature and achievements available pertaining to the objectives envisaged in the previous chapter.

2.1 PATHOGEN AND PATHOGENESIS

Ralstonia solanacearum is a complex pathogen differing in host range and pathogenicity. Geographical variation occurs in the organism. Several races and strains occur in the same area although they attack different hosts (French and Sequeria, 1970). Buddenhagen *et al.* (1962) observed race 1 of the pathogen affecting tomato, tobacco and other solanaceous crops. Rath and Addy (1977) reported ten isolates causing wilt of tomato belonging to race 1.

2.2 DISEASE REACTION

Much of the early breeding work on disease resistance was carried out at North Carolina in USA. The disease reaction study will help the breeder in identifying resistance source and developing disease resistant hybrid / variety.

First report of bacterial wilt was from Italy in 1882 by Walker (1952). In India, bacterial wilt was first observed in 1892 by Cappel in potato, four years before Smith (1896) could describe the disease and its causal agent. The bacterial nature of this disease was established by Coleman (1909). The first report on bacterial wilt of tomato in India was by Hedayathullah and Saha (1941) from West Bengal. Since, then the reports on this dreaded disease are flowing in from most of the countries, wherever solanaceous vegetables are grown.

In field tests Louisiana Pink and T 414 from Puerto Rico showed good resistance to bacterial wilt (Schaub and Baver, 1944). Abeygunawardena and Siriwardena (1963) reported that in Sri Lanka, North Carolina lines 1960-8, 1960-2a, 1962-B2, 1861-57-55M and also Masterglobe and Rahangala Selection-1 were most resistant. The North Carolina lines were superior in wilt resistance to local cultivated varieties and out yielded the commercial varieties Marglobe and Pearson.

Rao *et al.* (1975) tested 23 wilt resistant cultivars and lines from USA and Philippines for their reaction to an Indian isolate of *Pseudomonas solanacearum*, only one line, CRA 66 selection A from Hawaii was resistant. Jenkins and Nesmith (1976) evaluated the resistance of cultivars Venus and Saturn to Indian isolate and American isolate of *P. solanacearum*. They found both of them as susceptible and concluded that Indian isolate was more virulent than American isolate. Ramachandran *et al.* (1980) observed that out of 36 tomato genotypes La Bonita and CL-32-d-1-19GS were resistant to bacterial wilt in Kerala. Hanudin (1987) reported resistance in tomato cultivars Intan, Ratna, CL 32-6-125-d-O, moderate resistant AV 22 and AV 15, Venus, Bonset and Gerldton to *P. solanacearum*.

Sinha *et al.* (1988) reported in their field trial BWR-1, BWR-5 and LE-79 as resistant. Whereas, Sharma and Kumar (1997) reported the above envisaged genotypes as moderately resistant. Among the 213 tomato genotypes evaluated by Sharma *et al.* (1997b), 88 BWR-1 was rated as immune, 83-2211, 84 BWR-3, 84 BWR-14 and CL 5955-223 D4-22-0 as highly resistant. Mahanta *et al.* (1998) identified BT-12, BT-14 and Pusa Sheetal as free from wilt among the 23 genotypes. Among the three lines evaluated against Philippines and Taiwan strains of *R. solanacearum,* H-7996 was found better compared to L-390 and L-1801-1 (Anon., 2000a).

The three entries CLN-2116-DC1F_1-180-31-10-25-8-0, CLN-2114-DC1F_1-50-2-168-2-17-0 and CLN-2116-CD1F1-180-31-9-34-4-0 were found to exhibit bacterial wilt resistance consistently for three seasons among eight lines evaluated by Sadashiva *et al.* (2002).

2.3 HETEROSIS

When two parental populations are crossed, the F_1 population mean, may be superior to mid parental value. This superiority in mean is called as heterosis. The magnitude of heterosis depends on accumulation of favourable dominant alleles in the F_1 population. If the parental populations differ from each other for more favourable dominant alleles, the magnitude of heterosis will also be proportionately higher. This relationship is evidenced in the basic formula for heterosis (Falconer, 1981).

Heterosis in $F_1 = \sum dy^2$

Where, d = Magnitude of dominance

y = Differences between the parental populations for allelic frequencies at the locus.

Hedrick and Booth were the first to observe the phenomenon of hybrid vigour as early as 1907. Later, Wellington (1912, 1922) presented evidence indicating good commercial possibilities for first generation hybrid tomatoes. Though, tomato is a self pollinated crop where degree of heterosis was theoretically considered less (Gallias, 1988), but considerable degree of heterosis has been documented and utilised. However, the unusual high heterosis observed in tomato crop has been attributed to the fact that tomato was basically a highly out crossing genus which was later evolved into a self-pollinated one (Rick, 1965). Based on reports of various scientists, the heterosis with respect to different characters is reviewed here.

2.3.1 Plant height

Significant positive heterosis in tomato for plant height was observed by Prabhushankar (1990), Satyanarayana (1990), Dundi (1991), Dod *et al.* (1992), Singh and Singh (1993), Xue (1994), Dod *et al.* (1995), Nagaraja (1995), Dharmatti (1995), Ghosh *et al.* (1997) and Sajjan (2001). For the same character significant negative heterosis has also been noticed by Sharma *et al.* (1997a), Patil (1997), Srivastava *et al.* (1998), Kulkarni (1999), Baishya *et al.* (2001) and Mohan and Ranganath (2002).

2.3.2 Plant spread

Reduced plant spread is desired character in tomato for increasing productivity. Patil (1996) observed significant heterobeltiosis and standard heterosis in desired direction. Whereas the relative heterosis remained non-significant in the study of Patil (1997).

2.3.3 Number of primary branches per plant

Significant positive heterosis for number branches per plant was observed by Prabhushankar (1990), Dundi (1991), Singh and Singh (1993), Nagaraja (1995), Dharmatti (1995), Ghosh *et al.* (1997), Patil (1997), Srivastava *et al.* (1998), Kulkarni (1999) and Mohan and Ranganath (2002) However, Ashwathappa (1980) and Sajjan (2001) observed significant negative heterosis for this trait over better and best parent respectively in tomato.

2.3.4 Days to 50 per cent flowering

Earliness to flowering is expressed as negative heterosis and was an established manifestation of heterosis among tomato hybrids as it has been observed by several workers like Prabhushankar (1990), Dundi (1991), Patil (1997), Ghosh *et al.* (1997), Baishya *et al.* (2001) and Mohan and Ranganath (2002).

However, Singh and Singh (1993) and Pujari and Kale (1994) indicated positive heterosis for earliness.

2.3.5 Number of flowers per cluster

In a study of eight tomato lines from inter variety hybrids Svanosia and Vandoni (1974) observed heterosis for flower number. The hybrids were intermediate between their parents with respect to number of flowers produced (Popova and Mikhailov, 1969), while Gowda (1979) noticed reduced number of flowers in F_1 in general. However, both of them have reported increased number of flowers in F_1 derived from Tiny Tim parent. Significant heterosis for this trait was observed by Patil (1984) in tomato ranging from -14.69 to 48.83, -7.79 to 52.97 and -20.67 to 35.72 per cent over mid, lower and higher parent respectively.

Patil (1997) and Sajjan (2001) obtained significant positive economic heterosis while, Kulkarni (1999) observed only negative economic heterosis for all the hybrids.

2.3.6 Number of clusters per plant

Positive heterosis for clusters per plant has significant effect on yield. Kanthaswamy and Balakrishnan (1989), Prabhushankar (1990), Dundi (1991), Nagaraja (1995), Dharmatti (1995), Patil (1997) and Sajjan (2001) reported positive heterosis for this trait in tomato.

Similarly, negative heterosis has also noticed by Kulkarni (1999) and it ranged from -0.51 to -50.00 in 6 x 6 diallel study.

2.3.7 Number of fruits per cluster

Ashwathappa (1980) observed significant heterosis over mid parent while, that over better parent was non-significant. Curatero and Cubero (1982) reported more number of fruits per cluster in F_1 than parents. Patil (1984) observed heterosis over mid parent (-12.68 to 48.82%), lower parent (-10.16 to 53.32%) and higher parent (-17.12 to 20.50%) for this character in tomato. Kanthaswamy and Balakrishnan (1989), Prabhushankar (1990), Dundi (1991), Pujari and Kale (1994), Patil (1997), Kulkarni (1999), Sajjan (2001) and Roopa *et al.* (2002) also observed heterosis for number of fruits per cluster.

2.3.8 Number of fruits per plant

Number of fruits per plant is considered an important component of yield in tomato. Manifestation of heterosis for this characters was very much apparent with the works of Prabhushankar (1990), Dundi (1991), Tendulkar (1994), Dharmatti (1995), Nagaraja (1995), Sureshkumar *et al.* (1995), Dod *et al.* (1995), Sharma *et al.* (1997a), Srivastava *et al.* (1998), Mageswari and Natarajan (1999) and Sajjan (2001).

Significant negative heterosis has also been noticed by Patil (1997), Kulkarni (1999) and Baishya *et al.* (2001)

2.3.9 Average fruit weight

This trait is also an important component of yield and heterosis has been reported by Patil (1984), Prabhushankar (1990), Dundi (1991), Xue (1994), Dod *et al.* (1995), Sharma *et al.* (1997a), Patil (1997), Kulkarni (1999), Mageswari and Natarajan (1999), Sajjan (2001), Baishya *et al.* (2001) and Roopa *et al.* (2002) in tomato.

Tendulkar (1994) reported the heterosis ranging from –9.63 to 51.40, -6.71 to 33.24 and –6.64 to 4.36 per cent over their respective mid, better and best parent, respectively. However, Ashwathappa (1980) and Alvarez (1985) observed high negative heterosis over mid and better parent.

2.3.10 Yield per plant

Heterosis for yield is a common phenomenon in tomato, though the degree of heterosis varies widely, which can be attributed to the variation in the potentialities of parents chosen for the crossing programme. An overview of work on heterosis in tomato for fruit yield per plant revealed a wide range of both relative heterosis and heterobeltiosis (Hedrick and Booth, 1907).

Ashwathappa (1980) noticed heterosis for fruit yield and was highly significant over mid parent (112.06%). Whereas, it was non significant over better parent (35.99%). Dixit *et al.* (1980) observed the highest heterosis for yield over better parent in the cross Kalyanpur Kuber x Pusa Ruby. Sonene *et al.* (1981) tested 157 hybrids, of which 13 recorded 80 to 155 per cent higher yield than the control Pusa Ruby. Among 28 F_1 hybrids and parents evaluated by Singh and Singh (1993) hybrid Punjab Chhuhara x 84-8 showed the highest heterosis for fruit yield per plant over the mean and better parent values and produced the highest fruit yield per pant (1200 g).

Positive heterosis for yield per plant has been reported by Prabhushankar (1990), Dundi (1991), Pujari and Kale (1994), Sureshkumar *et al.* (1995), Patil (1996), Patil (1997), Sharma *et al.* (1997a), Kulkarni (1999), Mageswari and Natarajan (1999), Chadha and Kumar (2001), Sajjan (2001), Baishya *et al.* (2001) and Roopa *et al.* (2002).

2.4 FRUIT PHYSICAL CHARACTERS

2.4.1 Fruit shape Index

Ashwathappa (1980) observed a very low heterosis (3.66%) over mid parent and negative heterosis (-3.18%) over better parent in tomato. Patil (1984) observed the heterosis percentages ranging from –35.24 to 18.58, -19.70 to 40.40 and –50.57 to 10.12 over mid, lower and higher parents, respectively. Significant heterosis in desired direction has been evidenced by Dundi (1991), Tendulkar (1994), Reddy and Reddy (1994), Kulkarni (1999) and Chadha and Kumar (2001).

2.4.2 Number of locules per fruit

Negative heterosis for locule is a desirable expression in tomato hybrids/ varieties and such tendency has been observed by Prabhushankar (1990), Satyanarayana (1990), Dod and Kale (1992), Sundaram *et al.* (1994), Dod *et al.* (1995), Dharmatti (1995), Kulkarni (1999) and Sajjan (2001). However, Dundi (1991), Ghosh *et al.* (1997), Srivastava *et al.* (1998) and Chadha and Kumar (2001) obtained positive heterosis for this trait. Tendulkar (1994) reported significant negative heterosis in 29 crosses over mid and better parents and 18 crosses were able to exhibit significant negative heterosis over commercial check.

2.4.3 Pericarp thickness

This trait plays important role in governing the firmness of tomato fruits. Sidhu *et al.* (1981), Patil (1984), Prabhushankar (1990), Dundi (1991), Reddy and Reddy (1994), Ghosh *et al.* (1997), Patil (1997), Chadha and Kumar (2001), Sajjan (2001) and Roopa *et al.* (2002) noticed increased pericarp thickness in the hybrids over their parents.

Significant negative heterosis has also been observed in tomato by Dod and Kale (1992), Dod *et al.* (1995) and Kulkarni (1999).

2.5 FRUIT QUALITY PARAMETERS

2.5.1 Total Soluble Solids

Total soluble solids (TSS) are related to yield of concentrated tomato products and hence high TSS is a preferable character in processing tomatoes. The positive heterosis for soluble solids was observed by Sonene *et al.* (1981), Satyanarayana (1990), Dundi (1991), Dod and Kale (1992) , Reddy and Reddy (1994), Tendulkar (1994), Dod *et al.,* (1995), Patil (1997), Ghosh *et al.* (1997), Mageswari and Natarajan (1999), Sajjan (2001) and Dhatt *et al.* (2001).

While, Prabhushankar (1990), Nagaraja (1995) and Chadha and Kumar (2001) noticed negative heterosis for this trait. Valicek and Obeidat (1987) observed three hybrids being intermediate between their parents in soluble solids content. Dharmatti (1995) observed heterosis for TSS which ranged from –100 to 386.07 per cent over mid parent, -100 to 282.59 per cent over better parent, -100.to 22.85 per cent over best parent and –100 to 68.11 per cent over commercial check.

2.5.2 pH of fruit juice

A pH value exceeding 4.5 is undesirable for standard processing methods and hence negative heterosis is of immense value to evolve processing tomatoes.

Zhou and Xue (1990) observed negatively significant heterosis in 13 and positively significant heterosis in two out of 20 combinations. Satyanarayana (1990), Tendulkar (1994), Patil (1997), Ghosh *et al.* (1997) and Srivastava *et al.* (1998) observed negative heterosis for p^H over mid and better parent.

2.5.3 Titratable acidity

Acidity influences the storability of processed tomatoes and tomato products by inhibiting the spore germination of thermophilic organisms.

The positive heterosis for acidity was observed in some hybrids by Patil (1984), Satyanarayana (1990), Reddy and Reddy (1994), Patil (1996), Patil

(1997), Mageswari and Natarajan (1999) and Dhatt *et al.* (2001). Negative heterosis has also been registered in the hybrids studied by Ghosh *et al.* (1997).

2.5.4 Ascorbic acid

Patil (1984) reported heterosis for ascorbic acid content which ranged from –36.37 to 38.87, -31.70 to 75.61 and –40.43 to 30.57 per cent over mid parent, lower parent and higher parent respectively. A 8x8 diallel study in tomato by Prabhushankar (1990) also witnessed significant positive and negative heterosis. Dod and Kale (1992), Dod *et al.* (1995), Ghosh *et al.* (1997), Mageswari and Natarajan (1999), Dhatt *et al.* (2001) and Singh *et al.* (2002) noticed similar results.

2.5.5 Lycopene

Fruit colour as a component of quality is important to the grower, as it affects product appearance and ultimately consumer acceptance in tomato. Increased lycopene content is desirable. Lycopene content is increased by crimson gene (*og*) and the high pigment (*hp*) gene.

Bhutani (1981) studied the heterosis for carotenoid and lycopene and concluded that HS 102 x Best of All and G_2 x Best of All as heterotic hybrids for higher lycopene and carotenoid content. Tikoo (1981) recorded higher lycopene content in some F_1 hybrids than their parents. Onate (1986), Rajput (1987), Satyanarayana (1990), Patil (1996), Patil (1997) and Singh *et al.* (2002) also recorded heterosis for lycopene content.

2.6 COMBINING ABILITY

The general combining ability (gca) coming from the two parents, the specific combining ability (sca) arising from the interaction between the genotypes of the two parents, determines the performance of the progeny developed by crossing such parents. This is represented as:

$$X\text{-}X = gca_p + gca_q + sca_{pq}$$

Where,

X = True mean of cross between p and q

X = Mean of all crosses

Popular line x tester analysis developed from the concept of North Carolina Designs is helpful in determining the gca and sca effects. Thus it is possible to estimate the potentiality of the crosses and also to apportion the course for this superiority interms of gca and sca effects.

The gca reflects the breeding value of the parental genotype concerned and helps in identifying genotypes to be used for developing superior populations. The sca effect represent the non reliable component of the genotype value arising due to contribution from dominance deviation and inter action deviation (Patil, 1995). Hence, if the sca effect is the main cause for superiority of a cross, it is inferred that superiority of this cross cannot be fixed through selection.

In general, a good relationship exists between the performance of the parents and the average performance of their F_1 crosses, as reported by Powers (1945) and Moore and Currence (1950) in tomato. In pursuit of rendering a genetic improvement in crop plants, the vegetable breeder, must posses an adequate knowledge of combining ability and allied genetic parameters. Such knowledge has been steadily increasing in tomato and reports available have been summarised below.

2.6.1 Plant height

Anbu *et al.* (1981), Dod *et al.* (1995), Sharma *et al.* (1999) and Bhatt *et al.* (2001) observed higher SCA variance than GCA variance in tomato. Contrary to these results Pradeepkumar *et al.* (1997) and Patil (1997) obtained higher GCA variance than SCA variance. There by indicating the pre-ponderance of additivity in governing this character. Significant gca and sca effects were observed by Prabhushankar (1990), Dundi (1991), Dharmatti (1995), Srivastava *et al.* (1998) Sharma *et al.* (1999) and Sajjan (2001) and were of the opinion that both the effects were important.

2.6.2 Plant spread

For this trait higher SCA variance than GCA variance was recorded by Patil (1996) in tomato. Further he observed highly significant negative gca and sca effects whereas, Patil (1997), reported higher GCA variance than SCA variance and only significant negative gca effect.

2.6.3 Number of primary branches per plant

Higher magnitude of GCA variance was observed by Nagaraja (1995). Contrary to it Kalloo *et al.* (1974) and Dharmatti (1995) observed higher SCA variance than GCA variance there by indicating the importance of non-additive gene effects for primary branches per plant in tomato.

Significant gca and sca effect in desirable direction were noted by Prabhushankar (1990), Satyanarayana (1990), Patil (1996), Patil (1997), Kulkarni (1999) and Sajjan (2001).

2.6.4 Days to 50 per cent flowering

In a line x tester analysis Anbu *et al.* (1981) and Tendulkar (1994) found that combining ability variances exhibited larger variance for SCA for days to flowering in tomato. Contrary to this in similar study Singh and Singh (1980) and Patil (1997) reported higher GCA variance than SCA variance. Swamy and Mathai (1982) observed significant general and specific combining ability effects for days to flowering and that the ratio of GCA variance to SCA variance was more than unity, indicating the importance of additive variance for this character in tomato. The estimated components of SCA variance were larger in magnitude than due to GCA variance (Patil, 1984). Prabhushankar (1990), Dundi (1991) and Srivastava *et al.* (1998) observed significant negative gca and sca effects for this character. Where as Patil (1997) observed only significant negative gca effects.

2.6.5 Number of flowers per cluster

The 8x8 half diallel study of tomato by Patil (1997) yielded significant positive gca effects for six parents and significant sca effects for all the 28 crosses of tomato. Similarly, Prabhushankar (1990), Patil (1996), Kulkarni (1999) and Sajjan (2001) obtained significant gca and sca effects in tomato.

Bhatt *et al.* (2001) reported the preponderance of non-additive gene effects for this trait. Where as Tendulkar (1994) obtained preponderance of additive gene effects in tomato.

2.6.6 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 tomato hybrids four crosses had significant positive sca effect for this trait. Dholaria and Quadri (1983) reported that small and medium fruited cultivars of tomato 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 five parents and six crosses respectively in tomato.

The higher SCA variance than GCA variance was observed by Prabhushankar (1990), Satyanarayana (1990), Tendulkar (1994), Dharmatti (1995), Kulkarni (1999) and Sajjan (2001).

2.6.7 Number of fruits per cluster

The preponderance of additive gene effects in controlling this character was observed by Prabhushankar (1990). The non additive gene effects were more dominant than additive gene effects in the studies of Satyanarayana (1990), Patil (1996), Patil (1997), Kulkarni (1999), Sajjan (2001) and Bhatt *et al.* (2001).

2.6.8 Number of fruits per plant

Nandapuri and Tyagi (1976) observed significant gca and sca effects for this character in tomato. Similar observations were also made by Prabhushankar (1990), Dundi (1991) and Dharmatti (1995) in tomato.

Greater magnitude of GCA variance was observed by Kalloo *et al.* (1974), Lonkar and Borikar (1988), Tendulkar (1994) and Sajjan (2001). Whereas, greater magnitude of SCA variance was observed by Prabhushankar (1990), Dundi (1991), Dod *et al.* (1995), Dharmatti (1995), Pradeepkumar *et al.* (1997), Patil (1997), Srivastava *et al.* (1998), Kulkarni (1999) and Bhatt *et al.* (2001) in tomato. All these reports indicate that the trait, number of fruits, per plant is governed by both additive and non-additive gene effects in tomato.

2.6.9 Average fruit weight

Higher magnitude of GCA variance than SCA variance was observed by Prabhushankar (1990), Tendulkar (1994), Dod *et al.* (1995), Patil (1996), Pradeepkumar *et al.* (1997) and Patil (1997). The results of Patil (1984), Dharmatti (1995) and Sajjan (2001) evidenced the preponderance of non-additive gene effects in governing this character in tomato.

The gca effects in 6 x6 diallel study by Kulkarni (1999) ranged from -1.61 to 0.72 where as the sca effects ranged from –4.56 to 4.11.

2.6.10 Yield per plant

Singh and Nandapuri (1974), Dixit *et al.* (1980) and Lonkar and Borikar (1988) reported high GCA variance for this trait. While, high SCA variance was observed by Prabhushankar (1990), Dundi (1991), Dharmatti (1995), Dod *et al.* (1995), Pradeepkumar *et al.* (1997), Srivastava *et al.* (1998), Kulkarni (1999), Sajjan (2001) and Bhatt *et al.* (2001).

In a 10 x 10 diallel analysis of tomato Patil (1996) obtained significant positive gca and sca effects for only three parents and crosses respectively. Other scientists who evidenced significant gca and sca effects in tomato were Tendulkar (1994) and Sharma *et al.* (1999).

2.7 FRUIT PHYSICAL CHARACTERS

2.7.1 Fruit shape index

Significant gca and sca effects were registered for tomato fruit shape index by Dundi (1991), Tendulkar (1994) and Chadha *et al.* (2002).

Singh and Mital (1978) and Dundi (1991) reported that GCA variance was predominant than SCA variance whereas Tendulkar (1994), Kulkarni (1999) and Sajjan (2001) observed predominance of SCA variance in tomato hybrids.

2.7.2 Number of locules per fruit

Dod *et al.* (1995) from their 12 x 12 diallel analysis of tomato revealed the importance of additive gene effects in governing this character. Similar observations were made by Patil (1997), Pradeepkumar *et al.* (1997) and Chadha *et al.* (2002).

Contradictory to these Dharmatti (1995), Srivastava *et al.* (1998), Kulkarni (1999) and Sajjan (2001) observed preponderance of non-additive gene effects for number of locules per tomato fruit.

Further significant gca and sca effects in parents and hybrids of tomato were obtained by Patil (1984), Prabhushankar (1990) and Dundi (1991) in desired direction.

2.7.3 Pericarp thickness

Pradeepkumar *et al.* (1997) from line x tester analysis of tomato genotypes reported higher SCA variance for pericarp thickness than GCA variance. Similar results were obtained by Prabhushankar (1990), Tendulkar (1994), Sajjan (2001) and Chadha *et al.* (2002). On the contrary Patil (1984), Dundi (1991), Dod *et al.* (1995), Patil (1996) and Patil (1997) observed higher magnitude of GCA variance for tomato hybrids.

Among 24 crosses of tomato Sharma *et al.* (1999) observed significant positive sca effect for six crosses, the highest being registered in the cross BTN-46 x AC-402.

2.8 FRUIT QUALITY PARAMETERS

2.8.1 Total soluble solids

Dhatt *et al.* (2001) in a line x tester analysis of tomato involving ripening mutants as testers observed highly significant sca effect for 34 crosses out of 60 crosses and highly significant gca effects for six parents out of 17 parents in desired direction. Similar results were obtained by Patil (1997), Sharma *et al.* (1999) and Sajjan (2001). Whereas, Dundi (1991), Dod *et al.* (1995), Patil (1996) and Patil (1997) reported that, the trait TSS is under the control of additive gene effects in tomato. On the contrary Prabhushankar (1990), Satyanarayana (1990), Dod *et al.* (1995), Dharmatti (1995), Pradeepkumar *et al.* (1997) and Kulkarni (1999) noticed preponderance of non-additive gene effects for this trait.

2.8.2 pH of fruit juice

Significant negative gca and sca effects were observed by Tendulkar (1994) for pH of tomato fruit juice. Rajput (1987) observed importance of non-additive gene effects but, Patil (1997) observed importance of additive gene effects for pH.

2.8.3 Titratable acidity

Lukyanenko and Lukyanenko (1981) observed dominance for high free acid content, which was usually higher when the high content free acids parent was used as maternal parent in tomato hybrids. Over dominance for high total acid content was observed by Daskaloff and Kantantinova (1981). Monma and Kamimura (1982) also reported dominance for high acidity, in a cross between Ark-60-90-1 and Morioka-10. Patil (1984), Patil (1996), Patil (1997) and Dhatt *et al.* (2001) observed highly significant gca and sca effects for this character in tomato.

2.8.4 Ascorbic acid

Kalloo *et al.* (1974) noted a very high SCA variance compared to GCA variance in a study of 8 x 8 diallel study. Contrasting results were also reported by Dod *et al.* (1995) and Pradeepkumar *et al.* (1997). In a study involving *rin, nor* and *alc* alleles Dhatt *et al.* (2001) observed preponderance of non-additive gene effects for ascorbic acid and further he noted significant gca and sca effects in tomato.

2.8.5 Lycopene content

Daskaloff *et al.* (1967) observed that low lycopene content was dominant or over dominant in F_1 hybrids of tomato. Similar type of observations were also made by Tikoo (1981) and Rajput (1987). On the contrary Roy and Choudhary (1972) observed partial to complete dominance for intense colour development in tomato fruits.

Bhutani and Kalloo (1983), Patil (1996), Patil (1997) and Pradeepkumar *et al.* (1997) found higher magnitude of non-additive genetic variance than additive genetic variance for lycopene in tomato fruit.

2.9 ISOLATION OF TRANSGRESSIVE SEGREGANTS IN F_2 POPULATION

As early as in 1944, Larson and Currence studied the extent of hybrid vigour in F_1 and F_2 of tomato crosses. The average yield increase of F_1 over the parents was 39 per cent and in F_2 generation, the increase was 23 per cent. Two F_2 populations were significantly lower yielding than their parents. This was attributed to small fruit size and low yielding ability of the parents involved. Joubert and Lag (1949), observed that F_2 yields were lower than F_1 hybrids but sufficient vigour was obtained in some F_2's for practicable use.

Choudhury *et al.* (1965) recorded a wide range of retention of hybrid vigour in different combinations in the segregating population of tomato. The F_2 generations of the best combinations were *viz*. Improved Meeruti x Pusa Ruby, Local x Best of All, Improved Meeruti x Local and they out yielded their respective best parents by 18.92, 18.78 and 15.19 per cent respectively. The F_2 generation of all the 11 crosses showed 15.23 per cent increase in total yield over the total average of all the seven parents. As regard to main economically useful characters the F_2 populations close to F_1 (Rudas, 1978).

Chandrasekaran *et al.* (1983) evaluated F_3 progeny of four crosses. The progenies of LE713 x LE68 and LE 744 x LE 113 were promising on the basis of height, number of laterals, earliness, fruit weight and yield.

Reddy (1985) found that the F_2's exceeded the mid parental values for yield (4 crosses), number of fruits per plant (1 cross), average fruit weight (6 crosses), number of fruiting clusters (6 crosses), primary and secondary branches (6 crosses). Further, he observed that there was no inbreeding depression in case of Sel. 22 x Sel. 1, the F_2 mean was 19.88 per cent higher than its F_1.

On the contrary, Hiiop (1973), observed deterioration in the yield, earliness, appearance, flavour of the fruit and disease resistance in F_2 and F_3 hybrids of tomato compared to F_1. However, F_2 and F_3 hybrids showed better resistance to *Cladosporium fulvum.* The decreased yield was also noted from F_1 to F_2 by Szwadiak (1982) in tomato crosses.

Kedar and Rabinowitch (1980) opined that the high cost of F_1 hybrid seed will probably not allow their use in developing countries and in direct seeded fields in general. F_2 segregants would be more economical if disease resistant, heterotic and fairly uniform combination could be found. In nematode infested soils, one of the three F_2 segregants out yielded the four parental lines and was slightly inferior to the corresponding F_1 hybrid. In non-infested soils, the F_2 segregants were either similar or superior to the nematode resistant parent. The uniformity of some of F_2 segregants was satisfactory.

Few plants in the F_2 generation of cross 20/6 Alcobasa x L-58 and 20/5 Alcobasa x N-229 8MF_6 produced flowers and fruits continuously of desirable weight in spite of tomato leaf curl virus (TLCV) infection until late maturity. So, Dharmatti (1995), suggested that it is possible to evolve genotypes that react weakly to TLCV and produce normal fruits by adopting comprehensive selection strategies in tomato. Patil (1997) in his experiment identified the segregant CC-SF x CC-BF/96/3-8 as best from fresh market point of view with no major insect pests and diseases. The segregant SP28-2-2 x CC-BF/96/21-5 as the best from processing point as it had desirable processing traits. Monma *et al.* (1997) in their F_2 population of two tomato crosses (D9 x TPL-5, TPL-5 x Hawaii 7998), were able to isolate plants with both high bacterial wilt resistance and large fruit size and they indicated that the selection of resistance in the early generations is apparently effective. Contrary to this Mohamed *et al.* (1997) suggested to go for selection after several generations of selfing i.e. single seed descent method for accumulating bacterial wilt resistant genes. Since, the genetic nature of *L. esculentum* var. *cerasiformae* LA1421 is complex with a duplicate epistasis.

Okasha *et al.* (2001a) obtained positive inbreeding depression between F_1 and F_2 for yield, while negative inbreeding depression for earliness of flowering. The same authors (Okasha *et al.,* 2001b) in their experiment for quality parameters obtained inbreeding depression in desired direction for titratable acidity in tomato. They concluded that F_2 population of Dora, Rocky and Peto Pride 2 could be used as promising genotypes to reduce hybrid seed cost in tomato.

2.10 INHERITANCE OF BACTERIAL WILT RESISTANCE

The pattern in which the bacterial wilt resistance inherits is genotype, race, biovar, strain, environment specific and genetically determined. This inheritance patter helps the breeder in adopting the appropriate wilt resistant hybrid / variety. The literature available on source and pattern of inheritance for bacterial wilt resistance in tomato has been banked and presented here.

The source of resistance derived from *L. pimpinellifolium* (PI 127085A) was found to be partially dominant in the seedling stage and resistance was controlled by recessive genes in mature plants (Acosta *et al.*, 1964). Suzuki *et al.* (1964) stated that resistance to *P. solanacearum* was quantitatively inherited. Digat and Derieux (1968) made several crosses between resistant and susceptible cultivars and suggested partial dominance of resistance.

Tikoo *et al.* (1983) reported the presence of two independent gene systems for wilt resistance. Recessive genes in CRA 66 Sel.A from Hawaii 7998 and single dominant gene in 663-12-3, from Taiwan governed the resistance. Sreelathakumari (1983) reported a complimentary and hypostatic type of digenic recessive gene system responsible for wilt resistance.

The tomato line LE-79 resistant to bacterial wilt showed monogenic incompletely dominant gene action (Rajan and Peter, 1986). Nirmaladevi (1987) suggested digenic model for bacterial wilt resistance when BWR-1 was used as resistance source. But, the resistance in CRA 66 Sel.A was governed by polygenes. Thoquet *et al.* (1996) was also of the same opinion when he used Hawaii 7996 as resistance source. However, Oliveira *et al* (1999) stated that, the resistance is either oligogenic or polygenic depending on the genotype isolate combinations.

2.11 MANAGEMENT OF BACTERIAL WILT OF TOMATO

2.11.1 Soil amendments

Host resistance has shown some promise for control of bacterial wilt, but it may be somewhat site specific since the same tomato lines show different reaction at different places due to variation in strain / biovar / environmental factors. These factors have forced the other approaches to be included in an overall management scheme, in addition to breeding for resistance to control bacterial wilt of tomato (Michel *et al.,* 1997).

The use of soil amendments (SAs) is a widespread means to control disease caused by soil borne plant pathogens (Huang and Huang, 1993). Various SAs are known to suppress bacterial wilt of tomato, tobacco, potato and banana. One such soil amendment is gypsum ($CaSO_4$ $2H_2O$). The calcium content in plant tissues has been associated with increased resistance to some diseases. The presence of calcium in tissues interferes with hydrolysis by pectolytic enzymes (Edgington *et al.,* 1961).

The moderate (4.4 mM) and high (20.4 mM) Ca concentration in nutrient solution increased the resistance in highly resistant (Hawaii 7998) and moderately resistant (Zuiei) tomato cultivars against bacterial wilt. But, it has not made any impact on the resistance of susceptible cultivar 'Ponderosa' (Yamazaki and Hoshina, 1995). Michel *et al.* (1997) observed significant decrease in area under disease progress curve (AUDPC) of tomato bacterial wilt when soil amendment (200 kg N + CaO 5000 kg ha^{-1}) was added. Further, they reported that, there was significant decline in *R. solanacearum* population in soil as CaO content increased from 200 Kg to 5000 kg ha^{-1}. When the SA was tested under four locations, it influenced the AUDPC in both moderately resistant and susceptible cultivar, but it differed with location. During winter season, at CHES, Ranchi, when urea 200 kg + lime 5000 $kgha^{-1}$ was applied, 72.6 per cent of tomato population survived (Anon., 1999). The tomato cultivar 'Bonny Best' when received 160 ppm of Ca showed significant decline in the disease index for *Fusarium* wilt, compared to plants received the 13 and 20 ppm of Ca (Edgington and Walker, 1958). Deficient calcium (Ca) after inoculation, regardless of pre-inoculation Ca nutrition, significantly increased severity of wilt and growth of *Fusarium* in tomato (Corden, 1965). Adequate Ca after inoculation interferes with pathogenesis by limiting growth of the pathogen in the host.

Sharma and Kumar (2000) obtained 60.9 per cent control of bacterial wilt and 43.8 per cent decrease in *R. solancearum* population over initial population with the application of lime ($CaCo_3$).

2.11.2 Crop rotation with non hosts

Tomato is one of the quick money spinning crops. This made the crop to grow round the year, as it is photo insensitive. But, year round culture of tomato and other solanaceous vegetables made the bacterial wilt caused by *R. solanacearum* a devastating disease.

Crop rotation with non-hosts is one of the means to starve the pathogen of its hosts. This crop rotation reduces the population of *R. solanacearum* and there by allows the cultivation of solanaceous crops in the following season. A limited work has been done in this respect in tomato crop. So, the literature available with other solanaceous vegetables also has been penned here under.

Sohi *et al.* (1981) reported that, crop rotation sequences involving cowpea – maize – cabbage, okra – cowpea – maize were significantly superior over the control and other crop sequences in reducing tomato mortality due to bacterial wilt. While, in brinjal the crop rotation sequences involving maize-okra-radish, maize-cowpea-maize, okra-cowpea-maize and finger millet – eggplant – French bean were highly and significantly superior to the control. The potato bacterial wilt was brought down to one third in (potato-wheat-wheat-potato) and (potato-maize-maize-potato) rotations and to one fifth in (potato-millet-millet-potato) rotation (Kishore *et al.,* 1992).

Shekhawat *et al.* (1988) studied the incidence of brown rot in various crop rotations in Karnataka. They found that, the crop rotation sequences involving Gramineae family crop (potato-wheat-potato, potato – fingermillet – knolkhol – potato, potato- sorghum-potato) and onion (potato-onion-potato) have brought down the brown rot to 1.6, 2.3, 2.5 and 1.8 per cent respectively. Verma and Shekhawat (1991) in their crop rotation experiment, observed decline in bacterial wilt incidence in potato from 15.55 to 6.35 per cent in potato-wheat-lupin-maize-potato and from 15.02 to 7.52 per cent in potato-wheat-potato-maize – potato.

The bacterial wilt incidence in tomato was maximum in crop sequence following egg plant, in contrast, very low wilt incidence was observed in rice followed by tomato (Michel *et al.,* 1996). Among six crop sequences tested at Central Potato Research Institute (CPRI), Shimla, the crop sequence potato – paddy-potato and potato – beans – potato were found equally effective in reducing wilt incidence (Anon., 1999).

2.12 HISTOPATHOLOGY OF RESISTANT AND SUSCEPTIBLE GENOTYPES

When a pathogen enters into the host it brings several histological changes to multiply and establish itself. While doing so, it affects many physiological and metabolic activities which in turn affect the growth and development of plant. Since, the *R. solanacearum* lodges in the xylem tissue which is water conducting tissue. So, any change in this tissue leads to wilting of plant. Literature available on histological changes in xylem tissue aftermath of *R. solanacearum* entry in tomato is reviwed briefly here.

Wallis and Truter (1978) from their histopathological studies of root concluded that for wilting of tomato plant infected with *P. solanacearum* several factors are responsible. Some of them are : formation of tyloses and later breakdown of these, releasing bacteria in to xylem vessels there by blocking the xylem vessels; the presence of host breakdown products resulting possibly from the degradative action of bacterial or plant pectinolytic, cellulolytic and hemicellulolytic enzymes on vessel and cell walls, particularly during the later stages of pathogenesis. Grimault and Prior (1993) are of the opinion that, wilt occurs as a result of mechanical plugging of the water-conducting vessels with tyloses and exopolysaccharides.

In contrast to the above results Prior *et al.* (1990) and Grimault *et al.* (1994) reported that the resistance to wilting in tomato is closely related to the restriction of invasion by *P. solanacearum.* The limitation of spread of *P. solanacearum* in the vascular tissue of resistant plants has been attributed to the production of tyloses, an induced physical barrier. Grimault *et al.* (1994) further observed the colonised metaxylem vessels and cell wall breakdown forming cavities in the second internode of wilting cv. Floradel of tomato.

Material and Methods

III. MATERIAL AND METHODS

The study on "Investigations on bacterial wilt resistance in tomato" was undertaken during the year 2000-2002 in the Department of Horticulture, University of Agricultural Sciences, Dharwad. The details of material used for the investigation: development of F_1's and their evaluation; management of bacterial wilt of tomato through soil amendment, effect of crop rotation with non hosts on bacterial wilt incidence in tomato; experimental designs adopted and; statistical procedures followed are outlined in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE AND CLIMATE

Geographically Dharwad is located at 15° 26′ north latitude, 76° 07′ east longitude at an altitude of 678m above the mean sea level. Olericulture Unit of Department of Horticulture, Dharwad is situated in the agro-climatic Zone–VIII.

The average annual rainfall of last 49 years (1950-1999) is 783.29 mm, fairly well distributed from April to November with two peaks, one in July and other in October. The mean monthly maximum temperature range from 27.05°c to 38.23°c while, mean monthly minimum temperature range between 13.48°c and 21.47°c. The mean relative humidity (RH) fluctuates between 56.62 and 88.39 per cent. The details of weather data are presented in Appendix – I.

3.2 EXPERIMENTAL SITE

Field experiments (except evaluation of genotypes for growth and yield parameters and heterosis and combining ability studies) were conducted at Olericulture Unit, Department of Horticulture, UAS, Dharwad in wilt sick field/pot. The wilt sick field was maintained by growing continuously solanaceous vegetables. The type of soil is red soil (Inceptisol). The physical and chemical properties of the soil are presented in Appendix – II.

3.3 EXPERIMENT– I: EVALUATION FOR BACTERIAL WILT RESISTANCE AND *PER SE* PERFORMANCE OF GENOTYPES

3.3.1 Evaluation for bacterial wilt resistance

The material consisted of 212 genotypes (Appendix-III) maintained by the Department of Horticulture, UAS, Dharwad.

The seeds of these 212 genotypes were sown in the nursery beds during 1st week of January 2000. The seedlings were raised by following regular nursery practices (Anon., 2002b). The 30 days old seedlings of 212 genotypes were transplanted to the main field under epiphytotic conditions along with susceptible check Pusa Ruby at a spacing of 60 cm x 60 cm. The susceptible check (Pusa Ruby) interplanted after every 10 rows.

The experiment was laid out in a randomized block design (RBD) with two replications. A row consisting of 15 plants formed a replication under each treatment.

Of the 212, genotypes, 57 genotypes were selected based on the reaction to bacterial wilt. These 57 genotypes including susceptible check Pusa Ruby were subjected to artificial inoculation during *kharif* 2000. The artificial inoculation was made 20 to 22 days after transplanting to main field. An injury was made at 3rd leaf axil. Half ml of inoculum of the concentration 6×10^8 cfu/ml ($OD_{600}=0.3$) was poured at the injured site. Fifteen days after the inoculation the symptoms of wilting were recorded as per the scale suggested by Mew and Ho (1976). The observations were recorded regular intervals of 15 days and the last observation was on 60 days after inoculation. Here also 15 plants a row formed a replication and two such replications were laid in RBD.

Recommended package of practices (Anon., 2002b) were followed to raise the crop.

3.3.2 *Per se* performance of tomato genotypes

The above 212 including 57 genotypes which were selected based on wilt reaction were assessed for their *per se* performance for yield and other characters under wilt free soil.

3.3.3 Inoculum material and its preparation

a) Collection of sample

Ralstonia solanacearum (Yabuuchi *et al.*, 1995) infected plants were collected from Olericulture Unit. The presence of the pathogen was tested by placing longitudinal sections containing vascular tissues from diseased plants in a test tube with clean water. The infected tissue shows fine milky white strands composed of masses of bacteria, which oozes out from the margin of the cut portion within a few minutes.

b) Isolation of *Ralstonia solanacearum*

The bacterial wilt confirmed tissue was used for isolation. The outer parts of infected material were removed with a sterilised scalpel. The small pieces were placed in sterilised distilled water for 10 to 15 minutes. The inoculation loop was dipped in the ooze and streaked on Kelman's medium

(1954). The composition of Kelman's medium was 10% peptone, 0.1% casein hydrolysate, 0.5% glucose, 1.7% agar and 0.005% triphenyl tetrazolium chloride (TTC) for one litre of distilled water. The streaked plates were incubated at 31 ± 1°c for 24-36 hours. The virulent (pink colour at centre with fluidal nature) colonies were isolated (Plate 1 and 1a) and suspended in sterilized distilled water in screw capped vials and stored at room temperature. They were regularly renewed and checked for virulence by plating on TTC Kelman's medium.

The *R. solanacearum* culture ($OD_{600} = 0.3$) was inoculated to the seedlings in main field on the third leaf axil (Plate 2) from the top to ensure the presence of sufficient inoculum. Before this inoculation, the bacterial suspension was used for pathogenicity test on susceptible check Pusa Ruby to satisfy Koch's postulate.

3.4 DEVELOPMENT AND UTILIZATION OF TOMATO HYBRIDS

The material was generated in 5 line x 10 tester design of mating to produce 50 hybrids. The material for development of tomato hybrids was selected on the basis of Experiment-I. The material comprised of 5 lines *viz.*, Megha (L-15) Martha, Sonali, Arka Alok (BWR-5) and Shakti which exhibited resistance to bacterial wilt and 10 testers *viz.*, L-101, W.94 12 DWD-1 x 79 B 1390 SP-2-2, 88/FM/Firm/J, W.94 30 ① DWD-1 x DWD-2/10, W.94 FM DWD-1 x DWD-2 59/7, L-50, 88/L-15/DT-14, DWD-1, Arka Vikas and Arka Saurabh (with desirable agronomic characters and range of resistance to reaction to bacterial wilt). The salient features of the parental lines are presented in Table 1.

Plate 1. Electron microscopic view of *Ralstonia solanacearum*

Plate 1a. Culture of *Ralstonia solanacearum* on TTC medium

Plate 2. Mass cultured *Ralstonia solanacearum* in nutrient broth used for inoculation

Table 1. Salient features of fifteen parents and a commercial check

Sl. No.	Parent	Source	Salient features
I.	**Lines**		
1.	Megha (L-15)	UAS, Dharwad	Medium sized round fruits, large leaved, jointed, determinate type and bred for resistance against bacterial wilt *Stemphyllium* and *Septoria* leaf spot
2.	Martha	Dr. Y.S. Parmar UHF, Solan (HP)	Medium sized smooth oval fruits with nipple, broad leaved and thick foliage, jointed, pedicel, determinate type, found resistant to bacterial wilt.
3.	Sonali	KKV, Dapoli (MH)	Medium sized oval fruits with firm skin, broad leaved, jointed, determinate type, bacterial wilt resistant
4.	Arka Alok (BWR – 5)	IIHR, Bangalore	Fruits large, square round with ridges and light green shoulder, medium to broad leaved, jointed, determinate type, resistant to bacterial wilt.
5.	Shakti	KAU, Thrissur	Small round fruits with green shoulder, jointed, small leaved with moderate foliage cover, resistant to bacterial wilt.
II.	**Testers**		
1.	L-101	UAS, Dharwad	Medium to large flat round fruits with green shoulder, jointed pedicel, determinate type, moderate foliage cover.
2.	SP 2-2 (W.94 12 DWD-1 x 79B 1390 SP-2-2)	UAS, Dharwad	Large round fruits, joint less pedicel, very thick foliage covering the fruits, determinate type.
3.	88/Firm/J (88/FM/Firm/J)	UAS, Dharwad	Medium sized flat fruits with ridges, jointed, when fruits immature pale green in colour on ripening turns to red.
4.	W.94 30 ① (W.94 30 ① DWD-1 x DWD-2/10)	UAS, Dharwad	Fruits are oblong with nipple, medium in size, smooth, purple pigmentation on petiole, determinate type.
5.	W.94 FM 59/7 (W.94 FM DWD-1 x DWD-2 59/7)	UAS, Dharwad	Fruits are flat with ridges and medium in size, concentrated fruit maturity, jointed, determinate type.

Contd….

6.	L-50	UAS, Dharwad	Fruits are large in size with ridges, flat in shape, jointed, determinate.
7.	88/DT-14 (88/L-15/DT-14)	UAS, Dharwad	Flat, medium sized fruits with ridges, jointed, when fruits are immature light green in colour, turn to red upon ripening, determinate.
8.	DWD-1	UAS, Dharwad	Large to medium fruits, oblong in shape, joint less, semi determinate type.
9.	Arka Vikas	IIHR, Bangalore	Fruits oblate, medium large with light green shoulder, ridged, dark green foliage, jointed, semi determinate type.
10.	Arka Saurabh	IIHR, Bangalore	Fruits medium large, round, nipple tipped with light green shoulder, light green foliage, semi determinate type.
III	**Commercial check**		
1.	US-1031	US Agri seeds Hyderabad	Fruits are oblong in shape, medium in size, determinate, jointed and resistant to bacterial wilt.

3.4.3 Hybridisation programme

The parental seeds were sown during *rabi*, 2000 in the nursery beds. The healthy four-week-old seedlings were transplanted in a crossing block at a spacing of 90 cm x 60 cm. The testers were planted 15 days prior to lines planting to ensure the sufficient availability of pollen for pollination.

Healthy flower buds in a cyme preferably of the first flush, which were expected to open the next day, selected for emasculation. Emasculation was carried out between 4 and 6 pm. 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 am to 12 noon. The ripe fruits were harvested and the seeds extracted by fermentation method. Simultaneously, same 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 by fermentation method.

3.5 EXPERIMENT – II: EVALUATION OF F_1 HYBRIDS

3.5.1 Nursery raising

The nursery beds of size 7.5m x 1.2m x 0.2 m in height were prepared. Nursery beds were applied with 20 kg well-decomposed farm yard manure (FYM) and half kg of 15:15:15 NPK complex. The seeds of 15 parents, 50 hybrids and one resistant and susceptible check were sown in rows spaced at 10 cm apart during first week of May 2001. The beds were watered regularly. The seedlings were raised by following regular nursery practices.

Thirty day old seedlings were transplanted to main field (wilt sick) in randomized block design with three replications. Each entry was represented by single row of 15 plants spaced at 75 cm apart in a row, which were kept apart at 75 cm. Each seedling was artificially inoculated and observations were recorded as outlined under 3.3.1. The crop was raised by following recommended package of practices (Anon., 2002b).

The same set of parents (15), hybrids (50) and commercial check (US-1031) were raised in bacterial wilt free soil under staked condition (Plate 3) to assess the *per se* performance for various characters.

3.6 EXPERIMENT-III : INHERITANCE OF BACTERIAL WILT RESISTANCE AND ISOLATION OF TRANSGRESSIVE SEGREGANT WITH BACTERIAL WILT RESISTANCE

Out of 50 F_1 hybrids, four F_1s Arka Alok x L-101, Arka Alok x W.94 12 DWD-1 X 79B 1390 SP-2-2, Arka Alok x W.94 30 ① DWD-1 x DWD-2/10 and Arka Alok x Arka Vikas were selfed to get F_2 population. The four F_2 populations + 4 F_1's + their respective parents (5) + resistant check US-1031 formed the material for selection of transgressive segregants and study of inheritance of bacterial wilt resistance.

The above listed 14 entries were sown in raised nursery beds during *kharif*, 2002. Sufficient F_2 seeds were sown to get maximum population. The thirty days old seedlings were transplanted to the main field at a spacing of 60 cm x 60 cm. Twenty to twenty two days after transplanting each plant was inoculated at third leaf axil with a inoculum load of $6x10^8$ cfu/ml (OD_{600}=0.3). Separate blocks were made for parents, F_1's and F_2's. The each F_2 population consisted of 249, 252, 253 and 250 plants in the order mentioned above. Parents, check and F_1's had each a population of 15 plants. Recommended package of practices (Anon., 2002b) were followed for raising the crop. The wilted plants were (Plate 4) counted at 50^{th} day after

Plate 3. General view of experimental plot (F_1's)

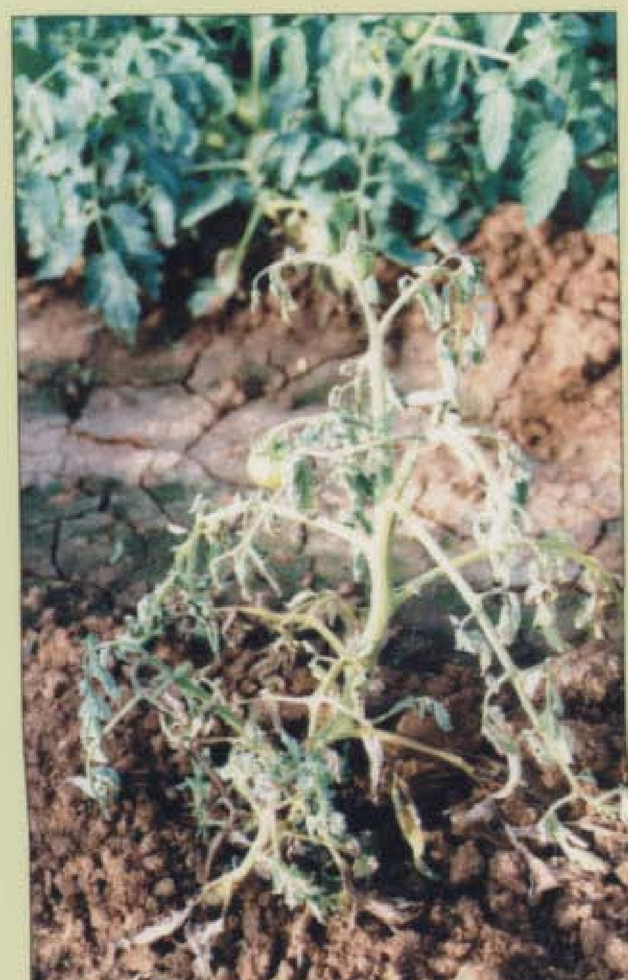

Plate 4. Bacterial wilt infected tomato plant

transplanting and the final count was taken for calculating inheritance pattern.

3.7 EXPERIMENT - IV: MANAGEMENT OF BACTERIAL WILT OF TOMATO THROUGH SOIL AMENDMENT

Details of the experiment

Tomato	:	cv. L-15 (Megha) and Pusa Ruby
Design	:	RBD
Replication	:	Three
Plot size	:	4.2 x 3.6 m
Spacing	:	60 x 60 cm
Number of treatments	:	12
Soil amendment	:	Gypsum
Factor-I	:	Tomato cultivars (V)
V_1	:	L-15 (Megha) (Resistant to BW)
V_2	:	Pusa Ruby (Susceptible to BW)
Factor-II	:	Gypsum levels (G)
G_0	:	Recommended dose of fertilizer (RDF)
G_1	:	RDF +125 kg gypsum ha^{-1}
G_2	:	RDF + 187.5 kg gypsum ha^{-1}
G_3	:	RDF +250 kg gypsum ha^{-1}
G_4	:	RDF +375 kg gypsum ha^{-1}
G_5	:	RDF +500 kg gypsum ha^{-1}

The experiment was laid out in wilt sick plot with artificial inoculation being exercised at 3rd leaf axil with an inoculum concentration of $6x10^8$ cfu/ml (OD_{600}=0.3).

This experiment was carried out during *kharif*, 2001 and *kharif*, 2002. Recommended package of practices were followed for raising the crop.

3.8 EXPERIMENT - V: HISTOPATHOLOGY OF RESISTANT AND SUSCEPTIBLE GENOTYPE

The resistant cultivar L-15 (Megha) and susceptible cultivar Pusa Ruby were used for this study. Seeds of both these cultivars sown during *kharif*, 2002. One week before transplanting they were inoculated (OD_{600}=0.3) to root with *R. solanacearum* in the nursery. The main stem of healthy and wilted plants from respective cultivar were taken for study.

The plant sample collected were fixed in the standard fixative, FAA (formaline, acetic acid and 70% alcohol at the ratio of 1:1:18) prepared fresh. The samples were allowed to remain in the fixative for 24 hours. Very fine thin hand cut sections were taken from these stem segments. Then they were put on microslides and stained with dilute safranin solution. Temporary slides prepared by suspending them in glycerol and a cover slip was placed over them. These temporary slides were subjected for observation under microscope at 10x10, 10x40 magnification.

3.9 EXPERIMENT - VI: EFFECT OF CROP ROTATION WITH NON-HOSTS ON BACTERIAL WILT INCIDENCE OF TOMATO

The material for this study consisted of two non-host crops *viz.*, maize and sorghum, and tomato (host crop) which were used in crop rotation. Three different crop sequences were laid out in pots (12" diameter) containing *R. solanacearum* infested soil. The crop sequence and season of planting followed were as follows.

Details of the experiment

Season	Crop
Kharif, 2000 & 2001(May to July)	Tomato var. Pusa Ruby
2000 & 2001 (August, September and October)	Non hosts - Maize and Sorghum Host : Tomato
2000 & 2001 (January to March)	Tomato var. Pusa Ruby

Design : Completely randomized design (CRD)

Treatments : Three

Crop sequence

a) Tomato-Tomato-Tomato

b) Tomato-Maize-Tomato

c) Tomato-Sorghum-Tomato

3.10 OBSERVATION 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 (analysis). The details of observations recorded in each experiment and techniques adopted for recording the observations were as follows.

3.10.1 Plant height

Height of the plants from the base to the tip of the plant at 60 days after transplanting measured in cm and the average was calculated.

3.10.2 Plant spread

Measurement were made in East-West and North-South directions and the average was calculated to obtain plant spread in centimeters

3.10.3 Number of primary branches per plant

Number of primary branches per plant was counted on 70 days after transplanting and the average was calculated.

3.10.4 Days for 50 per cent flowering

Number of days from transplanting to first flower appearance in 50 per cent of the plants in each row were recorded and the average was computed.

3.10.5 Number of flowers per cluster

Flower number per cluster recorded for the first inflorescence of each plant and the average was calculated.

3.10.6 Clusters per plant

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

3.10.7 Number of fruits per cluster

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

3.10.1 Plant height

Height of the plants from the base to the tip of the plant at 60 days after transplanting measured in cm and the average was calculated.

3.10.2 Plant spread

Measurement were made in East-West and North-South directions and the average was calculated to obtain plant spread in centimeters

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Flower number per cluster recorded for the first inflorescence of each plant and the average was calculated.

3.10.6 Clusters per plant

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

3.10.7 Number of fruits per cluster

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

3.10.8 Number of fruits per plant

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

3.10.9 Average fruit weight

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

$$\text{Average fruit weight} = \frac{\text{Total fruit weight from all the pickings}}{\text{Total number of fruits from all the pickings}}$$

3.10.10 Yield per plant

Yield determined by adding the total fruit weight over all the pickings from each reference plant and expressed in kilograms.

3.11 FRUIT PHYSICAL PARAMETERS

Five fruits were randomly selected after 2^{nd} picking per entry per replication and used for recording the following observations.

3.11.1 Fruit shape index

The polar (L) and equatorial diameter (D) of the fruits was measured with the help of vernier calipers. The shape index was calculated by the ratio L/D.

3.11.2 Number of locules per fruit

Number of locules was counted by cutting the fruit transversely in the middle and the average was calculated.

3.11.3 Pericarp thickness

The fruits selected for recording locules per fruit were used for measuring pericarp thickness. The pericarp thickness was measured in cm with the help of vernier calipers and the mean was computed.

3.12 QUALITY ATTRIBUTES OF FRUITS

The fruits utilized for recording pericarp thickness were blended in a waring blender and the juice was filtered through muslin cloth. Again this juice was homogenized using lab mixer and taken for various estimations.

3.12.1 Total soluble solids (TSS)

A drop of juice was used to record the TSS (%) with the help of Erma hand refractometre at ambient temperature. Read value was corrected according to table for temperature correction of the reading.

3.12.2 pH of fruit juice

The above prepared juice was used to record the pH using digital pH meter.

3.12.3 Titratable acidity

$$\text{Titratable acidity (TA) (milliequivalent / 100g)} = \frac{\text{ml of NaOH consumed x N of NaOH}}{\text{Sample weight (g)}} \times 100$$

Known weight (1g) of juice was taken in 150 ml beaker and drops of phenolphthalein indicator was used. It was titrated with 0.1 N NaOH with continuous stirring. During titration colour change from red to faint pink was indicative of end point of titration. The titratable acidity was expressed in per cent citric acid by using the formula as suggested by Leonard *et al.* (1980).

Per cent citric acid = TA x 0.06404

3.12.4 Ascorbic acid

Ascorbic acid content in red ripe tomato fruits was analysed using the method suggested by Ranganna (1977).

3.12.5 Lycopene content

The lycopene content was estimated using the method developed by Adsule and Ambadan (1979). One gram of juice was poured in a stoppered conical flask to which 20 ml of acetone was added. The contents were shaken on electrical shaker (100 rpm) for 30 minutes. Then 40 ml of petroleum ether (grade 60-80°) was added to each flask to bring the pigment in petroleum ether phase for measuring the colour intensity. To separate the ether layer from the acetone layer, 5 ml of 5 per cent sodium sulphate was added. Petroleum ether layer was separated using Buckner funnel and this solution was used for measuring optical density (colour intensity) in spectronic 21 D at 503 nm. Lycopene content of the sample was calculated as given below using the relationship that an optical density (OD) of 1.0 = 3.1206 g of lycopene ml^{-1} (Ranganna, 1994).

$$\text{Lycopene content} = \frac{3.1206 \times OD \times 40}{\text{Weight of sample}} \times 100$$

3.13 DISEASE INCIDENCE

The number of plants wilted in each entry in the field were recorded and expressed as per cent. They were scored as per the scale given by Mew and Ho (1976).

Reaction	Per cent wilt
Resistant	< 20% wilt
Moderately resistant	20-40% wilt
Moderately susceptible	40-60% wilt
Susceptible	> 60% wilt

The per cent wilt incidence was converted to Arc sine values for statistical analysis (Snedecor and Cochran, 1967).

3.13.1 Yield per ha

Yield per plot was determined by adding the total fruit weight of all the plants in the plot from all the pickings and yield per ha was computed using this value and expressed in t ha^{-1}.

3.13.2 Calcium content of leaf (%)

Calcium content in leaves was estimated at two different stages *viz.* at flowering and fruit set stage using standard versanate method using EDTA and a pinch of murexide indicator and expressed as g/100 g of leaves.

3.14 STATISTICAL ANALYSIS

3.14.1 Line x tester analysis

3.14.1.1 Analysis of variance

Analysis of variance (ANOVA) for individual character was carried out on the basis of mean value per treatment per replication following the procedure described by Panse and Sukhatme (1967) from randomized block design (RBD). Analysis was carried out only to know the significance or otherwise of the difference seen between means of parents and hybrids.

Significance of treatments was tested at 5 and 1 per cent probability. The model of analysis of variance table adopted is given below.

ANOVA table for parents and hybrids.

Source of variation	Degrees of freedom	Mean sum of squares
Replication	(r-1)	
Treatments	(e-1)	
Parents	(p-1)	
Parents Vs crosses	1	
Crosses	(lt-1)	
Lines	(l-1)	M_1
Testers	(t-1)	M_2
Lines x testers	1	M_3
Error	(e-1) (r-1)	M_4
Total	(ltr-1)	

Where,

r = number of replication

e = number of treatments

l = number of lines

t = number of testers

3.14.1.2 Estimation of heterosis

The magnitude of heterosis was estimated in relation to mid parent (MP), better parent (BRP), Best parent (BSP) and commercial check (CC) (US 1031) as percentage increase or decrease of F_1's over the respective mid parent value/ better parent value/best parent/commercial check.

Average values over replications were used for estimating the heterosis over mid parent, better parent, best parent and the commercial check (economic heterosis). The designation of a cross as heterotic depended upon the trait.

Per cent heterosis of F_1's over MP, BRP, BSP and CC was calculated using the methods of Turner (1953) and Hayes *et al.* (1955).

$$\text{Mid parent value} = \frac{P_1 + P_2}{2}$$

a) Heterosis over mid parent (MP) (%) = $\frac{F_1 - \overline{MP}}{\overline{MP}} \times 100$

b) Heterosis over better parent (BP) (%) = $\frac{F_1 - BRP}{BRP} \times 100$

c) Heterosis over best parent (BSP) (%) = $\frac{F_1 - BSP}{BSP} \times 100$

d) Economic heterosis (CC) (%) = $\frac{F_1 - CC}{CC} \times 100$

Testing whether heterosis was significant or not was done by comparing the mean deviations with values of critical difference (CD) obtained separately from MP and CC by using the formula.

$$\text{CD for heterosis over MP} = \sqrt{\frac{3 \times E_r MSS}{2 \times r}} \times \text{'t' value}$$

$$\text{CD for heterosis over BRP,BSP and CC} = \sqrt{\frac{2 \times E_r MSS}{r}} \times \text{'t' value}$$

Where,

r = number of replications

t = table 't' value at error degrees of freedom

Er MSS = Error mean sum of squares

3.15 COMBINING ABILITY ANALYSIS

3.15.1 Analysis of variance for combining ability

For combining ability analysis, only crosses were considered and analysed based on the line x tester analysis as proposed by Kempthrone (1957) and emphasised by Arunachalam (1974). Analysis of variance adopted for combining ability is given below.

ANOVA for combining ability

Source	df'	MSS	Expectation
Replication	(r-1)	-	-
Crosses	(dt-1)	-	-
Lines	(d-1)	M_1	$\sigma^2_e + r\sigma^2_d + tr\sigma^2_l$
Testers	(t-1)	M_2	$\sigma^2_e + r\sigma^2_d + dr\sigma^2_t$
Line x testers	(d-1) (t-1)	M_3	$\sigma^2_e + r\sigma^2_d$
Error (LT)	(r-1) (dt-1)	M_4	σ^2_e

Where, d = number of lines

t = number of testers

COV (half sibs) and COV (full sibs) were estimated by equating the observed mean squares to their expectations. Since number of lines and testers used were different, weighed average of COV (half sibs) was computed by deriving least square estimates as proposed by Arunachalam (1974). Least square estimates were derived as follows.

$$Y = COV\ (halfsibs) = \frac{\tfrac{1}{2}\ [t\ (a+c-2b)+d(b+c-2a)]}{dt-t^2-d^2}$$

$$X = COV\ (fullsibs) = \frac{[t(a+c-2b)+d(b+c-2a)-1/2[t^2(a+c)+d^2(b+c)-dt\ (a+b)]]}{dt-t^2-d^2}$$

Where,

$a = (M_2 - M_4)/r \qquad b = (M_1 - M_4)/r \qquad c = (M_3 - M_4)/r$

The least square estimates of X and Y were used to compute components of combining ability variances as follows:

$\sigma^2_{gca} = Y$ and $\sigma^2_{gca} = X - 2Y$

3.15.2 Estimation of combining ability effects

The combining ability effects were estimated as follows:

General combining ability effects (gca effects) of i^{th} line

$$g_i = \frac{X_i..}{tr} - \frac{X...}{dtr}$$

Where,

$Xi..$ = Total of i^{th} line over all testers and replication and.

$X.../dtr$ = Overall mean

General combining ability effects (gca effects) of j^{th} tester

$$g_j = \frac{X._j.}{dr} - \frac{X...}{dtr}$$

Where.

$X._j.$ = Total of j^{th} tester over all the lines and replications

Specific combining ability effects (sca) due to ij^{th} cross

$$s_{ij} = \frac{X_{ij}.}{r} - \frac{X...}{dtr} - \frac{X._j.}{dr} - \frac{X...}{dtr}$$

Where.

$X_{ij}.$ = Total of ij^{th} cross over all the lines and replications

3.15.3 Standard errors for combining ability estimates

The variance of different estimates was calculated by multiplying the error variance by their respective coefficients as shown below.

Error variance = M4 = Error mean squares from combining ability analysis

Variance of (g_i) lines $= \frac{M_4}{rt}$

Variance of (g_j) lines $= \frac{M_4}{rd}$

Variance of hybrids (S_{ij}) $= \frac{M_4}{r}$

The square root of variance of the estimates was used as standard error meant for testing the significance of combining ability effects.

3.15.4 Proportional contribution of lines, testers and their interaction

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

Where,

SS(d) = Sum of squares due to lines effect

SS(t) = Sum of squares due to crosses

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

Where,

SS(t) = Sum of squares due to testers effect

$$\text{Contribution of (line x tester)} = \frac{SS\ (d \times t)}{SS\ (c)} \times 100$$

Where,

SS(dxt) = Sum of squares due to interaction.

3.15.5 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 using the formula given below.

$$\chi^2 = \frac{[(\text{Observed mean}) - (\text{Expected mean})]^2}{\text{Expected mean}}$$

The chi-square value was compared with table χ^2 at (1) degrees of freedom for the significance. Non-significance of chi-square value indicated the adequacy of additive dominance model.

3.15.6 Statistical analysis for randomized block design and completely randomized design over years

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.

Experimental Results

IV. EXPERIMENTAL RESULTS

The results of experiments conducted during 2000-2002 at Olericulture Unit, Department of Horticulture, University of Agricultural Sciences, Dharwad on "Investigations on Bacterial Wilt Resistance in Tomato" are presented in this chapter.

4.1 EXPERIMENT – I: EVALUATION OF TOMATO GENOTYPES FOR BACTERIAL WILT RESISTANCE

The 212 genotypes were screened against *Ralstonia solanacearum* in filed under epiphytotic conditions during January to April 2000. The *per se* performance for 11 traits are presented in Appendix-III. Among 212 genotypes, 57 genotypes were selected for further study based on the performance of January to April, 2000 and they were subjected to artificial inoculation in field during *kharif,* 2000. The *per se* performance of selected genotypes for 11 characters is presented in Table 2.

4.1.1 Plant height

The genotypes differed significantly for this trait. Pusa Ruby (98.20 cm) registered significantly higher plant height over check L-15 (81.55 cm). However, it remained on par with the three genotypes BT-12 (97.30 cm), Kangdaghat Local (97.40 cm) and L-101 (93.50 cm).

4.1.2 Number of primary branches per plant

Significant differences were noticed among the genotypes for this trait. The lowest number of primary branches noticed in 88/L-15 W-7 (3.75) while, Arka Alok registered significantly higher number (6.85) of branches per plant. The check (L-15) recorded 6.10 primary branches per plant.

Table 2. *Per se* performance of tomato genotypes

Sl. No.		Plant height (cm)	No. of primary branches/ plant	Days to 50% flowering	No. of flowers/ cluster	No. of cluster/ plant	No. of fruits/ cluster	No. of fruits /plant	Average fruit weight (g)	Yield/ plant (kg)	TSS (%)	Wilt incidence* (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
1	C x D / 8-4-2	54.30	4.60	49.50	5.45	11.80	2.50	26.90	40.39	1.08	2.90	36.63 (37.21)
2	B x O / 3-9-1	59.10	4.75	47.50	5.00	14.75	2.00	28.65	49.27	1.41	3.55	76.59 (61.09)
3	B x O / 1-17	50.80	5.35	47.00	4.85	11.65	2.40	26.95	32.76	0.88	5.70	69.93 (56.76)
4	A x O / 5-2-P	55.90	4.50	46.50	6.50	10.15	2.90	27.25	35.73	0.98	4.65	16.65 (23.94)
5	L-15 W-7	64.55	3.75	49.00	5.65	11.40	2.65	27.75	47.34	1.32	3.70	19.98 (26.49)
6	Marikrit	53.90	5.40	48.50	5.25	11.90	2.65	29.35	31.23	0.91	4.40	3.33 (7.45)
7	A x O / 14-8-1P	62.30	4.80	49.00	4.70	13.40	2.00	25.45	37.56	0.95	3.20	13.32 (21.39)
8	EC-711492	87.50	5.75	47.50	4.20	9.10	2.90	25.85	43.66	1.13	4.25	69.93 (56.76)
9	B x O / 7-15P	63.80	4.70	50.00	6.85	9.15	2.45	20.25	41.40	0.84	3.65	63.27 (52.71)
10	S-22	84.30	6.30	51.50	5.00	10.20	2.90	27.60	41.85	1.15	4.35	63.27 (52.71)
11	L-1	48.30	5.35	43.50	5.75	9.15	3.35	29.40	24.22	0.71	4.25	69.93 (56.76)
12	88 / Petoproc	64.60	5.10	46.00	4.50	10.65	2.50	23.50	44.30	1.04	4.05	49.15 (44.94)
13	88 / DT-14	67.95	6.65	49.00	5.25	14.80	1.90	25.95	47.51	1.23	3.30	16.65 (23.94)
14	L-15/DT-1	76.95	4.75	48.00	5.60	10.90	3.20	33.40	33.35	1.11	3.25	19.98 (26.49)
15	BT-12	97.30	6.50	43.00	5.50	12.25	2.50	29.05	45.58	1.33	4.55	23.31 (28.77)
16	88/Petoproc / J	69.35	6.10	48.50	5.80	10.00	3.65	34.10	33.20	1.13	4.15	43.29 (41.11)
17	UC-204 B (B)	66.95	5.55	49.00	4.90	11.00	2.75	28.95	26.38	0.77	4.15	49.95 (44.94)
18	Solan Vajr	58.35	6.55	45.50	5.35	8.30	2.90	25.95	43.34	1.13	3.35	66.60 (54.70)
19	Kangdaghat Local	97.40	4.20	42.50	5.55	12.15	3.35	36.15	38.64	1.39	3.25	56.61 (48.77)
20	B x O / 3-8-3	70.40	5.75	46.50	4.50	6.20	3.50	20.50	45.99	0.94	3.70	63.27 (52.71)
21	GKVK-24	73.25	4.30	49.50	4.90	10.15	3.35	31.55	23.87	0.76	3.95	63.27 (52.71)
22	86 / 15-1-3	63.35	5.95	45.00	6.45	13.15	2.65	33.55	34.70	1.16	3.95	69.93 (56.76)
23	A x O / 14-8-4	66.80	4.90	50.00	4.60	11.60	2.75	28.05	32.52	0.91	4.15	43.29 (41.11)
24	Punjab Chhuhara	60.55	6.00	47.00	5.45	10.25	3.80	36.95	27.16	0.99	3.95	76.59 (61.09)
25	L-36	66.30	5.05	47.00	5.30	13.50	2.00	25.00	41.38	1.04	3.20	43.29 (41.11)
26	A x O/7	62.65	4.60	49.50	5.45	13.45	3.15	41.30	28.77	1.19	4.35	16.65 (23.94)
27	88 / Firm / J	76.70	6.55	43.50	5.05	9.85	2.50	23.00	53.12	1.22	3.90	29.97 (33.15)
28	79 B 1390 (O)	46.55	4.90	47.00	5.50	13.10	2.90	35.40	20.88	0.74	4.65	49.95 (44.94)
29	A x O / 1-11	58.40	4.65	47.50	4.65	12.80	1.90	23.95	35.02	0.84	3.40	46.62 (43.00)
30	W.B x O / 7-17-29	64.35	5.20	51.50	4.70	10.50	2.70	26.45	41.34	1.09	4.85	46.62 (43.05)

Contd…

1	2	3	4	5	6	7	8	9	10	11	12	13
31	SP-2-2	65.95	6.10	47.50	4.15	8.95	3.00	25.15	48.62	1.21	4.25	9.99 (18.14)
32	W.B x O / 7-17-51	53.25	5.60	50.50	3.85	13.65	1.90	24.70	51.80	1.27	4.40	56.61 (48.77)
33	L-15 W-6	66.75	3.75	47.00	5.00	12.25	2.90	33.25	39.97	1.33	4.05	19.98 (26.49)
34	L-50	82.60	5.70	49.50	4.90	13.45	2.10	25.15	58.84	1.47	3.25	16.65 (23.94)
35	W.94.30 ①	77.35	5.70	49.00	4.00	11.65	3.10	34.40	45.94	1.58	4.10	29.97 (33.15)
36	Marutham	73.60	4.10	46.50	4.95	9.60	2.45	21.75	40.33	0.88	4.75	69.93 (56.76)
37	88/DT-12	65.95	3.90	49.00	3.85	13.40	2.45	31.35	33.45	1.05	4.40	16.65 (23.94)
38	L-60	62.45	4.15	49.50	4.90	11.80	2.40	27.85	32.48	0.90	4.30	36.63 (37.21)
39	Sonali	83.40	6.70	49.50	5.45	12.60	2.55	30.30	31.51	0.96	4.85	0.00 (00.02)
40	W.94 FM 59/7	58.60	5.60	47.50	4.85	15.90	2.50	36.70	45.96	1.69	5.10	16.65 (23.94)
41	B x O / 3-9	64.80	3.75	43.00	4.00	7.75	3.00	22.60	53.22	1.20	3.15	69.93 (56.76)
42	L-42	56.20	5.15	48.50	4.90	8.25	2.90	22.60	51.64	1.17	4.35	56.61 (48.77)
43	PKM-1	66.05	5.10	46.50	4.65	8.80	2.80	23.80	38.62	0.92	4.90	76.59 (61.09)
44	T-19	76.05	4.55	46.00	5.40	11.65	2.95	33.05	33.17	1.10	3.50	43.29 (41.11)
45	Solan Gola	72.95	4.15	47.00	4.85	8.40	3.00	23.70	47.79	1.12	4.15	43.29 (41.11)
46	Martha	84.20	5.70	50.00	5.85	12.70	3.10	36.40	39.95	1.09	3.25	16.65 (23.94)
47	L-22	71.55	5.10	49.50	6.45	8.55	3.00	24.80	40.24	0.99	3.05	73.26 (58.82)
48	T-101	82.05	4.85	49.00	5.80	9.15	2.75	23.40	38.62	0.90	4.15	56.61 (48.77)
49	DWD-1 (C)	78.40	6.60	53.00	4.75	9.50	2.70	21.95	55.02	1.20	5.35	16.65 (23.94)
50	DWD-2 (D)	56.50	5.80	49.50	5.45	8.95	2.60	22.10	48.05	1.06	4.65	29.97 (33.15)
51	Arka Saurabh	83.55	6.00	48.50	4.90	11.25	2.85	31.30	41.36	1.30	4.85	63.27 (52.71)
52	Arka Alok	84.05	6.85	49.00	5.45	11.00	2.90	28.45	47.70	1.36	4.95	0.00 (0.02)
53	Arka Vikas	85.20	6.65	48.50	4.90	14.50	2.50	34.25	38.08	1.30	5.25	69.93 (56.79)
54	L-101	93.50	6.55	49.00	5.20	14.15	2.95	38.85	28.99	1.13	5.15	29.97 (33.15)
55	Pusa Ruby	98.20	5.90	49.50	4.50	12.50	2.10	24.10	19.03	0.46	4.35	76.59 (61.09)
56	Shakti	84.30	6.40	50.00	5.90	20.85	3.35	67.05	21.26	1.42	4.40	0.00 (00.02)
	Check L-15 (Megha) [A]	81.55	6.10	48.50	5.80	12.35	3.10	33.35	36.55	1.22	5.15	9.99 (18.14)
	S.Em±	1.97	0.28	0.86	0.14	1.31	0.09	2.53	2.30	0.08	0.10	2.15
	CD at 5%	5.46	0.78	2.37	0.39	3.63	0.25	7.01	6.37	0.22	0.28	5.95

Values in parenthesis indicated transformed value
*Wilt incidence recorded under artificial epiphytotic conditions and its is separate experiment

4.1.3 Days to 50 per cent flowering

The genotype Kangdaghat Local took significantly lesser number of days for flowering (42.5 days). However, S-22 took significantly more number of days (51.50 days) for flowering compared to check L-15 (48.50 days).

4.1.4 Number of flowers per cluster

Number of flowers per cluster differed significantly among the genotypes. The highest number of flowers per cluster was noticed in the genotype B x O/17-15-P (6.85) followed by A x O / 5-2-P (6.50), 86/15-1-3 (6.45) and L-22 (6.45). All these four genotypes remained on par with each other but were significant compared to check L-15 (5.80).

4.1.5 Number of clusters per plant

Highest number of clusters per plant was recorded by Shakti (20.85) followed by W.94 FM 59/7 (15.90), Arka Vikas (14.50) and L-101 (14.15) whereas, check L-15 recorded 12.35 clusters per plant.

4.1.6 Number of fruits per cluster

Among the genotypes significant differences were noticed for number of fruits per cluster. The range for this trait was from 1.90 (88/DT-14, A x O/1-11 and B x O/15-7-17) to 3.80 (Punjab Chhuhara). There were six genotypes which had significantly higher number of fruits per cluster compared to L-15 (3.10).

4.1.7 Number of fruits per plant

The number of fruits per plant varied significantly among the genotypes. The two genotypes Shakti (67.50) and W.94 FM A x O/7 (41.30) produced significantly higher number of fruits per plant compared to L-15 (33.35). Lowest number of fruits per plant recorded by the genotype B x O/7-15 (20.25).

4.1.8 Average fruit weight

The average fruit weight varied significantly among the genotypes. Significantly higher fruit weight was recorded in L-50 (58.84 g). While, popular variety Pusa Ruby recorded only 19.03 g. The check L-15 had the average fruit weight of 36.55 g and 21 genotypes were significantly superior to it.

4.1.9 Yield per plant

The genotypes differed significantly for yield per plant. The yield per plant ranged from 0.45 kg to 1.68 kg. The check (L-15) yielded 1.22 kg of fruits per plant and three genotypes in the order of merit L-50 (1.47 kg), W.94 30 ① (1.58 kg) and W.94 FM 59/7 (1.69 kg) given significantly higher yield over it. There were 12 genotypes 88/DT-14 (1.23 kg), 88/L-15 W-7 (1.32 kg), B x O/3-9-1 (1.41 kg), BT-12 (1.33 kg), Kangdaghat Local (1.39 kg), 88/Firm/J (1.22 kg), W.B x O/7-17-51 (1.27 kg), L-15 W-6 (1.33 kg), Arka Saurabh (1.30 kg), Arka Alok (1.30 kg), Arka Vikas (1.30 kg) and Shakti (1.42 kg) which were on par with check L-15 (1.22 kg).

4.1.10 Total soluble solids (TSS)

The total soluble solids among the genotypes varied from 2.90 (C x D/8-4-2) to 5.70 per cent (B x O/1-17), with a mean value of 4.15 per cent. The only genotype which had significantly higher TSS over check (5.15%) was B x O/1-17 (5.70%).

4.1.11 Per cent wilt incidence

Wilt incidence differed among the genotypes. Plants of Sonali, Arka Alok and Shakti did not wilt and these genotypes were significantly superior over other genotypes. The check L-15 registered 9.99 per cent wilt incidence which was on par with genotype Marikrit (3.33%). Highest wilt incidence noticed in four genotypes (B x O /3-9-1; Punjab Chhuhara, PKM-1 and Pusa Ruby).

4.2 EXPERIMENT-II: EVALUATION OF F_1 HYBRIDS

4.2.1 Analysis of variance

The analysis of variance for 19 characters is presented in Table 3. The results revealed that all the entries comprising parents and hybrids showed significant differences for all the characters except for pH of fruit juice. Among the parents, lines (females) exhibited significant differences for all the characters except plant height, plant spread, days to 50 per cent flowering and pH of fruit juice. Similarly, the testers (males) also differed significantly for all the characters except for pH of fruit juice. The contribution of line vs. tester showed highly significant variation for all the characters except for number of primary branches per plant, number of clusters per plant, total soluble solids, pH of fruit juice and titratable acidity. The variance for the hybrids was highly significant for all the characters. Variance, for parents vs. hybrids was also significant for all the characters except for number of flowers per cluster and pH of fruit juice.

4.2.2 Magnitude of heterosis

The *per se* values of the parents and hybrids and magnitude of heterosis over mid, better, best and commercial check are presented in Table 4 to 23.

Table 3: Analysis of variance in respect of nineteen traits in line x tester study of tomato

Sl. No.	Source	Mean of sum of squares								
		Replication	Treatment	Parents	Lines	Testers	Lines Vs. Testers	Hybrids	Parents Vs. Hybrids	Error
	Degrees of freedom	2	65	14	4	9	1	49	1	130
1.	Plant height	32.592	196.802**	189.709**	14.416	266.299**	201.571**	193.563**	31.873*	7.333
2.	Plant spread	9.274	186.610**	92.790**	12.394	126.975**	106.711**	189.715**	1364.875**	7.884
3.	Number of primary branches/plant	0.403	3.301**	1.091**	0.831**	1.327**	0.002	3.960**	5.146**	0.090
4.	Days to 50% flowering	5.015	18.385**	12.355**	4.166	12.774**	41.344**	19.883**	34.461**	2.518
5.	Number of flowers per cluster	0.001	0.714**	0.912**	0.157**	0.756**	5.329**	0.686**	0.035	0.110
6.	Number of clusters per plant	17.577	134.911**	23.266**	42.646**	15.610**	14.641	119.656**	2451.386**	4.758
7.	Number of fruits per cluster	0.124	0.682**	0.542**	0.355**	0.374**	2.809**	0.718**	1.232**	0.043
8.	Number of fruits per plant	53.557	788.829**	359.704**	533.485**	183.803**	1247.689**	735.860**	9811.762**	14.176
9.	Average fruit weight	4.764	432.300**	498.909**	139.287**	389.124**	2925.468**	394.660**	2377.419**	12.182
10.	Yield per plant	0.019	0.458**	0.115**	0.077**	0.117**	0.246**	0.465**	2.931**	0.012
11.	Fruit shape index	0.000	0.033**	0.077**	0.020**	0.105**	0.057**	0.019**	0.061**	0.003
12.	Number of locules per fruit	0.004	3.212**	5.959**	0.520**	5.978**	27.545**	2.424**	10.880**	0.034
13.	Pericarp thickness	0.004	0.035**	0.031**	0.013**	0.035**	0.056**	0.035**	0.033**	0.001
14.	Total soluble solids	0.280	1.598**	1.254**	1.554**	1.256**	0.036	1.676**	2.537**	0.067
15.	pH of fruit juice	0.030	0.031*	0.014	0.005	0.017	0.024	0.025**	0.008	3.317
16.	Titratable acidity	0.002	0.021**	0.009**	0.008**	0.011**	0.000	0.023**	0.046**	0.020
17.	Ascorbic acid	9.707	368.637**	287.077**	677.205**	102.094**	391.417**	343.423**	2506.745**	0.001
18.	Lycopene	0.007	6.365**	2.757**	2.993**	2.807**	1.371**	6.995**	31.313**	0.009
19.	Per cent wilt incidence	2.992	507.845**	858.487**	416.371**	510.157**	5761.920**	244.155**	9005.975**	18.309

* and ** indicate significant at 1 and 5 per cent level of probability, respectively

4.2.2.1 Plant height (cf. Table 4)

Among the parents, the maximum plant height was recorded in L-101 (90.32 cm) and the minimum in W.94 FM 59/7 (61.26 cm). Whereas in hybrids higher and lower values for plant height were registered by Sonali x DWD-1 (100.28 cm) and Sonali x 88/Firm/J (67.40 cm) respectively.

The range of heterosis over mid parent value was from −18.94 (Sonali x 88/Firm/J) to 20.45 per cent (Sonali x DWD-1). Out of 50 hybrids, 16 showed significant positive heterosis, while 16 had significant negative heterosis for this trait. Heterosis in F_1's over their respective better parent ranged from −20.98 (Sonali x 88/Firm/J) to 17.57 per cent (Sonali x DWD-1). Five and 23 crosses displayed significant positive and negative heterosis over better parent, respectively. Three crosses (Sonali x DWD-1; Shakti x L-101 and Martha x 88/Firm/J) recorded positive heterosis over best parent. All the 50 hybrids exhibited significant positive heterosis over commercial check and the highest was noticed in Sonali x DWD-1.

4.2.2.2 Plant spread (cf. Table 5)

The range of variation for this trait among the parents was 47.98 cm (L-101) to 66.10 cm (W.94 30 ①). Among the hybrids also wide range of variation was noticed for this trait. The highest and lowest plant spread was recorded by crosses Sonali x 88/Firm/J (44.76 cm) and Shakti x L-101 (84.64 cm) respectively.

The range of mid parent heterosis varied from −25.61 (Sonali x 88/Firm/J) to 53.75 per cent (Shakti x L-101). Out of 50 hybrids, 28 and six crosses showed significant positive and negative heterosis. Heterosis in F_1's over their better parents ranged from −22.39 (Sonali x 88/Firm/J) to 76.40

Table 4. ***Per se*** **performance and magnitude of heterosis for plant height**

Sl No.	F_1 Hybrid	Line (cm)	Tester (cm)	F1 *per se* (cm)	Mid parent value (cm)	Heterosis per cent over MP	BRP	BSP	CC
1	L-15 x L-101	83.08	90.32	89.20	86.67	2.80	-1.24	-1.23	32.44**
2	L-15 x SP-2-2	83.08	69.64	82.30	76.36	7.77**	-0.94	-8.88**	22.19**
3	L-15 x 88/Firm/J	83.08	81.02	80.19	82.05	-2.27	-3.48	-11.22**	19.06**
4	L-15 x W.94 30 ①	83.08	80.72	83.29	81.90	1.70	0.25	-7.78**	23.67**
5	L-15 x W.94 FM 59/7	83.08	61.26	67.87	72.17	-5.96*	-18.31**	-24.85**	0.77
6	L-15 x L-50	83.08	81.21	73.49	82.14	-10.53**	-11.54**	-18.63**	9.12**
7	L-15 x 88/DT-14	83.08	71.76	85.15	77.42	9.98**	2.48	-5.72*	26.43**
8	L-15 x DWD-1	83.08	81.82	72.86	82.45	-11.63**	-12.30**	-19.33**	8.18*
9	L-15 x A.Vikas	83.08	88.53	89.66	85.81	4.48*	1.27	-0.73	33.13**
10	L-15 x A.Saurabh	83.08	89.43	88.13	86.26	2.17	-1.45	-2.42	30.85**
11	Martha x L-101	86.66	90.32	79.33	88.49	-10.35**	-12.16**	-12.16**	17.78**
12	Martha x SP-2-2	86.66	69.64	78.57	78.15	0.54	-9.34**	-13.01**	16.66**
13	Martha x 88/Firm/J	86.66	81.02	97.06	83.84	15.77**	12.00**	7.47**	44.11**
14	Martha x W.94 30 ①	86.66	80.72	74.86	83.69	-10.55**	-13.62**	-17.11**	11.15**
15	MarthaxW.94 FM 59/7	86.66	61.26	77.80	73.96	5.19*	-10.22**	-13.85**	15.52**
16	Martha x L-50	86.66	81.21	88.49	83.94	5.42*	2.12	-2.02	31.38**
17	Martha x 88/DT-14	86.66	71.76	74.97	79.21	-5.35*	-13.48**	-16.99**	11.31**
18	Martha x DWD-1	86.66	81.82	88.50	84.24	5.06*	2.12	-2.02	31.40**
19	Martha x A.Vikas	86.66	88.53	89.64	87.59	2.34	1.25	-0.75	33.09**
20	Martha x A.Saurabh	86.66	89.43	88.70	88.05	0.74	-0.82	-1.79	31.70**
21	Sonali x L-101	85.29	90.32	84.75	87.81	-3.48	-6.16*	-6.16*	25.84**
22	Sonali x SP-2-2	85.29	69.64	93.27	77.46	20.41**	9.35**	3.27	38.49**
23	Sonali x 88/Firm/J	85.29	81.02	67.40	83.15	-18.94**	-20.98**	-25.38**	0.07
24	Sonali x W.94 30 ①	85.29	80.72	85.97	83.01	3.57	0.80	-4.81*	27.64**
25	Sonali x W.94 FM 59/7	85.29	61.26	71.34	73.28	-2.64	-16.36**	-21.01**	5.92
26	Sonali x L-50	85.29	81.21	79.58	83.25	-4.41	-6.69*	-11.89**	18.16**
27	Sonali x 88/DT-14	85.29	71.76	68.64	78.53	-12.59**	-19.52**	-24.00**	1.92
28	Sonali x DWD-1	85.29	81.82	100.28	83.25	20.45**	17.57**	11.03**	48.89**
29	Sonali x A.Vikas	85.29	88.53	93.30	86.91	7.35**	5.38*	3.30	38.53**
30	Sonali x A.Saurabh	85.29	89.43	93.22	87.36	6.71**	4.24	3.21	38.41**
31	A.Alok x L-101	84.36	90.32	88.37	87.34	1.18	-2.16	-2.16	31.21**
32	A.Alok x SP-2-2	84.36	69.64	82.32	77.00	6.91**	-2.42	-8.85**	22.23**
33	A.Alok x 88/Firm/J	84.36	81.02	78.24	82.69	-5.38*	-7.25*	-13.37**	16.17**
34	A.Alok x W.94 30 ①	84.36	80.72	76.19	82.54	-7.69**	-9.68**	-15.64**	13.13**
35	A.Alok x W.94 FM 59/7	84.36	61.26	83.69	72.81	14.94**	-0.79	-7.34**	24.26**
36	A.Alok x L-50	84.36	81.21	76.01	82.78	-8.18**	-9.90**	-15.84**	12.86**
37	A.Alok x 88/DT-14	84.36	71.76	79.82	78.06	2.25	-5.38*	-11.62**	18.52**
38	A.Alok x DWD-1	84.36	81.82	75.34	83.09	-9.33**	-10.69**	-16.58**	11.86**
39	A.Alok x A.Vikas	84.36	88.53	92.68	86.45	7.21**	4.68	2.61	37.61**
40	A.Alok x A.Saurabh	84.36	89.43	75.84	86.89	-12.72**	-15.19**	-16.03**	12.61**
41	Shakti x L-101	80.91	90.32	97.45	85.61	13.83**	7.89**	7.90**	44.69**
42	Shakti x SP-2-2	80.91	69.64	82.92	75.27	10.16**	2.48	-8.19**	23.12**
43	Shakti x 88/Firm/J	80.91	81.02	80.97	80.96	0.01	-0.06	-10.35**	20.22**
44	Shakti x W.94 30 ①	80.91	80.72	78.68	80.82	-2.64	-2.76	-12.88**	16.82**
45	Shakti x W.94 FM 59/7	80.91	61.26	69.51	71.08	-2.21	-14.09**	-23.04**	3.21
46	Shakti x L-50	80.91	81.21	84.69	81.06	4.47	4.28	-6.23*	25.75**
47	Shakti x 88/DT-14	80.91	71.76	79.68	76.34	4.38	-1.52	-11.78**	18.31**
48	Shakti x DWD-1	80.91	81.82	76.58	81.36	-5.88*	-6.40*	-15.21**	13.70**
49	Shakti x A.Vikas	80.91	88.53	80.45	84.72	-5.04*	-9.13**	-10.93**	19.45**
50	Shakti x A.Saurabh	80.91	89.43	74.13	85.17	-12.96**	-17.11**	-17.92**	10.06**
	Commercial check								
1.	US-1031	67.35							
	S.Em±	1.56							
	CD at 5%					3.74	4.33	4.33	4.33
	CD at 1%					4.91	5.69	5.69	5.69

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 5. *Per se* performance and magnitude of heterosis for plant spread

Sl No.	F_1 Hybrid	Line (cm)	Tester (cm)	F1 *per se* (cm)	Mid parent value (cm)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	58.14	47.98	72.79	53.06	37.18**	51.70**	51.69**	31.08**
2	L-15 x SP-2-2	58.14	48.18	64.91	53.16	22.10**	34.72**	35.27**	16.89**
3	L-15 x 88/Firm/J	58.14	62.66	63.35	60.40	4.88	8.96	32.02**	14.08**
4	L-15 x W.94 30 ①	58.14	66.10	63.73	62.12	2.59	9.61	32.82**	14.77**
5	L-15 x W.94 FM 59/7	58.14	57.59	51.11	57.87	-11.68**	-11.25*	6.51	-7.59
6	L-15 x L-50	58.14	48.63	53.32	53.39	-0.13	9.64	11.13*	-3.98
7	L-15 x 88/DT-14	58.14	58.26	63.51	58.20	9.13*	9.24	32.36**	14.37**
8	L-15 x DWD-1	58.14	57.04	55.39	57.59	-3.82	-2.89	15.44**	-0.25
9	L-15 x A.Vikas	58.14	58.68	65.15	58.41	11.54**	12.06**	35.78**	17.32**
10	L-15 x A.Saurabh	58.14	62.86	69.84	60.50	15.44**	20.12**	45.56**	25.77**
11	Martha x L-101	61.64	47.98	62.67	54.81	14.34**	30.62**	30.60**	12.86**
12	Martha x SP-2-2	61.64	48.18	58.60	54.91	6.72	21.63**	22.13**	5.53
13	Martha x 88/Firm/J	61.64	62.66	81.43	62.15	31.02**	32.11**	69.70**	46.64**
14	Martha x W.94 30 ①	61.64	66.10	56.52	63.87	-11.51**	-8.31	17.78**	1.78
15	MarthaxW.94 FM 59/7	61.64	57.59	61.67	59.62	3.44	7.08	28.52**	11.06**
16	Martha x L-50	61.64	48.63	71.26	55.14	29.24**	46.54**	48.50**	28.33**
17	Martha x 88/DT-14	61.64	58.26	53.89	59.95	-10.11**	-7.50	12.31**	-2.95
18	Martha x DWD-1	61.64	57.04	70.82	59.34	19.35**	24.16**	47.60**	27.53**
19	Martha x A.Vikas	61.64	58.68	72.17	60.16	19.96**	22.98**	50.41**	29.96**
20	Martha x A.Saurabh	61.64	62.86	71.75	62.25	15.26**	16.40**	49.54**	29.21**
21	Sonali x L-101	57.68	47.98	63.64	52.83	20.46**	32.64**	32.63**	14.60**
22	Sonali x SP-2-2	57.68	48.18	73.95	52.93	39.71**	53.48**	54.11**	33.17**
23	Sonali x 88/Firm/J	57.68	62.66	44.76	60.17	-25.61**	-22.39**	-6.72	-19.39**
24	Sonali x W.94 30 ①	57.68	66.10	64.57	61.89	4.33	11.95**	34.57**	16.28**
25	Sonali x W.94 FM 59/7	57.68	57.59	53.81	57.64	-6.64	-6.56	12.15*	-3.09
26	Sonali x L-50	57.68	48.63	63.07	53.16	18.65**	29.69**	31.43**	13.57**
27	Sonali x 88/DT-14	57.68	58.26	52.71	57.97	-9.07**	-8.62	9.86*	-5.07
28	Sonali x DWD-1	57.68	57.04	78.51	57.36	36.87**	37.64**	63.61**	41.38**
29	Sonali x A.Vikas	57.68	58.68	73.35	58.18	26.07**	27.17**	52.87**	32.09**
30	Sonali x A.Saurabh	57.68	62.86	73.37	60.27	21.74**	27.20**	52.91**	32.13**
31	A.Alok x L-101	60.71	47.98	65.75	54.35	20.98**	37.04**	37.02**	18.40**
32	A.Alok x SP-2-2	60.71	48.18	63.32	54.45	16.29**	31.42**	31.96**	14.03**
33	A.Alok x 88/Firm/J	60.71	62.66	59.92	61.69	-2.87	-1.30	24.88**	7.91*
34	A.Alok x W.94 30 ①	60.71	66.10	63.23	63.41	-0.28	4.15	31.78**	13.86**
35	A.Alok x W.94 FM 59/7	60.71	57.59	64.45	59.15	8.96**	11.91**	34.31**	16.06**
36	A.Alok x L-50	60.71	48.63	60.77	54.67	11.16**	24.97**	26.66**	9.44*
37	A.Alok x 88/DT-14	60.71	58.26	62.18	59.49	4.52	6.73	29.56**	11.98**
38	A.Alok x DWD-1	60.71	57.04	56.97	58.88	-3.24	-0.12	18.73**	2.59
39	A.Alok x A.Vikas	60.71	58.68	73.19	59.69	22.62**	24.73**	52.54**	31.80**
40	A.Alok x A.Saurabh	60.71	62.86	54.15	61.79	-12.36**	-10.81*	12.85**	-2.48
41	Shakti x L-101	62.12	47.98	84.64	55.05	53.75**	76.40**	76.40**	52.42**
42	Shakti x SP-2-2	62.12	48.18	62.81	55.15	13.89**	30.37**	30.89**	13.11**
43	Shakti x 88/Firm/J	62.12	62.66	61.68	62.39	-1.13	-0.71	28.55**	11.08**
44	Shakti x W.94 30 ①	62.12	66.10	61.74	64.11	-3.69	-0.61	28.67**	11.20**
45	Shakti x W.94 FM 59/7	62.12	57.59	56.70	59.86	-5.28	-1.55	18.16**	2.10
46	Shakti x L-50	62.12	48.63	69.60	55.38	25.67**	43.12**	45.06**	25.34**
47	Shakti x 88/DT-14	62.12	58.26	64.90	60.19	7.83*	11.40*	35.26**	16.87**
48	Shakti x DWD-1	62.12	57.04	66.18	59.58	11.08**	16.02**	37.92**	19.17**
49	Shakti x A.Vikas	62.12	58.68	68.49	60.40	13.39**	16.72**	42.74**	23.34**
50	Shakti x A.Saurabh	62.12	62.86	61.65	62.49	-1.34	-0.76	28.48**	11.02**
	Commercial check								
1.	US-1031	55.53							
	S.Em±	1.62							
	CD at 5%					3.88	4.48	4.48	4.48
	CD at 1%					5.10	5.90	5.90	5.90

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

per cent (Shakti x L-101). Twentynine and three crosses exhibited significant positive and negative heterosis over better parent. Only one cross (Sonali x 88/Firm/J) exhibited negative heterosis over the best parent. Among the 50 hybrids, one and 38 crosses had significant negative and positive heterosis over commercial check.

4.2.2.3 Number of primary branches per plant (cf. Table 6)

Among the parents (females) Sonali and Arka Alok (7.00 No.) had the highest number of primary branches per plant while, testers 88/Firm/J and 88/DT-14 (7.00 No.) recorded the highest number of primary branches per plant. The hybrids, exhibited a good amount of variation for number of primary branches per plant and it ranged from 3.00 (Martha x 88/Firm/J) to 8.43 (Shakti x SP-2-2).

The range of mid parental heterosis varied from –53.85 (Martha x 88/Firm/J) to 34.02 per cent (Shakti x SP-2-2). Out of 50 crosses, nine showed significant positive heterosis, while 21 had significant negative heterosis for this trait. Heterosis over better parent ranged from –57.14 (Martha x 88/Firm/J) to 30.49 per cent (Shakti x SP-2-2). Six and 26 crosses exhibited significant positive and negative heterosis over better parent respectively. Only three crosses *viz.*, Shakti x SP-2-2, Arka Alok x Arka Vikas and Shakti x L-50 registered significant positive heterosis over best parent in the order of merit. Out of 50 crosses, 10 were able to exhibit significant positive heterosis over commercial check and the highest being in Shakti x SP-2-2.

Table 6. *Per se* performance and magnitude of heterosis for number of primary branches per plant

Sl No.	F_1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	6.00	6.56	5.43	6.28	-13.54**	-17.23**	-22.38**	-14.22**
2	L-15 x SP-2-2	6.00	6.46	4.30	6.23	-30.97**	-33.44**	-38.57**	-32.07**
3	L-15 x 88/Firm/J	6.00	7.00	5.33	6.50	-18.00**	-23.86**	-23.81**	-15.79**
4	L-15 x W.94 30 ①	6.00	6.03	3.30	6.02	-45.18**	-45.37**	-52.86**	-47.06**
5	L-15 x W.94 FM 59/7	6.00	5.03	5.70	5.52	3.26	-5.00	-18.57**	-9.95**
6	L-15 x L-50	6.00	5.66	5.33	5.83	-8.57*	-11.16**	-23.81**	-15.79**
7	L-15 x 88/DT-14	6.00	7.00	6.47	6.50	-0.46	-7.57	-7.62	2.21
8	L-15 x DWD-1	6.00	6.67	5.33	6.34	-15.93**	-20.08**	-23.81**	-15.79**
9	L-15 x A.Vikas	6.00	6.97	6.00	6.48	-7.41*	-13.92**	-14.29**	-5.21
10	L-15 x A.Saurabh	6.00	6.90	6.83	6.45	5.89	-1.01	-2.38	-7.89*
11	Martha x L-101	6.00	6.56	6.60	6.28	5.09	0.61	-5.71	4.26
12	Martha x SP-2-2	6.00	6.46	6.57	6.23	5.46	1.70	-6.19	3.79
13	Martha x 88/Firm/J	6.00	7.00	3.00	6.50	-53.85**	-57.14**	-57.14**	-52.61**
14	Martha x W.94 30 ①	6.00	6.03	3.40	6.02	-43.52**	-43.62**	-51.43**	-46.29**
15	MarthaxW.94 FM 59/7	6.00	5.03	4.33	5.52	-21.56**	-27.83**	-38.10**	-31.59**
16	Martha x L-50	6.00	5.66	6.30	5.83	8.06	5.00	-10.00**	-0.47
17	Martha x 88/DT-14	6.00	7.00	4.33	6.50	-33.38**	-38.14**	-38.10**	-31.59**
18	Martha x DWD-1	6.00	6.67	5.73	6.34	-9.62**	-14.09**	-18.10**	-9.47*
19	Martha x A.Vikas	6.00	6.97	6.03	6.48	-6.94	-13.48**	-13.81**	-4.74
20	Martha x A.Saurabh	6.00	6.90	4.77	6.45	-26.05**	-30.86**	-31.90**	-24.64**
21	Sonali x L-101	7.00	6.56	5.73	6.78	-15.48**	-18.14**	-18.10**	-9.48*
22	Sonali x SP-2-2	7.00	6.46	5.77	6.73	-14.26**	-17.57**	-17.62**	-9.47*
23	Sonali x 88/Firm/J	7.00	7.00	5.43	7.00	-22.43**	-22.42**	-22.38**	-14.22**
24	Sonali x W.94 30 ①	7.00	6.03	4.43	6.52	-32.05**	-36.71**	-36.67**	-30.02**
25	Sonali x W.94 FM 59/7	7.00	5.03	6.30	6.02	4.65	-10.00**	-10.00**	-00.47
26	Sonali x L-50	7.00	5.66	6.30	6.33	-0.47	-10.00**	-10.00**	-0.47
27	Sonali x 88/DT-14	7.00	7.00	7.43	7.00	6.14*	6.14*	6.91	17.38**
28	Sonali x DWD-1	7.00	6.67	6.37	6.84	-6.87*	-9.00**	-9.05**	0.63
29	Sonali x A.Vikas	7.00	6.97	7.00	6.98	0.28	0.00	0.00	10.58**
30	Sonali x A.Saurabh	7.00	6.90	7.00	6.95	0.72	0.00	0.00	10.58**
31	A.Alok x L-101	7.00	6.56	7.43	6.78	9.58**	6.14*	6.19	17.38**
32	A.Alok x SP-2-2	7.00	6.46	6.67	6.73	-0.89	-4.71	-4.76	5.37
33.	A.Alok x 88/Firm/J	7.00	7.00	7.00	7.00	0.00	0.00	0.00	10.58**
34	A.Alok x W.94 30 ①	7.00	6.03	6.43	6.52	-1.38	-8.14*	-8.10*	1.58
35	A.Alok x W.94 FM 59/7	7.00	5.03	6.67	6.02	10.80**	-4.71	-4.76	5.37
36	A.Alok x L-50	7.00	5.66	6.63	6.33	4.74	-5.29	-5.24	4.74
37	A.Alok x 88/DT-14	7.00	7.00	6.63	7.00	-5.28	-5.29	-5.24	4.74
38	A.Alok x DWD-1	7.00	6.67	6.63	6.84	-3.07	-5.29	-5.24	4.74
39	A.Alok x A.Vikas	7.00	6.97	7.83	6.98	12.17**	11.86**	11.90**	23.69**
40	A.Alok x A.Saurabh	7.00	6.90	6.00	6.95	-13.67**	-14.29**	-14.29	-5.21
41	Shakti x L-101	6.13	6.56	7.37	6.35	16.06**	12.35**	5.24	16.43**
42	Shakti x SP-2-2	6.13	6.46	8.43	6.29	34.02**	30.49**	20.48**	33.18**
43	Shakti x 88/Firm/J	6.13	7.00	5.67	6.56	-13.56**	-19.00**	-19.05**	-10.43**
44	Shakti x W.94 30 ①	6.13	6.03	6.43	6.08	5.75	4.89	-8.10*	1.58
45	Shakti x W.94 FM 59/7	6.13	5.03	6.40	5.58	14.69**	4.40	-8.57*	1.11
46	Shakti x L-50	6.13	5.66	7.63	5.89	29.54**	24.47**	9.05*	20.54**
47	Shakti x 88/DT-14	6.13	7.00	5.97	6.56	-9.00*	-14.71**	-14.76**	-5.68
48	Shakti x DWD-1	6.13	6.67	6.33	6.40	-1.09	-5.09	-9.52**	0.00
49	Shakti x A.Vikas	6.13	6.97	7.07	6.55	7.93*	1.43	0.95	11.69**
50	Shakti x A.Saurabh	6.13	6.90	6.40	6.52	-1.84	-7.25*	-8.57*	1.11
	Commercial check								
1.	US-1031	6.33							
	S.Em±	0.17							
	CD at 5%					0.41	0.47	0.47	0.47
	CD at 1%					0.54	0.62	0.62	0.62

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

4.2.2.4 Days to 50 per cent flowering (cf. Table 7)

Nine days difference was observed for days to 50 per cent flowering between early flowered parent 88/Firm/J (42.00 days) and late flowered parent Martha (51.00 days). The difference for fifty per cent flowering among the hybrids also remained same. The crosses Sonali x L-101 and Sonali x SP-2-2 and Arka Alok x W.94 30 ① were early flowering compared to other crosses. The commercial check US-1031 took 49.00 days for 50 per cent flowering.

The heterosis over mid parent ranged from −13.38 (Sonali x L-101) to 9.89 per cent (L-15 x 88/Firm/J). As many as 23 crosses showed significant negative heterosis over mid parent, while five crosses exhibited significant positive heterosis. The range for heterobeltiosis was from −13.10 (Sonali x L-101) to 20.64 per cent (Martha x 88/Firm/J). While none of the crosses manifested heterosis in desired direction over best parent. However, 25 crosses exhibited significant negative heterosis over commercial check.

4.2.2.5 Number of flowers per cluster (cf. Table 8)

The highest number of flowers (5.93) per cluster was noticed in female parent Shakti. Whereas, among (male) parents Arka Saurabh (5.87) has recorded highest number of flowers per cluster. In hybrids the range for number of flowers per cluster varied from 4.30 (Martha x SP-2-2 and Arka Alok x SP-2-2) to 6.63 (Sonali x Arka Vikas).

The magnitude of heterosis over mid parent ranged between −22.81 (Martha x Arka Saurabh) and 30.00 per cent (Sonali x Arka Vikas). Out of 50 crosses, 11 crosses showed significant positive heterosis over mid parent, while, 26 crosses exhibited significant negative heteorosis. The range of

Table 7. *Per se* performance and magnitude of heterosis for 50 per cent flowering

Sl No.	F1 Hybrid	Line (days)	Tester (days)	F1 *per se* (days)	Mid parent value (days)	Heterosis per cent over MP	Heterosis per cent over BRP	Heterosis per cent over BSP	Heterosis per cent over CC
1	L-15 x L-101	49.00	48.66	50.00	48.83	2.39	2.75	19.05**	2.04
2	L-15 x SP-2-2	49.00	45.66	48.00	47.33	1.42	5.12	14.29**	-2.04
3	L-15 x 88/Firm/J	49.00	42.00	50.00	45.50	9.89**	19.05**	19.05**	2.04
4	L-15 x W.94 30 ①	49.00	47.00	50.00	48.00	4.17	6.38*	19.05**	2.04
5	L-15 x W.94 FM 59/7	49.00	46.67	47.00	47.84	-1.75	0.71	11.90**	-4.08
6	L-15 x L-50	49.00	48.00	49.00	48.50	1.03	2.08	16.67**	0.00
7	L-15 x 88/DT-14	49.00	47.00	48.00	48.00	0.00	2.13	14.29**	-2.04
8	L-15 x DWD-1	49.00	49.66	51.00	49.33	3.39	4.08	21.43**	4.08
9	L-15 x A.Vikas	49.00	47.66	47.00	48.33	-2.76	-1.38	11.90**	-4.08
10	L-15 x A.Saurabh	49.00	47.33	45.00	48.16	-6.57*	-4.92	7.14*	-8.16**
11	Martha x L-101	51.00	48.66	46.00	49.83	-7.68**	-5.46	9.52**	-6.12*
12	Martha x SP-2-2	51.00	45.66	50.00	48.33	3.45	9.50**	19.05**	2.04
13	Martha x 88/Firm/J	51.00	42.00	50.67	46.50	7.53**	20.64**	20.63**	3.41
14	Martha x W.94 30 ①	51.00	47.00	50.00	49.00	2.04	6.38*	19.05**	2.04
15	MarthaxW.94 FM 59/7	51.00	46.67	44.67	48.84	-8.54**	-4.29	6.35*	-8.84**
16	Martha x L-50	51.00	48.00	44.33	49.50	-10.44**	-7.64**	5.56	-9.53**
17	Martha x 88/DT-14	51.00	47.00	46.00	49.00	-6.12**	-2.13	9.52**	-6.12*
18	Martha x DWD-1	51.00	49.66	45.00	50.33	-10.59**	-9.38**	7.14*	-8.16**
19	Martha x A.Vikas	51.00	47.66	46.00	49.33	-6.76**	-3.48	9.52**	-6.12*
20	Martha x A.Saurabh	51.00	47.33	50.33	49.16	2.37	6.34*	19.84**	2.71
21	Sonali x L-101	48.33	48.66	42.00	48.49	-13.38**	-13.10**	0.00	-14.28**
22	Sonali x SP-2-2	48.33	45.66	42.00	46.99	-10.62**	-8.02**	0.00	-14.28**
23	Sonali x 88/Firm/J	48.33	42.00	48.00	45.16	6.28*	14.29**	14.29**	-2.04
24	Sonali x W.94 30 ①	48.33	47.00	45.00	47.66	-5.59*	-4.26	7.14*	-8.16**
25	Sonali x W.94 FM 59/7	48.33	46.67	48.00	47.50	1.05	2.85	14.29**	-2.04
26	Sonali x L-50	48.33	48.00	44.00	48.16	-8.64**	-8.33**	4.76	-10.20**
27	Sonali x 88/DT-14	48.33	47.00	44.67	47.66	-6.27*	-4.96	6.35*	-8.83**
28	Sonali x DWD-1	48.33	49.66	48.00	48.99	-2.02	-0.71	14.29**	-2.04
29	Sonali x A.Vikas	48.33	47.66	48.00	47.99	0.02	0.71	14.29**	-2.04
30	Sonali x A.Saurabh	48.33	47.33	50.00	47.83	4.54	5.64*	19.05**	2.04
31	A.Alok x L-101	48.66	48.66	44.67	48.66	-8.22**	-8.20**	6.35*	-8.83**
32	A.Alok x SP-2-2	48.66	45.66	44.33	47.16	-6.00*	-2.92	5.56	-9.53**
33	A.Alok x 88/Firm/J	48.66	42.00	47.00	45.33	3.68	11.90**	11.90**	-4.08
34	A.Alok x W.94 30 ①	48.66	47.00	42.00	47.83	-12.19**	-10.64**	0.00	-14.28**
35	A.Alok x W.94 FM 59/7	48.66	46.67	45.00	47.66	-5.58*	-3.57	7.14*	-8.16**
36	A.Alok x L-50	48.66	48.00	49.00	48.33	1.38	2.08	16.67**	0.00
37	A.Alok x 88/DT-14	48.66	47.00	44.00	47.83	-8.01**	-6.38*	4.76	-10.20**
38	A.Alok x DWD-1	48.66	49.66	49.00	49.16	-0.33	0.69	16.67**	0.00
39	A.Alok x A.Vikas	48.66	47.66	43.67	48.16	-9.32**	-8.37**	3.97	-12.21**
40	A.Alok x A.Saurabh	48.66	47.33	43.00	47.99	-10.40**	-9.15**	2.38	-12.24**
41	Shakti x L-101	48.00	48.66	48.00	48.33	-0.69	0.00	14.29**	-2.04
42	Shakti x SP-2-2	48.00	45.66	46.00	46.83	-1.77	0.74	9.52**	-6.21*
43	Shakti x 88/Firm/J	48.00	42.00	47.67	45.00	5.93*	13.50**	13.49**	-2.71
44	Shakti x W.94 30 ①	48.00	47.00	44.00	47.50	-7.37**	-6.38*	4.76	-10.20**
45	Shakti x W.94 FM 59/7	48.00	46.67	44.00	47.34	-7.05**	-5.72*	4.76	-10.20**
46	Shakti x L-50	48.00	48.00	50.67	48.00	5.56*	5.56*	20.63**	3.40
47	Shakti x 88/DT-14	48.00	47.00	45.33	47.50	-4.56	-3.55	7.94*	-7.48**
48	Shakti x DWD-1	48.00	49.66	44.33	48.83	-9.22**	-7.65**	5.56	-9.53**
49	Shakti x A.Vikas	48.00	47.66	48.00	47.83	0.35	0.71	14.29**	-2.04
50	Shakti x A.Saurabh	48.00	47.33	45.00	47.66	-5.58*	-4.92	7.14*	-8.16**
	Commercial check								
1.	US-1031	49.00							
	S.Em±	0.92							
	CD at 5%					2.20	2.54	2.54	2.54
	CD at 1%					2.89	3.35	3.35	3.35

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 8. *Per se* performance and magnitude of heterosis for number of flowers per cluster

Sl No.	F1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over MP	BRP	BSP	CC
1	L-15 x L-101	5.57	5.00	5.37	5.29	1.51	-3.59*	-9.55**	7.40**
2	L-15 x SP-2-2	5.57	4.33	4.60	4.95	-7.07**	-17.41**	-22.47**	-8.00**
3	L-15 x 88/Firm/J	5.57	5.00	5.43	5.29	2.65*	-2.51	-8.43**	8.60**
4	L-15 x W.94 30 ①	5.57	4.27	5.97	4.92	21.34**	7.18**	0.56	19.40**
5	L-15 x W.94 FM 59/7	5.57	4.97	5.33	5.27	1.14	-4.31**	-10.11**	6.60**
6	L-15 x L-50	5.57	4.63	5.67	5.10	11.18**	1.80	-4.49**	13.40**
7	L-15 x 88/DT-14	5.57	5.33	5.33	5.45	-2.20	-4.31**	-10.11**	6.60**
8	L-15 x DWD-1	5.57	4.33	4.63	4.95	-6.47**	-16.88**	-21.91**	-7.40**
9	L-15 x A.Vikas	5.57	4.70	5.33	5.14	3.70**	-4.31**	-10.11**	6.60**
10	L-15 x A.Saurabh	5.57	5.87	5.63	5.72	-1.23	-4.09**	-5.06**	12.60**
11	Martha x L-101	5.57	5.00	5.30	5.29	0.19	-4.85**	-10.67**	6.00**
12	Martha x SP-2-2	5.57	4.33	4.30	4.95	-13.13**	-22.80**	-27.53**	-14.00**
13	Martha x 88/Firm/J	5.57	5.00	4.97	5.29	-6.05**	-10.77**	-16.29**	-0.60
14	Martha x W.94 30 ①	5.57	4.27	4.63	4.92	-5.89**	-16.88**	-21.91**	-7.40**
15	MarthaxW.94 FM 59/7	5.57	4.97	5.30	5.27	0.57	-4.85**	-10.67**	6.00**
16	Martha x L-50	5.57	4.63	5.03	5.10	-1.37	-9.69**	-15.71**	0.60
17	Martha x 88/DT-14	5.57	5.33	5.33	5.45	-2.20	-4.31**	-10.11**	6.60**
18	Martha x DWD-1	5.57	4.33	5.00	4.95	1.01	-10.23**	-15.73**	0.00
19	Martha x A.Vikas	5.57	4.70	5.33	5.14	3.70**	-4.31**	-10.11**	6.60**
20	Martha x A.Saurabh	5.57	5.87	4.40	5.72	-22.81**	-25.04**	-25.84**	-12.00**
21	Sonali x L-101	5.50	5.00	5.00	5.25	-4.76**	-9.09**	-15.73**	0.00
22	Sonali x SP-2-2	5.50	4.33	4.33	4.92	-11.99**	-21.27**	-26.97**	-13.40**
23	Sonali x 88/Firm/J	5.50	5.00	5.63	5.25	7.23**	2.36	-5.06**	12.60**
24	Sonali x W.94 30 ①	5.50	4.27	4.60	4.89	-5.93**	-16.36**	-22.47**	-8.00**
25	Sonali x W.94 FM 59/7	5.50	4.97	4.60	5.24	-12.21**	-16.36**	-22.47**	-8.00**
26	Sonali x L-50	5.50	4.63	4.53	5.07	-10.65**	-17.64**	-23.60**	-9.40**
27	Sonali x 88/DT-14	5.50	5.33	4.97	5.42	-8.30**	-9.64**	-16.29**	-0.60
28	Sonali x DWD-1	5.50	4.33	5.00	4.92	1.63	-9.09**	-15.73**	0.00
29	Sonali x A.Vikas	5.50	4.70	6.63	5.10	30.00**	20.55**	11.80**	32.60**
30	Sonali x A.Saurabh	5.50	5.87	4.97	5.69	-12.65**	-15.33**	-16.29**	-0.60
31	A.Alok x L-101	5.30	5.00	5.03	5.15	-2.33	-5.09**	-15.17**	0.60
32	A.Alok x SP-2-2	5.30	4.33	4.30	4.82	-10.78**	-18.87**	-27.53**	-14.00**
33	A.Alok x 88/Firm/J	5.30	5.00	4.37	5.15	-15.15**	-17.55**	-26.40**	-12.60**
34	A.Alok x W.94 30 ①	5.30	4.27	5.67	4.79	18.37**	6.98**	-4.49**	13.40**
35	A.Alok x W.94 FM 59/7	5.30	4.97	4.93	5.14	-4.09**	-6.98**	-16.85**	-1.40
36	A.Alok x L-50	5.30	4.63	4.70	4.97	-5.43**	-11.32**	-20.79**	-6.00**
37	A.Alok x 88/DT-14	5.30	5.33	4.97	5.32	-6.58**	-6.75**	-16.29**	-0.60
38	A.Alok x DWD-1	5.30	4.33	4.70	4.82	-2.40	-11.32**	-20.79**	-6.00**
39	A.Alok x A.Vikas	5.30	4.70	4.70	5.00	-6.00**	-11.32**	-20.79**	-6.00**
40	A.Alok x A.Saurabh	5.30	5.87	5.73	5.59	2.50*	-2.39	-3.37*	14.60**
41	Shakti x L-101	5.93	5.00	4.97	5.47	-9.15**	-16.19**	-16.29**	-0.60
42	Shakti x SP-2-2	5.93	4.33	4.90	5.13	-4.48**	-17.37**	-17.42**	-2.00
43	Shakti x 88/Firm/J	5.93	5.00	5.00	5.47	-8.59**	-15.68**	-15.73**	0.00
44	Shakti x W.94 30 ①	5.93	4.27	5.33	5.10	4.51**	-10.12**	-10.11**	6.60**
45	Shakti x W.94 FM 59/7	5.93	4.97	5.60	5.45	2.75*	-5.56**	-5.62**	12.00**
46	Shakti x L-50	5.93	4.63	5.40	5.28	2.27	-8.94**	-8.99**	8.00**
47	Shakti x 88/DT-14	5.93	5.33	5.07	5.63	-9.94**	-14.50**	-14.61**	1.40
48	Shakti x DWD-1	5.93	4.33	4.83	5.13	-5.85**	-18.55**	-18.54**	-3.40*
49	Shakti x A.Vikas	5.93	4.70	4.40	5.32	-17.29**	-25.80**	-25.84**	-12.00**
50	Shakti x A.Saurabh	5.93	5.87	4.97	5.90	-15.76**	-16.19**	-16.29**	-0.60
	Commercial check								
1.	US-1031	5.00							
	S.Em±	0.06							
	CD at 5%					0.14	0.17	0.17	0.17
	CD at 1%					0.18	0.22	0.22	0.22

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

better parent heterosis varied from –25.80 (Shakti x Arka Vikas) to 20.55 per cent (Sonali x Arka Vikas) and only three crosses *viz.*, Sonali x Arka Vikas, L-15 x W. 94 30 ① and Arka Alok x W.94 30 ① were able to manifest significant positive heterosis. With respect to heterosis over best parent only one cross Sonali x Arka Vikas showed significant positive heterosis. The maximum heterosis over commercial check was also manifested by Sonali x Arka Vikas.

4.2.2.6 Number of clusters per plant (cf. Table 9)

The differences among testers varied from 9.00 (DWD-1) to 16.20 (W.94 FM 59/7). The range among the lines was from 10.86 (L-15) to 20.27 (Shakti). The hybrids ranged from 12.83 (Arka Alok x Arka Saurabh) to 41.90 (Sonali x SP-2-2). However the commercial check US-1031 had 13.06 clusters per plant.

The magnitude of heterosis over mid parent exhibited by the F_1's for number of cluster per plant extended form 2.50 (Arka Alok x W. 94 FM 59/7) to 253.59 per cent (Sonali x SP-2-2). All the crosses were able to display significant positive heterosis over mid parent except (L-15 x 88/Firm/J, L-15 x L-50, Sonali x W. 94 FM 59/7, Arka Alok x L-101, Arka Alok x 88/Firm/J, Arka Alok x W.94 30 ①, Arka Alok x W.94 FM 59/7, Arka Alok x L-50, Arka Alok x A. Saurabh and Shakti x W. 94 FM 59/7). Per cent heterosis over better parental values in case of hybrids varied form –11.29 (Arka Alok x W. 94 FM 59/7) to 192.39 (Sonali x SP-2-2). Fifty four per cent of the crosses manifested positive heterosis over best parent and the highest being noticed in Sonali x SP-2-2. Except two crosses (L-15 x L-50 and Arka Alok x Arka Saurabh) all other crosses registered desirable positive heterosis over commercial check.

Table 9. *Per se* performance and magnitude of heterosis for number of clusters per plant

Sl No.	F1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over MP	BRP	BSP	CC
1	L-15 x L-101	10.86	12.96	23.63	11.91	98.40**	82.33**	16.61	80.93**
2	L-15 x SP-2-2	10.86	09.36	21.00	10.11	107.72**	93.37**	3.62	60.79**
3	L-15 x 88/Firm/J	10.86	12.36	13.67	11.61	17.74	10.59	-32.57**	4.67
4	L-15 x W.94 30 ①	10.86	13.33	20.40	12.09	68.73**	53.04**	0.66	56.20**
5	L-15 x W.94 FM 59/7	10.86	16.20	18.37	13.53	35.77**	13.39	-9.38	40.66**
6	L-15 x L-50	10.86	12.26	12.67	11.56	9.60	3.34	-37.50**	-2.99
7	L-15 x 88/DT-14	10.86	13.33	20.97	12.09	73.45**	57.31**	3.45	60.56**
8	L-15 x DWD-1	10.86	09.00	13.67	9.93	37.66**	25.87	-32.57**	4.67
9	L-15 x A.Vikas	10.86	15.53	25.40	13.19	92.57**	63.55**	25.33**	94.48**
10	L-15 x A.Saurabh	10.86	12.36	18.40	11.61	58.48**	48.86**	-9.21	40.88**
11	Martha x L-101	12.26	12.96	24.70	12.61	95.87**	90.58**	21.87*	89.13**
12	Martha x SP-2-2	12.26	09.36	20.67	10.81	91.21**	68.59**	1.97	58.27**
13	Martha x 88/Firm/J	12.26	12.36	28.17	12.31	128.83**	127.91**	38.98**	115.69**
14	Martha x W.94 30 ①	12.26	13.33	29.67	12.79	131.97**	122.58**	46.38**	127.18**
15	MarthaxW.94 FM 59/7	12.26	16.20	31.63	14.23	122.27**	95.25**	56.09**	142.19**
16	Martha x L-50	12.26	12.26	25.73	12.26	109.86**	109.86**	26.97**	97.01**
17	Martha x 88/DT-14	12.26	13.33	20.33	12.79	58.95**	52.51**	0.33	55.66**
18	Martha x DWD-1	12.26	09.00	18.90	10.63	77.79**	54.16**	-6.74	44.72**
19	Martha x A.Vikas	12.26	15.53	19.33	13.89	39.16**	24.46*	-4.61	48.01**
20	Martha x A.Saurabh	12.26	12.36	25.80	12.31	109.58**	108.74**	27.30**	97.55**
21	Sonali x L-101	14.33	12.96	17.67	13.65	29.45**	23.31	-12.83	35.29**
22	Sonali x SP-2-2	14.33	09.36	41.90	11.85	253.59**	192.39**	106.74**	220.83**
23	Sonali x 88/Firm/J	14.33	12.36	16.53	13.35	23.82*	15.35	-18.42*	26.57
24	Sonali x W.94 30 ①	14.33	13.33	21.33	13.83	54.22**	48.84**	5.26	63.32**
25	Sonali x W.94 FM 59/7	14.33	16.20	17.67	15.26	15.79	9.07	-12.83	35.29**
26	Sonali x L-50	14.33	12.26	17.30	13.29	30.17**	20.73	-14.64	32.46*
27	Sonali x 88/DT-14	14.33	13.33	19.63	13.83	41.94**	36.98*	-3.12	50.31**
28	Sonali x DWD-1	14.33	09.00	21.17	11.66	86.71**	51.92**	7.40	66.69**
29	Sonali x A.Vikas	14.33	15.53	27.17	14.93	81.98**	74.95**	34.05**	108.04**
30	Sonali x A.Saurabh	14.33	12.36	17.33	13.35	29.81**	20.94	-14.77	32.69*
31	A.Alok x L-101	11.83	12.96	14.17	12.39	14.36	9.33	-30.10**	7.66
32	A.Alok x SP-2-2	11.83	09.36	19.83	10.59	87.25**	67.62**	-2.14	51.84**
33	A.Alok x 88/Firm/J	11.83	12.36	13.77	12.09	13.89	11.41	-32.07**	7.66
34	A.Alok x W.94 30 ①	11.83	13.33	15.47	12.58	22.97	16.05	-23.68**	18.45
35	A.Alok x W.94 FM 59/7	11.83	16.20	14.37	14.02	2.50	-11.29	-29.11**	10.03
36	A.Alok x L-50	11.83	12.26	13.77	12.05	14.27	12.32	-32.07**	5.44
37	A.Alok x 88/DT-14	11.83	13.33	15.60	12.58	24.01*	17.03	-23.03**	19.45
38	A.Alok x DWD-1	11.83	09.00	15.33	10.42	47.12**	29.58*	-24.34**	17.38
39	A.Alok x A.Vikas	11.83	15.53	23.83	13.68	74.19**	53.44**	17.60*	82.46**
40	A.Alok x A.Saurabh	11.83	12.36	12.83	12.09	6.12	3.80	-36.68**	-1.76
41	Shakti x L-101	<u>20.27</u>	12.96	23.77	16.62	43.03**	17.27*	17.27*	82.01**
42	Shakti x SP-2-2	20.27	09.36	23.03	14.82	55.46**	13.65	13.65	76.34**
43	Shakti x 88/Firm/J	20.27	12.36	28.47	16.32	74.46**	40.46**	40.46**	117.99**
44	Shakti x W.94 30 ①	20.27	13.33	33.60	16.80	100.00**	65.79**	65.79**	157.27**
45	Shakti x W.94 FM 59/7	20.27	16.20	20.17	18.24	10.60	-0.49	-0.49	54.44**
46	Shakti x L-50	20.27	12.26	23.90	16.27	46.93**	17.93*	17.93*	83.00**
47	Shakti x 88/DT-14	20.27	13.33	22.73	16.80	34.12**	12.17	12.17	74.04**
48	Shakti x DWD-1	20.27	09.00	29.10	14.64	98.86**	43.59**	43.59**	122.82**
49	Shakti x A.Vikas	20.27	15.53	35.50	17.90	98.32**	75.16**	75.16**	171.82**
50	Shakti x A.Saurabh	20.27	12.36	25.47	16.32	56.08**	25.66**	25.66**	95.02**
	Commercial check								
1.	US-1031	13.06							
	S.Em±	1.26							
	CD at 5%					3.01	3.49	3.49	3.49
	CD at 1%					3.96	4.59	4.59	4.59

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

4.2.2.7 Number of fruits per cluster (cf. Table 10)

The mean values for this trait indicated that there was more variation among males 1.93 (88/DT-14) to 3.13 (W.94 30 ①) compared to females 2.53 (Sonali) to 3.36 (L-15). The *per se* performance of hybrids was in the range of 1.47 (Shakti x 88/Firm/J) to 3.33 (L-15 x Arka Vikas, L-15 x Arka Saurabh and Martha x 88/DT-14). Whereas commercial check recorded 2.86 fruits per cluster.

Heterosis over mid parent exhibited by the F_1's for number of fruits per cluster was in the range of -48.42 (Shakti x 88/Firm/J) to 30.58 per cent (Martha x 88/DT-14). Significant positive and negative heterosis was observed in six and 24 crosses respectively over mid parent. Per cent heterosis over better parental values in case of hybrids varied from –55.86 Shakti x 88/Firm/J to 21.09 per cent (Sonali x W.94 FM 59/7). One and 34 crosses displayed significant positive and negative heterosis over better parent. All the 50 crosses showed negative heteosis over best parent of which 42 were significant. Whereas over commercial check significant positive heterosis was registered by four crosses L-15 x L-101 (14.34%), L-15 x Arka Vikas (16.43%), L-15 x Arka Saurabh (16.43%), Maratha x 88/DT-14 (16.43%) and Martha x Arka Vikas (15.38%).

4.2.2.8 Number of fruits per plant (cf. Table 11)

Among the parents, the maximum number of fruits (65.33) per plant was registered by female parent Shakti. The two testers W.94 FM 59/7 and Arka Vikas recorded 40.53 and 39.46 number of fruits per plant, respectively. The cross Shakti x Arka Vikas recorded the highest number (101.43) of fruits per plant. Where as commercial check recorded 36.03 fruits per plant.

Table 10. ***Per se*** **performance and magnitude of heterosis for number of fruits per cluster**

Sl No.	F_1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	3.36	2.80	3.27	3.08	6.16	-2.67	-2.97	14.34*
2	L-15 x SP-2-2	3.36	2.33	2.37	2.85	-16.84**	-29.46**	-29.70**	-17.13**
3	L-15 x 88/Firm/J	3.36	2.36	2.80	2.86	-2.09	-16.66**	-16.83**	-2.09
4	L-15 x W.94 30 ①	3.36	3.13	3.07	3.25	-5.54	-8.63	-8.91	7.34
5	L-15 x W.94 FM 59/7	3.36	2.56	3.03	2.96	2.36	-9.82*	-9.90*	5.94
6	L-15 x L-50	3.36	2.13	2.63	2.75	-4.36	-21.73**	-21.78**	-8.04
7	L-15 x 88/DT-14	3.36	1.93	2.37	2.65	-10.56	-29.46**	-29.70**	-17.13**
8	L-15 x DWD-1	3.36	2.70	2.93	3.03	-3.30	-12.79*	-12.87*	2.45
9	L-15 x A.Vikas	3.36	2.60	3.33	2.98	11.74*	-0.89	-0.99	16.43**
10	L-15 x A.Saurabh	3.36	2.80	3.33	3.08	8.11	-0.89	-0.99	16.43**
11	Martha x L-101	3.16	2.80	2.30	2.98	-22.02**	-27.22**	-31.68**	-19.58**
12	Martha x SP-2-2	3.16	2.33	2.80	2.75	1.82	-11.39*	-16.83**	-2.09
13	Martha x 88/Firm/J	3.16	2.36	2.27	2.76	-17.75**	-28.16**	-32.67**	-20.63**
14	Martha x W.94 30 ①	3.16	3.13	1.63	3.15	-48.25**	-48.42**	-51.49**	-43.01**
15	MarthaxW.94 FM 59/7	3.16	2.56	2.13	2.86	-25.52**	-32.59**	-36.63**	-25.52**
16	Martha x L-50	3.16	2.13	2.40	2.65	-9.43	-24.05**	-28.71**	-16.08**
17	Martha x 88/DT-14	3.16	1.93	3.33	2.55	30.58**	5.37	-0.99	16.43**
18	Martha x DWD-1	3.16	2.70	2.60	2.93	-11.26*	-17.72**	-22.77**	-9.09
19	Martha x A.Vikas	3.16	2.60	3.30	2.88	14.58**	4.43	-1.98	15.38**
20	Martha x A.Saurabh	3.16	2.80	2.27	2.98	-23.83**	-28.16**	-32.67**	-20.63**
21	Sonali x L-101	2.53	2.80	2.97	2.66	11.65*	6.07	-11.88*	3.85
22	Sonali x SP-2-2	2.53	2.33	1.97	2.43	-18.93**	-22.13**	-41.58**	-31.12**
23	Sonali x 88/Firm/J	2.53	2.36	1.87	2.45	-23.67**	-26.08**	-44.55**	-34.62**
24	Sonali x W.94 30 ①	2.53	3.13	2.87	2.83	1.41	-8.31	-14.85**	0.35
25	Sonali x W.94 FM 59/7	2.53	2.56	3.10	2.55	21.57**	21.09**	-7.92	8.39
26	Sonali x L-50	2.53	2.13	2.23	2.33	-4.29	-11.86	-33.66**	-22.03**
27	Sonali x 88/DT-14	2.53	1.93	1.83	2.23	-17.94**	-27.67**	-45.54**	-36.01**
28	Sonali x DWD-1	2.53	2.70	1.93	2.62	-26.34**	-28.52**	-42.57**	-32.52**
29	Sonali x A.Vikas	2.53	2.60	2.50	2.56	-2.34	-3.85	-25.74**	-12.58*
30	Sonali x A.Saurabh	2.53	2.80	2.77	2.66	4.14	-1.07	-17.82**	-3.15
31	A.Alok x L-101	2.93	2.80	2.97	2.86	3.85	1.37	-11.88*	3.85
32	A.Alok x SP-2-2	2.93	2.33	2.27	2.63	-13.68*	-22.53**	-32.67**	-20.67**
33	A.Alok x 88/Firm/J	2.93	2.36	2.20	2.65	-16.98**	-24.91**	-34.65**	-23.07**
34	A.Alok x W.94 30 ①	2.93	3.13	3.10	3.03	2.31	-0.96	-7.92	8.39
35	A.Alok x W.94 FM 59/7	2.93	2.56	2.57	2.75	-6.54	-12.29*	-23.76**	-10.14
36	A.Alok x L-50	2.93	2.13	2.83	2.53	11.86*	-3.41	-15.84**	-1.05
37	A.Alok x 88/DT-14	2.93	1.93	1.50	2.43	-38.27**	-48.81**	-55.45**	-47.55**
38	A.Alok x DWD-1	2.93	2.70	2.57	2.82	-8.86	-12.29*	-23.76**	-10.13
39	A.Alok x A.Vikas	2.93	2.60	2.43	2.76	-11.95*	-17.06**	-27.72**	-15.03*
40	A.Alok x A.Saurabh	2.93	2.80	2.07	2.86	-27.62**	-29.35**	-38.61**	-27.62**
41	Shakti x L-101	3.33	2.80	2.50	3.06	-18.30**	-24.92**	-25.74**	-12.58*
42	Shakti x SP-2-2	3.33	2.33	2.33	2.83	-17.67**	-30.03**	-30.69**	-18.53**
43	Shakti x 88/Firm/J	3.33	2.36	1.47	2.85	-48.42**	-55.86**	-56.44**	-48.60**
44	Shakti x W.94 30 ①	3.33	3.13	2.37	3.23	-26.63**	-28.82**	-29.70**	-17.13**
45	Shakti x W.94 FM 59/7	3.33	2.56	2.63	2.95	-10.85*	-21.02**	-21.78**	-8.04
46	Shakti x L-50	3.33	2.13	2.70	2.73	-1.09	-18.92**	-19.80**	-5.59
47	Shakti x 88/DT-14	3.33	1.93	2.03	2.63	-22.81**	-39.04**	-39.60**	-29.02**
48	Shakti x DWD-1	3.33	2.70	1.90	3.02	-37.08**	-42.94**	-43.56**	-33.56**
49	Shakti x A.Vikas	3.33	2.60	3.03	2.96	2.36	-9.01	-9.90*	5.94
50	Shakti x A.Saurabh	3.33	2.80	2.57	3.06	-16.01**	-22.82**	-23.76**	-10.14
	Commercial check								
1.	US-1031	2.86							
	S.Em±	0.12							
	CD at 5%					0.29	0.33	0.33	0.33
	CD at 1%					0.38	0.44	0.44	0.44

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 11. *Per se* performance and magnitude of heterosis for number of fruits per plant

Sl No.	F1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	35.10	35.50	72.97	35.30	106.71**	105.54**	11.68*	102.53**
2	L-15 x SP-2-2	35.10	20.70	54.53	27.90	95.45**	55.35**	-16.53**	51.35**
3	L-15 x 88/Firm/J	35.10	27.30	36.97	31.20	18.49*	5.33	-43.42**	2.78
4	L-15 x W.94 30 ①	35.10	38.63	61.03	36.86	65.57**	57.98**	-6.58	69.38**
5	L-15 x W.94 FM 59/7	35.10	40.53	53.73	37.82	42.09**	32.57**	-17.76**	49.13**
6	L-15 x L-50	35.10	23.93	31.17	29.52	5.59	-11.19	-52.30**	-13.48
7	L-15 x 88/DT-14	35.10	25.50	49.03	30.15	67.52**	39.68**	-24.95**	36.08**
8	L-15 x DWD-1	35.10	22.10	38.10	28.60	33.22**	8.55	-41.68**	5.75
9	L-15 x A.Vikas	35.10	39.46	82.87	37.28	122.29**	110.01**	26.84**	130.00**
10	L-15 x A.Saurabh	35.10	33.70	59.40	34.40	72.67**	69.23**	-9.08	64.86**
11	Martha x L-101	38.86	35.50	54.33	37.18	46.13**	39.80**	-16.84**	50.79**
12	Martha x SP-2-2	38.86	20.70	55.50	29.78	86.36**	42.82**	-15.05**	54.04**
13	Martha x 88/Firm/J	38.86	27.30	61.00	33.08	84.40**	56.97**	-6.63	69.30**
14	Martha x W.94 30 ①	38.86	38.63	46.10	38.75	18.97**	18.63*	-29.44**	27.95**
15	MarthaxW.94 FM 59/7	38.86	40.53	64.80	39.69	63.27**	59.88**	-0.82	79.85**
16	Martha x L-50	38.86	23.93	60.13	31.39	91.56**	54.73**	-7.96	66.88**
17	Martha x 88/DT-14	38.86	25.50	65.73	32.18	104.26**	69.15**	0.61	82.43**
18	Martha x DWD-1	38.86	22.10	47.10	30.48	54.53**	21.20**	-27.91**	30.72**
19	Martha x A.Vikas	38.86	39.46	59.50	39.16	51.94**	50.78**	-8.93	65.14**
20	Martha x A.Saurabh	38.86	33.70	55.07	36.28	51.79**	41.71**	-15.71**	52.84**
21	Sonali x L-101	35.26	35.50	49.63	35.38	40.27**	39.80**	-24.03**	37.75**
22	Sonali x SP-2-2	35.26	20.70	78.77	27.98	181.52**	123.39**	20.56**	118.62**
23	Sonali x 88/Firm/J	35.26	27.30	27.93	31.28	-10.71	-20.79*	-57.24**	-22.48**
24	Sonali x W.94 30 ①	35.26	38.63	57.80	36.95	56.43**	49.62**	-11.53*	60.42**
25	Sonali x W.94 FM 59/7	35.26	40.53	52.83	37.89	39.43**	30.35**	-19.13**	46.63**
26	Sonali x L-50	35.26	23.93	36.10	29.59	22.00*	2.38	-44.74**	0.19
27	Sonali x 88/DT-14	35.26	25.50	33.63	30.38	10.69	-4.62	-48.52**	-6.66
28	Sonali x DWD-1	35.26	22.10	40.60	28.68	41.56**	15.14	-37.86**	12.68
29	Sonali x A.Vikas	35.26	39.46	65.17	37.36	74.44**	65.15**	-0.26	80.87**
30	Sonali x A.Saurabh	35.26	33.70	44.90	34.48	30.22**	27.34**	-31.28**	24.62**
31	A.Alok x L-101	33.96	35.50	39.53	34.73	13.82	11.35	-39.49**	9.71
32	A.Alok x SP-2-2	33.96	20.70	42.60	27.33	55.87**	25.44**	-34.80**	18.23*
33	A.Alok x 88/Firm/J	33.96	27.30	27.80	30.63	-9.24	-18.14*	-57.45**	-22.84**
34	A.Alok x W.94 30 ①	33.96	38.63	44.63	36.29	22.98**	15.53	-31.68**	23.87**
35	A.Alok x W.94 FM 59/7	33.96	40.53	34.50	37.25	-7.38	-14.88*	-47.19**	-4.25
36	A.Alok x L-50	33.96	23.93	36.63	28.95	26.53**	7.86	-43.93**	1.67
37	A.Alok x 88/DT-14	33.96	25.50	21.47	29.73	-27.78**	-36.78**	-67.14**	-40.41**
38	A.Alok x DWD-1	33.96	22.10	36.93	28.03	31.75**	8.84	-43.47**	2.49
39	A.Alok x A.Vikas	33.96	39.46	56.53	36.71	53.99**	43.26**	-13.47**	56.89**
40	A.Alok x A.Saurabh	33.96	33.70	25.20	33.83	-25.51**	-25.79**	-61.43**	-30.06**
41	Shakti x L-101	65.33	35.50	56.63	50.42	12.32*	-13.32**	-13.32**	57.17**
42	Shakti x SP-2-2	65.33	20.70	51.30	43.02	19.25**	-21.48**	-21.48**	42.38**
43	Shakti x 88/Firm/J	65.33	27.30	38.87	46.32	-16.08**	-40.50**	-40.51**	7.88
44	Shakti x W.94 30 ①	65.33	38.63	75.37	51.98	44.99**	15.37**	15.36**	109.18**
45	Shakti x W.94 FM 59/7	65.33	40.53	50.70	52.93	-4.21	-22.39**	-22.40**	40.72**
46	Shakti x L-50	65.33	23.93	61.13	44.63	36.97**	-6.43	-6.43	69.66**
47	Shakti x 88/DT-14	65.33	25.50	44.07	45.42	-2.97	-32.54**	-32.55**	22.20**
48	Shakti x DWD-1	65.33	22.10	51.97	43.72	18.87**	-20.45**	-20.46**	44.24**
49	Shakti x A.Vikas	65.33	39.46	101.43	52.39	93.61**	55.26**	55.26**	181.51**
50	Shakti x A.Saurabh	65.33	33.70	61.07	49.52	23.32**	-6.52	-6.53	69.49**
	Commercial check								
1.	US-1031	36.03							
	S.Em±	2.17							
	CD at 5%					5.19	6.02	6.02	6.02
	CD at 1%					6.82	7.90	7.90	7.90

* and ** indicate significant at 5 and 1% level of probability, respectively

The magnitude of heterosis over mid, better and best parent ranged from −27.78 (Arka Alok x 88/DT-14) to 181.52 (Sonali x SP-2-2) , -40.50 (Shakti x 88/Firm / J) to 123.39 (Sonali x SP-2-2) and−67.14 (Arka Alok x 88/DT-14) to 55.26 per cent (Shakti x Arka Vikas) respectively. Out of 50 hybrids, 39, 27 and five hybrids showed significant heterosis in positive direction. While two, 11 and 35 crosses showed significant heterosis in negative direction over mid, better and best parents respectively. The maximum heterosis (181.51%) over commercial check was manifested by Shakti x Arka Vikas.

4.2.2.9 Average fruit weight (cf. Table 12)

The magnitude of variation among the parents for this trait was considerable (22.28 g in Shakti to 66.10 g in L-50). The cross Arka Alok x 88/DT-14 recorded a highest fruit weight of 73.10 g while commercial check US-1031 recorded 42.69 g fruit weight.

Mid parent heterosis exhibited by the hybrids for average fruit weight varied from −45.73 (Shakti x Arka Saurabh) to 57.59 per cent (Arka Alok x L-101). The cross Arka Alok x L-101 recorded the highest heterobeltiosis while, Arka Alok x 88/DT-14 recorded the highest significant positive heterosis over best and commercial check. Out of 50 hybrids, six, three and one crosses had significant heterosis in positive direction over mid, better and best parent respectively. A total of 66, 78 and 98 per cent of crosses showed significant negative heterosis over mid, better and best parent respectively. Whereas, six and 37 crosses recorded significant positive and negative heterosis over commercial check, respectively.

Table 12. *Per se* performance and magnitude of heterosis for average fruit weight

Sl No.	F1 Hybrid	Line (g)	Tester (g)	F1 *per se* (g)	Mid parent value (g)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	36.10	33.10	29.62	34.60	-14.39*	-17.95*	-55.19**	-30.62**
2	L-15 x SP-2-2	36.10	61.94	33.77	49.02	-31.11**	-45.47**	-48.91**	-20.68**
3	L-15 x 88/Firm/J	36.10	47.62	44.25	41.86	5.70	-7.07	-33.06**	3.65
4	L-15 x W.94 30 ①	36.10	43.31	26.76	39.71	-32.61**	-38.21**	-59.52**	-37.32**
5	L-15 x W.94 FM 59/7	36.10	43.85	28.32	39.97	-29.15**	-35.42**	-57.16**	-33.66**
6	L-15 x L-50	36.10	<u>66.10</u>	46.20	51.10	-9.59*	-30.11**	-30.10**	8.22
7	L-15 x 88/DT-14	36.10	58.06	31.12	47.08	-33.89**	-46.40**	-52.92**	-27.10**
8	L-15 x DWD-1	36.10	55.83	29.16	45.96	-36.55**	-47.77**	-55.88**	-31.69**
9	L-15 x A.Vikas	36.10	34.46	27.38	35.28	-22.39**	-24.16**	-58.58**	-35.86**
10	L-15 x A.Saurabh	36.10	41.39	27.73	38.74	-28.43**	-33.00**	-58.05**	-35.04**
11	Martha x L-101	29.22	33.10	32.19	31.16	3.31	-2.75	-51.30**	-24.59**
12	Martha x SP-2-2	29.22	61.94	27.71	45.58	-39.21**	-55.27**	-58.09**	-35.09**
13	Martha x 88/Firm/J	29.22	47.62	33.87	38.42	-11.84	-28.87**	-48.76**	-20.66**
14	Martha x W.94 30 ①	29.22	43.31	28.49	36.26	-21.43**	-34.22**	-56.90**	-33.26**
15	MarthaxW.94 FM 59/7	29.22	43.85	29.63	36.54	-18.91**	-32.43**	-55.18**	-30.59**
16	Martha x L-50	29.22	66.10	35.18	47.66	-26.18**	-46.78**	-46.78**	-17.59**
17	Martha x 88/DT-14	29.22	58.06	31.95	43.64	-26.78**	-44.97**	-51.67**	-25.16**
18	Martha x DWD-1	29.22	55.83	31.09	42.53	-26.89**	-44.31**	-52.96**	-27.17**
19	Martha x A.Vikas	29.22	34.46	34.20	31.84	7.41	-0.75	-48.26**	-19.88**
20	Martha x A.Saurabh	29.22	41.39	28.59	35.31	-19.03**	-30.93**	-56.74**	-33.03**
21	Sonali x L-101	29.78	33.10	30.75	31.44	-2.19	-7.09	-53.48**	-27.97**
22	Sonali x SP-2-2	29.78	61.94	25.09	45.86	-45.29**	-59.49**	-62.04**	-41.23**
23	Sonali x 88/Firm/J	29.78	47.62	38.78	38.70	0.21	-18.56**	-41.34**	-9.16
24	Sonali x W.94 30 ①	29.78	43.31	24.82	36.55	-32.10**	-42.70**	-62.46**	-41.86**
25	Sonali x W.94 FM 59/7	29.78	43.85	31.59	36.82	-14.20*	-27.96**	-52.22**	-26.00**
26	Sonali x L-50	29.78	66.10	59.25	47.94	23.59**	-10.36*	-10.37*	38.79**
27	Sonali x 88/DT-14	29.78	58.06	40.99	43.92	-6.67	-29.40**	-38.00**	-3.98
28	Sonali x DWD-1	29.78	55.83	35.89	42.81	-16.16**	-35.72**	-45.71**	-15.93*
29	Sonali x A.Vikas	29.78	34.46	25.56	32.12	-20.42**	-25.83**	-61.33**	-40.13**
30	Sonali x A.Saurabh	29.78	41.39	28.92	35.58	-18.72**	-30.13**	-56.25**	-32.25**
31	A.Alok x L-101	39.96	33.10	57.57	36.53	57.59**	44.07**	-12.91**	34.86**
32	A.Alok x SP-2-2	39.96	61.94	59.78	50.95	17.33**	-3.49	-9.57*	40.03**
33	A.Alok x 88/Firm/J	39.96	47.62	46.90	43.79	7.10	-1.51	-29.06**	9.86
34	A.Alok x W.94 30 ①	39.96	43.31	49.83	41.64	19.67**	15.05*	-24.62**	16.73*
35	A.Alok x W.94 FM 59/7	39.96	43.85	41.83	41.91	-0.19	-4.61	-36.72**	-2.01
36	A.Alok x L-50	39.96	66.10	59.52	53.03	12.24**	-9.95*	-9.96*	39.42**
37	A.Alok x 88/DT-14	39.96	58.06	73.10	49.01	49.15**	25.92**	10.59*	71.23**
38	A.Alok x DWD-1	39.96	55.83	39.03	47.89	-18.50**	-30.09**	-40.96**	-8.57
39	A.Alok x A.Vikas	39.96	34.46	35.68	37.21	-4.11	-10.71	-46.03**	-16.42*
40	A.Alok x A.Saurabh	39.96	41.39	32.71	40.67	-19.57**	-20.98**	-50.52**	-23.38**
41	Shakti x L-101	22.28	33.10	25.78	27.69	-6.89	-22.11*	-61.00**	-39.61**
42	Shakti x SP-2-2	22.28	61.94	30.09	42.11	-28.54**	-51.42**	-54.49**	-29.52**
43	Shakti x 88/Firm/J	22.28	47.62	23.99	34.95	-31.36**	-49.62**	-63.71**	-43.80**
44	Shakti x W.94 30 ①	22.28	43.31	24.53	32.79	-25.19**	-43.36**	-62.89**	- 42.54**
45	Shakti x W.94 FM 59/7	22.28	43.85	25.48	33.06	-22.93**	-41.89**	-61.46**	-40.31**
46	Shakti x L-50	22.28	66.10	35.96	44.19	-18.63**	-45.60**	-45.60**	-15.76*
47	Shakti x 88/DT-14	22.28	58.06	26.33	40.17	-34.46**	-54.65**	-60.17**	-38.32**
48	Shakti x DWD-1	22.28	55.83	23.84	39.06	-38.96**	-57.30**	-63.94**	-44.15**
49	Shakti x A.Vikas	22.28	34.46	21.12	28.37	-25.56**	-38.71**	-68.06**	-50.53**
50	Shakti x A.Saurabh	22.28	41.39	17.28	31.84	-45.73**	-58.25**	-73.86**	-59.52**
	Commercial check								
1.	US-1031	42.69							
	S.Em±	2.02							
	CD at 5%					4.83	5.59	5.59	5.59
	CD at 1%					6.35	7.36	7.36	7.36

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

4.2.2.10 Yield per plant (cf. Table 13)

Among the parents, males recorded higher yield compared to females and displayed a range of variation from 1.18 kg (L-101) to 1.77 kg (W.94 FM 59/7) per plant. The higher yield of 1.45 kg was recorded by the female parent Shakti. Among the hybrids, the highest yield of 2.53 kg was registered by Arka Alok x SP-2-2 followed by Arka Alok x L-101 (2.27 kg), L-15 x Arka Vikas (2.26 kg), Sonali x SP-2-2 (2.23 kg) and Arka Alok x W.94 30 ① (2.22 kg). Commercial check had a yield potential of 1.53 kg.

Mid parent heterosis for yield per plant ranged from -40.44 (Arka Alok x Arka Saurabh) to 93.13 per cent (Arka Alok x SP-2-2). There were 38 and 12 crosses which exhibited positive and negative heterosis over their mid parents respectively. In all there were 35, 28 and 13 crosses with significant positive heterosis over mid, better and best parent respectively. The crosses exhibiting positive significant heterosis over best parent were Arka Alok x SP-2-2, Arka Alok x L-101, L-15 x Arka Vikas, Sonali x SP-2-2, Arka Alok x W.94 30 ①, Shakti x L-50, Shakti x Arka Vikas, Sonali x L-50, Martha x L-50, Martha x 88/DT-14, Martha x 88/Firm/J, Arka Alok x Arka Vikas and Arka Alok x L-50 in that order. There were as many as 19 crosses showing significant positive heterosis over US-1031.

4.2.2.11 Fruit shape index (FSI) (cf. Table 14)

The parents showed a lot of variation for fruit shape index. The range for fruit shape index varied from 0.760 (88/Firm/J) to 1.41 (W.94 30 ①). Out of 50 crosses, 96 per cent of crosses recorded lower fruit shape compared to commercial check. The fruit shape index was highest in Arka Alok x W. 94 30 ① (1.163) followed by Martha x W.94 30 ① (1.160). The commercial check had fruit shape index value of 1.070.

Table 13. ***Per se*** **performance and magnitude of heterosis for yield per plant**

Sl No.	F_1 Hybrid	Line (kg)	Tester (kg)	F1 *per se* (kg)	Mid parent value (kg)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	1.28	1.18	1.90	1.23	54.47**	48.44**	7.16	24.18**
2	L-15 x SP-2-2	1.28	1.27	1.84	1.27	44.88**	43.75**	3.77	20.26**
3	L-15 x 88/Firm/J	1.28	1.30	1.64	1.29	26.13**	25.15**	-7.53	7.18
4	L-15 x W.94 30 ①	1.28	1.67	1.63	1.47	10.88*	-2.39	-7.72	6.54
5	L-15 x W.94 FM 59/7	1.28	1.77	1.52	1.53	-0.65	-14.12**	-14.12**	-0.65
6	L-15 x L-50	1.28	1.57	1.44	1.43	0.69	-8.28	-18.83**	-5.88
7	L-15 x 88/DT-14	1.28	1.36	1.52	1.32	15.15**	11.76*	-14.12**	-0.65
8	L-15 x DWD-1	1.28	1.23	1.12	1.25	-10.40	-12.50*	-36.91**	-26.79**
9	L-15 x A.Vikas	1.28	1.36	2.26	1.32	71.21**	66.18**	27.68**	47.71**
10	L-15 x A.Saurabh	1.28	1.38	1.65	1.33	24.06**	19.56*	-6.78	7.84
11	Martha x L-101	1.13	1.18	1.75	1.15	52.17**	48.31**	-1.13	14.38**
12	Martha x SP-2-2	1.13	1.27	1.53	1.20	27.50**	20.47**	-13.37**	0.00
13	Martha x 88/Firm/J	1.13	1.30	2.05	1.22	68.03**	57.69**	15.82**	33.98**
14	Martha x W.94 30 ①	1.13	1.67	1.31	1.40	-6.43	-21.55**	-26.08**	-14.38**
15	MarthaxW.94 FM 59/7	1.13	1.77	1.92	1.45	32.41**	8.47	8.29	25.49**
16	Martha x L-50	1.13	1.57	2.10	1.35	55.55**	33.75**	18.64**	37.25**
17	Martha x 88/DT-14	1.13	1.36	2.10	1.25	68.00**	54.41**	18.64**	37.25**
18	Martha x DWD-1	1.13	1.23	1.46	1.18	23.73**	18.69**	-17.33**	-4.58
19	Martha x A.Vikas	1.13	1.36	1.90	1.25	52.00**	39.71**	7.34	24.18**
20	Martha x A.Saurabh	1.13	1.38	1.57	1.26	24.60**	13.76**	-11.49*	2.61
21	Sonali x L-101	1.05	1.18	1.53	1.12	36.61**	29.66**	-13.75**	0.00
22	Sonali x SP-2-2	1.05	1.27	2.23	1.16	92.24**	75.59**	25.80**	45.75**
23	Sonali x 88/Firm/J	1.05	1.30	1.08	1.17	-7.69	-16.92**	-39.17**	-29.41**
24	Sonali x W.94 30 ①	1.05	1.67	1.43	1.36	5.15	-14.37**	-19.02**	-6.54
25	Sonali x W.94 FM 59/7	1.05	1.77	1.66	1.41	17.73**	-6.21	-6.21	8.49
26	Sonali x L-50	1.05	1.57	2.13	1.31	62.59**	35.67**	20.53**	39.22**
27	Sonali x 88/DT-14	1.05	1.36	1.39	1.21	14.87*	2.21	-21.66**	-9.15
28	Sonali x DWD-1	1.05	1.23	1.46	1.14	28.07**	18.69**	-17.70**	-4.58
29	Sonali x A.Vikas	1.05	1.36	1.66	1.21	37.19**	22.05**	-6.03	8.49
30	Sonali x A.Saurabh	1.05	1.38	1.30	1.22	6.56	-5.79	-26.55**	-15.03**
31	A.Alok x L-101	1.35	1.18	2.27	1.26	80.16**	68.15**	28.25**	48.36**
32	A.Alok x SP-2-2	1.35	1.27	2.53	1.31	93.13**	87.41**	42.75**	65.36**
33	A.Alok x 88/Firm/J	1.35	1.30	1.29	1.33	-3.01	-4.44	-27.12**	-15.68**
34	A.Alok x W.94 30 ①	1.35	1.67	2.22	1.51	47.02**	32.93**	25.42**	45.09**
35	A.Alok x W.94 FM 59/7	1.35	1.77	1.44	1.56	-7.69	-18.64**	-18.46**	-5.88
36	A.Alok x L-50	1.35	1.57	2.00	1.46	36.98**	27.38**	12.81**	30.72**
37	A.Alok x 88/DT-14	1.35	1.36	1.54	1.36	13.23*	13.23*	-13.09**	0.65
38	A.Alok x DWD-1	1.35	1.23	1.44	1.29	11.63*	6.66	-18.33**	-5.88
39	A.Alok x A.Vikas	1.35	1.36	2.01	1.36	47.79**	47.79**	13.75**	31.37**
40	A.Alok x A.Saurabh	1.35	1.38	0.81	1.36	-40.44**	-41.30**	-54.43**	-47.06**
41	Shakti x L-101	1.45	1.18	1.46	1.32	10.61*	0.69	-17.51**	-4.58
42	Shakti x SP-2-2	1.45	1.27	1.54	1.36	13.23*	6.21	-12.81**	0.65
43	Shakti x 88/Firm/J	1.45	1.30	0.93	1.37	-32.12**	-35.86**	-47.27**	-39.22**
44	Shakti x W.94 30 ①	1.45	1.67	1.85	1.56	18.58**	10.77*	4.52	20.92**
45	Shakti x W.94 FM 59/7	1.45	1.77	1.29	1.61	-19.87**	-27.12**	-26.93**	-15.68**
46	Shakti x L-50	1.45	1.57	2.20	1.51	45.69**	40.12**	24.11**	43.79**
47	Shakti x 88/DT-14	1.45	1.36	1.16	1.41	-17.73**	-20.00**	-34.46**	-24.18**
48	Shakti x DWD-1	1.45	1.23	1.24	1.34	-7.46	-14.48*	-29.94**	-18.95**
49	Shakti x A.Vikas	1.45	1.36	2.14	1.41	51.77**	47.58**	21.09**	39.87**
50	Shakti x A.Saurabh	1.45	1.38	1.05	1.42	-26.05**	-27.58**	-40.49**	-31.37**
	Commercial check								
1.	US-1031	1.53							
	S.Em±	0.06							
	CD at 5%					0.14	0.16	0.16	0.16
	CD at 1%					0.19	0.22	0.22	0.22

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 14. ***Per se*** **performance and magnitude of heterosis for fruit shape index**

Sl No.	F1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	0.950	0.893	0.947	0.922	2.71	6.05	24.56**	-11.49**
2	L-15 x SP-2-2	0.950	0.967	0.990	0.959	3.23	4.21	30.26**	-7.48
3	L-15 x 88/Firm/J	0.950	0.760	0.930	0.855	8.77	22.37**	18.42**	-13.08**
4	L-15 x W.94 30 ①	0.950	1.410	1.050	1.180	-11.02**	10.52	38.16**	-1.87
5	L-15 x W.94 FM 59/7	0.950	0.773	0.857	0.862	-0.58	-10.86*	12.72*	-19.91**
6	L-15 x L-50	0.950	0.873	0.833	0.912	-8.66*	-4.58	9.65	-22.15**
7	L-15 x 88/DT-14	0.950	0.927	0.873	0.939	-7.03	-5.83	14.91*	-18.41**
8	L-15 x DWD-1	0.950	1.067	0.913	1.009	-9.51*	-3.89	20.18**	-14.67**
9	L-15 x A.Vikas	0.950	0.847	0.920	0.899	2.33	8.62	21.05**	-14.02**
10	L-15 x A.Saurabh	0.950	0.983	0.933	0.967	-3.52	-1.79	22.81**	-12.80**
11	Martha x L-101	1.093	0.893	1.037	0.993	4.36	16.04**	36.40**	-3.08
12	Martha x SP-2-2	1.093	0.967	0.983	1.030	-4.53	1.72	29.39**	-8.13
13	Martha x 88/Firm/J	1.093	0.760	1.013	0.927	9.35*	33.33**	33.33**	-5.33
14	Martha x W.94 30 ①	1.093	1.410	1.160	1.252	-6.79*	6.71	52.63**	8.41
15	MarthaxW.94 FM 59/7	1.093	0.773	0.927	0.933	-0.71	19.83**	21.93**	-13.36**
16	Martha x L-50	1.093	0.873	0.930	0.983	-5.42	6.49	22.37**	-13.08**
17	Martha x 88/DT-14	1.093	0.927	0.937	1.010	-7.26	1.08	23.25**	-12.43**
18	Martha x DWD-1	1.093	1.067	0.997	1.080	-7.72*	-6.56	31.14**	-6.82
19	Martha x A.Vikas	1.093	0.847	0.863	0.970	-11.00**	1.97	13.60*	-19.35**
20	Martha x A.Saurabh	1.093	0.983	0.923	1.038	-10.93**	-5.78	21.49**	-13.74**
21	Sonali x L-101	1.030	0.893	0.903	0.962	-6.13	1.12	18.86**	-15.61**
22	Sonali x SP-2-2	1.030	0.967	0.977	0.999	-2.20	1.03	28.51**	-8.69
23	Sonali x 88/Firm/J	1.030	0.760	0.920	0.895	2.79	21.05**	21.05**	-14.02**
24	Sonali x W.94 30 ①	1.030	1.410	0.913	1.220	-25.16**	-11.36**	20.18**	-14.67**
25	Sonali x W.94 FM 59/7	1.030	0.773	0.910	0.902	0.89	17.72**	19.74**	-14.95**
26	Sonali x L-50	1.030	0.873	0.957	0.952	0.53	9.62	25.88**	-10.56*
27	Sonali x 88/DT-14	1.030	0.927	0.940	0.979	-3.98	1.40	23.68**	-12.15**
28	Sonali x DWD-1	1.030	1.067	0.953	1.049	-9.15*	-7.48	25.44**	-10.94**
29	Sonali x A.Vikas	1.030	0.847	0.833	0.939	-11.28**	-1.65	9.65	-22.15**
30	Sonali x A.Saurabh	1.030	0.983	0.890	1.007	-11.61**	-9.18*	17.11**	-16.82**
31	A.Alok x L-101	1.080	0.893	1.043	0.987	5.67	16.79**	37.28**	-2.52
32	A.Alok x SP-2-2	1.080	0.967	0.907	1.024	-11.43**	-6.20	19.30**	-15.23**
33	A.Alok x 88/Firm/J	1.080	0.760	0.990	0.920	7.61*	30.26**	30.26**	-7.48
34	A.Alok x W.94 30 ①	1.080	1.410	1.163	1.245	-6.59*	7.69	53.07**	8.69*
35	A.Alok x W.94 FM 59/7	1.080	0.773	0.880	0.927	-5.07	13.84*	15.79**	-17.76**
36	A.Alok x L-50	1.080	0.873	0.873	0.977	-10.64**	0.00	14.91*	-18.41**
37	A.Alok x 88/DT-14	1.080	0.927	0.910	1.004	-9.36*	-1.83	19.74**	-14.95**
38	A.Alok x DWD-1	1.080	1.067	1.007	1.074	-6.24	-5.62	32.46**	-5.89
39	A.Alok x A.Vikas	1.080	0.847	0.840	0.964	-12.86**	-0.83	10.53	-21.49**
40	A.Alok x A.Saurabh	1.080	0.983	1.053	1.032	2.03	7.12	38.60**	-1.59
41	Shakti x L-101	0.927	0.893	0.827	0.910	-9.12*	-7.39	8.77	-22.71**
42	Shakti x SP-2-2	0.927	0.967	0.890	0.947	-6.02	-3.99	17.11**	-16.82**
43	Shakti x 88/Firm/J	0.927	0.760	0.927	0.844	9.83*	21.97**	21.93**	-13.36**
44	Shakti x W.94 30 ①	0.927	1.410	1.023	1.169	-12.49**	10.36*	34.65**	-4.39
45	Shakti x W.94 FM 59/7	0.927	0.773	0.783	0.850	-7.88	1.29	3.07	-26.82**
46	Shakti x L-50	0.927	0.873	0.833	0.900	-7.44	-4.58	9.65	-22.15**
47	Shakti x 88/DT-14	0.927	0.927	0.913	0.927	-1.51	-1.51	20.18**	-14.67**
48	Shakti x DWD-1	0.927	1.067	0.860	0.997	-13.74**	-7.22	13.16*	-19.63**
49	Shakti x A.Vikas	0.927	0.847	0.840	0.887	-5.29	-0.83	11.40	-21.50**
50	Shakti x A.Saurabh	0.927	0.983	0.897	0.955	-6.07	-3.24	17.98**	-16.17**
	Commercial check								
1.	US-1031	1.070							
	S.Em±	0.032							
	CD at 5%					0.077	0.088	0.088	0.088
	CD at 1%					0.101	0.117	0.117	0.117

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

The relative heterosis ranged from –25.16 (Sonali x W.94 30 ①) to 9.83 per cent (Shakti x 88/Firm/J). There were three crosses which expressed significant positive heterosis over their mid parent value. While, 11 crosses exhibited significant positive heterosis over their better parent value. None of the hybrids displayed negative heterosis over best parent. On the other hand except Arka Alok x W. 94 30 ① and Martha x W.94 30 ① all expressed negative heterosis over commercial check.

4.2.2.12. Number of locules per fruit (cf. Table 15)

The locule number influences the shelf life of tomato and those with less number of locules keep better. A greater range of variation observed among testers 2.03 (W.94 30 ①) to 6.64 (88/Firm/J), compared to lines 2.75 (L-15) to 5.73 (Arka Alok). Hybrids range from 2.00 (L-15 x W.94 30 ① and Martha x W.94 30 ①) to 6.40 (Arka Alok x W.94 FM 59/7). The commercial check had 3.00 locules per fruit.

The magnitude of heterosis over mid parental value was -48.79 to 30.33 per cent. Out of 50 crosses 31 showed significant heterosis in desired direction and 8 in non-desired direction over mid parent. The significant negative heterosis over better parent and commercial check has been observed in seven and five crosses respectively. However, as many as 31 crosses showed significant positive heterosis over better parent and commercial check. The two hybrids *viz.*, Martha x W.94 30 ① and L-15 x W.94 30 ① had non-significant negative heterosis (-1.64%) for number of locules per fruit over the best parent.

4.2.1.13 Pericarp thickness (cf. Table 16)

The differences among testers varied from 0.357 cm (88/DT-14) to 0.727 cm (W.94 30 ①). The range in females was form 0.337 cm (Shakti) to

Table 15. ***Per se*** **performance and magnitude of heterosis for number of locules per fruit**

Sl No.	F_1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	2.75	4.57	3.00	3.66	-18.03**	9.09	47.54**	0.00
2	L-15 x SP-2-2	2.75	5.52	3.00	4.14	-27.53**	9.09	47.54**	0.00
3	L-15 x 88/Firm/J	2.75	6.64	3.38	4.69	-27.93**	22.91**	66.23**	12.66*
4	L-15 x W.94 30 ①	2.75	2.03	2.00	2.39	-16.32**	-1.47	-1.64	-33.33**
5	L-15 x W.94 FM 59/7	2.75	5.15	3.73	3.95	-5.57	35.64**	83.44**	24.33**
6	L-15 x L-50	2.75	5.52	3.61	4.14	-12.80**	31.27**	77.70**	20.33**
7	L-15 x 88/DT-14	2.75	3.69	3.47	3.22	7.76	26.18**	70.66**	15.66**
8	L-15 x DWD-1	2.75	5.69	2.93	4.22	-30.56**	6.55	43.93**	-2.33
9	L-15 x A.Vikas	2.75	5.60	3.15	4.18	-24.64**	14.55**	54.92**	5.00
10	L-15 x A.Saurabh	2.75	3.06	3.33	2.91	14.43**	21.09**	63.77**	11.00*
11	Martha x L-101	2.83	4.57	2.57	3.70	-30.39**	-9.18	26.56**	-14.33**
12	Martha x SP-2-2	2.83	5.52	3.07	4.17	-26.37**	8.49	50.82**	2.33
13	Martha x 88/Firm/J	2.83	6.64	3.56	4.74	-24.89**	25.79**	75.08**	18.66**
14	Martha x W.94 30 ①	2.83	2.03	2.00	2.43	-17.70**	-1.47	-1.64	-33.33**
15	MarthaxW.94 FM 59/7	2.83	5.15	3.45	3.99	-13.53**	21.91**	69.84**	15.00**
16	Martha x L-50	2.83	5.52	3.62	4.17	-13.18**	27.92**	78.20**	20.66**
17	Martha x 88/DT-14	2.83	3.69	2.53	3.26	-22.39**	-10.60*	24.59**	-15.66**
18	Martha x DWD-1	2.83	5.69	3.42	4.26	-19.72**	20.84**	68.20**	14.00**
19	Martha x A.Vikas	2.83	5.60	3.54	4.22	-16.11**	25.08**	74.10**	18.00**
20	Martha x A.Saurabh	2.83	3.06	2.76	2.95	-6.44	-2.47	35.74**	-8.00
21	Sonali x L-101	2.85	4.57	3.50	3.71	-5.53	22.81**	72.30**	16.66**
22	Sonali x SP-2-2	2.85	5.52	3.75	4.18	-10.28**	31.57**	84.26**	25.00**
23	Sonali x 88/Firm/J	2.85	6.64	2.48	4.75	-47.78**	-12.98*	22.13**	-17.33**
24	Sonali x W.94 30 ①	2.85	2.03	2.99	2.44	22.54**	47.29**	47.21**	-0.33
25	Sonali x W.94 FM 59/7	2.85	5.15	3.26	4.00	-18.50**	14.39**	60.33**	8.66
26	Sonali x L-50	2.85	5.52	3.24	4.18	-22.48**	13.68*	59.34**	8.00
27	Sonali x 88/DT-14	2.85	3.69	4.00	3.27	22.32**	40.35**	96.72**	33.33**
28	Sonali x DWD-1	2.85	5.69	3.83	4.27	-10.30**	34.38**	88.20**	27.66**
29	Sonali x A.Vikas	2.85	5.60	4.00	4.23	-5.48	40.35**	96.72**	33.33**
30	Sonali x A.Saurabh	2.85	3.06	3.32	2.95	12.54**	16.14**	63.44**	10.66*
31	A.Alok x L-101	5.73	4.57	4.10	5.15	-20.39**	-10.28**	101.64**	36.66**
32	A.Alok x SP-2-2	5.73	5.52	4.20	5.63	-25.40**	-23.91**	106.39**	40.00**
33	A.Alok x 88/Firm/J	5.73	6.64	3.17	6.19	-48.79**	-44.68**	55.74**	5.66
34	A.Alok x W.94 30 ①	5.73	2.03	3.15	3.88	-18.81**	55.17**	54.92**	5.00
35	A.Alok x W.94 FM 59/7	5.73	5.15	6.40	5.44	17.65**	24.27**	214.75**	113.33**
36	A.Alok x L-50	5.73	5.52	5.83	5.63	3.55	5.62	186.89**	94.33**
37	A.Alok x 88/DT-14	5.73	3.69	4.93	4.71	4.67	33.60**	142.62**	64.33**
38	A.Alok x DWD-1	5.73	5.69	5.10	5.71	-10.68**	-10.37**	150.82**	139.00**
39	A.Alok x A.Vikas	5.73	5.60	4.73	5.67	-16.58**	-15.54**	132.79**	57.80**
40	A.Alok x A.Saurabh	5.73	3.06	5.25	4.40	19.32**	71.57**	158.20**	75.00**
41	Shakti x L-101	3.28	4.57	4.00	3.93	1.78	21.95**	96.72**	33.33**
42	Shakti x SP-2-2	3.28	5.52	3.83	4.40	-12.95**	16.76**	88.52**	27.66**
43	Shakti x 88/Firm/J	3.28	6.64	3.17	4.96	-36.08**	-3.35	55.74**	5.66
44	Shakti x W.94 30 ①	3.28	2.03	2.83	2.65	6.79	39.41**	39.34**	-5.66
45	Shakti x W.94 FM 59/7	3.28	5.15	5.50	4.22	30.33**	67.68**	170.39**	83.33**
46	Shakti x L-50	3.28	5.52	3.55	4.40	-19.32**	8.23	74.75**	18.33**
47	Shakti x 88/DT-14	3.28	3.69	3.19	3.48	-8.33	-2.74	57.05**	6.33
48	Shakti x DWD-1	3.28	5.69	4.07	4.48	-9.15**	24.08**	100.00**	35.66**
49	Shakti x A.Vikas	3.28	5.60	4.29	4.44	-3.37	30.79**	110.98**	43.00**
50	Shakti x A.Saurabh	3.28	3.06	3.92	3.17	23.65**	28.10**	92.62**	30.66**
	Commercial check								
1.	US-1031	3.00							
	S.Em±	0.11							
	CD at 5%					0.26	0.30	0.30	0.30
	CD at 1%					0.35	0.40	0.40	0.40

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 16. ***Per se*** **performance and magnitude of heterosis for pericarp thickness**

Sl No.	F_1 Hybrid	Line (cm)	Tester (cm)	F1 *per se* (cm)	Mid parent value (cm)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	0.343	0.383	0.593	0.363	63.36**	54.83**	-18.43**	-1.17
2	L-15 x SP-2-2	0.343	0.483	0.627	0.413	51.82**	29.81**	-13.28**	4.50
3	L-15 x 88/Firm/J	0.343	0.480	0.477	0.412	15.77**	-0.63	-34.39**	-20.50**
4	L-15 x W.94 30 ①	0.343	0.727	0.727	0.530	37.16**	1.38	0.00	21.16**
5	L-15 x W.94 FM 59/7	0.343	0.363	0.500	0.353	41.64**	37.74**	-31.22**	-16.66**
6	L-15 x L-50	0.343	0.560	0.523	0.452	15.71**	-6.61	-28.06**	-12.83**
7	L-15 x 88/DT-14	0.343	0.357	0.593	0.350	69.43**	66.11**	-18.43**	-1.17
8	L-15 x DWD-1	0.343	0.437	0.757	0.390	94.10**	73.22**	4.12	26.16**
9	L-15 x A.Vikas	0.343	0.410	0.553	0.377	46.68**	34.87**	-23.93**	-7.83
10	L-15 x A.Saurabh	0.343	0.500	0.490	0.422	16.11**	-2.00	-32.60**	-18.33**
11	Martha x L-101	0.370	0.383	0.453	0.376	20.48**	18.27**	-37.69**	-24.50**
12	Martha x SP-2-2	0.370	0.483	0.483	0.427	13.11*	0.00	-33.56**	-19.50**
13	Martha x 88/Firm/J	0.370	0.480	0.523	0.425	23.05**	8.96	-28.06**	-12.83**
14	Martha x W.94 30 ①	0.370	0.727	0.540	0.544	-0.74	-27.06**	-25.72**	-10.00**
15	MarthaxW.94 FM 59/7	0.370	0.363	0.367	0.367	0.00	-0.81	-49.52**	-38.83**
16	Martha x L-50	0.370	0.560	0.477	0.465	2.58	-14.82**	-34.39**	-20.50**
17	Martha x 88/DT-14	0.370	0.357	0.270	0.364	-25.83**	-27.03**	-62.86**	-55.00**
18	Martha x DWD-1	0.370	0.437	0.370	0.404	-8.42	-15.33*	-49.11**	-38.33**
19	Martha x A.Vikas	0.370	0.410	0.417	0.390	6.92	1.71	-42.64**	-30.50**
20	Martha x A.Saurabh	0.370	0.500	0.397	0.435	-8.73	-20.60**	-45.39**	-33.83**
21	Sonali x L-101	0.423	0.383	0.473	0.403	17.37**	11.82*	-34.94**	-21.16**
22	Sonali x SP-2-2	0.423	0.483	0.597	0.453	31.78**	23.60**	-17.86**	0.50
23	Sonali x 88/Firm/J	0.423	0.480	0.513	0.452	13.49**	6.88	-29.44**	-14.50**
24	Sonali x W.94 30 ①	0.423	0.727	0.450	0.570	-21.05**	-37.24**	-38.10**	-25.00**
25	Sonali x W.94 FM 59/7	0.423	0.363	0.477	0.393	21.37**	12.76*	-34.39**	-20.50**
26	Sonali x L-50	0.423	0.560	0.503	0.492	2.24	-10.18*	-30.81**	-16.17**
27	Sonali x 88/DT-14	0.423	0.357	0.517	0.390	32.56**	22.22**	-28.89**	-13.83**
28	Sonali x DWD-1	0.423	0.437	0.477	0.430	10.93*	9.15	-34.39**	-20.50**
29	Sonali x A.Vikas	0.423	0.410	0.420	0.417	0.72	-0.71	-42.23**	-30.00**
30	Sonali x A.Saurabh	0.423	0.500	0.553	0.462	19.69**	10.60*	-23.93**	-7.83
31	A.Alok x L-101	0.497	0.383	0.517	0.440	17.50**	4.02	-28.89**	-13.83**
32	A.Alok x SP-2-2	0.497	0.483	0.687	0.490	40.20**	38.23**	-5.50	14.50**
33	A.Alok x 88/Firm/J	0.497	0.480	0.600	0.489	22.70**	20.72**	-17.46**	0.00
34	A.Alok x W.94 30 ①	0.497	0.727	0.477	0.607	-21.42**	-33.47**	-34.39**	-20.50**
35	A.Alok x W.94 FM 59/7	0.497	0.363	0.387	0.430	-10.00**	-22.13**	-46.77**	-35.50**
36	A.Alok x L-50	0.497	0.560	0.367	0.529	-30.62**	-34.46**	-49.52**	-38.33**
37	A.Alok x 88/DT-14	0.497	0.357	0.563	0.427	31.85**	13.28*	-22.56**	-6.17
38	A.Alok x DWD-1	0.497	0.437	0.453	0.467	-2.99	-8.85	-37.69**	-24.50**
39	A.Alok x A.Vikas	0.497	0.410	0.500	0.454	10.13*	0.60	-31.22**	-16.66**
40	A.Alok x A.Saurabh	0.497	0.500	0.447	0.499	-10.42*	-10.60*	-38.51**	-25.50**
41	Shakti x L-101	0.337	0.383	0.357	0.360	-0.83	-6.78	-50.89**	-40.50**
42	Shakti x SP-2-2	0.337	0.483	0.320	0.410	-21.95**	-33.74**	-55.98**	-46.66**
43	Shakti x 88/Firm/J	0.337	0.480	0.333	0.409	-18.58**	-30.63**	-54.19**	-44.50**
44	Shakti x W.94 30 ①	0.337	0.727	0.453	0.527	-14.04**	-36.82**	-37.69**	-24.50*
45	Shakti x W.94 FM 59/7	0.337	0.363	0.197	0.350	-43.71**	-45.73**	-72.90**	-67.17**
46	Shakti x L-50	0.337	0.560	0.370	0.449	-17.59**	-33.12**	-49.11**	-38.33**
47	Shakti x 88/DT-14	0.337	0.357	0.427	0.347	23.05**	19.61**	-41.27**	-28.83**
48	Shakti x DWD-1	0.337	0.437	0.360	0.387	-6.98	-17.62**	-50.48**	-40.00**
49	Shakti x A.Vikas	0.337	0.410	0.377	0.374	0.80	-8.05	-48.14**	-37.17**
50	Shakti x A.Saurabh	0.337	0.500	0.433	0.419	3.34	-13.40*	-40.44**	-27.83**
	Commercial check								
1.	US-1031	0.600							
	S.Em±	0.02							
	CD at 5%					0.04	0.05	0.05	0.05
	CD at 1%					0.06	0.07	0.07	0.07

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

0.497 cm (Arka Alok). The hybrids ranged from 0.197 cm (Shakti x W. 94 FM 59/7) to 0.757 cm (L-15 x DWD -1). The check had 0.6 cm pericarp thickness.

Heterosis over mid parent exhibited by the hybrids for pericarp thickness extended from –43.71 (Shakti x W.94 59/7) to 94.10 per cent (L-15 x DWD-1). Significant positive and negative heterosis was observed in 26 and 11 crosses respectively over mid parent. Per cent heterosis over better parental values in case of hybrids varied from –45.73 (Shakti x W.94 FM 59/7) to 73.22 per cent (L-15 x DWD-1). As many as 16 and 18 crosses displayed significant positive and negative heterosis respectively over better parent. Only one cross L-15 x DWD-1 showed positive heterosis while 47 crosses showed significant negative heterosis over best parent (W.94 30①). The cross L-15 x DWD-1 recorded the highest significant positive heterosis over check (26.16%).

4.2.1.14 Total soluble solids (TSS) (cf. Table 17)

TSS indicated wider variation among the testers 3.45 per cent (88/DT-14) to 5.58 per cent (DWD-1), compared to lines, 3.43 per cent (Martha) to 5.17 per cent (L-15). The F_1's showed wider range of variation from 3.13 per cent (L-15 x L-101) to 6.58 per cent (Martha x DWD-1). The commercial check recorded 4.54 per cent of total soluble solids.

There were 21 and 14 hybrids which exhibited significant positive and negative heterosis over mid parents respectively. Per cent heterobeltiosis range from –40.15 (L-15 x L-101) to 49.60 per cent (Martha x Arka Saurabh). As many as 14 and 21 hybrids expressed significant positive and negative heterosis over their better parent values. Out of 50 hybrids only five hybrids manifested significant positive heterosis over best parent *viz.*, Martha x

Table 17. ***Per se* performance and magnitude of heterosis for total soluble solids**

Sl No.	F1 Hybrid	Line (%)	Tester (%)	F1 *per se* (%)	Mid parent value (%)	Heterosis per cent over MP	BRP	BSP	CC
1	L-15 x L-101	5.17	5.23	3.13	5.20	-39.80**	-40.15**	-43.91**	-31.06**
2	L-15 x SP-2-2	5.17	4.33	4.13	4.75	-13.05**	-20.12**	-26.01**	-9.03
3	L-15 x 88/Firm/J	5.17	4.76	4.73	4.96	-4.64	-8.51*	-15.27**	4.18
4	L-15 x W.94 30 ①	5.17	4.57	4.27	4.87	-12.32**	-17.41**	-23.63**	-5.95
5	L-15 x W.94 FM 59/7	5.17	4.27	6.33	4.72	34.11**	22.44**	13.37**	39.43**
6	L-15 x L-50	5.17	4.87	3.73	5.02	-25.69**	-27.85**	-33.17**	-17.84**
7	L-15 x 88/DT-14	5.17	3.45	4.17	4.31	-3.25	-19.34**	-25.42**	-8.15
8	L-15 x DWD-1	5.17	<u>5.58</u>	4.50	5.37	-16.20**	-19.35**	-19.45**	-0.88
9	L-15 x A.Vikas	5.17	5.03	5.08	5.10	-0.39	-1.74	-9.01*	11.89*
10	L-15 x A.Saurabh	5.17	3.83	4.67	4.50	3.77	-9.67*	-16.47**	2.86
11	Martha x L-101	3.43	5.23	4.73	4.33	9.24*	-9.56*	-15.27**	4.18
12	Martha x SP-2-2	3.43	4.33	4.50	3.88	15.98**	3.93	-19.45**	-0.88
13	Martha x 88/Firm/J	3.43	4.76	4.40	4.09	7.57	-7.56	-21.24**	-3.08
14	Martha x W.94 30 ①	3.43	4.57	5.40	4.00	35.00**	18.16**	-3.34	-18.94**
15	MarthaxW.94 FM 59/7	3.43	4.27	5.92	3.85	53.76**	38.64**	5.91	30.39**
16	Martha x L-50	3.43	4.87	5.00	4.15	20.48**	2.67	-10.50**	10.13*
17	Martha x 88/DT-14	3.43	3.45	4.40	3.44	27.91**	27.54**	-21.24**	-3.08
18	Martha x DWD-1	3.43	5.58	6.58	4.51	45.89**	17.92**	17.84**	44.93**
19	Martha x A.Vikas	3.43	5.03	4.17	4.23	-1.42	-17.09**	-25.42**	-8.15
20	Martha x A.Saurabh	3.43	3.83	5.73	3.63	57.85**	49.60**	2.63	26.21**
21	Sonali x L-101	5.11	5.23	4.65	5.17	-10.05**	-11.08**	-16.77**	2.42
22	Sonali x SP-2-2	5.11	4.33	4.80	4.72	1.69	-6.07	-14.08**	5.72
23	Sonali x 88/Firm/J	5.11	4.76	4.25	4.94	-13.96**	-15.26**	-23.93**	-6.38
24	Sonali x W.94 30 ①	5.11	4.57	4.33	4.84	-10.54**	-15.26**	-22.43**	-4.62
25	Sonali x W.94 FM 59/7	5.11	4.27	4.25	4.69	-9.38*	-16.83**	-23.93**	-6.39
26	Sonali x L-50	5.11	4.87	4.67	4.99	-6.41	-8.61*	-16.47**	2.86
27	Sonali x 88/DT-14	5.11	3.45	5.08	4.28	18.69**	-0.58	-9.01*	11.89*
28	Sonali x DWD-1	5.11	5.58	5.33	5.35	-0.37	-4.48	-4.53	22.02**
29	Sonali x A.Vikas	5.11	5.03	3.67	5.07	-27.61**	-28.18**	-34.37**	-19.16**
30	Sonali x A.Saurabh	5.11	3.83	4.47	4.47	0.00	-12.52**	-20.05**	-1.54
31	A.Alok x L-101	4.73	5.23	5.08	4.98	-2.01	-2.86	-9.01*	11.89*
32	A.Alok x SP-2-2	4.73	4.33	4.60	4.53	1.55	-2.75	-17.66**	1.32
33	A.Alok x 88/Firm/J	4.73	4.76	3.99	4.75	-16.00**	-16.17**	-28.52**	-12.11**
34	A.Alok x W.94 30 ①	4.73	4.57	4.81	4.65	3.44	1.69	-13.96**	-5.95
35	A.Alok x W.94 FM 59/7	4.73	4.27	4.75	4.50	5.55	0.42	-14.98**	4.63
36	A.Alok x L-50	4.73	4.87	5.90	4.80	22.92**	21.14**	5.61	29.95**
37	A.Alok x 88/DT-14	4.73	3.45	6.17	4.09	50.85**	30.44**	10.38**	35.90**
38	A.Alok x DWD-1	4.73	5.58	5.77	5.15	12.04**	3.41	3.22	27.09**
39	A.Alok x A.Vikas	4.73	5.03	4.50	4.88	-7.78*	-10.54*	-19.45**	-0.88
40	A.Alok x A.Saurabh	4.73	3.83	5.50	4.28	28.50**	16.28**	-1.55	21.15**
41	Shakti x L-101	4.26	5.23	6.25	4.75	31.57**	19.50**	11.87**	37.66**
42	Shakti x SP-2-2	4.26	4.33	4.97	4.29	15.85**	14.78**	-11.10**	9.47*
43	Shakti x 88/Firm/J	4.26	4.76	4.62	4.51	2.44	-2.94	-17.36**	1.76
44	Shakti x W.94 30 ①	4.26	4.57	5.10	4.42	15.38**	11.60*	-8.71*	12.33**
45	Shakti x W.94 FM 59/7	4.26	4.27	4.78	4.26	12.21**	11.94*	-14.38**	5.28
46	Shakti x L-50	4.26	4.87	4.08	4.56	-10.52**	-16.22**	-26.91**	-10.13*
47	Shakti x 88/DT-14	4.26	3.45	4.65	3.85	20.77**	9.15	-16.77**	2.42
48	Shakti x DWD-1	4.26	5.58	4.14	4.92	-15.85**	-25.81**	-25.95**	-8.81
49	Shakti x A.Vikas	4.26	5.03	5.33	4.65	14.62**	5.96	-4.53	17.40**
50	Shakti x A.Saurabh	4.26	3.83	6.17	4.05	52.34**	44.83**	10.38**	35.90**
	Commercial check								
1.	US-1031	4.54							
	S.Em±	0.15							
	CD at 5%					0.36	0.42	0.42	0.42
	CD at 1%					0.47	0.55	0.55	0.55

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

DWD-1 (17.84%), L-15 x W.94 FM 59/7 (13.37%), Shakti x L-101 (11.87%), Arka Alok x 88/DT-14 (10.38%) and Shakti x Arka Saurabh (10.30%). Eighteen and six hybrids were able to exhibit significant economic heterosis in positive and negative direction over commercial check US-1031 respectively.

4.2.1.15 pH of fruit juice (cf. Table 18)

The lines showed a narrow range of variation from 4.32 (Arka Alok) to 4.43 (L-15), where as the testers showed a wider range from 4.18 (L-101) to 4.43 (88/DT-14). The crosses for pH of fruit juice ranged from 4.11 (Arka Alok x W.94 FM 59/7) to 4.56 (Arka Alok x SP-2-2). The commercial check had pH value of 4.41.

Out of 50 cross combinations, four crosses manifested significant heterosis over mid parent of which only one cross Arka Alok x W.94 FM 59/7 showed significant negative heterosis (-4.42%). Whereas over better parent three crosses manifested significant heterosis but it was in positive direction. The heterosis over better parent ranged from –3.97 (Arka Alok x W.94 FM 59/7) to 6.69 per cent (Shakti x L-101). There were only two crosses Arka Alok x W.94 FM 59/7 (-1.83%), Shakti x W.94 30 ① (-0.08%) which manifested negative heterosis over the best parent. The three hybrids which manifested significant negative heterosis over commercial check were Arka Alok x W.94 FM 59/7 (-6.80%), Arka Alok x L-50 (-5.22%) and Arka Alok x W.94 30 ① (-5.22%).

4.2.1.16 Titratable acidity (cf. Table 19)

The range for titratable acidity among lines varied from 0.270 per cent citric acid (Arka Alok) to 0.403 per cent citric acid (Shakti), while in testers

Table 18. *Per se* performance and magnitude of heterosis for pH of fruit juice

Sl No.	F_1 Hybrid	Line	Tester	F1 *per se*	Mid parent value	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	4.43	4.18	4.42	4.31	2.55	5.74*	5.58*	0.23
2	L-15 x SP-2-2	4.43	4.34	4.25	4.39	-3.18	-2.07	1.59	-3.63
3	L-15 x 88/Firm/J	4.43	4.35	4.36	4.39	-0.68	0.23	4.14	-1.13
4	L-15 x W.94 30 ①	4.43	4.35	4.31	4.39	-1.82	-0.92	3.03	-2.27
5	L-15 x W.94 FM 59/7	4.43	4.28	4.31	4.36	-1.15	0.70	2.95	-2.27
6	L-15 x L-50	4.43	4.29	4.23	4.36	-2.98	-1.40	1.12	-4.08
7	L-15 x 88/DT-14	4.43	4.43	4.34	4.43	-2.03	-2.03	3.67	-1.58
8	L-15 x DWD-1	4.43	4.33	4.28	4.38	-2.28	-1.15	2.23	-2.95
9	L-15 x A.Vikas	4.43	4.27	4.24	4.35	-2.53	-0.70	1.27	-3.85
10	L-15 x A.Saurabh	4.43	4.30	4.32	4.37	-1.14	0.47	3.27	-2.04
11	Martha x L-101	4.36	4.18	4.36	4.27	2.10	4.31	4.14	-1.13
12	Martha x SP-2-2	4.36	4.34	4.28	4.35	-1.61	-1.38	2.39	-2.95
13	Martha x 88/Firm/J	4.36	4.35	4.37	4.36	0.23	0.46	4.54	-0.91
14	Martha x W.94 30 ①	4.36	4.35	4.36	4.36	0.00	-0.23	4.30	-1.13
15	MarthaxW.94 FM 59/7	4.36	4.28	4.37	4.32	1.16	2.10	4.38	-0.91
16	Martha x L-50	4.36	4.29	4.28	4.33	-1.15	-0.23	2.31	-2.95
17	Martha x 88/DT-14	4.36	4.43	4.36	4.39	-0.68	0.00	4.14	-1.13
18	Martha x DWD-1	4.36	4.33	4.42	4.35	1.61	2.08	5.66*	0.23
19	Martha x A.Vikas	4.36	4.27	4.39	4.32	1.62	2.81	5.02	-0.45
20	Martha x A.Saurabh	4.36	4.30	4.42	4.33	2.08	2.79	5.66*	0.23
21	Sonali x L-101	4.37	4.18	4.36	4.28	1.87	4.30	4.14	-1.13
22	Sonali x SP-2-2	4.37	4.34	4.49	4.36	2.98	3.46	7.33**	1.81
23	Sonali x 88/Firm/J	4.37	4.35	4.41	4.36	1.15	1.38	5.34*	0.00
24	Sonali x W.94 30 ①	4.37	4.35	4.35	4.36	-0.23	0.00	3.90	-1.36
25	Sonali x W.94 FM 59/7	4.37	4.28	4.37	4.33	0.92	2.10	4.46	-0.91
26	Sonali x L-50	4.37	4.29	4.35	4.33	0.46	1.39	4.06	-1.36
27	Sonali x 88/DT-14	4.37	4.43	4.44	4.40	0.91	1.60	6.06*	0.68
28	Sonali x DWD-1	4.37	4.33	4.36	4.35	0.23	0.69	4.14	-1.13
29	Sonali x A.Vikas	4.37	4.27	4.51	4.32	4.39*	5.62	7.81**	2.27
30	Sonali x A.Saurabh	4.37	4.30	4.50	4.34	3.69	4.65	7.65**	2.04
31	A.Alok x L-101	4.32	4.18	4.38	4.25	3.06	4.78	4.78	-0.68
32	A.Alok x SP-2-2	4.32	4.34	4.56	4.33	5.31*	5.56*	8.92**	3.40
33	A.Alok x 88/Firm/J	4.32	4.35	4.49	4.34	3.46	3.94	7.25**	1.81
34	A.Alok x W.94 30 ①	4.32	4.35	4.35	4.34	0.23	0.69	4.06	-1.36
35	A.Alok x W.94 FM 59/7	4.32	4.28	4.11	4.30	-4.42*	-3.97	-1.83	-6.80*
36	A.Alok x L-50	4.32	4.29	4.18	4.31	-3.02	-2.56	0.00	-5.22*
37	A.Alok x 88/DT-14	4.32	4.43	4.40	4.38	0.46	1.85	5.18*	-0.23
38	A.Alok x DWD-1	4.32	4.33	4.28	4.33	-1.15	-0.93	2.39	-2.95
39	A.Alok x A.Vikas	4.32	4.27	4.38	4.29	2.09	2.58	4.70	-0.68
40	A.Alok x A.Saurabh	4.32	4.30	4.46	4.31	3.48	3.72	6.61*	1.13
41	Shakti x L-101	4.36	4.18	4.46	4.27	4.45*	6.69**	6.69*	1.13
42	Shakti x SP-2-2	4.36	4.34	4.24	4.35	-2.53	-2.30	1.43	-3.85
43	Shakti x 88/Firm/J	4.36	4.35	4.36	4.36	0.00	0.23	4.22	-1.13
44	Shakti x W.94 30 ①	4.36	4.35	4.18	4.36	-4.13	-3.91	-0.08	-5.22*
45	Shakti x W.94 FM 59/7	4.36	4.28	4.31	4.32	-0.23	0.70	2.95	-2.26
46	Shakti x L-50	4.36	4.29	4.20	4.33	-3.00	-2.10	0.40	-4.76
47	Shakti x 88/DT-14	4.36	4.43	4.41	4.39	0.45	1.15	5.34*	0.00
48	Shakti x DWD-1	4.36	4.33	4.32	4.35	-0.69	-0.23	3.27	-2.04
49	Shakti x A.Vikas	4.36	4.27	4.36	4.32	0.93	2.11	4.22	-1.13
50	Shakti x A.Saurabh	4.36	4.30	4.44	4.33	2.54	3.26	6.22*	0.68
	Commercial check								
1.	US-1031	4.41							
	S.Em±	0.08							
	CD at 5%					0.19	0.22	0.22	0.22
	CD at 1%					0.25	0.29	0.29	0.29

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 19. ***Per se*** **performance and magnitude of heterosis for titratable acidity**

Sl No.	F_1 Hybrid	Line (%CA)	Tester (%CA)	F1 *per se* (%CA)	Mid parent value (%CA)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	0.310	0.360	0.500	0.335	49.25**	38.89**	20.00*	45.77**
2	L-15 x SP-2-2	0.310	0.260	0.340	0.285	19.30*	9.68	-18.40**	-0.87
3	L-15 x 88/Firm/J	0.310	0.233	0.413	0.272	52.15**	33.30**	-0.80	19.53**
4	L-15 x W.94 30 ①	0.310	0.417	0.323	0.364	-11.26*	-22.54**	-22.40**	-5.83
5	L-15 x W.94 FM 59/7	0.310	0.300	0.380	0.305	24.59**	22.58**	-8.00**	10.78
6	L-15 x L-50	0.310	0.293	0.323	0.302	7.18	3.23	-22.40**	-6.71
7	L-15 x 88/DT-14	0.310	0.300	0.417	0.305	36.61**	34.52**	0.00	22.45**
8	L-15 x DWD-1	0.310	0.313	0.473	0.312	51.87**	51.12**	13.60*	37.03**
9	L-15 x A.Vikas	0.310	0.300	0.334	0.305	10.38	7.74	-19.20**	-0.87
10	L-15 x A.Saurabh	0.310	0.413	0.240	0.362	-33.64**	-41.89**	-42.40**	-30.03**
11	Martha x L-101	0.350	0.360	0.560	0.355	58.69**	55.55**	34.29**	63.27**
12	Martha x SP-2-2	0.350	0.260	0.443	0.305	45.36**	26.57**	6.40	29.15**
13	Martha x 88/Firm/J	0.350	0.233	0.223	0.292	-23.43**	-36.28**	-46.40**	-34.98**
14	Martha x W.94 30 ①	0.350	0.417	0.417	0.384	8.59	0.00	0.00	21.57**
15	MarthaxW.94 FM 59/7	0.350	0.300	0.310	0.325	-4.62	-11.43	-25.60**	-9.62
16	Martha x L-50	0.350	0.293	0.307	0.322	-4.66	-12.28	-26.40**	-10.49
17	Martha x 88/DT-14	0.350	0.300	0.260	0.325	-20.00**	-25.71**	-37.60**	-24.19**
18	Martha x DWD-1	0.350	0.313	0.320	0.332	-3.52	-8.57	-23.20**	-6.71
19	Martha x A.Vikas	0.350	0.300	0.380	0.325	16.92*	8.57	-8.80	10.78
20	Martha x A.Saurabh	0.350	0.413	0.413	0.382	8.30	0.00	-0.80	20.41**
21	Sonali x L-101	0.290	0.360	0.340	0.325	4.62	-5.56	-18.40**	-0.87
22	Sonali x SP-2-2	0.290	0.260	0.373	0.275	35.76**	28.62**	-10.40	8.74
23	Sonali x 88/Firm/J	0.290	0.233	0.260	0.262	-0.64	-10.34	-37.60**	-24.19**
24	Sonali x W.94 30 ①	0.290	0.417	0.240	0.354	-30.03**	-42.45**	-42.40**	-30.03**
25	Sonali x W.94 FM 59/7	0.290	0.300	0.270	0.295	-8.47	-10.00	-35.20**	-21.28**
26	Sonali x L-50	0.290	0.293	0.280	0.292	-4.00	-4.44	-32.80**	-18.36*
27	Sonali x 88/DT-14	0.290	0.300	0.253	0.295	-14.12*	-15.66	-39.20**	-26.24**
28	Sonali x DWD-1	0.290	0.313	0.380	0.302	25.97**	21.41**	-8.80	10.78
29	Sonali x A.Vikas	0.290	0.300	0.183	0.295	-37.85**	-39.00**	-56.00**	-46.64**
30	Sonali x A.Saurabh	0.290	0.413	0.217	0.352	-38.39**	-47.46**	-48.00**	-35.86**
31	A.Alok x L-101	0.270	0.360	0.310	0.315	-1.59	-13.89*	-25.60**	-9.62
32	A.Alok x SP-2-2	0.270	0.260	0.320	0.265	20.75*	18.52*	-23.20**	-6.71
33	A.Alok x 88/Firm/J	0.270	0.233	0.480	0.252	90.73**	77.78**	15.20*	39.94**
34	A.Alok x W.94 30 ①	0.270	0.417	0.450	0.344	30.81**	7.91	8.00	31.19**
35	A.Alok x W.94 FM 59/7	0.270	0.300	0.433	0.285	52.05**	44.33**	4.00	26.24**
36	A.Alok x L-50	0.270	0.293	0.447	0.282	58.58**	52.56**	7.20	30.32**
37	A.Alok x 88/DT-14	0.270	0.300	0.540	0.285	89.47**	80.00**	29.60**	57.43**
38	A.Alok x DWD-1	0.270	0.313	0.510	0.292	74.86**	62.93**	22.40**	48.68**
39	A.Alok x A.Vikas	0.270	0.300	0.310	0.285	8.77	3.33	-25.60**	-8.75
40	A.Alok x A.Saurabh	0.270	0.413	0.350	0.342	2.44	-15.25*	-16.00**	2.04
41	Shakti x L-101	0.403	0.360	0.450	0.382	17.90**	11.66	8.00	31.19**
42	Shakti x SP-2-2	0.403	0.260	0.360	0.332	8.54	-10.67	-13.60*	4.96
43	Shakti x 88/Firm/J	0.403	0.233	0.307	0.318	-3.66	-23.02**	-26.40**	-10.49
44	Shakti x W.94 30 ①	0.403	0.417	0.320	0.410	-21.95**	-23.26**	-23.20**	-6.71
45	Shakti x W.94 FM 59/7	0.403	0.300	0.297	0.352	-15.64**	-26.30**	-28.80**	-13.41
46	Shakti x L-50	0.403	0.293	0.403	0.348	15.79*	0.00	-3.20	17.49*
47	Shakti x 88/DT-14	0.403	0.300	0.407	0.352	15.64*	0.99	-2.40	18.65*
48	Shakti x DWD-1	0.403	0.313	0.407	0.358	13.49*	0.99	-2.40	-18.65*
49	Shakti x A.Vikas	0.403	0.300	0.330	0.352	-6.16	-18.11**	-20.80**	-3.79
50	Shakti x A.Saurabh	0.403	0.413	0.267	0.408	-34.69**	-35.35**	-36.00**	-22.16**
	Commercial check								
1.	US-1031	0.343							
	S.Em±	0.02							
	CD at 5%					0.04	0.05	0.05	0.05
	CD at 1%					0.06	0.07	0.07	0.07

* and ** indicate significant at 5 and 1 per cent level of probability, respectively

Underlined figure indicate best parent value

CA – Citric acid

0.233 per cent citric acid (88/Firm/J) to 0.417 per cent citric acid (W.94 30 ①). However, the hybrids showed a very high variation from 0.183 (Sonali x Arka Vikas) to 0.560 per cent citric acid (Martha x L-101). The commercial check recorded 0.343 per cent citric acid.

A total of 22, 15 and six crosses exhibited significant positive heterosis and 11, 14 and 28 crosses displayed significant negative heterosis over mid, better and best parent respectively. The highest significant positive heterosis over mid, better and best parent was expressed by Arka Alok x 88/Firm/J (90.73%), Arka Alok x 88/DT-14 (80.00%) and Martha x L-101 (34.29%), respectively. The per cent economic heterosis ranged between –46.64 (Sonali x Arka Vikas) and 63.27 (Martha x L-101).

4.2.1.17 Ascorbic acid (cf. Table 20)

Among the lines variation was from 5.89 mg /100g (Martha) to 37.05 mg/100 g ascorbic acid (Sonali) whereas in testers the range was from 8.62 mg/100g (Arka Saurabh) to 25.51 mg/100 g ascorbic acid (DWD-1). The hybrids displayed large amount of variation from 9.21 mg/100g (Arka Alok x W.94 30①) to 43.32 mg/100 g ascorbic acid (Martha x L-101). The commercial check recorded 40.71 mg/100g ascorbic acid.

The magnitude of heterosis over mid parent extended from –60.18 (Sonali x SP-2-2) to 412.70 per cent (Martha x W.94 FM 59/7). There were a total of 33 hybrids which exhibited significant positive heterosis over mid parent. Out of 50 hybrids 21 and 19 hybrids revealed significant heterobeltiosis in positive and negative direction respectively. The highest significant positive heterobeltiosil was registered by Martha x W. 94 FM 59/7 (294.48%). Only 22 per cent of the crosses exhibited significant positive

Table 20. *Per se* performance and magnitude of heterosis for ascorbic acid

Sl No.	F_1 Hybrid	Line (mg/ 100 g)	Tester (mg/ 100 g)	F1 *per se* (mg/ 100 g)	Mid parent value (mg/ 100 g)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	35.99	13.47	42.45	24.73	71.65**	17.95**	14.56**	4.27
2	L-15 x SP-2-2	35.99	14.33	40.91	25.16	62.51**	13.68**	10.42*	0.49
3	L-15 x 88/Firm/J	35.99	18.68	40.40	27.34	47.77**	12.25**	9.02*	-0.76
4	L-15 x W.94 30 ①	35.99	14.25	36.83	25.12	46.61**	2.33	-0.59	-9.53**
5	L-15 x W.94 FM 59/7	35.99	10.88	24.76	23.44	5.63	-31.20**	-33.19**	-39.18**
6	L-15 x L-50	35.99	19.34	17.01	27.66	-38.50**	-52.74**	-54.09**	-58.22**
7	L-15 x 88/DT-14	35.99	24.39	37.68	30.19	24.81**	4.69	1.70	-7.44*
8	L-15 x DWD-1	35.99	25.51	42.45	30.75	38.05**	17.94**	14.56**	4.27
9	L-15 x A.Vikas	35.99	23.05	42.28	29.52	43.22**	17.48**	14.11**	3.86
10	L-15 x A.Saurabh	35.99	8.62	35.69	22.31	59.97**	-0.83	-3.68	-12.33**
11	Martha x L-101	5.89	13.47	43.32	9.68	347.52**	221.60**	16.92**	6.41
12	Martha x SP-2-2	5.89	14.33	41.00	10.11	305.53**	186.11**	10.65**	0.71
13	Martha x 88/Firm/J	5.89	18.68	41.14	12.28	235.01**	120.23**	11.04**	1.05
14	Martha x W.94 30 ①	5.89	14.25	21.39	10.07	112.41**	50.10**	-42.27**	-47.45**
15	MarthaxW.94 FM 59/7	5.89	10.88	42.92	8.38	412.17**	294.48**	15.84**	5.43
16	Martha x L-50	5.89	19.34	37.29	12.62	195.48**	92.81**	0.65	-8.40*
17	Martha x 88/DT-14	5.89	24.39	14.85	15.14	-1.92	-39.11**	-59.95**	-63.52**
18	Martha x DWD-1	5.89	25.51	22.29	15.70	41.97**	-12.62*	-39.85**	-45.25**
19	Martha x A.Vikas	5.89	23.05	29.62	14.47	104.69**	28.50**	-20.06**	-27.24**
20	Martha x A.Saurabh	5.89	8.62	28.73	7.25	296.27**	233.29**	-22.45**	-29.43**
21	Sonali x L-101	37.05	13.47	30.76	25.26	21.77**	-16.98**	-16.98**	-24.44**
22	Sonali x SP-2-2	37.05	14.33	10.23	25.69	-60.18**	-72.38**	-72.40**	-74.87**
23	Sonali x 88/Firm/J	37.05	18.68	35.17	27.86	26.24**	-5.07	-5.07	-13.61**
24	Sonali x W.94 30 ①	37.05	14.25	18.88	25.65	-26.40**	-49.04**	-49.04**	-53.62**
25	Sonali x W.94 FM 59/7	37.05	10.88	24.86	23.96	3.75	-32.90**	-32.91**	-38.93**
26	Sonali x L-50	37.05	19.34	25.82	28.19	-8.41	-30.31**	-30.33**	-36.57**
27	Sonali x 88/DT-14	37.05	24.39	34.61	30.72	12.66**	-6.58	-6.60	-14.98**
28	Sonali x DWD-1	37.05	25.51	40.58	31.28	29.73**	9.53*	9.51*	-0.32
29	Sonali x A.Vikas	37.05	23.05	42.03	30.05	39.86**	13.44**	13.42**	3.24
30	Sonali x A.Saurabh	37.05	8.62	23.75	22.84	3.98	-35.89**	-35.89**	-41.66**
31	A.Alok x L-101	8.86	13.47	30.71	11.16	175.18**	127.98**	-17.11**	-24.56**
32	A.Alok x SP-2-2	8.86	14.33	24.89	11.59	114.75**	73.69**	-32.84**	-38.86**
33	A.Alok x 88/Firm/J	8.86	18.68	23.41	13.77	70.00**	25.32**	-36.82**	-42.49**
34	A.Alok x W.94 30 ①	8.86	14.25	9.21	11.56	-20.30**	-35.36**	-75.13**	-77.37**
35	A.Alok x W.94 FM 59/7	8.86	10.88	22.61	9.87	129.07**	107.81**	-38.98**	-44.46**
36	A.Alok x L-50	8.86	19.34	13.89	14.10	-1.48	-28.17**	-62.51**	-65.88**
37	A.Alok x 88/DT-14	8.86	24.39	22.14	16.63	33.13**	-9.22	-40.25**	-45.62**
38	A.Alok x DWD-1	8.86	25.51	10.57	17.18	-38.47**	-58.56**	-71.48**	-74.04**
39	A.Alok x A.Vikas	8.86	23.05	15.08	15.95	-5.45	-34.57**	-59.30**	-62.96**
40	A.Alok x A.Saurabh	8.86	8.62	11.43	8.74	30.78*	29.01	-69.15**	-71.92**
41	Shakti x L-101	29.75	13.47	35.47	21.61	64.14**	19.23**	-4.27	-12.87**
42	Shakti x SP-2-2	29.75	14.33	16.39	22.04	-25.64**	-44.90**	-55.76**	-59.74**
43	Shakti x 88/Firm/J	29.75	18.68	28.49	24.22	17.63**	-4.24	-23.11**	-30.02**
44	Shakti x W.94 30 ①	29.75	14.25	14.05	22.00	-36.14**	-52.77**	-62.08**	-65.48**
45	Shakti x W.94 FM 59/7	29.75	10.88	33.59	20.32	65.38**	12.91**	-9.34*	-17.48**
46	Shakti x L-50	29.75	19.34	18.50	24.54	-24.61**	-37.82**	-50.07**	-54.55**
47	Shakti x 88/DT-14	29.75	24.39	30.49	27.07	12.63*	2.48	-17.70**	-25.10**
48	Shakti x DWD-1	29.75	25.51	20.02	27.63	-27.54**	-32.70**	-45.97**	-50.82**
49	Shakti x A.Vikas	29.75	23.05	30.92	26.40	17.12**	3.93	-16.55**	-24.05**
50	Shakti x A.Saurabh	29.75	8.62	10.84	19.18	-43.48**	-63.57**	-70.75**	-73.37**
	Commercial check								
1.	US-1031	40.71							
	S.Em±	1.05							
	CD at 5%					2.51	2.91	2.91	2.91
	CD at 1%					3.30	3.82	3.82	3.82

* and ** indicate significant at 5 and 1 per cent level of probability, respectively

Underlined figure indicate best parent value

heterosis over best parent. None of the hybrids expressed significant positive heterosis over the commercial check.

4.2.1.18 Lycopene (cf. Table 21)

The lycopene content of tomato fruits was varied from 2.03 (L-15) to 5.57 mg/100g (88/DT-14) for the parents. Whereas, the cross combination Arka Alok x W. 94 30 ① was recorded a highest mean value of 8.21 mg/100g. The commercial check had the lycopene content of 3.39 mg/100g of fruit juice.

Mid parent heterosis exhibited by the hybrids for lycopene varied from -63.93 (Shakti x 88/Firm/J) to 158.10 per cent (Martha x SP-2-2). A total of 35 crosses expressed significant positive heterosis over mid parent. There were 27 and 10 crosses exhibiting significant positive heterosis and 19 and 39 crosses exhibiting significant negative heterosis over better and best parent respectively. The economic hetterosis range between –63.72 (Shakti x 88/Firm/J) and 142.18 per cent (Arka Alok x W. 94 30 ①).

4.2.1.19 Per cent wilt incidence (cf. Table 22)

The female parent recorded wilt incidence of 0.00 (Sonali, Arka Alok and Shakti) to 17.76 per cent (Martha). While a greater magnitude was noticed in the males 11.10 (SP-2-2) to 71.04 per cent (Arka Vikas). The range of variation among the hybrids was from 0.00 (24 crosses) to 15.54 per cent (6 crosses). The check recorded 4.44 per cent wilt incidence.

Mid parent heterosis exhibited by the F1's for wilt incidence varied from –97.25 (Martha x Arka Vikas) to -2.80 per cent (L-15 x W.94 FM 59/7). There were a total of 41 crosses with significant negative heterosis over mid parent. Whereas, over better parent 14 crosses showed negative heterosis

Table 21. ***Per se*** **performance and magnitude of heterosis for lycopene**

Sl No.	F_1 Hybrid	Line (mg/ 100 g)	Tester (mg/ 100 g)	F1 *per se* (mg/ 100 g)	Mid parent value (mg/ 100 g)	Heterosis per cent over			
						MP	BRP	BSP	CC
1	L-15 x L-101	2.03	2.81	2.34	2.42	-3.31	-16.73**	-57.98**	-30.97**
2	L-15 x SP-2-2	2.03	2.85	4.33	2.44	77.58**	51.93**	-22.36**	27.73**
3	L-15 x 88/Firm/J	2.03	3.98	5.45	3.01	81.15**	36.93**	-2.33	60.76**
4	L-15 x W.94 30 ①	2.03	2.71	3.71	2.37	56.54**	36.90**	-33.53**	9.44**
5	L-15 x W.94 FM 59/7	2.03	3.61	5.98	2.82	112.06**	65.65**	7.17**	76.40**
6	L-15 x L-50	2.03	4.15	2.66	3.09	-13.91**	-35.90**	-52.30**	-21.53**
7	L-15 x 88/DT-14	2.03	5.57	3.92	3.80	3.16*	-29.62**	-29.77**	15.63**
8	L-15 x DWD-1	2.03	2.35	4.01	2.19	83.10**	70.64**	-28.03**	18.28**
9	L-15 x A.Vikas	2.03	2.78	3.64	2.41	51.04**	30.94**	-34.79**	7.37**
10	L-15 x A.Saurabh	2.03	3.05	1.53	2.54	-39.76**	-49.83**	-72.50**	-55.75**
11	Martha x L-101	2.20	2.81	5.87	2.51	133.86**	108.89**	5.32**	73.15**
12	Martha x SP-2-2	2.20	2.85	6.53	2.53	158.10**	129.12**	17.15**	92.63**
13	Martha x 88/Firm/J	2.20	3.98	3.75	3.09	21.36**	-5.74**	-32.76**	29.49**
14	Martha x W.94 30 ①	2.20	2.71	4.92	2.45	100.82**	81.55**	-11.78**	45.13**
15	MarthaxW.94 FM 59/7	2.20	3.61	5.07	2.91	74.22**	40.44**	-9.09**	49.56**
16	Martha x L-50	2.20	4.15	3.63	3.17	14.51**	-12.53**	-34.85**	7.08**
17	Martha x 88/DT-14	2.20	5.57	4.03	3.88	3.86*	-27.67**	-27.67**	18.88**
18	Martha x DWD-1	2.20	2.35	5.83	2.27	156.82**	148.23**	4.60**	71.97**
19	Martha x A.Vikas	2.20	2.78	4.19	2.49	68.27**	50.72**	-24.87**	23.59**
20	Martha x A.Saurabh	2.20	3.05	5.25	2.63	99.62**	72.13**	-5.80**	54.87**
21	Sonali x L-101	3.58	2.81	4.48	3.19	40.43**	25.14**	-19.67**	32.15**
22	Sonali x SP-2-2	3.58	2.85	4.85	3.22	50.62**	35.49**	-12.97**	43.06**
23	Sonali x 88/Firm/J	3.58	3.98	5.00	3.78	32.27**	25.63**	-10.34**	47.49**
24	Sonali x W.94 30 ①	3.58	2.71	1.99	3.15	-36.82**	-44.41**	-64.26**	-41.29**
25	Sonali x W.94 FM 59/7	3.58	3.61	2.89	3.59	-19.49**	-19.94**	-48.24**	-14.75**
26	Sonali x L-50	3.58	4.15	4.20	3.86	8.81**	1.20	-24.63**	23.89**
27	Sonali x 88/DT-14	3.58	5.57	6.37	4.57	39.38**	14.36**	14.17**	87.91**
28	Sonali x DWD-1	3.58	2.35	2.07	2.96	-30.06**	-42.17**	-62.88**	-38.94**
29	Sonali x A.Vikas	3.58	2.78	3.45	3.18	8.49**	-3.63	-38.08**	1.76
30	Sonali x A.Saurabh	3.58	3.05	5.73	3.32	72.59**	60.05**	2.81*	69.03**
31	A.Alok x L-101	4.43	2.81	7.20	3.62	98.89**	62.53**	29.11**	112.38**
32	A.Alok x SP-2-2	4.43	2.85	3.35	3.64	-7.96**	-24.38**	-39.99**	-1.17
33	A.Alok x 88/Firm/J	4.43	3.98	4.00	4.21	-4.98**	-9.71**	-28.27**	17.99**
34	A.Alok x W.94 30 ①	4.43	2.71	8.21	3.57	129.99**	85.32**	47.16**	142.18**
35	A.Alok x W.94 FM 59/7	4.43	3.61	4.99	4.02	24.13**	12.64**	-10.46**	47.19**
36	A.Alok x L-50	4.43	4.15	4.95	4.29	15.38**	11.74**	-11.24**	46.02**
37	A.Alok x 88/DT-14	4.43	5.57	2.50	5.00	-50.00**	-55.11**	-55.11**	-26.25**
38	A.Alok x DWD-1	4.43	2.35	2.76	3.39	-18.58**	-37.70**	-50.51**	-18.58**
39	A.Alok x A.Vikas	4.43	2.78	3.43	3.61	-4.98**	-22.57**	-38.49**	1.17
40	A.Alok x A.Saurabh	4.43	3.05	4.60	3.74	22.99**	3.84*	-17.51**	35.69**
41	Shakti x L-101	2.84	2.81	4.80	2.83	69.61**	69.01**	-13.93**	41.59**
42	Shakti x SP-2-2	2.84	2.85	3.73	2.85	30.87**	30.88**	-33.11**	10.03**
43	Shakti x 88/Firm/J	2.84	3.98	1.23	3.41	-63.93**	-69.09**	-78.00**	-63.72**
44	Shakti x W.94 30 ①	2.84	2.71	6.80	2.77	145.48**	139.43**	21.94**	100.58**
45	Shakti x W.94 FM 59/7	2.84	3.61	2.65	3.23	-17.95**	-26.59**	-52.42**	-21.83**
46	Shakti x L-50	2.84	4.15	4.14	3.49	18.62**	-0.24	-25.82**	22.12**
47	Shakti x 88/DT-14	2.84	5.57	5.95	4.21	41.33**	6.82**	6.63**	75.52**
48	Shakti x DWD-1	2.84	2.35	2.90	2.59	11.97**	2.11	-48.00**	-14.45**
49	Shakti x A.Vikas	2.84	2.78	2.52	2.81	-10.32**	-11.26**	-54.81**	-29.49**
50	Shakti x A.Saurabh	2.84	3.05	2.37	2.95	-19.66**	-22.29**	-57.50**	-30.08**
	Commercial check								
1.	US-1031	3.39							
	S.Em±	0.05							
	CD at 5%					0.12	0.14	0.14	0.14
	CD at 1%					0.15	0.18	0.18	0.18

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value

Table 22. ***Per se*** **performance and magnitude of heterosis for per cent bacterial wilt incidence**

Sl. No.	F1 Hybrid	Line (%)	Tester (%)	F1 *per se* (%)	Mid parent value (%)	Heterosis per cent over***			
						MP	BRP	BSP	CC
1	L-15 x L-101	11.10	35.52	4.44	23.31	-63.45**	-46.97**	1174.17**	0.00
2	L-15 x SP-2-2	11.10	11.10	6.66	11.10	-22.54	-22.54	1761.25**	46.12
3	L-15 x 88/Firm/J	11.10	28.86	8.88	19.98	-33.98**	-11.27	2032.08**	67.42*
4	L-15 x W.94 30 ①	11.10	35.52	11.10	23.31	-31.07**	0.00	2302.92**	88.62**
5	L-15 x W.94 FM 59/7	11.10	17.76	13.32	14.43	-2.80	11.27	2573.75**	109.91**
6	L-15 x L-50	11.10	17.76	8.88	14.43	-22.49	-11.27	2032.08**	67.42*
7	L-15 x 88/DT-14	11.10	15.54	8.88	13.32	-19.38	-11.27	2032.08**	67.42*
8	L-15 x DWD-1	11.10	17.76	11.10	14.43	-12.29	0.00	2302.92**	88.62**
9	L-15 x A.Vikas	11.10	71.04	13.32	41.07	-45.42**	8.84	2515.42**	105.30**
10	L-15 x A.Saurabh	11.10	64.38	15.54	37.74	-37.67**	17.69	2727.92**	121.98**
11	Martha x L-101	17.76	35.52	11.10	26.64	-37.32**	-22.46	2302.92**	88.62**
12	Martha x SP-2-2	17.76	11.10	13.32	14.43	-4.92	8.84	2515.42**	105.30**
13	Martha x 88/Firm/J	17.76	28.86	13.32	23.31	-26.89*	-15.60	2515.42**	105.30**
14	Martha x W.94 30 ①	17.76	35.52	15.54	26.64	-24.71*	-6.86	2786.25**	126.59**
15	MarthaxW.94 FM 59/7	17.76	17.76	2.22	17.76	-77.83**	-77.83**	587.08	-46.12
16	Martha x L-50	17.76	17.76	15.54	17.76	-6.86	-6.86	2786.25**	126.59**
17	Martha x 88/DT-14	17.76	15.54	13.32	16.65	-12.60	-9.38	2515.42**	105.29**
18	Martha x DWD-1	17.76	17.76	15.54	17.76	-6.52	-6.86	2786.25**	126.59**
19	Martha x A.Vikas	17.76	71.04	15.54	44.40	-43.85**	-6.86	2786.25**	126.59**
20	Martha x A.Saurabh	17.76	64.38	15.54	41.07	-42.11**	-8.74	2727.92**	121.98**
21	Sonali x L-101	<u>0.00</u>	35.52	4.44	17.76	-45.42**	1174.17**	1174.17**	0.00
22	Sonali x SP-2-2	0.00	11.10	0.00	5.55	-92.01**	0.00	0.00	-92.15**
23	Sonali x 88/Firm/J	0.00	28.86	0.00	14.43	-95.19**	0.00	0.00	-92.15**
24	Sonali x W.94 30 ①	0.00	35.52	0.00	17.76	-95.72**	0.00	0.00	-92.15**
25	Sonali x W.94 FM 59/7	0.00	17.76	0.00	8.88	-93.75**	0.00	0.00	-92.15**
26	Sonali x L-50	0.00	17.76	2.22	8.88	-57.04*	587.08	587.08	-46.03
27	Sonali x 88/DT-14	0.00	15.54	0.00	7.77	-93.30**	0.00	0.00	-92.15**
28	Sonali x DWD-1	0.00	17.76	0.00	8.88	-93.70**	0.00	0.00	-92.15**
29	Sonali x A.Vikas	0.00	71.04	0.00	35.52	-65.00**	1174.17**	1174.17**	-92.15**
30	Sonali x A.Saurabh	0.00	64.38	0.00	32.19	-63.37**	1174.17**	1174.17**	-92.15**
31	A.Alok x L-101	0.00	35.52	0.00	17.76	-95.72**	0.00	0.00	-92.15**
32	A.Alok x SP-2-2	0.00	11.10	0.00	5.55	-92.01**	0.00	0.00	-92.15**
33	A.Alok x 88/Firm/J	0.00	28.86	2.22	14.43	-66.93**	587.08	587.08	-46.03
34	A.Alok x W.94 30 ①	0.00	35.52	0.00	17.76	-95.72**	0.00	0.00	-92.15**
35	A.Alok x W.94 FM 59/7	0.00	17.76	0.00	8.88	-93.75**	0.00	0.00	-92.15**
36	A.Alok x L-50	0.00	17.76	0.00	8.88	-93.75**	0.00	0.00	-92.15**
37	A.Alok x 88/DT-14	0.00	15.54	0.00	7.77	-93.30**	0.00	0.00	-92.15**
38	A.Alok x DWD-1	0.00	17.76	0.00	8.88	-93.70**	0.00	0.00	-92.15**
39	A.Alok x A.Vikas	0.00	71.04	2.22	35.52	-81.13**	587.08	587.08	-46.03
40	A.Alok x A.Saurabh	0.00	64.38	2.22	32.19	-79.71**	587.08	587.08	-46.03
41	Shakti x L-101	0.00	35.52	0.00	17.76	-95.72**	0.00	0.00	92.15**
42	Shakti x SP-2-2	0.00	11.10	0.00	5.55	-92.01**	0.00	0.00	-92.15**
43	Shakti x 88/Firm/J	0.00	28.86	2.22	14.43	-66.93**	587.00	587.08	46.03
44	Shakti x W.94 30 ①	0.00	35.52	0.00	17.76	-95.72**	0.00	0.00	-92.15**
45	Shakti x W.94 FM 59/7	0.00	17.76	0.00	8.88	-93.75**	0.00	0.00	-92.15**
46	Shakti x L-50	0.00	17.76	0.00	8.88	-93.75**	0.00	0.00	-92.15**
47	Shakti x 88/DT-14	0.00	15.54	0.00	7.77	-93.30**	0.00	0.00	-92.15**
48	Shakti x DWD-1	0.00	17.76	0.00	8.88	-93.70**	0.00	0.00	-92.15**
49	Shakti x A.Vikas	0.00	71.04	0.00	35.52	-97.25**	0.00	0.00	-92.15**
50	Shakti x A.Saurabh	0.00	64.38	0.00	32.19	-97.05**	0.00	0.00	-92.15**
	Commercial check								
1.	US-1031	4.44							
	S.Em±	2.47							
	CD at 5%					5.90	6.85	6.85	6.85
	CD at 1%					7.76	8.99	8.99	8.99

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
Underlined figure indicate best parent value
***Transformed values taken for estimation

while, one cross Martha x W.94 FM 59/7 had significant negative heterosis to the tune of −77.83 per cent. Among the 50 cross combinations none of the crosses had desirable negative heterosis over best parent. While, over the commercial check as many as 24 crosses displayed significant negative heterosis.

4.3. COMBINING ABILITY STUDIES

4.3.1 Analysis of Variance

The analysis of variance for combining ability with respect to 19 traits is presented in Table 23. Differences among lines were significant for 13 traits out of 19. While, variation among testers was significant only for eight traits. For all the characters line x tester variance was significant.

Contribution of line was more for average fruit weight, number of locules per fruit, pericarp thickness and per cent wilt incidence. While, maximum contribution recorded by testes for number of fruits per plant and fruit shape index. The contribution of Line x tester was of higher magnitude than either line or tester for rest of the characters.

The estimates of SCA variance were greater in magnitude than those of GCA variance for all the characters studied except number of primary branches per plant, number of clusters per plant, average fruit weight, number of locules per fruit, pericarp thickness, pH of fruit juice and ascorbic acid. Further, it was evident that variance due to dominance (σ^2D) was higher than variance due to additivity (σ^2D) in all the cases except number of primary branches per plant, number of clusters per plant, number of fruits per plant, average fruit weight, number of locules per fruit, pericarp thickness, pH of fruit juice and ascorbic acid.

Table 23. Analysis of variance for combining ability

Sl. No.	Source	Mean sum of squares						Contribution of line	Contribution of tester	Contribution of line x tester	Random effect [z]			
		Replication	Crosses	Lines	Testers	Line x Testers	Error				σ^2_{GCA}	σ^2_{SCA}	σ^2_A	σ^2_D
	Degrees of freedom	2	49	4	9	36	128							
1.	Plant height	31.585	193.563**	79.013	306.552	178.044**	7.437	3.33	29.09	67.58	-3.30	76.65	-6.60	76.65
2.	Plant spread	12.170	189.715**	97.827	256.555	183.215**	7.664	4.21	24.84	70.95	-2.81	71.42	-5.62	71.42
3.	Number of primary branches/plant	0.401	3.960**	17.963**	5.347*	2.057**	0.092	37.03	24.80	38.17	0.53	0.14	1.06	1.2
4.	Days to 50% flowering	6.107	19.883**	49.760**	13.437	18.175**	2.477	20.43	12.41	67.16	1.05	2.95	2.10	2.95
5.	Number of flowers per cluster	0.001	0.686**	0.799	0.812	0.642**	0.011	9.51	21.72	68.77	0.005	0.22	0.01	0.22
6.	Number of clusters per plant	16.555	119.656**	550.521**	105.384	75.350*	4.802	37.56	16.18	46.26	15.84	0.46	31.68	0.46
7.	Number of fruits per cluster	0.116	0.719**	1.509*	0.976	0.566**	0.043	17.14	24.94	57.92	0.03	0.17	0.06	0.17
8.	Number of fruits per plant	49.262	735.860**	2437.801**	1492.503**	357.595**	14.334	27.04	37.25	35.70	69.34	124.96	138.68	124.95
9.	Average fruit weight	0.289	394.660**	2434.428**	548.331**	129.601**	7.105	50.35	25.52	24.13	76.83	-40.70	153.66	-40.70
10.	Yield per plant	0.034	0.466**	0.416	1.067**	0.321**	0.017	7.30	42.09	50.59	0.003	0.184	0.006	0.184
11.	Fruit shape index	0.001	0.018**	0.046**	0.048**	0.008**	0.002	20.08	47.72	32.19	0.001	0.005	0.002	0.005
12.	Number of locules per fruit	0.058	2.424**	13.115**	3.873**	0.874**	0.080	44.17	29.35	26.48	0.42	-0.08	0.84	-0.08
13.	Pericarp thickness	0.003	0.035**	0.207**	0.028	0.017**	0.001	47.87	14.85	37.28	0.006	-0.004	0.012	-0.004
14.	Total soluble solids	0.278	1.676**	2.819	1.510	1.590**	0.067	13.73	16.55	69.72	0.041	0.428	0.082	0.428
15.	pH of fruit juice	0.035	0.025**	0.050*	0.046*	0.017*	0.010	16.26	34.10	49.64	0.003	0.001	0.006	0.001
16.	Titratable acidity	0.002	0.023**	0.072**	0.027	0.016**	0.001	25.58	22.00	52.42	0.002	0.003	0.004	0.003
17.	Ascorbic acid	9.362	343.42**	1443.455**	424.756*	200.864**	3.287	34.31	22.72	42.97	41.42	-0.25	82.84	-0.25
18.	Lycopene	0.007	6.995	8.313	4.959	7.357**	0.008	9.70	13.02	77.28	0.032	2.13	0.064	2.13
19.	Per cent wilt incidence	5.875	244.155**	2525.518**	58.072	37.190**	17.516	84.44	4.37	11.19	0.696	281.88	1.392	281.88

* and ** indicate significant at 5 and 1 per cent level of probability, respectively
z : σ^2_{GCA} = GCA variance; σ^2_{SCA} = SCA variance; σ^2_A = Additive variance; σ^2_D = Dominance variance

4.3.2 Combining ability effects

Estimates of general combining ability (gca) and specific combining ability (sca) effects for all the characters are presented in Table 24 and 25 respectively.

4.3.2.1 Plant height

The lines (females) which possessed significant positive gca effects were Martha (1.77) and Sonali (1.75). The testers also showed significant positive gca effects of which Arka Vikas recorded highest (7.12) gca effect. The highest (-7.99) significant negative gca effect exhibited by the tester W.94 FM 59/7.

A total of 26 crosses (52%) showed positive sca effects. The highest (15.82) significant positive sca effect exhibited by the cross Sonali x DWD-1. Whereas Sonali x 88/Firm/J recorded highest significant negative sca effect.

4.3.2.2 Plant spread

Four out of five lines had significant gca effect with two (L-15 and Arka Alok) in desired direction and the other two (Martha and Shakti) in non-desired direction. Among the testers highest significant positive gca effect was observed in Arka Vikas (6.31), while, W.94 FM 59/7 recorded the highest significant negative gca effect.

Out of 50 crosses, significant sca effects were observed for 25 crosses. Thirteen hybrids showed significant negative sca effects and the highest being noticed in Sonali x 88/Firm/J (-17.48).

Table 24: Estimates of general combining ability effects of parents for different traits in line x tester study of tomato

Sl. No.	Parents	Plant height	Plant spread	No. of primary branches plant^{-1}	Days to 50% flowering	No. of flowers cluster-^{1}	No. of clusters plant^{-1}	No. of fruits cluster^{-1}	No. of fruits plant^{-1}	Average fruit weight	Yield plant^{-1}
	Lines										
1	L-15	-0.81	-1.85**	-0.65**	1.85**	0.28**	-2.71**	0.39**	2.88**	-2.15**	0.001
2	Martha	1.77*	1.92**	-0.94**	0.65	-0.10**	2.97**	-0.02	5.83**	-3.29**	0.12**
3	Sonali	1.75*	0.02	0.13	-0.68	-0.03	0.31	-0.12*	-2.36*	-0.42	-0.06
4	Arka Alok	-1.18	-1.77*	0.74**	-1.48**	-0.15**	-5.63**	-0.08	-14.51**	15.01**	0.11**
5	Shakti	-1.52*	1.68*	0.72**	-0.35	-0.01	5.05**	-0.17**	8.16**	-9.15**	-016**
	Testers										
1	L –101	5.79**	5.74**	0.46**	-0.51	0.08*	-0.74	0.23**	3.52*	0.60	0.13**
2	SP-2-2	1.85	0.56	0.30**	-0.58	-0.57**	3.77**	-0.18*	5.44**	0.70	0.28**
3	88/Firm/J	-1.26	-1.93	-0.76**	2.02**	0.03	-1.40	-0.41**	-12.58**	2.97**	-0.25**
4	W.94 30 ①	-2.23*	-2.20*	-1.25**	-0.45	0.19**	2.57**	0.08	5.89**	-3.70**	0.04
5	W.94 FM 59/7	-7.99**	-6.61**	-0.17	-0.91	0.10**	-1.08	0.17*	0.22	-3.22**	-0.08
6	L –50	-1.58	-0.55	0.39**	0.75	0.01	-2.85**	0.04	-6.06**	12.64**	0.32**
7	88/DT-14	-4.38**	-4.72**	0.12	-1.05	0.08*	-1.67*	-0.31**	-8.31**	6.12**	-0.11*
8	DWD-1	0.68	1.42	0.03	0.82	-0.22**	-1.77*	-0.14	-8.16**	-2.78**	-0.31**
8	Arka Vikas	7.12**	6.31**	0.74**	-0.11	0.23**	4.73**	0.40**	22.00**	-5.80**	0.35**
10	Arka Saurabh	1.98*	1.99*	0.15	0.02	0.09**	-1.56	0.08	-1.97	-7.54**	-0.37**
	Lines										
	S.Em±	0.497	0.505	0.055	0.287	0.019	0.400	0.038	0.691	0.486	0.024
	CD at 5%	1.376	1.398	0.152	0.795	0.052	1.108	0.105	1.914	1.346	0.066
	CD at 1%	1.810	1.839	0.200	1.045	0.069	1.456	0.138	2.516	1.770	0.087
	Testers										
	S.Em±	0.704	0.714	0.078	0.406	0.026	0.565	0.054	0.977	0.688	0.034
	CD at 5%	1.950	1.977	0.216	1.125	0.072	1.570	0.149	2.706	1.905	0.094
	CD at 1%	2.563	2.600	0.284	1.478	0.094	2.060	0.196	3.556	2.506	0.123

Table Cond....

Sl. No.	Parents	Fruit shape index	No. of locules fruit^{-1}	Pericarp thickness	Total soluble solids	pH of fruit juice	Titratable acidity	Ascorbic acid	Lycopene	Per cent wilt incidence
	Lines									
1	L-15	-0.01	-0.47**	0.11**	-0.37**	-0.05*	0.02**	8.20**	-0.46**	8.08**
2	Martha	0.04**	-0.58**	-0.05**	0.24**	0.01	0.01	4.41**	0.69**	11.09**
3	Sonali	-0.01	-0.20**	0.02**	-0.30**	0.06*	-0.08**	0.82	-0.11**	-5.07**
4	Arka Alok	0.04**	1.05**	0.03**	0.26**	0.01	0.06**	-9.45**	0.38**	-6.95**
5	Shakti	-0.06**	0.20**	-0.11**	0.16*	-0.03	-0.003	-3.97**	-0.51**	-7.89**
	Testers									
1	L –101	0.02	-0.20*	0.004	-0.08	0.04	0.08**	8.69**	0.72**	-0.91
2	SP-2-2	0.02	-0.07	0.07**	-0.25**	0.01	0.01	-1.16	0.34**	-1.51
3	88/Firm/J	0.02	-0.48**	0.02**	-0.45**	0.04	-0.02*	5.87**	-0.33**	0.80
4	W.94 30 ①	0.13**	-1.04**	0.05**	-0.06	-0.04	-0.01	-7.77**	0.91**	-0.21
5	W.94 FM 59/7	-0.06**	0.83**	-0.09**	0.36**	-0.06	-0.02*	1.90**	0.10**	-3.30*
6	L –50	-0.05**	0.34**	-0.03**	-0.17	-0.10**	-0.01	-5.35**	-0.30**	0.29
7	88/DT-14	-0.02	-0.01	-0.001	0.05	0.03	0.02*	0.11	0.34**	-1.08
8	DWD-1	0.01	0.23*	0.01	0.42**	-0.02	0.06**	-0.67	-0.70**	-0.21
8	Arka Vikas	-0.08**	0.31**	-0.02**	-0.30**	0.02	-0.05**	4.14**	-0.77**	2.95
10	Arka Saurabh	0.01	0.08	-0.01**	0.46**	0.08*	-0.06**	-5.76**	-0.32**	3.19*
	Lines									
	S.Em±	0.009	0.052	0.004	0.047	0.018	0.005	0.331	0.017	0.76
	CD at 5%	0.024	0.144	0.011	0.130	0.049	0.014	0.916	0.048	2.11
	CD at 1%	0.032	0.189	0.014	0.171	0.065	0.018	1.205	0.063	2.77
	Testers									
	S.Em±	0.012	0.073	0.006	0.067	0.026	0.007	0.468	0.024	1.09
	CD at 5%	0.033	0.202	0.016	0.185	0.072	0.019	1.296	0.068	3.02
	CD at 1%	0.043	0.266	0.021	0.244	0.094	0.025	1.704	0.089	3.97

* and ** indicate significant at 5 and 1 per cent level of probability, respectively

Table 25: Estimates of specific combining ability effects 19 characters in tomato (L x T) hybrids

Sl. No.	Hybrids	Plant height	Plant spread	No. of primary branches per plant	Days to 50% flowering	No. of flowers per cluster	No. of clusters per plant	No. of fruits per cluster	No. of fruits per plant	Average fruit weight	Yield per plant
1	2	3	4	5	6	7	8	9	10	11	12
1	L-15 x L-101	2.20	4.74*	-0.43	2.01	-0.04	5.55**	0.08	15.46**	-3.41	0.11
2	L-15 x SP-2-2	-0.76	2.04	-1.40**	0.08	-0.16	-1.58	-0.37*	-4.89	0.64	-0.10
3	L-15 x 88/Firm/J	0.23	2.97	0.69**	-0.52	0.08	-3.75*	0.29	-4.43	8.84**	0.24*
4	L-15 x W.94.30 ①	4.31	3.62	-0.85**	1.95	0.45**	-0.99	0.07	1.16	-1.97	-0.06
5	L-15 x W.94.FM 59/7	-5.36*	-4.59*	0.47	-0.59	-0.09	0.63	-0.05	-0.46	-0.90	-0.05
6	L-15 x L-50	-6.14**	-8.43**	-0.46	-0.25	0.32**	-3.30	-0.31	-16.75**	1.13	-0.54**
7	L-15 x 88/DT-14	8.31**	5.92**	0.95**	0.55	-0.07	3.82*	-0.23	3.36	-7.42**	-0.02
8	L-15 x DWD-1	-9.04**	-8.33**	-0.10	1.68	-0.47**	-3.38	0.16	-7.72*	-0.49	-0.03
9	L-15 x A.Vikas	1.33	-3.47	-0.14	-1.39	-0.22**	1.86	0.02	6.88*	0.74	0.26*
10	L-15 x A.Saurabh	4.94*	5.54*	1.28**	-3.52**	0.22**	1.34	0.34*	7.39*	2.84	0.34**
11	Martha x L-101	-10.26**	-9.15**	1.03**	-0.79	0.26**	0.94	-0.48**	-6.12*	0.30	-0.15
12	Martha x SP-2-2	-7.07**	-8.03**	1.16**	3.28*	-0.09	-7.59**	0.47**	-6.87*	-4.29*	-0.52**
13	Martha x 88/Firm/J	14.52**	17.28**	-1.34**	1.35	-0.02	5.07**	0.17	16.66**	-0.39	0.53**
14	Martha x W.94.30 ①	-6.70**	-7.36**	-0.46	3.15*	-0.51**	2.60	-0.95**	-16.72**	0.90	-0.50**
15	MarthaxW.94.FM 59/7	1.99	2.20	-0.60*	-1.72	0.24**	8.22**	-0.54**	7.66*	1.55	0.23*
16	Martha x L-50	6.27**	5.73*	0.80**	-3.72**	0.06	4.09*	-0.14	9.27**	-8.75**	0.01
17	Martha x 88/DT-14	-4.44*	-7.47**	-0.89**	-0.25	0.29**	-2.49	1.14**	17.12**	-5.46*	0.44**
18	Martha x DWD-1	4.02	3.33	0.59*	-3.12*	0.26**	-3.82*	0.23	-1.67	2.58	0.001
19	Martha x A.Vikas	-1.27	-0.22	0.19	-1.19	0.15	-.9.88**	0.40*	-19.43**	8.70**	-0.22*
20	Martha x A.Saurabh	2.93	3.68	-0.49*	3.01*	-0.64**	2.86	-0.31	0.11	4.84*	0.17
21	Sonali x L-101	-4.82*	-6.27**	-0.91**	-3.45**	-0.10	-3.43	0.29	-2.63	-4.01	-0.19
22	Sonali x SP-2-2	7.65**	9.21**	-0.71**	-3.39**	-0.12	16.30**	-0.26	24.59**	-9.78**	0.36**
23	Sonali x 88/Firm/J	-15.12**	-17.48**	0.02	0.01	0.58**	-3.89*	-0.13	-8.22**	1.64	-0.26*
24	Sonali x W.94.30 ①	4.23	2.60	-0.49*	-0.52	-0.61**	-3.07	0.38*	3.17	-5.65**	-0.19
25	Sonali x W.94.FM 59/7	-4.45*	-3.75	0.29	2.95*	-0.52**	-3.08	0.53**	3.88	0.64	0.16
26	Sonali x L-50	-2.62	-0.55	-0.27	-2.72*	-0.50**	-1.68	-0.20	-6.57*	12.44**	0.22*

Contd…

1	2	3	4	5	6	7	8	9	10	11	12
27	Sonali x 88/DT-14	-10.76**	-6.74**	1.14**	-0.25	-0.14	-0.53	-0.26	-6.79*	0.71	-0.09
28	Sonali x DWD-1	15.82**	12.92**	0.16	1.21	0.19*	1.70	-0.33*	0.12	4.50*	0.18
29	Sonali x A.Vikas	2.41	2.86	0.09	2.15	1.38**	0.61	-0.30	-5.57	-2.80	-0.27*
30	Sonali x A.Saurabh	7.47**	7.20**	0.67**	4.01**	-0.14	-2.94	0.29	-1.87	2.29	0.09
31	A.Alok x L-101	1.73	-2.38	0.18	0.01	0.04	-0.99	0.24	-0.57	7.38**	0.38**
32	A.Alok x SP-2-2	-0.37	0.37	-0.42	-0.25	-0.04	0.17	-0.005	0.57	9.48**	0.49**
33	A.Alok x 88/Firm/J	-1.35	-0.54	0.97**	-0.19	-0.57**	-0.73	0.15	3.80	-5.67**	-0.21*
34	A.Alok x W.94.30 ①	-2.43	3.04	0.89**	-2.72*	0.57**	-3.00	0.57**	2.16	3.93	0.43**
35	A.Alok x W.94.FM 59/7	10.82**	8.67**	0.04	0.75	-0.07	-0.45	-0.05	-2.30	-4.55*	-0.23*
36	A.Alok x L-50	-3.27	-1.06	-0.55*	3.08*	-0.22**	0.72	0.35*	6.11*	-2.71	-0.81**
37	A.Alok x 88/DT-14	3.45*	4.51*	-0.28	-0.12	-0.02	1.37	-0.64**	-6.81*	17.39**	-0.11
38	A.Alok x DWD-1	-6.19**	-6.84**	-0.19	3.01*	0.01	1.20	0.25	8.51**	-7.78**	-0.01
39	A.Alok x A.Vikas	4.71*	4.49*	0.30	-1.39	-0.43**	3.21	-0.41*	-2.05	-8.12**	-0.09
40	A.Alok x A.Saurabh	-6.99**	-10.24**	-0.94**	-2.19	0.74**	-1.51	-0.46**	-9.40**	-9.35**	-0.57**
41	Shakti x L-101	11.15**	13.07**	0.13	2.21	-0.16	-2.07	-0.13	-6.14*	-0.26	-0.16
42	Shakti x SP-2-2	0.56	-3.59	1.37**	0.28	0.42*	-7.30**	0.16	-13.40**	3.94	-0.23*
43	Shakti x 88/Firm/J	1.72	-2.22	-0.34	-0.65	-0.07	3.29	-0.48**	-7.80*	-4.42*	-0.30**
44	Shakti x W.94.30 ①	0.40	-1.90	0.91**	-1.85	0.10	4.45*	-0.07	10.22**	2.79	0.32**
45	Shakti x W.94.FM 59/7	-3.01	-2.53	-0.20	-1.39	0.45**	-5.32**	0.11	-8.77**	3.25	-0.11
46	Shakti x L-50	5.76**	4.32	0.47	3.61**	0.34**	0.17	0.31	7.94*	-2.11	0.39**
47	Shakti x 88/DT-14	3.55	3.78	-0.92**	0.08	-0.06	-2.17	-0.009	-6.88*	-5.22*	-0.22*
48	Shakti x DWD-1	-4.61*	-1.07	-0.47	-2.79*	0.008	4.29*	-0.315	0.87	1.18	0.06
49	Shakti x A.Vikas	-7.18**	-3.66	-0.44	1.81	-0.87**	4.20*	0.28	20.18**	1.47	0.31**
50	Shakti x A.Saurabh	-8.35**	-6.18**	-0.52*	-1.32	-0.16	0.45	0.14	3.78	-0.62	-0.06
	S.Em±	1.574	1.598	0.175	0.908	0.060	1.265	0.120	2.186	1.539	0.076
	CD at 5%	4.359	4.426	0.484	2.515	0.166	3.504	0.332	6.055	4.263	0.210
	CD at 1%	5.732	5.819	0.637	3.306	0.218	4.607	0.437	7.961	5.605	0.276

* and ** indicate significant at 5 and 1 per cent level of probability, respectively

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		Fruit shape index	No. of locules per fruit	Pericarp thickness	Total soluble solids	ρH of fruit juice	Titratable acidity	Ascorbic acid	Lycopene	Wilt incidence (%)
1	2	3	4	5	6	7	8	9	10	11
1	L-15 x L-101	0.005	0.04	0.005	-1.27**	0.07	0.05*	-2.29	-2.14**	-6.86*
2	L-15 x SP-2-2	0.05	-0.09	-0.02	-0.09	-0.06	-0.04*	6.03**	0.23**	-1.56
3	L-15 x 88/Firm/J	-0.02	0.70**	-0.12**	0.70**	0.01	0.06**	-1.52	2.02**	-1.71
4	L-15 x W.94.30 ①	-0.004	-0.12	0.09**	-0.14	0.05	-0.04*	8.56**	-0.96**	1.47
5	L-15 x W.94.FM 59/7	-0.01	-0.26	0.005	1.49**	0.06	0.02	-13.19**	2.12**	6.72*
6	L-15 x L-50	-0.04	0.12	-0.03	-0.57**	0.03	-0.05*	-13.69**	-0.79**	-1.20
7	L-15 x 88/DT-14	-0.03	0.32	0.01	-0.36	-0.001	0.02	1.53	-0.18*	0.17
8	L-15 x DWD-1	-0.02	-0.47*	0.16**	-0.39	-0.01	0.04*	7.07**	0.96**	1.47
9	L-15 x A.Vikas	0.07	-0.32	-0.01	0.90**	-0.09	0.01	2.10	0.65**	0.01
10	L-15 x A.Saurabh	0.004	0.08	-0.08**	-0.27	-0.06	-0.07**	5.40**	-1.91**	1.47
11	Martha x L-101	0.04	-0.28	0.02	-0.28	-0.05	0.12**	2.37	0.24**	-0.11
12	Martha x SP-2-2	-0.01	0.08	-0.01	-0.34	-0.09	0.07**	9.91**	1.28**	2.20
13	Martha x 88/Firm/J	0.01	0.99**	0.08**	-0.24	-0.03	-0.12**	3.01*	-0.83**	-0.12
14	Martha x W.94.30 ①	0.06	-0.01	0.06**	0.38	0.04	0.06**	-3.09*	-0.90**	3.06
15	MarthaxW.94.FM 59/7	0.01	-0.43	0.03	0.47*	0.07	-0.03	8.77**	0.06	-11.45**
16	Martha x L-50	0.001	0.23	0.07**	0.08	0.02	-0.05*	10.38**	-0.98**	2.55
17	Martha x 88/DT-14	-0.02	-0.51*	-0.16**	-0.73**	-0.04	-0.12**	-17.52**	-1.21**	1.76
18	Martha x DWD-1	0.01	0.13	-0.07**	1.08**	0.08	-0.10**	-9.30**	1.63**	3.06
19	Martha x A.Vikas	-0.04	0.18	0.01	-0.62**	0.01	0.07**	-6.77**	0.05	-0.10
20	Martha x A.Saurabh	-0.06	-0.37	-0.02	0.19	-0.02	0.11**	2.24	0.66**	-0.82
21	Sonali x L-101	-0.03	0.26	-0.03	0.17	-0.09	-0.01	-6.60**	-0.35**	7.02*
22	Sonali x SP-2-2	0.04	0.37	0.03	0.49*	0.06	0.08**	-17.28**	0.41**	-1.78
23	Sonali x 88/Firm/J	-0.02	-0.47*	0.001	0.15	-0.05	0.001	0.63	1.23**	-4.09
24	Sonali x W.94.30 ①	-0.14**	0.59*	-0.01	-0.15	-0.02	-0.03	-2.01	-3.02**	-3.08
25	Sonali x W.94.FM 59/7	0.05	-1.01**	0.07**	-0.66**	0.02	0.01	-5.71**	-1.32**	0.01
26	Sonali x L-50	0.09*	-0.54*	0.03	0.28	0.04	0.01	2.49	0.40**	1.12
27	Sonali x 88/DT-14	0.04	0.57*	0.02	0.48*	-0.01	-0.04*	5.83**	1.93**	-2.21

Contd…

1	2	3	4	5	6	7	8	9	10	11
28	Sonali x DWD-1	0.02	0.15	-0.03	0.36	-0.03	0.04*	12.58**	-1.33**	-3.08
29	Sonali x A.Vikas	-0.01	0.25	-0.06**	-0.59**	0.07	-0.05*	9.22**	0.12	3.16
30	Sonali x A.Saurabh	-0.03	-0.19	0.07**	-0.54*	0.01	-0.003	0.84	1.95**	2.91
31	A.Alok x L-101	0.06	-0.39	0.01	0.05	-0.02	-0.18**	3.62*	1.88**	-0.49
32	A.Alok x SP-2-2	-0.08*	-0.42	0.02	-0.26	0.18*	-0.15**	7.66**	-1.59**	0.10
33	A.Alok x 88/Firm/J	-0.000	-1.04**	0.09**	-0.67**	0.08	0.09**	-0.86	-0.27**	2.49
34	A.Alok x W.94.30 ①	0.06	-0.49*	-0.08**	-0.24	0.04	0.04*	-1.41	2.70**	-1.19
35	A.Alok x W.94.FM 59/7	-0.01	0.87**	-0.02	-0.72**	-0.19*	0.04*	2.32	0.29**	1.99
36	A.Alok x L-50	-0.05	0.81**	-0.11**	0.96**	-0.07	0.04*	0.84	0.65**	-1.70
37	A.Alok x 88/DT-14	-0.04	0.25	0.06**	1.01**	0.01	0.11**	3.64*	-2.43**	-0.33
38	A.Alok x DWD-1	0.03	0.18	-0.05**	0.24	-0.05	0.03	-7.16**	-1.14**	-1.19
39	A.Alok x A.Vikas	-0.05	-0.26	0.02	-0.31	-0.002	-0.05*	-7.45**	-0.40**	0.34
40	A.Alok x A.Saurabh	0.08*	0.48*	-0.04*	-0.07	0.02	-0.005	-1.20	0.32**	0.10
41	Shakti x L-101	-0.07	0.36	-0.01	1.32**	0.09	0.02	2.89	0.37**	0.44
42	Shakti x SP-2-2	-0.005	0.06	-0.11**	0.20	-0.09	-0.004	-6.32**	-0.32**	1.04
43	Shakti x 88/Firm/J	0.03	-0.18	-0.04*	0.05	-0.01	-0.03	-1.26	-2.15**	3.43
44	Shakti x W.94.30 ①	0.01	0.04	0.04*	0.15	-0.11	-0.03	-2.05	2.18**	-0.26
45	Shakti x W.94.FM 59/7	-0.04	0.83**	-0.08**	-0.58**	0.04	-0.04*	7.82**	-1.16**	2.83
46	Shakti x L-50	0.003	-0.62**	0.03	-0.76**	-0.02	0.05*	-0.03	0.73**	-0.76
47	Shakti x 88/DT-14	0.05	-0.63**	0.06**	-0.41	0.04	0.03	6.51**	1.90**	0.61
48	Shakti x DWD-1	-0.03	-0.002	-0.01	-1.29**	0.01	-0.01	-3.19*	-0.11	-0.26
49	Shakti x A.Vikas	0.03	0.15	0.03	0.62**	0.01	-0.02	2.91*	-0.42**	-3.42
50	Shakti x A.Saurabh	0.01	-0.000	0.08**	0.69**	0.04	-0.03	-7.28**	-1.02**	-3.66
	S.Em±	0.028	0.164	0.014	0.150	0.058	0.015	1.046	0.055	2.420
	CD at 5%	0.077	0.454	0.038	0.420	0.160	0.040	2.897	0.151	6.710
	CD at 1%	0.101	0.596	0.050	0.550	0.211	0.055	3.809	0.200	8.810

* and ** indicate significant at 5 and 1 per cent level of probability, respectively

4.3.2.3 Number of primary branches per plant

The highest (0.74) significant positive gca effect was expressed by Arka Alok and Arka Vikas among lines and testers respectively.

The sca effects were significant for 13 crosses in each direction. The cross Shakti x SP-2-2 attained the highest significant positive sca effect (1.37) and considered to be the best combination for this trait.

4.3.2.4 Days to 50 per cent flowering

Among the parents highest significant negative gca effect (-1.48) was noticed in Arka Alok and it was ideal character for early maturity. While, L-15 recorded highly significant positive gca effect among lines. Similarly among testers SP-2-2 had highly significant positive gca effect.

Out of 50 crosses, 16 crosses registered significant sca effect for this trait. Twenty seven crosses showed negative sca effects for this trait. The highest negatively significant sca effect was observed in the hybrid Martha x L-50 (-3.72). The other crosses which revealed significant negative sca effects were L-15 x Arka Saurabh, Martha x DWD-1, Sonali x L-101, Sonali x SP-2-2, Sonali x L-50, Arka Alok x W.94 30 ① and Shakti x DWD-1.

4.3.2.5 Number of flowers per cluster

Among the lines only L-15 recorded highly significant positive gca effects. While, eight out of 10 testers were positive general combiners, of these six had depicted significant positive gca effect.

The significant positive sca effects were observed in 15 crosses, while, 11 crosses exhibited significant negative sca effect. The cross Sonali x Arka Vikas with a positive value of 1.38 showed highest significant sca effect.

4.3.2.6 Number of clusters per plant

Among the lines Martha and Shakti showed highly significant gca effect in desired direction while, L-15 and Arka Alok showed highly significant negative gca effects. Three testers each had gca effects in desired (SP-2-2, W.94 30 ① and Arka Vikas) and non-desired (L-50, 88/DT-14 and DWD-1) direction.

The equal proportion of crosses showed negative and positive sca effect for this trait. The highest significant positive sca effect was noted in the cross Sonali x SP-2-2

4.3.2.7 Number of fruits per cluster

The parents, L-15, L-101, W.94 FM 59/7 and Arka Vikas were found to be significantly superior general combiners for higher number of fruits per cluster.

Among the 50 hybrids, only eight crosses exhibited significant positive sca effect for fruit number per cluster. The maximum sca effect was recorded in Martha x 88/DT-14. Seven crosses showed significant negative sca effect and the poorest cross combination was Martha x W.94 30 ①.

4.3.2.8 Number of fruits per plant

Significant positive general combining ability effect was observed in seven parents viz., Martha (5.83), Shakti (8.16), L-101 (3.52), SP-2-2 (5.44)

W.94 30 ① (5.89) and Arka Vikas (22.00). The parent Arka Alok recorded highest (-14.51) significant negative gca effect.

Out of 50 crosses 29 crosses showed significant sca effects of which 13 were in positive direction. The best cross with highest sca effect was Sonali x SP-2-2 (24.59) followed by Shakti x Arka Vikas (20.18); and the poorest combination was Martha x Arka Vikas (-19.43).

4.3.2.9 Average fruit weight

The female parent Arka Alok was the best general combiner which exhibited significant positive gca effect. Out of 10 testers, three showed significant positive gca effects and the highest gca value was recorded in L-50 (12.64) followed by 88/DT-14 (6.12) and 88/Firm/J (2.97).

Estimates of sca effects were significant for 21 crosses of which eight were in positive direction. The crosses Arka Alok x 88/DT-14 (12.39) and Sonali x SP-2-2 (-9.78) were the best and poorest combinations, respectively.

4.3.2.10 Yield per plant

Highly significant positive gca effects was noticed in the line Arka Alok and Martha for yield per plant. Whereas among testers Arka Vikas (0.35), L-50 (0.32), SP-2-2 (0.28) and L-101 (0.13), recorded significantly positive gca effects. The genotypes Arka Saurabh (-0.37), DWD-1 (-0.31), 88/Firm/J (-0.25) Shakti (-0.16) and 88/DT-14 (-0.11) exhibited significant negative gca effects for this character.

Twenty seven crosses manifested significant sca effects of which 14 were positive and 13 in negative direction respectively. The highest significant positive sca effect was noticed in Martha x 88/Firm/J (0.53) followed by Arka Alok x SP-2-2 (0.49), Martha x 88/DT-14 (0.44), Arka Alok x W.94 30 ① (0.43), Shakti x L-50 (0.39) and Arka Alok x L-101 (0.38).

4.3.2.11 Fruit shape index

The two lines Martha and Arka Alok contributed significant positive gca effect for fruit shape index. While only one tester W.94 30① had significant positive gca effects. Arka Vikas revealed highest gca effect (-0.08) in desirable direction.

The estimates of sca effect were significant for this trait for four crosses. The highest negative sca effect was displayed by the cross Sonali x W.94 30 ① while, the highest significant positive sca effect was noticed in the cross Sonali x L-50.

4.3.2.12 Number of locules per fruit

The gca effects were found significant for all the lines and seven testers. The estimates revealed that only three lines had highly significant desirable negative gca effects. The highly significant non-desirable positive gca observed in Arka Alok (1.05). Among the testers, the highest negative gca effect was observed in W.94 30 ①. Four testers exhibited significant positive gca effect.

The number of crosses showing positive and negative sca effect were 26 and 24 respectively. The highly significant negative sca effects obtained in the crosses Sonali x W.94 FM 59/7, Arka Alok x 88/Firm/J, Shakti x L-50 and Shakti x 88/DT-14. The highest significantly positive sca effect obtained in the cross Martha x 88/Firm/J.

4.3.2.13 Pericarp thickness

Significant positive combiners for pericarp thickness were L-15, Sonali and Arka Alok among the lines while, SP-2-2, 88/Firm/J and W.94 30① among the testers. The best positive general combiner was L-15 (0.11) and the poor combiner was W.94 FM 59/7 (-0.09).

Equal number of crosses (12) showed significant positive and negative sca effect. The highest significant positive sca effect (0.16) was also equal to the highest (-0.16) significant negative sca effect.

4.3.2.14 Total soluble solids

All the female parents had significant gca effects. Of these, Martha, Arka Alok and Shakti exhibited significant positive gca effects while L-15 and Sonali exhibited significant negatie gca effect. Three testers *viz.*, Arka Saurabh, DWD-1 and W.94 FM 59/7 recorded the highly significant positive gca effect in that order of merit.

Out of 50 crosses, 12 crosses each were significantly positive and negative in their specific combining ability effect. The highest significant desirable sca effect was recorded by the cross L-15 x W.94 FM 59/7 (1.49). The lowest (-1.29) sca effect exhibited by the cross Shakti x DWD-1.

4.3.2.15 pH of fruit juice

Among the lines L-15 exhibited significant gca effect in desired direction and Sonali in non desired direction. Similarly male parent L-50 displayed significant gca effect in desired direction while, Arka Saurabh in non-desired direction.

Out of 50 crosses, only two crosses exhibited significant sca effect. Of these, the cross Arka Alok x W.94 FM 59/7 manifested significant negative sca effect (-0.19).

4.3.2.16 Titratable acidity

The lines which contributed highly significant positive gca effects were Arka Alok and L-15. Three testers had significant gca effect, among which the higher value were registered by L-101 (0.08).

Estimates of sca effect were significant for 30 crosses of which 15 and 14 crosses recorded significant positive and negative sca effects respectively. The highest significant positive sca effect was displayed by the cross Martha x L-101 (0.12).

4.3.2.17 Ascorbic acid

Two lines *viz.*, L-15 and Martha recorded highly significant positive gca effects. While Arka Alok and Shakti recorded highly significant negative gca effect. Similarly, among testers also four in each direction recorded highly significant positive and negative gca effects. The testers L-101 recorded the highest significant positive gca effect of 8.69.

Out of 50 crosses, 31 crosses exhibited significant sca effect for this trait. The significant positive and negative sca effects were recorded by 17 and 14 crosses respectively. The highest significant positive sca effect was noticed in Sonali x DWD-1 (12.58).

4.3.2.18 Lycopene

The two lines (Martha and Arka Alok) were found to be positive general combiners for higher lycopene content of fruit. All the testers exhibited highly significant gca effect for this trait, of which 50 per cent contributed highly significant positive gca in desired direction. The highest significant positive gca effect was recorded in W.94 30 ①.

Among the 50 crosses, 26 crosses had positive sca effects of which 88.46 per cent of crosses registered significant positive sca effect in desired direction. The highly significant positive sca effect observed in the cross Arka Alok x W.94 30 ①.

4.3.2.19 Per cent wilt incidence

All lines had significant gca effects. While, only two testers had significant gca effects. The highest significant negative gca effect recorded in Shakti (-7.89).

Only four crosses were recorded significant sca effect of which two were in positive direction and two in the other negative direction. The highest significant negative sca effect recorded by the cross combination of Martha x W.94 FM 59/7 (-11.45) followed by L-15 x L-101 (-6.86).

4.4 INHERITANCE OF BACTERIAL WILT RESISTANCE IN TOMATO

The scoring of incidence of bacterial wilt on four F_2 populations of Arka Alok x L-101, Arka Alok x SP-2-2, Arka Alok x W.94 30 ① and Arka Alok x Arka Vikas constituting a total populations of 252, 246, 254 and 250 plants respectively suggested that it was not possible to make distinct classes as indicated in material and methods. However, plants were distinguished into wilted and non-wilted group.

From the Table 26, it can be noted that all the plants of F_2 populations of Arka Alok x L-101, Arka Alok x SP-2-2, Arka Alok x W.94 30 ① were

Table 26. Segregation in F_2 population for wilt incidence in tomato

Sl.No.	Crosses	Total No. of plants	Observed		Ratio	Expected		χ^2	Table χ^2 1 df, 5% probability
			Non-wilted	Wilted		Non-wilted	Wilted		
1.	A.Alok x L-101	252	All are resistant			All are resistant			
2.	A.Alok x SP-2-2	246	All are resistant			All are resistant			
3.	A.Alok x W.94 30 ①	254	All are resistant			All are resistant			
4.	A.Alok x A.Vikas	250	148	102	9:7	140.63	109.37	0.899	3.84

resistant to bacterial wilt. However, in the population of Arka Alok x Arka Vikas, there were 148 and 102 plants respectively under the group of non-wilted and wilted. A digenic ratio of 9:7 was fitting to chi-square test suggesting a duplicate recessive gene interaction for bacterial wilt resistance. The expected frequencies were 140.63 and 109.37 for non-wilted and wilted group respectively.

4.5 ISOLATION OF TRANSGRESSIVE SEGREGANTS

Analysis, of segregants in four different F_2 population for important yield component character revealed higher frequency of transgressive segregants for average fruit weight (Table 27).

The F_2 populations of Arka Alok x SP-2-2 recorded higher frequency of transgressive segregants (1.74%) for number of fruits per plant. The other three population showed 0.43 per cent of transgressive segregants. The desirable transgressive segregants frequency for average fruit weight was ranged between 2.61 (Arka Alok x SP-2-2) and 25.22 per cent (Arka Alok x W.94 30 ①). Higher frequency of transgressive segregants for yield per plant were observed in Arka Alok x W.94 30① followed by Arka Alok x SP-2-2. The least frequency of transgressive segregants manifested by Arka Alok x Arka Vikas.

4.6 MANAGEMENT OF BACTERIAL WILT OF TOMATO THROUGH SOIL AMENDMENT

4.6.1 Yield per ha

The two varieties L-15 and Pusa Ruby differed significantly in their yielding ability for both the years of experimentation (Table 28).

Table 27. Per cent transgressive segregants from four different F_2 population for three yield related traits

Sl.No.	Cross	No. of fruits plant^{-1}	Average fruit weight (g)	Yield plant^{-1} (kg)
1.	A.Alok x L-101	0.43	13.04	1.30
2.	A.Alok x SP-2-2	1.74	02.61	4.78
3.	A.Alok x W.94 30 ①	0.43	25.22	6.09
4.	A.Alok x A.Vikas	0.43	10.87	0.87

Table 28. Yield (t ha^{-1}) as influenced by gypsum application in tomato genotypes

Sl. No.	Gypsum levels (G)	2001			2002			**Pooled**		
		Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**
1.	RDF + G_0 *Control*	2.51 e	29.41 b	**15.97 c**	1.87 e	27.91 b	**14.89 b**	2.19 f	28.66 c	**15.43 d**
2.	RDF + G_1 (125 kg Gypsum ha^{-1})	3.35 de	29.83 b	**16.59 b**	2.40 de	28.13 b	**15.27 b**	2.88 e	28.98 c	**15.93 c**
3.	RDF + G_2 (187.5 kg Gypsum ha^{-1})	3.62 cd	31.01 a	**17.32 a**	3.25 cd	29.37 a	**16.31 a**	3.44 de	30.19 b	**16.81 b**
4.	RDF + G_3 (250 kg Gypsum ha^{-1})	3.78 cd	31.03 a	**17.41 a**	3.35 c	29.52 a	**16.44 a**	3.57 d	30.28 ab	**16.92 b**
5.	RDF + G_4 (375 kg Gypsum ha^{-1})	4.03 cd	31.19 a	**17.62 a**	3.40 c	29.89 a	**16.45 a**	3.72 d	30.54 ab	**17.13 ab**
6.	RDF + G_5 (500 kg Gypsum ha^{-1})	4.39 c	31.42 a	**17.91 a**	3.53 c	30.25 a	**16.89 a**	3.96 d	30.84 a	**17.39 a**
		3.62 b	30.65 a	**17.14**	2.97 b	29.18 a	**16.04**	3.29 b	29.92 a	**16.60**

In column means followed by same letter do not differ significantly by DMRT

The different levels of gypsum had significant effect on tomato yield. The significantly higher yield of 17.91 t/ ha^{-1} and 16.89 t ha^{-1} recorded in the plot where gypsum applied @ 500 kg ha^{-1} and it remained an par with G_2, G_3 and G_4 during both 2001 and 2002. During the year 2002 the control and gypsum application @ 125 kg ha^{-1} remained on par each other. The pooled data also followed the trend of 2001 except the significant difference between the G_2, G_3 and G_5.

The interaction effects were significant between gypsum and variety for yield. The variety L-15 produced significantly higher yield compared to Pusa Ruby at all levels of gypsum during both 2001 and 2002. The highest yield of 31.42 t ha^{-1} and 30.25 t ha^{-1} noticed in treatment combination L-15 and gypsum @ 500 kg ha^{-1} and it was on par with V_2 G_2, V_2 G_3 and V_2 G_4. Similarly, the Pusa Ruby also recorded highest yield with the application of 500 kg ha^{-1} and remained on par with V_1 G_2, V_1 G_3 and V_1 G_4 during both 2001 and 2002. The pooled data also reflected the same except significant difference between V_1 control and V_1G_1 and also between V_2G_2 and V_2G_5.

4.6.2 Per cent wilt incidence

The variety L-15 registered significantly lower wilt incidence compared to Pusa Ruby in both the years. The pooled data also showed same trend (Table 29).

The different gypsum levels showed significant influence on wilt incidence. Among the different gypsum levels, the plot which received the gypsum 500 kg ha^{-1} registered significantly lower wilt incidence but, on par with gypsum level 375 kg ha^{-1} during 2001. Similarly, during 2002 also the gypsum application @ 500 kg ha-1 recorded significantly lower wilt incidence compared to control, but, it was on par with rest of the treatments except

Table 29. Wilt incidence as influenced by gypsum application in tomato genotypes

Sl. No.	Gypsum levels (G)	2001			2002			Pooled		
		Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**
1.	RDF + G_0 Control	80.16 (63.56) a	12.69 (20.83) e	**46.53 (42.20) a**	87.29 (69.22) a	17.45 (24.11) d	**52.37 (46.66) a**	83.73 (66.39) a	15.07 (22.47) e	**49.40 (44.43) a**
2.	RDF + G_1 (125 kg Gypsum ha^{-1})	73.01 (58.69) b	11.11 (19.35) e	**42.05 (39.02) b**	78.57 (62.40) b	15.86 (23.37) d	**47.22 (42.88) b**	75.79 (60.55) b	13.48 (21.36) e	**44.64 (40.95) b**
3.	RDF + G_2 (187.5 kg Gypsum ha^{-1})	69.83 (56.68) bc	7.14 (15.31) f	**38.48 (35.99) c**	74.60 (59.72) bc	11.11 (19.44) e	**42.85 (39.57) c**	72.22 (58.19) bc	9.12 (17.37) f	**40.67 (37.78) c**
4.	RDF + G_3 (250 kg Gypsum ha^{-1})	69.04 (56.20) bcd	6.35 (14.47) f	**37.69 (35.34) c**	72.22 (58.21) c	10.31 (18.69) e	**41.26 (38.45) c**	70.63 (57.21) cd	8.33 (16.58) fg	**39.48 (36.89) c**
5.	RDF + G_4 (375 kg Gypsum ha^{-1})	66.66 (54.71) cd	6.35 (14.33) f	**36.50 (34.52) cd**	71.43 (57.70) c	9.52 (17.86) e	**40.47 (37.78) c**	69.04 (56.21) cd	7.93 (16.09) fg	**38.48 (36.15) cd**
6.	RDF + G_5 (500 kg Gypsum ha^{-1})	63.48 (52.79) d	5.76 (13.81) f	**34.12 (32.51) d**	70.63 (57.22) c	8.73 (17.12) e	**39.68 (37.17) c**	67.06 (55.01) d	7.25 (15.46) g	**36.90 (34.84) d**
		70.36 (57.11) a	8.07 (16.09) b	**39.22 (36.59)**	75.79 (60.74) a	12.16 (20.09) b	**43.98 (40.42)**	73.07 (58.93) a	10.12 (18.09) b	**41.59 (38.51)**

In column means followed by same letter do not differ significantly by DMRT

gypsum @ 125 kg ha^{-1}. The pooled data also followed the trend of the year 2001.

The interaction between the varieties and gypsum levels was significant. During both 2001 and 2002, the variety L-15 with application of gypsum 500 kg ha^{-1} registered the lowest wilt incidence of 5.76 and 8.73 per cent respectively and it was on par with V_2 G_4, V_2 G_3 and V_2 G_2. Similarly, the variety Pusa Ruby with gypsum level (500 kg ha^{-1}) showed lower wilt incidence in both the years. The same results depicted in the pooled data. However, the variety Pusa Ruby irrespective of gypsum level had significantly higher wilt incidence compared to variety L-15.

4.6.3 Calcium content in leaf at flowering stage

The calcium content in the two varieties at flowering stage differed significantly. The variety L-15 had significantly higher calcium content than the Pusa Ruby in both the years. The pooled data also mirrored the same results.

Significant differences were noticed among the different levels of gypsum applied. The calcium content was significantly higher with the application of gypsum @ 500 kg ha^{-1} and it was on par gypsum level @ 375 kg ha^{-1} during 2001. However, during the year 2002 and in pooled data the application of gypsum @ 500 kg ha^{-1} was recorded significantly higher calcium content compared to other treatments.

The interaction effects between the varieties and gypsum levels were significant. The variety L-15 in combination with gypsum level 500 kg ha^{-1} and 375 kg ha^{-1} recorded significantly higher calcium content (2.04 and 1.92 g/100 g) compared to rest of the combination during 2001. However, the combination of variety L-15 with gypsum 500 kg ha^{-1} was recorded significantly higher calcium content (2.09 g/100 g) compared to rest of the treatment combinations during 2002 and in pooled data (Table 30).

4.6.4 Calcium content at fruiting stage

Between the two varieties, L-15 had significantly higher calcium content compared to variety Pusa Ruby, during both the years.

The calcium content at fruiting stage was found significant among the different gypsum levels. The calcium content was significantly higher in the leaf tissue when the gypsum was applied @ 500 $kgha^{-1}$ during both the years and in pooled data.

For calcium content at fruiting stage the interaction effects were significant. The higher calcium content of 2.34 and 2.24 g/100 g observed in the variety L-15 when supplied with gypsum @ 500 kg ha^{-1} compared to rest of the treatments during both 2001 and 2002, respectively. The pooled data also reflected the same results. It is evident from Table 31 that L-15 had higher calcium content in leaf tissue compared to Pusa Ruby at all levels of gypsum application.

4.7 HISTOPATHOLOGY OF RESISTANT AND SUSCEPTIBLE TOMATO GENOTYPES

The histopathological investigations of resistant (L-15) and susceptible (Pusa Ruby) varieties revealed that there was aggregation of xylem vessels in the susceptible wilting plants compared to normal distribution of xylem vessels in the resistant plants.

Table 30. Calcium content in leaf (g/100 g) as influenced by gypsum application in tomato genotypes at flowering stage

Sl. No.	Gypsum levels (G)	2001			2002			**Pooled**		
		Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**
1.	RDF + G_0 Control	0.49 h	0.86 f	**0.67 d**	0.47 k	0.84 h	**0.65 f**	0.48 k	0.85 h	**0.66 f**
2.	RDF + G_1 (125 kg Gypsum ha^{-1})	0.57 gh	1.32 cd	**0.95 c**	0.56 j	1.29 e	**0.93 e**	0.57 jk	1.31 e	**0.94 e**
3.	RDF + G_2 (187.5 kg Gypsum ha^{-1})	0.62 gh	1.45 c	**1.04 c**	0.57 j	1.43 d	**0.99 d**	0.59 j	1.44 d	**1.02 d**
4.	RDF + G_3 (250 kg Gypsum ha^{-1})	0.73 fg	1.68 b	**1.21 b**	0.74 l	1.81 c	**1.27 c**	0.74 l	1.75 c	**1.24 c**
5.	RDF + G_4 (375 kg Gypsum ha^{-1})	1.07 e	1.92 a	**1.49 a**	1.02 g	1.89 b	**1.45 b**	1.05 g	1.91 b	**1.47 b**
6.	RDF + G_5 (500 kg Gypsum ha^{-1})	1.19 de	2.04 a	**1.61 a**	1.16 f	2.09 a	**1.62 a**	1.17 f	2.06 a	**1.62 a**
		0.78 b	1.55 a	**1.16**	0.75 b	1.56 a	**1.15**	0.76 b	1.55 a	**1.16**

In column means followed by same letter do not differ significantly by DMRT

Table 31. Calcium content in leaf (g/100 g) as influenced by gypsum application in tomato genotypes at fruit set stage

Sl. No.	Gypsum levels (G)	2001			2002			Pooled		
		Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**	Pusa Ruby (V_1)	L-15 (V_2)	**Mean**
1.	RDF + G_0 Control	1.02 g	1.40 d	**1.21 e**	1.00 i	1.36 f	**1.18 f**	1.01 j	1.38 f	**1.19 f**
2.	RDF + G_1 (125 kg Gypsum ha^{-1})	1.08 fg	1.50 d	**1.29 d**	1.07 hi	1.48 e	**1.28 e**	1.08 i	1.49 e	**1.29 e**
3.	RDF + G_2 (187.5 kg Gypsum ha^{-1})	1.12 efg	1.70 c	**1.41 c**	1.08 h	1.64 d	**1.36 d**	1.10 hi	1.67 d	**1.38 d**
4.	RDF + G_3 (250 kg Gypsum ha^{-1})	1.14 ef	1.93 b	**1.53 b**	1.12 gh	1.90 c	**1.51 c**	1.13 hi	1.92 c	**1.52 c**
5.	RDF + G_4 (375 kg Gypsum ha^{-1})	1.16 ef	2.02 b	**1.59 b**	1.14 gh	2.03 b	**1.58 b**	1.15 gh	2.02 b	**1.59 b**
6.	RDF + G_5 (500 kg Gypsum ha^{-1})	1.21 e	2.34 a	**1.79 a**	1.18 g	2.24 a	**1.71 a**	1.19 g	2.30 a	**1.75 a**
		1.12 b	1.82 a	**1.47**	1.10 b	1.77 a	**1.43**	1.11 b	1.80 a	**1.45**

In column means followed by same letter do not differ significantly by DMRT

Disturbance in the xylem vessels of wilted plants causing degradation of xylem vessels and there by causing cavities has been observed in contrast to intact xylem vessels in resistant plants.

Perhaps, the protrusions and bubble like structure observed in the wilted plants of cultivar Pusa Ruby may be perforation plates and tyloses in response to pathogen entry.

4.8 EFFECT OF CROP ROTATION WITH NON HOSTS ON BACTERIAL WILT INCIDENCE IN TOMATO

Initial wilt incidence during *kharif* 2000 and 2001 remained non-significant in all the treatments. However, from the Table 32, it is evident that the wilt incidence was higher during the *kharif* 2001 compared to *kharif*, 2000.

The pooled data indicated that the two crop sequences *viz.*, tomato - maize - tomato and tomato - sorghum - tomato reduced the wilt incidence significantly (45.72% and 43.57%) compared to tomato – tomato – tomato (94.28%) crop sequence (Table 33). However, the crop sequence tomato – maize – tomato and tomato – sorghum – tomato remained on par with each other.

Table 32. Initial wilt incidence in three different crop sequences

Sl. No.	Treatments	2000	2001	**Pooled**
1	Tomato – Tomato – Tomato	61.42 (58.78)	67.14 (55.16)	**64.28** **(56.97)**
2	Tomato – Maize – Tomato	68.57 (55.93)	65.71 (54.21)	**67.14** **(55.07)**
3	Tomato – Sorghum – Tomato	65.71 (55.07)	70.00 (56.88)	**67.85** **(55.97)**
	Mean	65.23 (56.91)	67.62 (55.41)	
	S.Em± CD at 1%	1.57 NS	1.47 NS	1.53 NS

Values in parenthesis indicate transformed value

Table 33. Wilt incidence recorded in tomato followed by non hosts

Sl. No.	Treatments	2000	2001	**Pooled**
1	Tomato – Tomato – Tomato	92.85 (78.31)	95.71 (83.57)	**94.28** **(80.94)**
2	Tomato – Maize – Tomato	42.86 (40.88)	48.57 (44.17)	**45.72** **(42.53)**
3	Tomato – Sorghum – Tomato	40.00 (39.23)	47.14 (43.35)	**43.57** **(41.29)**
	Mean	58.57 (52.81)	63.81 (57.03)	-
	S.Em± CD at 1%	1.76 7.21	1.53 6.27	1.65 6.76

Values in parenthesis indicate transformed value

Discussion

V. DISCUSSION

Tomato crop is prone to various biotic stresses *viz.*, fungal, bacterial and viral diseases. These will reduce the productivity and quality of tomato fruits. Among the biotic stresses bacterial wilt, incited by *Ralstonia solanacearum* is one of the devastating diseases in the tropical, sub-tropical and humid regions of the world (Hayward, 1991). The management of bacterial wilt consist of chemical, cultural, biological and the use of disease resistant cultivars. Disease incidence can be reduced by use of soil amendments and crop rotation with non-hosts. Another approach was host resistance exploitation, which was thought to be an attractive option to augment tomato yields. The development and utilisation of resistant varieties offers the most technically feasible, environmentally sound and economical means of disease control. This is more so in case of bacterial wilt disease as nothing parallel to resistant variety / hybrid is available to check bacterial wilt.

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

Disease management through use of resistance is often confronted with problem of break down of resistance. Therefore taking the realistic note of all the advantages and disadvantages associated with each of the method it was thought to manage the bacterial wilt through integrated means: Soil amendment, crop rotation, exploitation of resistance etc.

5.1 INTEGRATED MANAGEMENT OF BACTERIAL WILT OF TOMATO

5.1.1 Use of soil amendment

The use of soil amendments is one of the management practices followed to control the bacterial wilt caused by *R. solanacearum.* Various soil amendments have been tried in the management of bacterial wilt. However, studies with respect to soil amendment like gypsum have not been tried. Looking to its cost effectiveness, easy accessibility and wider use, gypsum has been included along with the resistant cultivar L-15 and susceptible cultivar Pusa Ruby.

It was evident from the studies that, the different levels of gypsum had good impact in reducing the wilt incidence (Table 29). As the gypsum levels increased from 125 kg ha^{-1} to 500 kg ha^{-1} the wilt incidence reduced from 44.64 per cent to 36.90 per cent. There was significant reduction in wilt incidence in all the gypsum levels compared to control. Verma and Shekhawat (1991) also reported decreased wilt incidence with increased application of $CuSo_4$. Further, it can be inferred that with the variety L-15, gypsum level 187.5 kg ha^{-1} and other higher levels had significantly lower wilt incidence compared to gypsum level 125 kg ha^{-1} and control but they were on par with each other. So with the resistant variety application of gypsum 187.5 kg ha^{-1} is sufficient to bring down the wilt incidence.

An insight into the calcium content of the two varieties revealed that the variety L-15 had significantly higher calcium content as compared to Pusa Ruby in both the years. Therefore, it seems that Ca nutrition is important for resistance to bacterial wilt in tomato. Many investigators have reported that increased Ca content in plant tissues induces resistance to some diseases and have outlined possible mechanisms: direct polygalacturonase inhibition by Ca and other pectolytic enzymes produced by the pathogen (Corden, 1965) and increased resistance in cell walls strengthened by Ca to these enzymes (Bateman and Lumsden, 1965). Results from this experiment indicate that Ca nutrition also may affect the resistance and that high Ca suppresses pathogen multiplication resulting in a suppression of disease development in resistant tomato cultivars. Similarly Yamazaki and Hoshina (1995) have also observed presence of higher Ca content in resistant tomato genotypes as compared to susceptible genotype. From the two years data it can also be inferred that the Ca uptake is genotype dependent character as in both the years the Ca content in L-15 was significantly higher compared to Pusa Ruby. The experiment conducted over two years on resistant and susceptible cultivars with different levels of gypsum may contribute to a new integrated management practices of bacterial wilt in tomatoes.

5.1.2 Crop rotation with non-hosts

Cultural methods have been used for overall management of bacterial wilt. More specifically among the cultural practices crop rotation was an effective control method in bacterial wilt infested soils. Its effect has been studied more with potato than other solanaceous vegetables. The non-host crop maize and sorghum which are very popular in this area and cultivated on large scale in *kharif* and *rabi* season respectively were used in this experiment. The effect of these crops in reducing the wilt incidence was studied for two years.

The results reveled that both maize and sorghum were equally effective in reducing the wilt incidence. When the tomato was grown continuously for three season the wilt incidence increased alarmingly form 64.28 to 94.28 per cent. Whereas, the wilt incidence reduced from its initial incidence of 67.14

and 67.85 per cent to 45.72 and 43.57 per cent in tomato – maize - tomato and tomato – sorghum- tomato respectively (Plate 5). The reduction in the wilt incidence when the non-host crops were used is mainly because the pathogen was deprived of its host for one season. Moreover, the non-host crops maize and sorghum roots are known to exudate HCN which is toxic to the pathogen (personal communication). As a result of these the pathogen population was considerably reduced. Similar views were expressed by Sohi *et al.* (1981), Verma and Shekhawat (1991) and Kishore *et al.* (1992) when Gramineae family crops were used in the crop rotation experiment in tomato and potato respectively. From this it can be suggested that to reduce the wilt incidence of tomato, the farmer may follow either sorghum or maize after the tomato crop.

5.2 SOURCE OF RESISTANCE TO BACTERIAL WILT

Any breeding programme, including one that involves host plant resistance to pathogens, must begin with extensive screening of germplasm. Success in locating resistance to bacterial wilt breeding is directly related to the availability of resistant genotypes in germplasm. The resistance genes to bacterial wilt in tomato originated from *L. esculentum* var *cerasiformae* and *L. pimpinellifolium* (Hanson *et al.,*1998). The development of varieties / hybrids with suitable horticultural traits is slow despite the availability of several sources of resistance. This is because of the polygenic nature of the resistance and the linkage of resistance with small fruit size (Sonoda, 1978). This has necessitated breeder to explore the better resistance source in cultivated tomatoes for bacterial wilt resistance breeding. In view of this an attempt was made to screen the 212 genotypes during January to April, 2000 in field under epiphytotic conditions. Based on the *per se* performance and reaction to wilt 57 genotypes were selected from 212 genotypes and they were subjected to artificial inoculation during *kharif*, 2000. Out of 57 genotypes 15 genotypes were selected for hybridisation based on their performance under field epiphytotic conditions and artificial epiphytotic conditions. The five genotypes *viz.*, L-15, Martha, Sonali, Arka Alok and Shakti were selected as female parents (Lines). The three lines Sonali, Arka Alok and Shakti which were released as bacterial wilt resitant from different institutions were found to be free from wilt incidence. While the other two lines had wilt incidence but it was less than 20 per cent (resistant) and they had good horticultural traits. All these lines had small to medium fruit size except Arka Alok. The testers selected had medium to large fruit size with different shape and they also represented range of reaction from resistant to susceptible. Thus, the genotypes selected for hybridisation were complementary to each other and diverse enough to cater the needs of consumers.

Similarly, Rao *et al.* (1975), Ramchandran *et al.* (1980), Sinha *et al.* (1988) Sharma and Kumar (1997) and Mahanta *et al.* (1998) also found resistance to bacterial wilt in tomato.

From the above investigations in the management of bacterial wilt it can be concluded that integrated approaches like application of gypsum on soil amendment @ 187.5 kg ha^{-1} + crop rotations with non host crops like sorghum / maize + growing resistant genotypes for bacterial wilt would considerably reduce the bacterial wilt incidence to a manageable level.

5.3 BREEDING FOR RESISTANCE TO BACTERIAL WILT

The term heterosis is synonymous with increased vegetative growth and high fruit production. The utilisation of hybrid vigour as a means of maximising 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. Studies on heterosis and feasibility of its exploitation along with bacterial wilt resistance are meager in tomato. In view of this, it is essential to identify the parents that give desirable F_1 hybrids with bacterial wilt resistance. With this objective in view, F_1's were developed and tested under artificially epiphytotic condition.

In the present investigation 24 hybrids were found free from wilt incidence while, five hybrids had 2.22 per cent wilt incidence. The rest had wilt incidence less than 20 per cent. Thus all the hybrids were resistant to bacterial wilt. The 24 hybrids were free from wilt incidence because the female parents (Sonali, Arka Alok and Shakti) used were also free from wilt incidence. The rest hybrids were also found resistant (<20% wilt incidence) because all the lines and five testers (SP-2-2, W-94, FM 59/7, L-50, 88/DT-14 and DWD-1) were also resistant to bacterial wilt. Similar findings were reported by Nirmaladevi (1987) and Satyanarayana (1990).

Combining ability analysis revealed the predominant role of non-additive gene effects for wilt incidence. Hence, heterosis breeding would be more practicable approach for developing bacterial wilt resistant tomato hybrids.

Hybrid vigour of small magnitude for individual yield components may have additive or synergistic effect on the end product.

It was evident from the results that there was a considerable degree of heterosis for fruit yield and its component characters (number of clusters per plant, number of fruits per plant and average fruit weight) along with resistance to bacterial wilt. The top three high yielding crosses for yield were; Arka Alok x SP-2-2 (2.53 kg), Arka Alok x L-101 (2.27 Kg) and L-15 x Arka

Vikas (2.26 kg), and all these had significant positive heterosis over the best parent and commercial check for yield. Considering the other component characters like average fruit weight (>50 g), number of fruits per plant and bacterial wilt resistance, only two of the above cross combinations *viz.*, Arka Alok x SP-2-2 (Plate 6) and Arka Alok x L-101 (Plate 7) qualify to be of commercial value (Table 34). The validity of their performance was confirmed from the results obtained during *kharif*, 2002 (Table 35). Obviously these two hybrids had significant positive sca effect for average fruit weight. The parental contribution (gca effect) for yield (Table 36) and their component characters came form both males and females in these crosses. Thus the above results proved that selection of parent is very important in the development of hybrids.

In the present study importance of both additivity and non additivity for yield has been observed with predominance of latter. These results are on line with Dharmatti (1995), Dod *et al.* (1995), Pradeepkumar *et al.* (1997), Srivastava *et al.* (1998), Kulkarni (1999), Sajjan (2001) and Bhatt *et al.* (2001).

For the yield components like number of fruits per plant and average fruit weight also importance of both additive and non-additive gene effects was observed with predominance of former. These findings are in conformity with Tendulkar (1994).

Thus the foregoing discussion reveals that heterosis breeding for yield and simple selection schemes for yield related characters should be adopted to bring the desired changes. Similar views were expressed by Tendulkar (1994). The best combinations could be Arka Alok x SP-2-2, Arka Alok x L-101 and

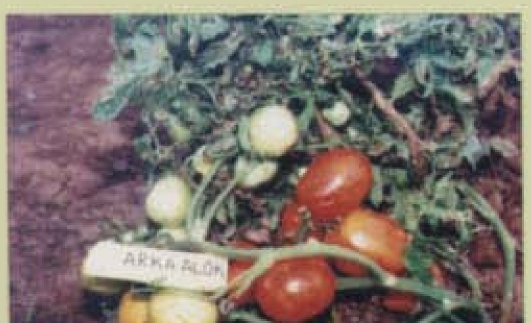
X

Line: Arka Alok

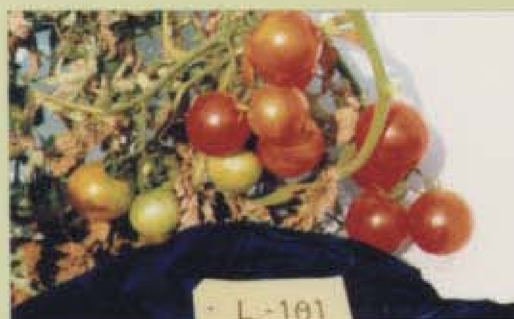
Tester: SP-2-2

↓

Plate 6. High yielding bacterial wilt resistant tomato hybrid



X



Line: Arka Alok

Tester: L-101

↓

Plate 7. High yielding bacterial wilt resistant tomato hybrid

Table 34. The best cross combination for economic characters

Sl.No.	Characters	Cross combination
1	Yield plant^{-1} (>2.00 kg)	L-15 x A. Vikas, Martha x 88/Firm/J, Martha x L-50, Martha x 88/DT-14, Sonali x SP-2-2, Sonali x L-50, A. Alok x L-101, A. Alok x SP-2-2, A. Alok, W.94 30 ①, A. Alok x A. Vikas, Shakti x L-50, Shakti x A. Vikas
2	Average fruit weight (>50 g)	A. Alok x L-101, A. Alok x SP-2-2, A. Alok x L-50, A. Alok x 88/DT-14
3	Free from wilt incidence	Sonali x SP-2-2, Sonali x 88/Firm/J, Sonali x W.94 30 ①, Sonali x W.94 FM 59/7, Sonali x 88/DT-14, Sonali x DWD-1, Sonali x A. Vikas, Sonali x A. Saurabh, A. Alok x L-101, A. Alok x SP-2-2, A. Alok x W.94.30 ①, A. Alok x W.94 FM 59/7, A. Alok x L-50, A. Alok x 88/DT-14, A. Alok x DWD-1, Shakti x L-101, Shakti x SP-2-2, Shakti x W.9430 ①, Shakti x W.94 FM 59/7, Shakti x L-50, Shakti x 88/DT-14, Shakti x DWD-1, Shakti x A. Vikas, Shakti x A. Saurabh

Table 35. ***Per se*** **performance of F_1 hybrids for the year 2001 and 2002**

Sl. No.	Crosses	Yield per plant (kg)		Per cent wilt incidence 2001
		2001	2002	
1.	A.Alok x SP-2-2	2.53	2.41	0.00
2.	A.Alok x L-101	2.27	2.19	0.00
3.	L-15 x A.Vikas	2.26	2.18	13.32
4.	Sonali x SP-2-2	2.23	2.34	0.00
5.	A.Alok x W.9430 (1)	2.22	2.28	0.00
6.	Shakti x L-50	2.20	2.09	0.00
7.	Shakti x A.Vikas	2.14	2.19	0.00
8.	Sonali x L-50	2.13	2.07	2.22
9.	Martha x L-50	2.10	1.93	15.54
10.	Martha x 88/DT-14	2.10	2.20	13.32
11.	Martha x 88/Firm/J	2.05	1.94	13.32
12.	A.Alok x A.Vikas	2.01	1.91	2.22
	Check US-1031	1.53	1.64	4.44

Table 36. *Per se* performance, gca and sca effects of potential hybrids

Sl. No.	Cross	*Per se* (kg)	gca effects		sca effects
			Line	Tester	
1.	A. Alok x SP-2-2	2.53	0.11**	0.28**	0.49**
2.	A.Alok x L-101	2.27	0.11**	0.13**	0.38**
3.	L-15 x A. Vikas	2.26	0.001	0.35**	0.26*
4.	Sonali x SP-2-2	2.23	-0.06	0.28**	0.36**
5.	A.Alok x W.94 30 ①	2.22	0.11**	0.04	0.43**

* and ** indicate significant at 5 and 1 per cent level of probability, respectively

L-15 x Arka Vikas. Not only these are high yielding but they were also found resistant to bacterial wilt.

When the fruit parameters *viz.*, number of locules per fruit and pericarp thickness were taken into consideration along with yield, the hybrid L-15 x Arka Vikas manifested the heterosis in desired direction. So this can be utilised for long distance market. The importance of quality parameter depends upon the processed product for which that cultivar / hybrid is to be used (Tigchelar, 1990). In this direction specific hybrids with significant positive or negative heterosis for individual traits were observed in the experiment and therefore could be commercially noted for specific processed tomato products in order to optimise the most important quality attributes for that particular product.

A case on point *viz.*, for concentrated tomato products, TSS represents an important parameter of raw fruit quality which may dramatically influence case yields. In this specific case, Martha x DWD-1 enjoys a comfortable position.

The two hybrids L-15 x W.94 FM 59/7 and Martha x Arka Saurabh had the *per se* performance as per the specified standards (TSS $> 5°$ brix, pH <4.5, total acidity $> 0.35\%$ interms of citric acid and lycopene > 5 mg/100 g of tomato juice) required for processing, they can be suggested for the utilisation for processing quality. Such hybrids were also observed by Patil (1997).

5.4 INHERITANCE OF BACTERIAL WILT RESISTANCE

The segregation pattern in the F2 population of A. Alok (resistant) x Arka Vikas (susceptible) revealed that, the bacterial wilt resistance is conditioned by digenes. A digenic ratio of 9:7 was fitting to chi-square test suggesting a duplicate recessive gene interaction for bacterial wilt resistance. A similar complementary and hypostatic type of digenic recessive system has been obtained by Sreelathakumari (1983). Nirmaladevi (1987) also suggested digenic model for bacterial wilt resistance. The other three populations *viz.* Arka Alok x L-101, Arka Alok x SP-2-2 and Arka Alok x W.94 30(1) involved both the parents with resistance, so all the plants in the F2 population were resistant.

Since the resistance was governed by two genes, there is every possibility of isolating a segregants possessing higher yield and bacterial wilt resistance. In this connection further study on isolation of transgressive segregatnts with bacterial wilt resistance was taken up.

5.5 ISOLATION OF TRANSGRESSIVE SEGREGANTS WITH BACTERIAL WILT RESISTANCE

Evidences of isolated transgressive segregants and possibility of recovering homozygous purelines from these, F_1's for yield and its components in the present investigation indicate the heterosis in *sensu stricto* to be due to one or more of the following causes : 1) complementary interaction of additive dominance or recessive genes at different loci, i.e. epistasis, 2) The accumulated action of favourable dominant or semidominant genes distributed among the two parents involved, i.e., dominance.

Combining distantly related parents possessing desirable traits in the required intensity, but controlled by different set of genes, tends to ensure release of transgressive segregants (Quisenberry and Reitz, 1967). The appearance of transgressive progenies in F_2 is the function of the following favourable genetic situations associated with parents involved (Sharma, 1994)

a) the character must be polygenically controlled : b) parents must be completely homozygous : c) parents should be complementary to each other for the positive and negative genes conditioning the trait in point, and d) there should be no linkage.

Heterosis would not have been due to overdominance, hence segregants almost equal to F_1's could be isolated (Janossy and Lupton, 1976).

Among the four F_2 populations, very high frequency of 39.96 per cent transgressive segregants for average fruit weight (Fig.1) observed in the F_2 population of Arka Alok x W.94 30 ①. The same cross was also able to produce the highest (6.08%) transgressive segregants for yield per plant followed by Arka Alok x SP-2-2 (4.78%) (Fig. 2). The transgressive segregants in Arka Alok x W.94 30 ① were able to yield more than 2 kg per plant (Plate 8). This yield was on par with many of the hybrids. This kind of bacterial wilt resistant segregatnts with higher fruit weight have been reported by Monma *et al.* (1997).

5.6 HISTOPATHOLOGY OF RESISTANT AND SUSCEPTIBLE CULTIVARS

The pathogen *Ralstonia solanacearum* brings about several changes in the vascular tissues aftermath of its entry (Wallis and Truter, 1978). An attempt was made to investigate the histopathological changes in the main stem of resistant (L-15) and susceptible cultivar (Pusa Ruby) after root inoculation.

The studies revealed the formation of cavities in the xylem vessels caused by cell wall degradation (Plate 9). Such cavities were described by Buddenhagen and Kelman (1964) and were observed by Grimault *et al.* (1994). This is due to degradation of cell wall caused by pectionolytic and

Plate 5. Crop rotation with non hosts

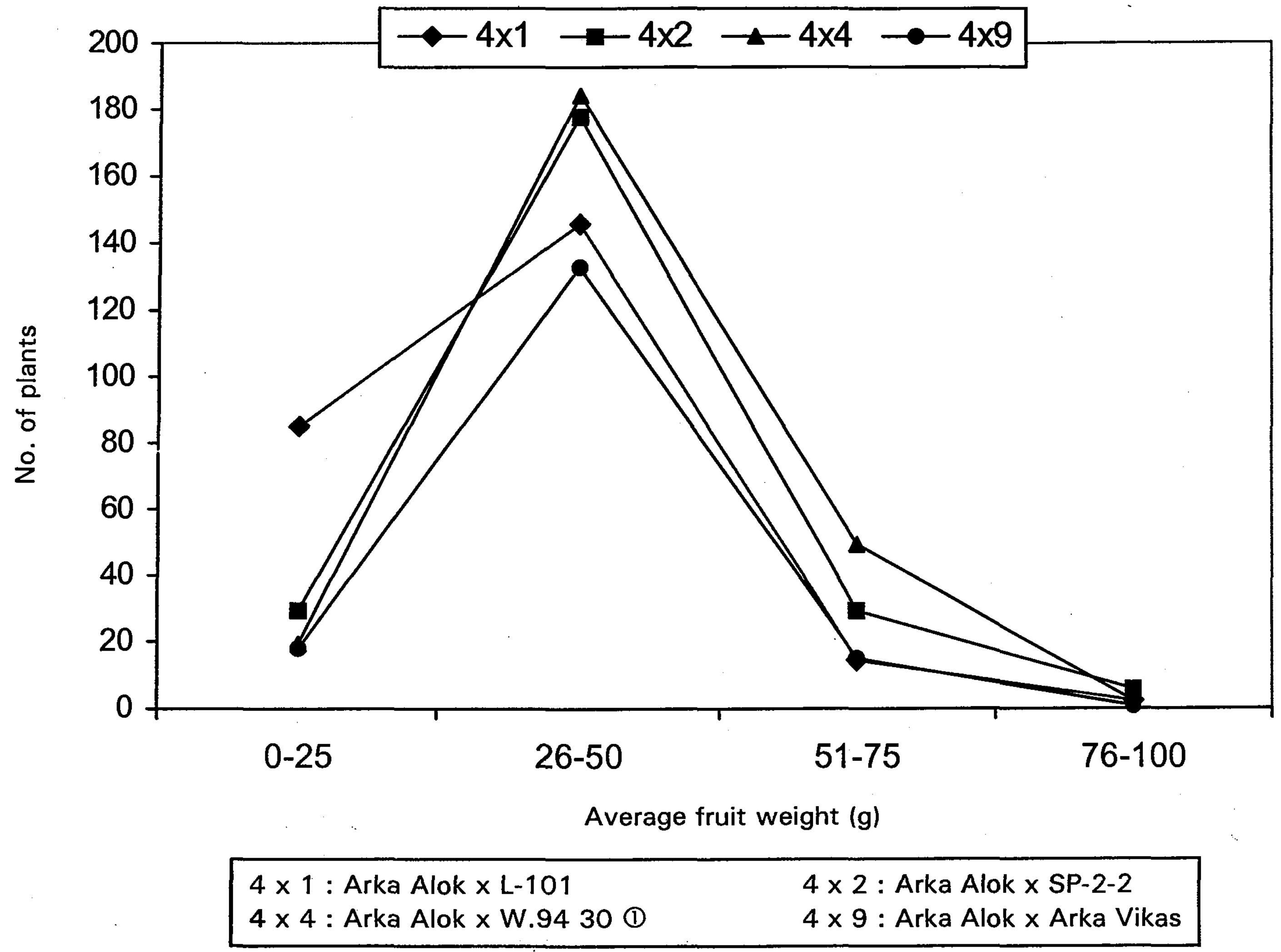
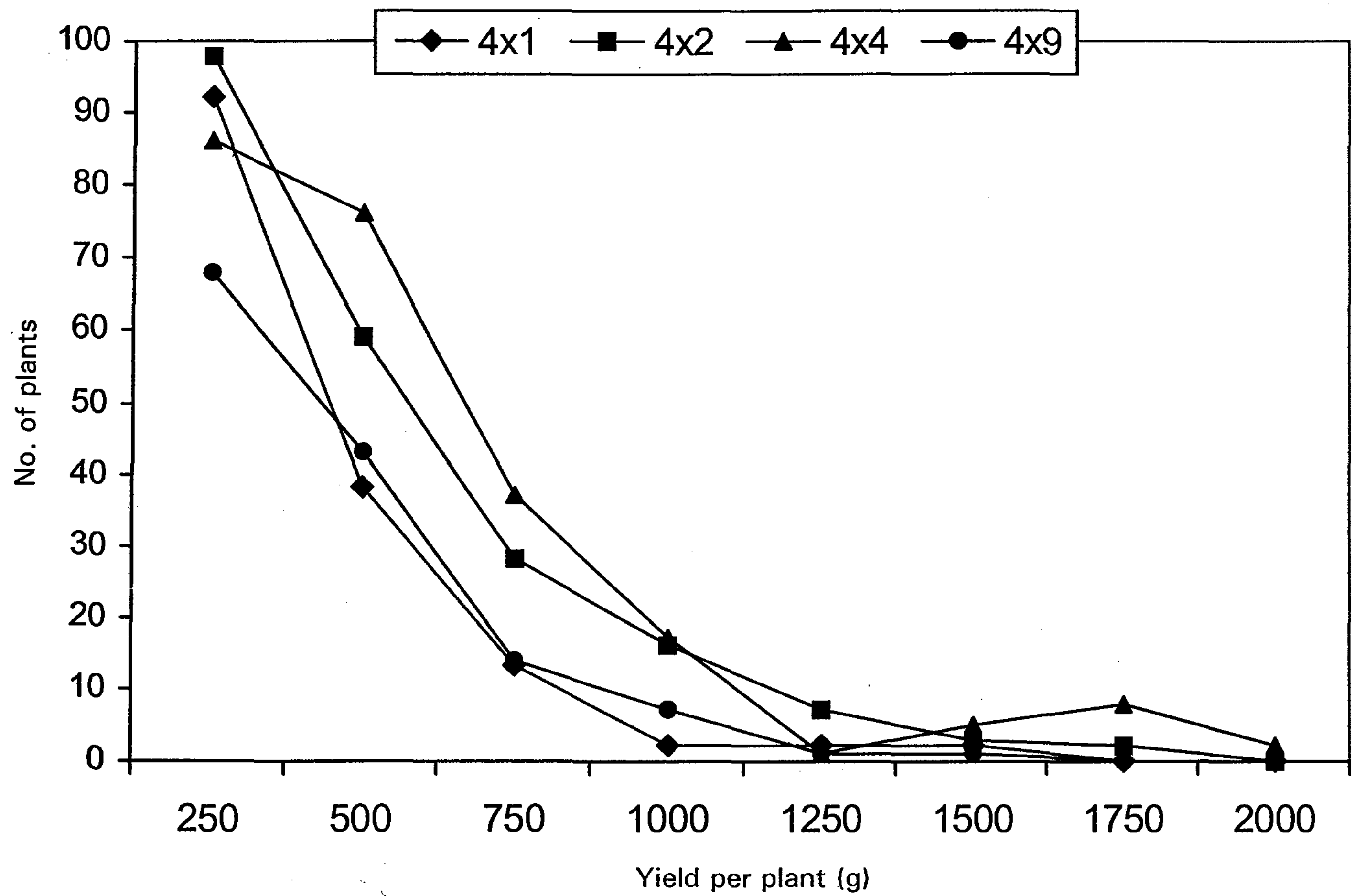


Fig.1: Frequency distribution for average fruit weight in four F_2 populations of tomato



4 x 1 : Arka Alok x L-101 | 4 x 2 : Arka Alok x SP-2-2
4 x 4 : Arka Alok x W.94 30 ① | 4 x 9 : Arka Alok x Arka Vikas

Fig.2: Frequency distribution for yield per plant in four F_2 populations of tomato

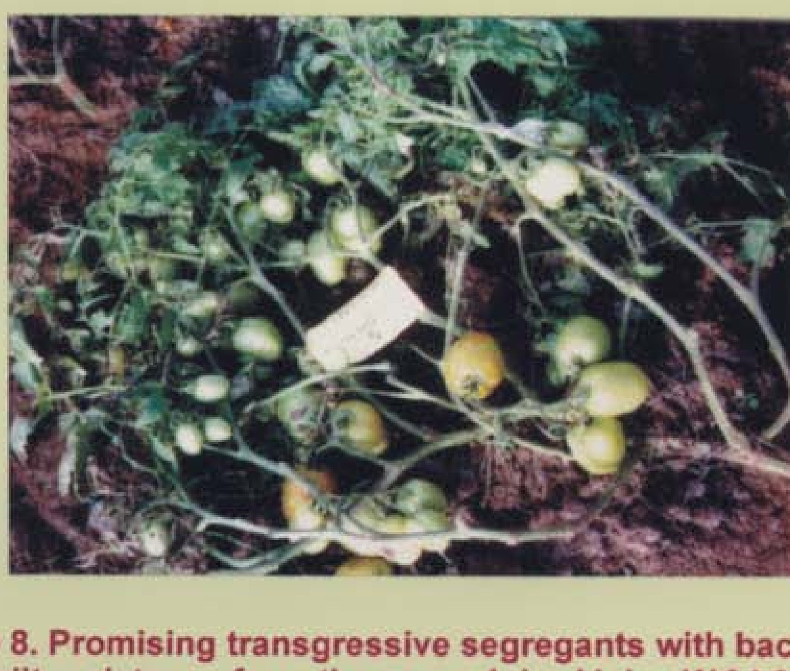


Plate 8. Promising transgressive segregants with bacterial wilt resistance from the cross Arka Alok x W.94 30 ①

cellulolytic enzymes. The degradation of cell wall perturbs sap flow and could contribute to wilt. Other histological changes such as aggregation of xylem vessels (Plate 10) in the wilting plant compared to normal distribution (Plate 11) of xylem vessels in the resistant plant may be in response to the pathogen entry. The bubble like structure (Plate 12) and the protrusion observed in the wilting plant may be the tyloses and perforation plates (Plate 13). These findings are in confirmity with Grimault *et al.* (1994).

Overall it can be inferred that Sonali, Arka Alok and Shakti can be used as donors in bacterial wilt resistance breeding programme. The cross combinations Arka Alok x SP-2-2 and Arka Alok x L-101 can be exploited in bacterial wilt prone areas as they showed high heterosis for yield and yield components and free from wilt incidence. The transgressive segregants with bacterial wilt resistance isolated can be used to develop pure lines after the population subjected to intense disease screening. For integrated management of bacterial wilt approaches like application of gypsum as soil amendment @ 187.5 kg ha^{-1} + crop rotations with non host crops like sorghum / maize + growing resistant genotypes for bacterial wilt would considerably reduce the bacterial wilt incidence to a manageable level.

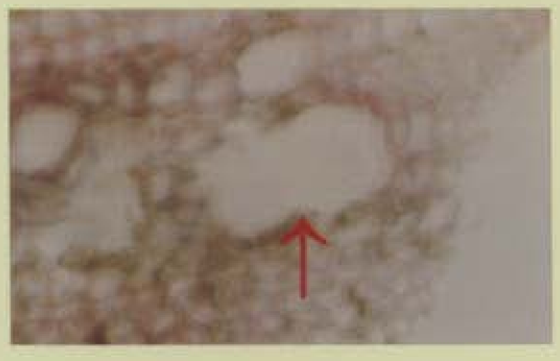


Plate 9. Cell wall degradation in xylem vessels forming cavity in the susceptible wilted plant

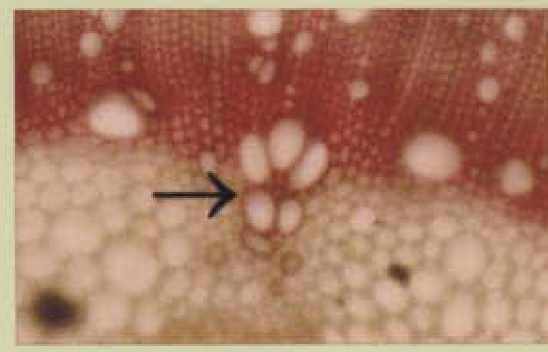


Plate 10. Aggregation of xylem vessels in the susceptible wilted plant

Plate 11. Normal distribution of xylem vessels in the resistant cultivar

Plate1 2. Bubble like structure in the xylem vessels of susceptible wilted plant

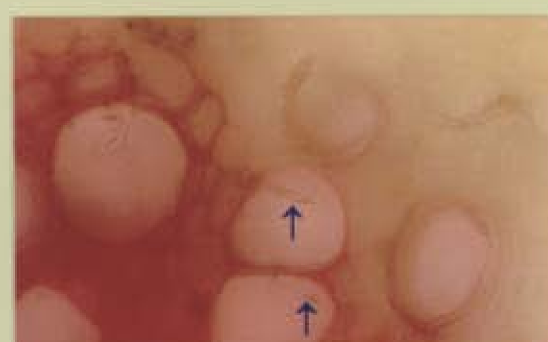


Plate 13. Perforation plates in the xylem vessels of susceptible wilted plant

FUTURE LINE OF WORK

Based on the present study the following suggestion are made in endeavouring to convert plant wealth to economic wealth :

1) The best three hybrids with resistance to bacterial wilt are Arka Alok x SP-2-2, Arka Alok x L-101 and L-15 x Arka Vikas should be tried on large scale trials for commercialization and stability,

2) Transgressive segregatns isolated in F_2 must be further selfed and selected to develop pure lines after the populations are subjected to intense disease screening,

3) Application of gypsum @ 187.5 kg ha^{-1} with resistant variety (L-15) which proved effective in reducing the bacterial wilt should be tried on large scale and also with other resistant varieties,

4) Efficacy of different soil amendments having Ca as one of the nutrients, need to be evaluated for reducing the wilt incidence along with resistant and susceptible genotypes,

5) The histological changes that occur in different parts of the plant (aerial, middle, collar and root) aftermath of pathogen entry need to be done under electron microscope, and

6) Other cereal crops should also be tried to reduce the bacterial wilt incidence.

Summary

VI. SUMMARY

The "Investigations on bacterial wilt resistance in tomato" were undertaken during 2000 to 2002 in the Olericulture Unit, Department of Horticulture, University of Agricultural Sciences, Dharwad. The study was mainly envisaged to find out the bacterial wilt resistant tomato genotype, utility of resistant genotype for the development of bacterial wilt resistant tomato hybrids with higher yield and quality, to understand the genetics of bacterial wilt resistance, to know the histological changes in bacterial wilt resistant (L-15) and susceptible (Pusa Ruby) genotypes and impact of crop rotation with non-hosts on wilt incidence.

The 212 genotypes were evaluated in field under epiphytotic conditions during 2002 (January to April). Out of 212 genotypes 57 genotypes were selected based on their *per se* performance and horticulture traits. The following five genotypes having resistance to bacterial wilt were used as female parents; L-15, Martha, Sonali, Arka Alok and Shakti. The 10 genotypes having higher fruit weight, other good horticultural traits and range of reaction to bacterial wilt were used as testers; L-101, SP-2-2, 88/Firm/J, W.94 30 ①, W.94 FM 59/7, L-50, 88/DT-14, DWD-1, Arka Vikas and Arka Saurabh in the crossing programme. All the 50 F_1's, parents (15) and commercial check US-1031 were evaluated in *kharif*, 2001 for resistance to bacterial wilt, yield and quality parameters.

All the 50 hybrids developed in the present investigations were having wide range of resistance to bacterial wilt. Among 50 hybrids, 24 hybrids were free from wilt incidence and five had 2.22 per cent wilt incidence. Thus, these 29 hybrids were superior compared to commercial check.

Considerable magnitude of heterosis was expressed in F_1's for yield and influencing characters. The three hybrids Arka Alok x SP-2-2 and Arka Alok x L-101 and L-15 x Arka Vikas qualify to be of commercial value as they manifested significant heterosis for yield and yield components with higher *per se* yield during both years.

Combining ability analysis for yield and yield components revealed that, yield is predominantly governed by non-additive gene effects while, the yield components governed by additive gene effects. The gca effects indicated that none of the parents were good general combiner for all the characters.

For long distance market the two fruit physical parameters *viz.*, number of locules per fruit and pericarp thickness play important role. So, when these two parameters were taken along with yield the cross L-15 x Arka Vikas was found good for this purpose.

For concentrated tomato products, Martha x DWD-1 enjoys a comfortable position. The two crosses *viz.*, L-15 x W.94 FM 59/7 and Martha x Arka Saurabh had the *per se* performance as per the specified standards required for processing. So they can be suggested for the utilisation for processing quality.

The inheritance of bacterial wilt resistance in Arka Alok x Arka Vikas has fit into a digenic ratio 9:7, suggesting a duplicate recessive gene interaction. Among the four F_2 populations, very high frequency of 39.96 per cent transgressive segregants for average fruit weight observed in the F_2 population of Arka Alok x W.94 30 ①. The same cross also thrown the highest (6.08%) transgressive segregants for yield per plant followed by Arka Alok x SP-2-2 (4.78%). The yield potential of some of the transgressive segregants in Arka Alok x W.94 30 ① was on par with many of the high yielding hybrids.

An insight into the impact of soil amendment on bacterial wilt incidence revealed that the gypsum level 187.5 kg ha^{-1} and other higher levels reduced the wilt incidence significantly compared to control and 125 kg ha^{-1}. With the resistant variety L-15, 187.5 kg gypsum ha^{-1} is sufficient to bring down the wilt incidence. In both the years the calcium content was significantly higher in resistant variety (L-15) compared to Pusa Ruby.

The histopathological investigations revealed the formation of cavities in the xylem vessels by cell wall degradation. Other histological changes observed in the wilting plant of susceptible cultivar Pusa Ruby were: aggregation of metaxylem vessels; formation of perforation plates and formation of tylose like structure in few of the xylem vessels.

When the two non-host crops maize and sorghum were used in the crop rotation experiment, the wilt incidence has reduced to 45.72 and 43.57 per cent from its initial incidence of 67.14 and 67.85 per cent respectively.

From these results it could be concluded that the three hybrids Arka Alok x SP-2-2, Arka Alok x L-101 and L-15 x Arka Vikas having higher yield and bacterial wilt resistance need to be commercialised. For integrated management of bacterial wilt approaches like application of gypsum as soil amendment @ 187.5 kg ha^{-1} + crop rotations with non host crops like sorghum / maize + growing resistant genotypes for bacterial wilt would considerably reduce the bacterial wilt incidence to a manageable level.

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Appendices

Appendix I : Meteorological data for the cropping season (2000-2002) and average of 50 years (1950-1999) as recorded at meteorological observatory, Main Agricultural Research Station, University of Agricultural Sciences, Dharwad

Month	Rainfall (mm)				Relative humidity (%)				Temperature (°C)							
									Maximum				Minimum			
	1950-1999	2000	2001	2002	1950-1999	2000	2001	2002	1950-1999	2000	2001	2002	1950-1999	2000	2001	2002
January	0.11	0.00	0.00	0.00	66.37	48.00	55.00	55.00	30.45	30.00	29.90	30.10	14.60	15.10	15.00	14.50
February	0.00	0.00	0.00	62.70	56.71	52.00	50.00	57.00	32.26	32.20	34.00	31.90	15.68	15.70	16.80	17.90
March	7.45	0.00	0.00	0.00	56.62	47.00	45.00	49.00	35.80	35.20	35.30	36.00	18.80	18.50	18.50	20.00
April	42.90	44.10	52.10	67.00	60.46	57.00	55.00	53.00	38.23	37.30	35.70	37.20	21.40	21.50	22.00	21.70
May	85.92	45.40	23.10	57.90	81.32	67.00	59.00	62.00	36.64	33.90	34.80	34.90	21.47	21.10	21.50	23.00
June	111.50	50.70	32.50	60.50	88.39	79.00	75.00	80.00	29.76	29.00	30.30	29.60	21.21	21.30	21.30	21.90
July	156.09	125.20	33.10	15.00	88.39	81.00	81.00	79.00	27.05	26.80	26.80	28.40	21.40	20.40	21.10	21.30
August	103.31	50.40	58.10	48.10	86.84	81.00	81.00	82.00	27.08	27.20	27.20	26.60	20.66	20.20	20.90	20.50
September	99.47	132.10	53.60	6.60	83.25	76.00	72.00	73.00	29.39	29.00	30.10	29.80	20.15	20.10	20.20	20.00
October	135.79	88.30	17.00	103.60	76.23	77.00	65.00	67.00	30.84	29.50	30.10	30.70	19.76	20.20	19.90	20.40
November	34.38	0.00	0.00	7.00	68.39	63.00	55.00	62.00	29.50	30.40	31.00	17.10	16.33	16.90	17.90	30.50
December	6.35	3.00	0.00	-	64.41	58.00	55.00	47.00	29.65	28.30	29.60	14.40	13.48	13.40	13.70	30.20
Total	**783.29**	**539.20**	**269.60**	**429.00**	-	-	-	-	-	-	-	-	-	-	-	-

Appendix II. Physical and chemical properties of the soil of experimental site

Sl. No.	Particulars	Value obtained	Method adopted
I.	**Physical properties**		
1.	Coarse sand	28.00%	International Pipette Method (Piper, 1966)
2.	Fine sand	29.20%	
3.	Silt	7.60%	
4.	Clay	35.20%	
II.	**Chemical properties**		
1.	Organic carbon	0.46%	Wet oxidation method (Jackson, 1973)
2.	Available nitrogen (N) (Kg/ha)	233.00	Alkaline permanganate method (Subbaiah and Asija, 1959)
3.	Available phosphorus (P_2O_5) (kg/ha)	31.00	Olsen's Method (Jackson, 1973)
4.	Available potassium (K_2O) (kg/ha)	296.00	NH_4OAC Extract method (Jackson, 1973)
III.	**Soil pH (1.2.5 soil water extract)**	6.70	pH meter (Piper, 1966)

Appendix III. *Per se* performance of tomato genotypes

Genotypes		Plant height (cm)	No. of primary branches/plant	Days to 50% flowering	No. of flowers/ cluster	No. of cluster/ plant	No. of fruits/cluster	No. of fruits /plant	Average fruit weight (g)	Yield/plant (kg)	TSS (%)	Wilt incidence* (%)
1	2	3	4	5	6	7	8	9	10	11	12	13
1	C x D / 2-4	53.80	4.75	44.00	4.75	9.50	2.80	26.35	26.24	0.70	3.50	19.98 (26.49)
2	C x D / 6-4	53.35	4.00	42.50	3.10	7.50	2.20	15.20	54.75	0.83	3.75	36.63 (37.21)
3	C x D / 3-15	52.95	4.50	43.00	4.25	6.30	2.50	16.50	52.19	0.86	3.25	16.65 (23.94)
4	C x D / 9-8-3	50.15	4.00	45.50	3.25	9.25	2.10	18.55	45.81	0.85	3.25	23.31 (28.77)
5	C x D / 8-4-2	53.75	4.50	48.50	4.50	8.50	2.65	21.35	44.17	0.94	3.00	26.64 (30.87)
6	C x D / 1-10-8	62.20	4.00	47.00	4.00	7.00	2.00	15.60	38.73	0.60	4.00	29.97 (33.15)
7	C x D / 1-11-3	61.50	4.00	43.50	5.75	8.00	2.75	21.75	33.53	0.73	3.75	16.65 (23.94)
8	C x D / 10-13-3	47.20	4.65	47.50	3.40	7.50	2.10	16.20	40.53	0.66	3.00	53.28 (46.88)
9	C x D / 1-9	52.15	4.40	39.50	4.00	7.50	2.05	14.70	36.60	0.54	3.00	29.97 (33.15)
10	C x D / 1-15-1	47.85	4.50	49.50	4.25	5.00	2.10	11.10	53.60	0.59	4.75	39.96 (39.15)
11	C x D / 2-12	65.30	4.65	49.00	5.00	7.70	2.00	14.85	38.41	0.57	3.25	36.63 (37.21)
12	C x D / 1-1	57.85	3.00	42.50	5.00	7.60	2.00	14.80	41.95	0.62	3.50	16.65 (23.94)
13	C x D / 1-3	60.35	4.10	43.50	4.85	9.00	2.00	17.00	37.99	0.64	3.75	36.63 (37.21)
14	C x D / 3-14	63.45	5.15	46.50	3.65	11.05	2.00	21.00	36.68	0.77	4.25	23.31 (28.77)
15	B x O / 2-21	51.05	4.00	47.00	4.75	9.15	2.35	20.70	40.29	0.84	3.25	43.29 (41.11)
16	B x O / 3-9-1	58.55	3.75	46.50	4.95	10.00	2.35	21.95	58.69	1.29	3.50	36.63 (37.21)
17	B x O / 7-15P	59.45	3.00	48.00	6.15	10.50	2.55	25.20	32.10	0.81	3.50	36.63 (37.21)
18	B x O / 3-1	77.80	3.25	47.50	5.00	7.70	3.75	25.85	42.77	1.09	5.75	63.27 (52.71)
19	B x O / 3-8-3	63.70	4.50	44.50	4.15	6.50	2.50	18.75	44.44	0.83	3.65	29.97 (33.15)
20	B x O / 6-21-1	62.30	5.85	46.50	4.80	6.00	2.50	16.00	49.95	0.80	3.80	49.95 (44.94)
21	B x O / 7-17-1	50.75	6.25	42.50	3.95	13.00	2.50	32.10	19.54	0.63	4.25	43.29 (41.11)
22	B x O / 5-21-5	47.05	5.25	44.00	4.00	8.00	2.10	16.00	47.22	0.75	3.75	53.28 (46.88)
23	B x O / 2-24	60.55	5.05	47.50	5.00	7.50	2.25	16.55	44.15	0.73	4.15	49.95 (44.94)
24	B x O / 6-22	50.20	3.85	46.00	4.75	8.50	2.05	16.10	46.07	0.74	4.75	63.27 (52.71)
25	B x O / 1-17	47.65	5.15	44.50	5.00	9.50	3.00	27.90	29.95	0.84	5.70	29.97 (33.15)
26	B x O / 3-8	41.85	5.25	40.50	4.85	7.00	2.15	14.90	40.20	0.60	5.15	49.95 (44.94)
27	B x O / 3-2	58.45	4.85	45.50	4.15	10.00	2.25	21.40	31.93	0.68	4.25	63.27 (52.71)
28	B x O / 3-9	55.45	4.55	41.00	3.90	7.50	2.35	18.05	63.42	1.14	3.00	29.97 (33.15)
29	B x O / 6-23	50.85	4.20	40.50	5.05	12.20	2.50	28.75	21.93	0.63	3.25	43.29 (41.11)
30	DWD-2 (D)	53.25	5.10	47.00	4.40	9.00	2.25	18.50	52.50	0.97	4.55	09.99 (18.14)
31	A x O / 11-18-6	58.30	5.50	41.50	5.45	6.00	3.00	19.15	47.31	0.90	4.75	16.65 (23.94)
32	A x O / 1-7	48.25	4.75	43.00	4.35	8.25	2.00	15.65	37.95	0.59	4.15	13.32 (21.39)
33	A x O / 14-18-1	51.35	4.00	43.50	3.70	8.10	2.40	18.30	41.76	0.76	3.25	19.98 (26.49)
34	A x O / 5-21-4	61.60	5.75	42.50	4.45	10.00	2.00	18.25	37.20	0.68	4.35	23.31 (28.77)
35	A x O / 4-2	47.15	4.00	42.50	5.80	10.70	2.50	22.75	35.18	0.80	3.30	29.97 (33.15)

Contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
36	A x O / 1-17-1	46.25	4.80	44.00	4.25	6.65	2.10	12.40	55.44	0.68	4.10	16.65 (23.94)
37	A x O / 14-13-9	52.50	4.00	47.00	5.00	8.55	2.00	16.55	40.42	0.67	4.50	19.98 (26.22)
38	A x O / SP-3	44.00	3.50	44.00	4.75	7.55	2.15	15.50	44.44	0.69	3.25	46.62 (43.00)
39	A x O / 16-7	52.25	3.50	47.00	4.75	7.30	2.35	16.20	37.45	0.61	3.20	16.65 (23.94)
40	A x O / 1-11	54.50	4.00	45.50	5.00	8.75	2.20	18.30	38.69	0.71	3.25	36.63 (37.21)
41	A x O / SP-1	51.00	5.00	45.00	5.00	8.55	2.00	15.35	52.89	0.90	3.25	53.28 (46.88)
42	A x O / 9-14-3	52.00	6.05	46.50	6.00	10.60	2.75	25.20	35.71	0.90	3.10	09.99 (18.14)
43	A x O / 11-8-3	53.50	5.00	47.50	6.50	6.25	2.75	17.05	33.63	0.57	4.20	43.29 (41.11)
44	A x O / 14-8-1-P	61.13	4.75	47.00	5.00	5.90	3.50	20.00	36.40	0.58	3.15	06.66 (14.89)
45	A x O / 90-7-8	57.50	5.00	44.50	5.00	6.20	2.00	13.00	60.59	0.79	4.15	16.65 (23.94)
46	S-22	80.03	5.50	49.50	5.00	10.05	2.55	24.15	42.47	1.03	4.25	36.63 (37.21)
47	GKVK-24	66.80	5.00	47.50	5.25	8.50	3.00	25.10	22.45	0.57	4.00	29.97 (33.15)
48	86/15-1-3	56.38	7.00	43.50	5.90	11.15	2.75	30.59	31.99	0.99	3.75	29.97 (33.15)
49	L-22	65.75	5.00	47.00	6.75	9.15	2.20	20.40	42.99	0.88	3.00	36.63 (37.21)
50	L-35	50.50	5.00	47.00	5.25	8.20	2.60	18.70	24.65	0.46	2.25	49.95 (44.94)
51	L-15	48.00	5.00	48.00	5.50	9.20	2.75	24.55	25.20	0.61	3.10	26.64 (31.05)
52	L-27	51.88	5.75	44.50	4.90	11.75	2.00	20.75	37.02	0.76	3.75	63.27 (52.71)
53	L-16	62.00	5.50	46.00	5.55	14.10	3.50	43.80	20.09	0.88	3.00	23.31 (28.77)
54	PRD-7	53.63	6.00	45.00	5.33	12.10	3.00	34.30	19.50	0.69	4.75	49.95 (44.94)
55	Punjab Chhuhara	81.88	6.00	44.50	5.00	13.50	2.75	36.15	24.96	0.89	4.00	63.25 (52.71)
56	79B1390 (O)	47.00	5.55	45.00	4.85	10.50	3.00	29.85	22.73	0.68	4.50	36.63 (37.21)
57	L-15-9	49.50	5.00	43.50	4.70	11.85	2.75	28.90	21.75	0.63	4.25	16.65 (23.94)
58	L-52	48.83	5.00	44.00	4.80	16.70	3.10	49.50	16.71	0.85	4.25	23.31 (28.77)
59	L-58	51.63	5.50	46.50	5.10	11.85	3.35	36.00	23.76	0.88	5.50	46.62 (43.05)
60	L-5	48.00	4.95	46.50	5.00	7.50	2.60	19.75	31.69	0.61	3.25	63.27 (52.71)
61	L-4	47.65	4.45	44.00	5.75	7.50	2.50	17.10	33.89	0.58	4.25	49.95 (44.94)
62	UC-204B (B)	82.85	4.60	47.00	4.90	10.00	2.10	22.35	30.97	0.69	5.00	36.63 (37.21)
63	A x O / 5-2-P	49.15	5.00	45.00	4.85	11.50	2.00	22.65	35.53	0.81	4.75	09.99 (18.14)
64	C x O / SP-2R	51.10	5.00	45.00	4.50	12.00	2.00	21.65	28.37	0.81	4.25	29.97 (33.15)
65	B x O / 7-3-P	41.75	4.85	46.50	4.50	6.75	2.75	15.70	62.55	0.98	3.25	43.29 (41.11)
66	C x D / 4-1-P	41.50	5.20	49.00	4.25	8.50	2.25	14.65	45.99	0.66	2.25	29.97 (33.15)
67	C x D / 7-9-P	44.00	4.75	47.00	5.00	7.00	2.15	14.30	50.62	0.72	4.00	16.65 (23.94)
68	A x O / 6-23-2-P	42.75	5.00	53.50	4.60	6.00	2.40	13.80	53.33	0.72	5.75	49.95 (44.94)
69	C x D / 1-8	43.00	4.50	56.50	5.00	6.75	2.25	14.40	48.14	0.69	4.75	49.95 (44.94)
70	L-15-10	47.50	5.00	45.00	5.50	6.30	2.90	23.85	35.95	0.86	4.75	16.65 (23.94)
71	L-54	44.00	5.00	45.50	4.45	9.00	2.00	16.40	37.87	0.62	6.75	09.99 (18.14)
72	TRSA	52.00	4.50	45.50	5.00	9.05	1.90	15.35	40.57	0.63	4.75	43.29 (41.11)

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1	2	3	4	5	6	7	8	9	10	11	12	13
73	L-15-2	52.00	4.00	48.50	5.25	7.70	2.45	17.10	42.71	0.73	4.75	16.65 (23.94)
74	B x O / 7-17-9	49.25	4.00	51.00	4.50	7.00	2.00	13.15	57.24	0.76	5.25	29.97 (33.15)
75	L-43	43.50	4.00	45.00	5.00	5.60	3.20	17.65	36.18	0.64	4.20	43.29 (41.11)
76	A x O / 14-8-4	62.25	4.25	48.50	4.75	13.10	2.00	25.25	32.65	0.83	4.25	23.31 (28.77)
77	L-12	49.50	4.50	47.50	4.00	7.20	3.00	20.95	29.94	0.63	4.65	63.27 (52.71)
78	Marikrit	48.50	5.25	46.50	4.00	13.25	2.00	24.95	33.48	0.84	4.50	0.00 (0.02)
79	L-7	51.00	5.50	49.50	4.25	9.40	3.00	27.00	24.37	0.66	4.75	16.65 (23.94)
80	L-23	48.75	5.00	45.00	5.00	7.25	2.50	16.60	36.19	0.60	4.75	23.31 (28.77)
81	L-6	48.00	4.00	47.50	4.00	7.70	2.20	14.80	54.36	0.80	4.20	43.29 (41.11)
82	L-33	44.85	5.00	49.00	4.25	9.15	3.00	26.20	25.88	0.69	4.65	13.32 (20.69)
83	L-3	49.40	5.50	47.00	5.00	9.45	3.10	28.65	20.15	0.58	5.50	29.97 (33.15)
84	L-14	49.40	4.80	43.50	5.15	9.00	2.05	16.50	51.97	0.85	4.25	49.95 (44.94)
85	L-19	52.60	5.60	43.50	5.35	8.30	3.10	23.50	28.84	0.68	4.45	36.63 (37.21)
86	T-19	78.35	5.00	44.00	5.50	9.45	3.20	28.45	33.77	0.96	3.35	33.30 (35.24)
87	L-18	63.50	4.00	46.00	6.50	9.00	3.05	25.75	42.65	1.09	3.25	16.65 (23.94)
88	L-17	60.35	4.00	47.00	6.50	9.90	3.10	29.05	19.06	0.55	3.00	29.97 (33.15)
89	L-24	46.95	5.90	45.50	6.10	7.70	2.80	19.40	40.31	0.78	3.25	63.27 (52.71)
90	L-8	62.30	4.60	46.00	6.00	7.75	2.50	20.25	51.98	1.05	3.50	29.97 (33.15)
91	L-36	58.00	5.50	44.50	5.50	7.50	3.00	21.70	37.98	0.83	3.25	29.97 (33.15)
92	AVRDC	59.50	4.50	46.00	5.80	11.15	3.10	31.50	29.59	0.87	3.75	43.29 (41.11)
93	L-42	50.35	4.50	46.00	4.65	9.10	2.05	16.20	59.03	0.95	4.25	36.63 (37.21)
94	L-50	81.65	5.50	47.50	4.50	12.10	2.10	21.75	66.95	1.45	3.75	09.99 (18.14)
95	L-20	62.45	4.95	42.50	5.05	9.50	3.20	29.90	30.36	0.91	4.50	16.63 (23.94)
96	DWD-1 (C)	72.20	6.40	50.00	4.50	11.00	2.10	20.30	51.78	1.10	3.25	13.32 (20.69)
97	L-60	61.75	5.00	46.00	4.50	11.00	3.05	30.70	27.46	0.84	4.10	29.97 (33.15)
98	A x O / 13-15-44P	64.00	3.75	45.50	4.45	15.25	2.30	32.55	26.20	0.85	4.40	33.30 (35.11)
99	W.B x O / 7-17-29	56.35	5.65	47.00	5.45	9.40	3.00	26.35	34.43	0.91	4.90	36.63 (37.21)
100	W.B x O / 7-17-51	63.65	4.00	48.00	4.55	10.75	3.05	29.25	39.30	1.15	4.15	23.31 (28.77)
101	W.94 FM 59/7	60.55	4.90	46.50	3.70	11.70	2.50	27.60	56.33	1.56	5.00	09.99 (18.14)
102	W.C x D FM	86.45	5.65	47.50	4.10	10.60	2.05	20.45	48.15	0.98	3.80	16.65 (23.94)
103	A x O FM	73.65	5.00	45.50	5.05	12.45	2.50	29.85	36.02	1.08	4.75	23.31 (28.77)
104	W.C x O / SP-2-2	64.15	5.95	46.00	4.90	9.75	2.50	23.10	47.14	1.08	4.25	16.65 (23.94)
105	W.94.30 ⓘ	74.30	5.40	47.00	5.05	12.15	2.90	32.50	44.98	1.46	4.00	23.31 (28.77)
106	78/5	76.75	5.75	47.00	4.55	12.55	2.05	23.40	53.40	1.25	3.65	63.27 (52.71)
107	Ç x D / 17-5-17	81.95	4.45	46.50	5.05	7.60	2.00	14.95	86.13	1.28	4.75	39.96 (39.17)
108	A x O / SP-1-2	66.55	5.05	49.50	5.10	10.55	2.30	22.75	54.47	1.24	4.75	16.65 (23.94)
109	A x O / 7	62.35	5.05	47.00	4.55	14.15	2.70	36.85	31.71	1.17	4.20	09.99 (18.14)

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1	2	3	4	5	6	7	8	9	10	11	12	13
110	82 / 3	47.65	5.60	45.50	4.10	11.00	3.05	34.50	21.00	0.73	4.15	49.95 (44.94)
111	FM 82/3	49.95	6.10	44.00	4.85	10.75	2.45	23.55	38.95	0.88	4.25	56.61 (46.77)
112	74/2	46.95	5.10	47.00	3.70	9.50	2.10	18.65	31.48	0.58	5.50	29.97 (33.15)
113	L-83	48.10	4.70	48.00	4.15	8.40	2.05	16.30	58.36	0.95	4.25	66.60 (54.77)
114	A x O / 21-FM	52.70	5.65	49.50	4.15	9.65	2.10	19.70	67.84	1.34	3.75	13.32 (21.39)
115	C x D / 10-175-59	57.00	6.05	50.00	4.85	13.65	2.20	28.85	46.46	1.34	4.15	19.98 (26.49)
116	78/5	63.70	4.85	48.50	4.90	7.55	2.15	16.15	64.85	1.04	4.65	63.27 (52.71)
117	SP-2-2	72.05	6.15	45.50	4.20	10.80	2.15	22.45	49.19	1.10	4.75	3.33 (7.45)
118	78 P_2	57.55	4.05	53.00	4.00	13.45	2.75	34.75	22.88	0.79	5.25	63.27 (52.84)
119	C x D / 17-5-30	54.40	5.05	47.00	7.00	9.80	3.10	28.85	27.42	0.75	5.50	16.65 (23.94)
120	C x D / 17-5-17-2	66.75	4.30	47.50	4.50	8.70	2.70	21.30	38.76	0.83	5.25	63.28 (52.71)
121	B x O / 7-17-1-41	80.95	5.20	46.50	4.45	10.25	2.40	22.10	31.84	0.71	5.00	38.63 (37.21)
122	B x O / 7-17-34P	64.00	5.10	46.00	5.05	9.25	2.35	20.10	47.13	0.94	4.75	23.31 (28.77)
123	FM 83/G	56.20	4.55	47.00	5.05	9.35	2.75	24.20	42.43	0.99	4.75	63.28 (52.71)
124	A x O / 13-5-38-2	52.90	4.70	47.50	3.95	11.70	2.15	24.45	36.49	0.89	4.65	16.65 (23.94)
125	A x O / 14-8-84-2	60.55	5.30	48.00	3.40	8.75	2.90	24.40	52.68	1.25	4.90	19.98 (26.49)
126	73/47	51.75	5.90	43.50	4.05	11.30	2.00	20.80	50.84	1.06	4.70	13.32 (21.39)
127	79/64	46.90	5.05	46.00	4.65	12.65	2.20	26.40	37.82	1.00	4.75	63.26 (52.71)
128	B x O / 7-17-24	52.95	5.85	47.00	5.30	11.20	3.05	31.80	24.29	0.77	5.50	56.63 (48.80)
129	PKM-1	62.00	5.10	43.00	4.50	9.60	2.25	20.20	39.95	0.81	4.70	36.63 (37.21)
130	87/17-1-22-3-22	62.05	5.95	48.00	4.90	8.75	2.90	24.20	38.07	0.92	4.70	36.63 (37.21)
131	Sonali	82.15	6.25	48.00	5.15	8.10	3.20	25.15	33.78	0.65	4.95	0.00 (0.02)
132	L-31	57.75	5.10	50.00	6.65	7.10	3.20	20.80	41.73	0.85	5.15	19.98 (26.49)
133	Alcobasa	56.65	3.90	49.50	5.65	7.60	2.50	17.75	38.67	0.68	4.75	49.97 (44.97)
134	004	46.10	4.85	46.00	9.50	7.15	4.00	30.10	31.33	0.94	5.20	26.64 (31.05)
135	AVRDC Alcobasa	56.75	4.55	46.50	4.55	7.45	2.15	15.95	45.63	0.72	5.40	29.97 (33.15)
136	Marutham	75.40	4.90	44.50	5.00	7.10	2.40	16.40	44.91	0.74	4.65	36.63 (37.21)
137	L-29	44.10	4.65	47.00	5.00	6.40	2.10	13.25	60.01	0.79	4.75	43.29 (41.11)
138	L-28	65.05	4.55	46.00	5.15	7.75	3.15	23.65	37.94	0.60	4.75	16.65 (23.94)
139	20/5 Alcobasa	72.50	4.20	47.50	5.15	9.35	2.20	19.10	39.98	0.76	5.40	43.28 (52.71)
140	20/6 Alcobasa	65.75	4.15	43.00	5.15	10.45	2.10	19.60	40.60	0.80	5.75	26.64 (31.05)
141	L-57	46.70	4.60	47.50	4.95	7.05	2.20	15.15	45.46	0.69	5.05	69.93 (56.76)
142	L-38	51.00	4.10	44.00	5.10	8.00	3.10	23.10	29.33	0.68	3.25	43.29 (41.11)
143	L-59	52.25	5.95	45.00	6.70	9.70	2.55	23.75	57.99	1.37	4.15	63.28 (52.71)
144	L-49	52.95	4.40	44.50	6.10	8.05	3.00	23.25	35.44	0.81	3.25	49.95 (44.94)
145	L-10	52.20	3.15	43.50	7.05	5.35	3.15	17.30	40.45	0.70	4.15	13.32 (21.39)
146	L-25	64.05	3.00	46.00	5.10	6.90	2.90	19.20	34.30	0.64	3.20	13.32 (20.69)

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1	2	3	4	5	6	7	8	9	10	11	12	13
147	L-28	55.80	4.05	43.50	7.00	6.60	2.35	14.90	42.03	0.61	5.25	49.95 (44.94)
148	L-2	51.40	4.15	48.50	4.10	8.15	2.55	20.15	36.71	0.73	4.75	23.31 (28.77)
149	L-30	55.60	2.50	47.00	5.10	7.65	2.65	19.90	38.45	0.77	3.25	29.97 (33.15)
150	L-31	58.15	3.10	48.50	5.15	7.15	2.90	19.05	38.44	0.73	2.80	09.99 (18.14)
151	L-9	53.25	4.00	48.00	4.95	7.85	2.50	18.60	37.74	0.69	2.75	36.63 (37.21)
152	L-1	52.30	4.10	43.00	5.00	6.50	2.85	16.60	42.53	0.70	3.40	29.97 (33.15)
153	L-32	98.55	7.10	48.00	5.85	9.55	3.15	27.95	30.32	0.85	4.05	16.65 (23.94)
154	L-10	42.30	5.05	44.00	4.55	7.85	3.15	23.40	29.94	0.70	3.65	56.61 (48.77)
155	L-19	52.95	4.65	48.00	5.75	9.35	2.60	23.35	29.84	0.69	3.30	23.31 (28.77)
156	L-15 W-11	50.85	4.50	46.50	8.05	7.10	2.50	15.50	60.13	0.93	3.25	13.32 (21.39)
157	L-15-4	51.60	4.00	48.50	5.50	8.60	2.50	20.25	34.21	0.68	3.30	16.65 (23.94)
158	L-15-6	50.85	3.95	52.50	6.60	9.65	3.20	29.20	23.22	0.68	3.25	19.98 (26.49)
159	L-15-5	54.15	5.05	47.00	6.95	7.90	3.50	25.25	23.23	0.58	2.75	16.65 (23.94)
160	88/AVRDC	50.65	4.85	52.00	4.55	8.50	1.90	14.65	38.57	0.57	4.35	23.31 (28.77)
161	008	66.60	5.05	49.50	4.50	9.30	2.30	20.80	30.94	0.64	4.85	63.27 (52.71)
162	001	69.90	5.55	46.50	3.60	9.50	2.15	18.25	45.16	0.82	3.75	13.32 (21.39)
163	Bush	75.60	4.15	46.00	4.30	10.10	2.15	20.65	32.37	0.67	4.80	19.98 (26.49)
164	Tomato PR	53.95	4.10	46.50	5.50	9.50	2.90	26.20	29.56	0.77	4.15	49.95 (44.94)
165	007	47.25	4.10	44.00	5.20	9.00	2.85	24.90	45.23	1.13	4.75	29.97 (33.15)
166	L-15 W-8	45.05	4.10	45.00	5.10	11.60	2.75	29.75	36.09	1.08	4.25	13.32 (21.39)
167	88/L-15/DT-2	49.20	3.65	46.50	5.00	8.15	2.40	18.75	37.90	0.71	3.75	16.65 (23.94)
168	88/L-15/DT-8	56.75	4.50	46.00	5.55	9.10	3.20	28.80	27.68	0.80	4.90	23.31 (28.77)
169	N-229-8MF	51.95	3.90	48.00	5.55	9.20	3.00	25.90	32.63	0.85	3.15	29.97 (33.15)
170	88/Petoproc/J	55.00	4.45	48.50	5.50	9.85	3.10	28.20	29.48	0.83	4.15	16.65 (23.94)
171	AVRDC Type	66.55	5.00	47.00	4.50	10.35	2.25	22.85	40.26	0.92	3.25	56.61 (48.77)
172	L-15/DT-13	64.35	5.20	48.50	5.00	10.90	2.45	24.15	39.10	0.94	4.10	19.98 (26.49)
173	17-3-4	72.65	4.90	46.00	5.10	6.65	2.00	12.10	61.27	0.73	3.75	43.30 (41.11)
174	L-15 W12	87.20	4.15	45.50	5.60	9.70	2.10	19.00	58.85	1.12	4.10	16.65 (23.94)
175	L-15 / DT-10	70.60	4.00	45.00	5.00	6.00	2.00	12.45	65.95	0.83	4.15	13.32 (21.39)
176	L-15 / DT-1	72.05	5.00	46.00	4.70	8.90	3.00	26.15	35.20	0.92	3.25	09.99 (18.14)
177	L-15 W 10	87.95	4.45	45.50	4.50	10.70	2.05	19.60	38.87	0.76	3.65	23.31 (28.77)
178	L-15 / DT-9	62.95	4.55	46.00	4.60	6.10	2.50	14.00	53.54	0.74	3.30	19.98 (26.49)
179	L-15 W-7	66.35	5.30	47.00	4.55	10.00	2.40	22.00	50.16	1.10	3.75	09.99 (18.14)
180	L-15 / DT-4	61.45	4.95	55.50	4.60	8.65	2.10	11.45	59.68	0.69	3.15	16.65 (23.94)
181	L-15 / DT-6	62.10	4.90	43.00	4.55	5.40	2.40	11.80	76.84	0.91	4.25	13.32 (20.69)
182	L-15 / DT-11	62.85	4.70	45.50	4.55	5.55	2.30	13.55	74.59	1.01	3.75	13.32 (21.39)
183	88 / Petoproc	62.20	4.55	44.00	4.45	9.20	2.00	17.40	44.94	0.78	4.10	23.31 (28.77)

Contd...

1	2	3	4	5	6	7	8	9	10	11	12	13
184	88 / DT-14	67.35	6.70	45.00	5.15	11.40	2.20	22.90	55.08	1.26	3.30	13.32 (21.39)
185	88 / Firm/J	75.05	6.25	44.00	4.80	10.40	2.40	23.20	49.51	1.13	3.70	19.98 (26.49)
186	88 / DT-12	64.70	4.50	47.00	4.00	11.35	2.50	27.35	40.89	1.12	4.30	09.99 (18.14)
187	BF / F/J Firm	60.35	5.20	49.00	5.05	7.10	2.50	18.00	60.06	1.07	4.25	49.95 (44.94)
188	T1	60.30	4.10	40.50	4.50	5.65	2.45	14.65	66.82	1.01	4.15	33.30 (35.11)
189	Solan Vajr	56.65	4.15	43.00	5.05	8.80	2.50	20.80	41.45	0.86	3.25	33.30 (35.11)
190	FT-9	56.35	4.65	42.50	4.65	11.10	2.00	20.50	49.26	0.95	2.80	46.62 (43.00)
191	Russian-I	103.25	4.55	43.00	5.05	10.95	2.50	26.80	49.83	1.36	3.75	56.61 (48.77)
192	Kangdaghat Local	95.45	4.00	40.50	5.15	10.60	3.10	31.65	40.26	1.27	3.15	23.31 (28.32)
193	EC-54092	79.85	4.65	45.00	5.15	12.00	2.55	27.80	45.90	1.27	4.80	26.64 (30.87)
194	Solan Gola	77.15	4.05	45.00	4.55	6.70	3.05	19.90	55.74	1.10	4.05	13.32 (20.69)
195	EC-711492	81.50	5.50	46.00	4.60	9.05	2.50	21.25	46.37	0.99	4.15	23.31 (26.32)
196	T-777	116.30	6.75	45.50	6.00	5.30	2.85	14.00	58.13	0.81	4.05	16.65 (22.97)
197	BT-12	99.05	6.00	41.50	5.45	11.05	2.25	23.40	51.27	1.18	4.55	9.99 (18.14)
198	EC-172031	73.50	4.15	42.00	4.45	8.25	2.40	17.30	58.06	1.00	4.15	46.62 (43.00)
199	Pepsi EC-42	112.95	5.55	45.00	5.00	12.30	2.35	27.05	35.16	0.95	4.25	33.30 (35.11)
200	A-2, Yas Wanth	79.60	4.55	45.50	4.50	12.20	1.90	21.25	36.60	0.85	4.60	49.95 (44.94)
201	Marhta	77.85	5.40	47.00	5.50	17.25	2.00	31.95	30.95	0.99	4.25	09.99 (18.14)
202	TBR-1	68.10	5.20	44.50	5.05	10.60	1.95	19.80	34.40	0.68	5.80	39.96 (39.15)
203	T-101	74.10	4.60	46.50	6.05	10.45	2.05	20.30	35.23	0.71	4.15	33.30 (35.11)
204	T-102	93.45	4.55	58.50	4.65	9.30	2.50	21.20	37.79	0.81	4.35	46.62 (43.00)
205	FT-4	97.90	5.05	59.00	4.85	10.30	2.10	18.00	40.64	0.74	4.90	63.27 (52.71)
206	Arka Alok	82.65	6.60	47.50	5.50	9.70	2.85	26.00	44.88	1.17	4.90	0.00 (00.02)
207	Arka Vikas	65.00	6.35	48.00	5.10	11.00	2.90	29.70	41.03	1.22	5.15	49.95 (44.97)
208	Arka Saurabh	91.15	5.80	45.50	4.95	11.90	2.70	30.10	42.91	1.28	4.85	29.97 (33.15)
209	L-101	94.45	6.55	49.00	5.10	12.10	3.00	35.50	37.08	1.30	5.15	16.65 (23.94)
210	Shakti	81.85	7.30	48.00	6.00	16.60	3.30	51.30	21.85	1.11	4.35	0.00 (00.02)
211	Pusa Ruby	97.55	5.70	47.50	4.55	10.65	2.10	20.30	24.72	0.42	4.35	69.93 (56.77)
	Check L-15 (Megha) (A)	80.55	5.75	44.00	5.50	11.25	3.10	3.10	34.88	1.12	3.75	03.33 (7.45)
	S.Em±	1.79	0.42	1.09	0.27	1.04	0.17	2.17	2.09	0.06	0.23	2.83
	CD at 5%	4.66	1.16	3.02	0.75	2.88	0.47	6.01	5.79	0.17	0.64	7.83

Values in parenthesis indicated transformed value
***Wilt incidence recorded under artificial epiphytotic conditions and its is separate experiment**

INVESTIGATIONS ON BACTERIAL WILT RESISTANCE IN TOMATO

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MAJOR ADVISOR

ABSTRACT

The "Investigations on bacterial wilt resistance in tomato" were undertaken during 2000 to 2002 in the Olericulture Unit, Department of Horticulture, University of Agricultural Sciences, Dharwad. Out of 212 genotypes 57 genotypes screened were selected based on their *per se* performance and horticultural traits.

All the 50 hybrids developed using L x T design in the present investigations had wide range of resistance to bacterial wilt. Considerable magnitude of heterosis was expressed in F_1's for yield and yield influencing characters. The three hybrids Arka Alok x SP-2-2 and Arka Alok x L-101 and L-15 x Arka Vikas qualify to be of commercial value as they manifested significant heterosis for yield and yield components with higher *per se* yield during both years. Combining ability analysis for yield and yield components revealed that, yield is predominantly governed by non-additive gene effects while, the yield components governed by additive gene effects.

The inheritance of bacterial wilt resistance in Arka Alok x Arka Vikas has fit into a digenic ratio 9:7, suggesting a duplicate recessive gene interaction. Among the four F_2 populations, very high frequency of 39.96 and 6.08 per cent transgressive segregants for average fruit weight and yield observed in the F_2 population of Arka Alok x W.94 30 ①.

An insight into the impact of soil amendment on bacterial wilt incidence revealed that the gypsum level 187.5 kg ha^{-1} and other higher levels reduced the wilt incidence significantly compared to control and 125 kg ha^{-1}. In both the years the calcium content was significantly higher in resistant variety (L-15) compared to Pusa Ruby. The histopathological investigations revealed the formation of cavities in the xylem vessels by cell wall degradation. When the two non-host crops maize and sorghum were used in the crop rotation experiment, the wilt incidence has reduced to 45.72 and 43.57 per cent from its initial incidence of 67.14 and 67.85 per cent respectively.