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DEVELOPMENT OF YELLOW VEIN MOSAIC VIRUS (YVMV) RESISTANT HYBRIDS IN OKRA [*Abelmoschus esculentus* (L.) Moench]

By

J. RAVI SANKAR

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THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
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2002

DECLARATION

I hereby declare that this thesis entitled **"Development of yellow vein mosaic virus (YVMV) resistant hybrids in okra [*Abelmoschus esculentus* (L.) Moench]"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Thrissur

J. RAVI SANKAR

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Sri. J. Ravi Sankar,** a candidate for the degree of **Master of Science in Horticulture** with major in **Olericulture,** agree that this thesis entitled **"Development of yellow vein mosaic virus (YVMV) resistant hybrids in okra [*Abelmoschus esculentus* (L.) Moench]"** may be submitted by **Sri. J. Ravi Sankar,** in partial fulfilment of the requirement for the degree.

Dr. K.V. Sureshbabu
(Chairman, Advisory Committee)
Assistant Professor (S.S.)
Department of Olericulture
College of Horticulture, Vellanikkara, Thrissur

Dr. T.R.Gopalakrishnan
(Member, Advisory Committee)
Associate Professor and Head
Department of Olericulture
College of Horticulture
Vellanikkara, Thrissur

Dr. Sally K. Mathew
(Member, Advisory Committee)
Associate Professor
AICVIP
College of Horticulture
Vellanikkara, Thrissur

Sri. S. Krishnan
(Member, Advisory Committee)
Assistant Professor
Department of Agricultural Statistics
College of Horticulture
Vellanikkara, Thrissur

EXTERNAL EXAMINER
Dr. V. KANTHASWAMY
Assoc. Prof (Hort)
Dept. of Vegetable Crops,
HC&RI, TNAU,
Coimbatore-3

DECLARATION

I hereby declare that this thesis entitled **"Development of yellow vein mosaic virus (YVMV) resistant hybrids in okra [*Abelmoschus esculentus* (L.) Moench]"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Thrissur

Dr.K.V.Sureshbabu
Chairman, Advisory Committee
Assistant Professor (S.S.)
Department of Olericulture
College of Horticulture
Kerala Agricultural University
Thrissur, Kerala

CERTIFICATE

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(Chairman, Advisory Committee)
Assistant Professor (S.S.)
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(Member, Advisory Committee)
Associate Professor and Head
Department of Olericulture
College of Horticulture
Vellanikkara, Thrissur

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(Member, Advisory Committee)
Associate Professor
AICVIP
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J. Ravi Sankar

To my Parents

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Introduction

INTRODUCTION

India is the second largest producer of vegetables in the world next to China, having the production of 87.5 million tonnes from 5.86 million hectare. However, this production is very meagre, considering our requirement of 285 gm per capita per day for a balanced diet. To supply at least 250 gm of vegetables per capita per day, we need at least 100 million tonnes of vegetables. With the current annual growth rate of production by 2.6 per cent, it is difficult to achieve this target. Population of our country is also increasing at the rate of 1.8 per cent. So in the year 2010 our vegetable requirement will be around 135 million tonnes (Attavar, 2000).

Kerala produced 5.98 lakh tonnes of vegetables from 0.75 lakh hectare in 1997-98 (FIB, 2000). It depends on the neighbouring states for meeting a major share of its vegetable requirement. It is estimated that, about 60 per cent of vegetable requirement of the state is met from out side sources and an amount of Rs.850 crores are spent yearly in this way (Gopalakrishnan, 1999). Even though by intensive production campaign, by implementing the projects like Intensive Vegetable Development Programme (IVDP) and Kerala Horticulture Development Programme (KHDP), some amount of area have been presently brought under vegetable cultivation.

In the last decade, the increase in area under vegetable crops in India was merely 0.42 per cent. In our country, only a meagre chance is there for increasing area under agriculture due to industrialization and urbanization. So only alternative to increase the production is, by increasing the productivity by improving the genetic base of crop species in order to attain our requirement. Vegetable cultivation is still dominated by locally available cultivars and land races, which shows lot of variability. It is estimated that area under local varieties is approximately 32.2 per cent under brinjal, 60 per cent under chilli, 46.71 per cent under cauliflower, 14.62 per cent under okra and 18.49 per cent under tomato. So the solution to increase production is by increasing productivity through evolving high yielding varieties and hybrids by utilizing these diverse local varieties and land races.

Hybrid varieties in India are of recent origin. However, it is estimated that presently about 10 per cent area of vegetables are under hybrids, of which, tomato covers 36 per cent, cabbage 30 per cent, brinjal 18 per cent, okra 7 per cent, melons and gourds each of 5 per cent. Looking back at the performance of vegetable crop hybrids during the past 25 years, there is no doubt that productivity has shown an upward trend. It is expected that after ten years more than 50 per cent area will be occupied by hybrids. Hybrid technology is going to stay in this country and it forms an important component of national plans for increasing vegetable production.

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the largest consuming vegetables, rich in vitamin A (86.67 µg/100g), Riboflavin (0.10 mg/100g), vitamin C (18 mg/100g) and minerals like calcium (66 mg/100g), phosphorus, iodine, iron and potassium (Kale *et al.*, 1986). Average Nutritive Value (ANV) of okra is 3.21, which is higher than tomato, brinjal and cucurbitaceous vegetables (Sharma and Arora, 1993). India is the largest producer of okra in the world with the production of 32.96 lakh tonnes in the year 2000 (NHB, 2001). It is also an important foreign xchange earner. Among fresh vegetables export, okra accounts 60 per cent excluding otato, onion and garlic.

Okra can be cultivated with ease, year round and is one of the best-adopted egetables in the tropical condition. Early bearing, extended period of harvest coupled vith short life span in this crop are some other plus points for vegetable growers.

Okra exhibits both high polyploidy and hybridity. So an array of cultivars, dapted to different agro climatic conditions are available in this crop, which display vide spectrum of variation with respect to important economic and quality characters nd consequently provide scope for genetic improvement.

Monoadelphous nature of flower, which eases the emasculation and ollination and presence of wide variation favours exploitation of hybrid vigour in this rop. Desirable heterosis expression in respect of important economic characters to an xtent to be exploited with greater profit has been reported by many workers. So leveloping hybrids in this crop is easy one, which will also be highly remunerative.

Virus diseases cause heavy loss in economically important plants. The xtent of loss due to these diseases will vary greatly depending upon the value of crop nd type of damage, which may be either qualitative or quantitative. The cheapest, implest, environment friendly and effective method to control virus diseases is to row resistant crop varieties.

In okra, Yellow Vein Mosaic (YVM) disease is the most destructive virus lisease transmitted by the vector white fly (*Bemesia tabaci*). The reported yield eduction due to this disease infection is up to 95.7 per cent (Pun and Doraisamy, 999), affecting the marketability of fruits. Even though, in okra many open pollinated varieties with resistant to YVM are available, F_1 hybrids combining resistance to this disease and other desirable traits are rather rare, particularly suitable to Kerala.

Considering all the facts in mind, the present study was formulated with the objectives of developing F_1 hybrids having YVM resistance and other desirable traits like earliness, high yield, ideal plant structure and fruit qualities.

Review of Literatur

REVIEW OF LITERATURE

Okra [*Abelmoschus esculentus* (L.) Moench] as one of the largest consuming vegetables relishes traditional food preparations and also furnishes rich amount of nutrients to our diet. Present day, vegetable breeders have been giving a lot of prominence to the heterosis breeding not only in the point of higher yield of F_1 hybrids, but also in terms of incorporation of desirable traits such as disease resistance in the hybrids. Since YVM is a devastating disease in okra, a breeding program involving the development of specific combiners with respect to fruit yield and YVMV resistance will be a significant development in terms of crop improvement. Several workers with respect to yield and yield contributing traits have reported highly significant positive heterosis in okra. In this context, exploitation of hybrid vigour, combining resistant to YVMV assumes paramount importance. The pertinent literature on the present study is reviewed under the following heads.

1) Combining ability studies
2) Heterosis with respect to quantitative traits
3) Yellow Vein Mosaic Virus disease

2.1 Combining ability studies

For developing a new variety through breeding programme, selection of potential parents based on their combining ability besides their special attributes is most important. Among a large number of crosses, only few of them showed superiority and the parents of such hybrids are considered as good combiners. General combining ability refers to the average performance of a line in a series of crosses, while specific combining ability is the deviation from the performance predicted on the basis of general combining ability. The *gca* is a measure of additive genetic factor while the *sca* is of non additive genetic factors (Sprague and Tatum, 1942). Knowledge about these aspects is most important for successful breeding programme. Some of the related literatures about combining ability are reviewed here.

2.1.1 Plant height

In a diallel analysis, Kulkarni (1976) found that the crosses Sevendhari x Pusa Sawani and Sevendhari x Dwarf Green exhibited good specific combining ability effects. The *gca* effects ranged between -7.70 and 7.10 and *sca* effects ranged between -5.40 and 3.80 was reported by Rao (1977). Singh and Singh (1978) found that the GCA and SCA variances were significantly different for this trait. Singh and Singh (1984) reported that the higher magnitude of *sca* effects than *gca* effects for this trait.

More and Patel (1990) observed Red Bhendi as a best general combiner for this trait. Chaudhury *et al.* (1991) in a line x tester analysis showed that the GCA variance and SCA variance compounds were significant for this character. Sivagamasundari *et al.* (1992a) reported that the *gca* effects ranged from -3.78 in EMS-8 to 2.40 in Arka Abhay for this trait. Sivakumar *et al.* (1995) noticed Punjab-7 as best general combiner for plant height. Singh *et al.* (1996) reported high estimates of *gca* in the cross Pusa Makhmali x Pusa Sawani. Ahmed *et al.* (1997) noticed higher *sca* and *gca* and reported Perkins Long Green and S-13-5 as best general combiners. Sivakumar (1999) found *gca* effects ranged from -7.68 to 10.66 and *sca* effects from -8.14 to 16.89 in okra hybrid combinations.

2.1.2 Internodal length

Singh and Singh (1984) observed significant *gca* effect (10.848) and *sca* effect (4.747) for internodal length. Results from a line x tester analysis conducted by Chaudhury *et al.* (1991) revealed that Parbhani Kranti was a best general combiner for this trait. Sivagamasundari (1992a) reported tnat out of six parents studied, three parents exhibited significant *gca* effect and highest negative significant *sca* effect was found in the cross Pusa Sawani x EMS-8. Ahmed *et al.* (1997) reported the best *gca* effect to the tune of -0.39 in Parbhani Kranti and best *sca* effect (-1.58) in the cross SB-5 x Pusa Sawani.

2.1.3 Number of primary branches

Singh and Singh (1984) recorded significant *gca* effect of 2.770 and *sca* effect of 3.074 in his fractional diallel analysis experiment. Results from combining ability studies done by Ahmed *et al.* (1997) revealed Perkins Long Green as a good general combiner with maximum *gca* effect of 0.09. Regarding the *sca* effect, Perkins Long Green x Pb-7 was recorded as best specific combiners with *sca* effect of 0.63. Sivakumar (1999) observed *gca* effects of parents ranged from -0.06 to 0.12 and *sca* effect of hybrids ranged from -0.12 to 0.39.

2.1.4 Days to flowering

Red Wonder and AE-107 were reported as poor combiners for days to flowering in the diallel experiment conducted by Kulkarni (1976). Singh and Singh (1984) reported the maximum *gca* and *sca* effects as 0.1229 and 0.1337 respectively. Chaudhury *et al.* (1991) indicated that Pusa Sawani and Punjab Padmini were marked as good combiners and the promising cross combination for this trait was identified as

Sel-6-2 x Parbhani Kranti. Dhankhar *et al.* (1996b) reported that 6(1) was the best general combiner and 6(1) x Parbhani Kranti was best specific combiner. Sivakumar (1999) reported that highest negative *gca* was -0.41 and highest negative *sca* was -2.41.

2.1.5 First fruiting node

Significant *gca* effect of 3.900 and *sca* effect of 0.621 was reported by Singh and Singh (1984). Ahmed *et al.* (1997) indicated Perkins Long Green as best combiner with the maximum negative *gca* effect of -0.22. He also observed the hybrid Pusa Makhmali x SB-8 as best specific combiner for this trait with the *sca* effect of -1.06.

2.1.6 Fruit length

The effect of *gca* was noted to be very high for fruit length in EC 68475 (Ramu, 1976). Thaker *et al.* (1981) recorded that EC 68475 and IC 18960 were the best general combiners. Singh and Singh (1984) observed maximum *gca* to the tune of 14.698 and *sca* to the tune of 2.011 in his experiment. Chaudhury *et al.* (1991) in his line x tester analysis found Sel-2 as a best general combiner and hybrid Sel-6-2 x Punjab Padmini as best specific combiner. Chavadhal and Malkchandale (1994) found that *A. ficulneus* and *A. manihot* showed high magnitude of *gca* effects and the cross combination of Parbhani Kranti x Assam TRO, *A. manihot* x Parbhani Kranti exhibited highly significant *sca* effect. Anithavasaline and Ganesan (1995) reported the parents Vaishali Vadhu and Local Akola found to show high *gca* effects for fruit length. Dhankhar *et al.* (1996b) studied the combining ability in a line x tester analysis. They found that among the lines Raj-12 showed higher *gca* effects. The tester Parbhani Kranti showed best general combining ability. Ahmed *et al.* (1997) reported that Shalimar Bhindi-3 as best general combiner with *gca* effect of one and hybrid Pusa Makhmali x SB-8 as best specific combiner with *sca* effect of 1.28. Sivakumar (1999) noticed the high *gca* effect of 1.29 and high *sca* effect of 1.59 in the cross IC 28080 x IC 34127A in his diallel analysis.

2.1.7 Fruit girth

Sharma and Mahajan (1978) found that the variance of SCA to be more than that of GCA indicating the non-additive gene action for this trait. Singh and Singh (1984) reported *gca* to the magnitude of 11.544 and *sca* to the magnitude of 1.465 in his fractional diallel analysis. Sivagamasundari *et al.* (1992a) revealed that the *gca* effects ranged from -0.104 in Pusa Sawani to 0.079 in Parbhani Kranti and *sca* effects ranged from -0.323 in Pusa Sawani x Arka Abhay to 0.597 in Parbhani Kranti x Arka Anamika. Ahmed *et al.* (1997) noticed in his experiment that SB-5 had the maximum *gca* effect of 0.47 and was the best general combiner and the hybrid, Perkins Long Green x SB-5 had the maximum *sca* effect of 0.4 and revealed to be a best specific combiner.

2.1.8 Number of fruits per plant

Kulkarni (1976) employed diallel analysis and found Sevendhari and AE-107 to be a good combiner. In a line x tester analysis, Rao (1977) reported that the *gca* effects ranged between -7.70 to 5.10 and *sca* effects ranged between -5.40 and 3.80. Singh and Singh (1984) reported the *gca* effect and *sca* effect to the magnitude of 136.44 and 124.38 respectively. Chaudhury *et al.* (1991) in a 5 x 3 line x tester analysis observed that the Punjab Padmini and Pusa Makhmali were good combiners for this trait. The hybrid Pusa Sawani x Punjab-7 showed highest *sca* effect. Sivagamasundari *et al.* (1992a) reported that the *gca* for this trait ranged from -1.194 in EMS-8 to 1.787 in Arka Abhay and *sca* from 3.250 in Arka Abhay x Arka Anamika to 3.917 in AE-674 x Arka Abhay. Dhankhar *et al.* (1996b) observed that Raj-12 was the best combiner and hybrid Raj-12 x Parbhani Kranti had the high *sca* effect. Ahmed *et al.* (1997) found the parent having high *gca* (1.90), Perkins Long Green as a best general combiner. He also reported that six crosses showed significant *sca* effect for this character. Results from Sivakumar (1999) revealed that the range of *gca* and *sca* effects were -1.004 to 1.64 and -1.10 to 3.41 respectively.

2.1.9 Yield per plant

Rao and Ramu (1976) reported a high GCA variance for this trait when compared to other characters. Highest *sca* effects were also noted by him in number of hybrids. The reports were also supported by Sharma and Mahajan (1978) and Elangovan (1979). In another study, Shukla *et al.* (1989) reported that KS-30 and KS-310 exhibited high *gca* effect for fruit yield. Estimates of *sca* effects showed that the best cross combination for yield was IC 12205 x Parbhani Kranti followed by KS-10 x Pusa Sawani. Chaudhury *et al.* (1991) found the varieties Punjab Padmini and Pusa Makhmali proved to be the best combiners for this trait. The combination of Pusa Sawani x P-7 reported to be promising as it exhibited the highest *sca* effects for this character. Anithavasaline and Ganesan (1995) studied the combining ability in line x tester analysis. They reported that among the testers, CO2 followed by AE-129 were the best general combiners. Ahmed *et al.* (1997) reported that in an 8 x 8 diallel analysis, the parent SB-5 exhibited highest *gca* effect and was the best general combiner. Among the crosses SB-5 x Pusa Makhmali and Perkins Long Green x SB-8 showed the highest *sca* effects for fruit yield per plant. Sivakumar (1999) observed the highest *gca* to the tune of 21.81 and highest *sca* to the tune of 35.92 in the cross IC 28079 x IC 128089.

2.2 Heterosis with respect to quantitative traits

Heterosis is the increase in vigour of F_1 over parental values, resulting from crossing between genetically dissimilar parents. This has been successfully utilized in the improvement of a number of crop species. The increase of F_1 value over mid parent value is designated as Relative heterosis (d_i), over the better parent value as heterobeltiosis (d_{ii}) and over the standard check as standard heterosis (d_{iii}) (Fanesco and Peterson, 1968). Being an often cross-pollinated species with high degree of heterosis, okra is a consonant material for improvement by utilizing this methodology. An array of works has been reported by many workers on hybrid vigour in this crop. Brief review of heterosis of different characters in okra has been furnished below.

2.2.1 Plant height

Heterosis for plant height was reported by Lal *et al.* (1975) and Singh *et al.* (1977) to an extent of 19.71 and 63.71 per cent respectively. Kulkarni and Virupakshappa (1977) found d_{iii} to the tune of 37 per cent, Rao (1977) and Sharma and Mahajan (1978) to 49.5 per cent. Singh and Singh (1979) and Elangovan (1979) in a line x tester analysis observed d_{iii} estimate of 28.26 per cent and 20.35 per cent over best parent respectively. El-Maksoud *et al.* (1984) mentioned heterosis to 143.87 per cent. Balachandran (1984) reported the d_{iii} estimate to 26.19 per cent in a cross Sel-2-2 x Pilicode Local. Sheela *et al.* (1988) reported high heterosis of 16.93 per cent over best parent. Line x tester analysis conducted by Shukla *et al.* (1989) revealed heterosis for plant height in a cross Sel-2 x Parbhani Kranti. Sivakumar (1992) reported that the cross AE-129 x P-7 registered the positive heterosis of 24.73 per cent. Singh and Mandal (1993) revealed that the cross Parbhani Kranti x 71-14 recorded highest heterosis over better parent (2.50 %) for plant height. Mohamed *et al.* (1994) and Dhankhar *et al.* (1996a) also reported positive and significant heterosis for this trait. Sivakumar (1999) reported d_{iii} estimate upto the tune of 31.3 per cent. Ahmed *et al.* (1999) also reported standard heterosis to 26.75 per cent.

2.2.2 Internodal length

Lal *et al.* (1975) reported positive heterosis (15.56%) for this trait, whereas Singh *et al.* (1977) observed negative heterosis (-0.52%) over better parent in the cross 6315 x Long Green. Singh and Singh (1979) reported negative heterosis to the tune of 23.06 per cent in the cross 6907 x Red Bhindi. Sivagamasundari *et al.* (1992b) observed d_{iii} estimate of -33.33 per cent in the cross Pusa Sawani x Parbhani Kranti in the 6 x 6 full diallel analysis. Kumbhani *et al.* (1993) in an 8 x 8 diallel analysis observed significant and negative heterosis for this character. Ahmed *et al.* (1999) reported d_{ii} estimate of -26.11 per cent for this trait.

2.2.3 Number of primary branches

Singh *et al.* (1975) mentioned the d_{iii} estimate upto 33.34 per cent in a cross 6305 x Faizabadi Hari Chikani. Singh *et al.* (1977) reported 29.31 per cent of d_{iii} in the cross 6302 x Long Green. Singh and Singh (1979) reported 64.55 per cent heterosis for this trait. Balachandran (1984) reported d_{iii} estimate of 145.92 per cent in Karingal Local x Kilichundan. Sheela *et al.* (1988) also reported positive heterosis for this trait. Singh and Mandal (1993) mentioned 68 and 44 per cent heterosis as d_i and d_{ii} respectively for this trait. Dayasagar (1994) reported 36.53 to 77.84 per cent of d_{ii} for Pusa Sawani x Janardhan and Pusa Sawani x Parbhani Kranti respectively. Dhankhar *et al.* (1996a) reported that increase in number of branches was observed in Raj-2 x Parbhani Kranti with the heterosis value of 86.57 per cent over standard check. Wankhade *et al.* (1997) reported 13.3 per cent heterobeltiosis for this trait. Rameshpathak and Syamal (1997) and Sivakumar (1999) also found positive heterosis for this character.

2.2.4 Days to flowering

Singh *et al.* (1975) reported -11.1 per cent of d_i, -10.26 per cent of d_{ii} and -10.26 per cent of d_{iii} for this character. Singh *et al.* (1977) and Rao (1977) also indicated earlier flowering in their works. Kulkarni and Virupakshappa (1977) indicated -5.36 per cent of mid parent heterosis in a cross Red wonder x AE-107. Singh and Singh (1979) reported -7.9 per cent d_{ii} for this trait. Research findings of EL-Maksoud *et al.* (1984), Sheela *et al.* (1988), Shukla *et al.* (1989) also revealed the same. Sivakumar (1992) registered maximum negative heterosis in the P-7 x AE-129 cross. Highly significant negative heterosis recorded by Singh and Mandal (1993) in the crosses using parents Sel-4 and KS-312 for this trait. Sivakumar (1999) annunciated about -15.19 per cent of d_{iii} and -11.32 per cent of d_{ii} for this character.

2.2.5 First fruiting node

Singh *et al.* (1975) revealed the standard heterosis to the range of -4.78 to -16.20 per cent in nine crosses. Singh *et al.* (1977) also reported negative heterosis for this trait. Singh and Singh (1979) found the negative significant heterosis (d_{iii}) to the tune of -25.44 in the cross 6319 x Long Green. In an experiment conducted by Sheela *et al.* (1988), the cross, Sevendhari x Kilichundan was evolved with -24.96 per cent d_{ii}. Ahmed *et al.* (1999) also reported significant negative heterosis of -32.09 per cent in the cross Pusa Makhmali x SB-8.

2.2.6 Fruit length

Singh *et al.* (1975) observed positive heterosis for fruit length. Singh and Singh (1979) reported 16.58 per cent d_{iii} in the cross 7105 x 6313. Heterosis was observed over mid parent and better parent by Elangovan (1979). Reports from Thaker *et al.* (1982) also showed heterosis for this trait. El-Maksoud *et al.* (1984) could not get heterosis for this trait. Balachandran (1984) observed 28.38, 13.01 and 36.75 per cent of d_i, d_{ii}, d_{iii} in his experiment. Sheela *et al.* (1988) in a 6 x 6 diallel experiment also revealed positive heterosis. Shukla *et al.* (1989), Sivagamasundari *et al.* (1992b), Kumbhani *et al.* (1993) also reported positive heterosis for this trait. Sivakumar (1999) and Ahmed *et al.* (1999) revealed 24.93 and 17.92 per cent of d_{iii} for this character respectively.

2.2.7 Fruit girth

Heterosis for fruit girth ranged from 4.19 to 8.09 per cent and -0.67 to 11.63 per cent over the better parent was annunciated by Singh *et al.* (1975, 1977) respectively. Singh and Singh (1979) reported in a line x tester analysis that standard heterosis upto 11.66 per cent was recorded among the F_1 hybrids. Elangovan (1979) also reported heterosis upto 6.15 per cent over the better parent. Balachandran (1984) revealed the standard heterosis upto 9.65 per cent in the cross Pusa Sawani x Pilicode Local. Sheela *et al.* (1988), Sivagamasundari *et al.* (1992b) and Kumbhani *et al.*

(1993) also revealed positive heterosis for this trait. Results of Sivakumar (1999) showed the standard heterosis to the tune of 23.59 per cent for this character. Ahmed *et al.* (1999) observed 1.12 per cent of standard heterosis in his experiment.

2.2.8 Number of fruits per plant

Elangovan (1979) reported the highest heterosis of 19.90 per cent of d_{ii} in the hybrid AE-1028 x AE-100. Singh and Singh (1979), Thaker *et al.* (1982), Nirmaladevi (1982), Balachandran (1984), El-Maksoud *et al.* (1984), Sheela *et al.* (1988) and Shukla *et al.* (1989) observed the heterosis for this trait. Sureshbabu and Dutta (1990) mentioned that F_1 hybrid between *A. esculentus* x *A. tetraphyllus* recorded a maximum of 23.82 per cent heterosis for this trait. Sivagamasundari *et al.* (1992b), Kumbhani *et al.* (1993), Sureshbabu *et al.* (1994), More and Patel (1997) also observed heterosis for this character. Ahmed *et al.* (1999) observed -29.02 to 74.77 per cent heterosis for this character. Singh and Sood (1999) also reported heterosis for this trait. Rattan and Bindal (2000) recorded maximum number of fruits in hybrid 410 x 407 followed by 409 x 421.

2.2.9 Crop duration

Raman (1965) reported in the line x tester cross that the duration of the F_1 hybrids were reduced and earlier cropping were there. But this is an undesirable attitude.

2.2.10 Yield per plant

Singh *et al.* (1975) observed hybrid vigour in most of the crosses and the maximum heterosis was 52.27 per cent. Singh and Singh (1979) reported that manifestation of heterosis over the superior parent was 70.28 per cent in the cross

7114 x Pusa Sawani. Elangovan (1979), Thaker *et al.* (1982), Nirmaladevi (1982), Balachandran (1984), El-Maksoud *et al.* (1984), Sheela *et al.* (1988) and Shukla *et al.* (1989) observed positive heterosis for this trait. Anithavasaline (1992) reported the hybrid Pusa Sawani x CO2 registered highest and significant positive heterobeltiosis of 110.90 per cent and standard heterosis of 115.20 per cent for this trait. Kumbhani *et al.* (1993), Singh and Mandal (1993), Mohamed *et al.* (1994) and Sureshbabu *et al.* (1994) observed positive heterosis. Singh *et al.* (1996) reported that the hybrid Pusa Makhmali x Parbhani Kranti showed the heterosis of 103.20 per cent over best parent. Wankhade *et al.* (1997) observed that the standard heterosis and heterobeltiosis value of 7.34 to 9.09 per cent and 6.07 to 9.09 per cent respectively from a diallel study in okra. More and Patel (1997) also mentioned the yield increase in F_1. Rameshpathak and Syamal (1997) reported 12.60 to 62.60 per cent d_{ii} in 13 hybrids. Sood (1999) observed maximum heterosis for fruit yield in the crosses P-7 x Parbhani Kranti and Parbhani Kranti x Arka Abhay. Panda and Singh (1999) and Sivakumar (1999) mentioned highest value of heterosis for this trait. Ahmed *et al.* (1999) observed -8.91 to 36.66 per cent heterosis in his experiment. Rattan and Bindal (2000) observed increased yield over parent in many crosses in his experiment.

2.2.11 Calcium content

Okra contains considerable amount of calcium. Raman (1965) observed heterosis for calcium content in okra F_1s that were studied by him.

2.2.12 Vitamin-A content

Balachandran (1984) got 16.80 per cent relative heterosis in the cross Sel-2-2 x Pilicode Local, 9.24 per cent heterobeltiosis and 16.89 per cent standard heterosis in the cross Sel-2-2 x Karingal Local.

2.3 Yellow Vein Mosaic Virus disease

Yellow Vein Mosaic Virus (YVMV) of okra is a most destructive virus disease infecting all stages of this crop. This disease was first reported by Kulkarni (1924) in the Bombay region. Later it was studied by Uppal *et al.* (1940) and Capoor and Varma (1950). The virus is neither sap nor seed transmissible, but it is readily transmitted through white fly (*Bemesia tabaci*) (Padda, 1968). The disease not only reduces yield adversely, but also affects marketability of the fruits. Pun and Doraisamy (1999) found the yield loss upto 95.7 per cent.

2.3.1 Incidence of YVMV

Chellaiah and Murugesan (1976) observed a significant increase in the incidence of YVMV and yield loss in okra sown in March-May compared with rest of the year. Goswami and Bhagabati (1992) in their experiment in Assam observed the lowest disease incidence on okra sown at beginning of October (16.7%) and highest incidence on crop sown in May and June (100%).

2.3.2 Breeding for resistance to YVMV

Naraini and Seth (1958) in their breeding experiment for YVMV resistance in okra inferred that, *H. manihot* var. *pungens*, *H. crinitus, H. vitifolius* and *H. panduraeformis* were immune. Earliest collection line IC 1542 from West Bengal was used by Joshi *et al.* (1960) for developing the resistant, symptom less carrier cultivar Pusa Sawani by crossing it with Pusa Makhmali. Out of 267 indigenous collections of okra, inbred lines IHR 15-1 and IHR 20-1 were found highly resistant to YVMV by Premnath (1970). Sandhu *et al.* (1974) in his screening test found that accession E 31830, 'Asuntem koko' from Ghana was *A. manihot* (L.) Medicus ssp.

Manihot that was immune to YVMV. Self-sterile F_1 but with many fruits without seeds and virus resistance was developed by Hossain and Chattopathyay (1976) by crossing *H. esculentus* x *H. ficulneus*. Arumugam and Muthukrishnan (1978) developed four resistant F_1s by crossing two resistant forms of *A. manihot* with susceptible okra cultivars, Pusa Sawani and CO1. Sharma and Sharma (1984) confirmed the results of Sandhu *et al.* (1974) and used that as a male parent in hybridization with Pusa Sawani for developing resistant 'Punjab Padmini'. Nerkar and Jambhale (1985) used the same resistant Ghana line *A. manihot* ssp. *Manihot* in his hybridization programme which resulted the cultivar 'Parbhani Kranti', which is used as one of the tester in this hybridization programme. They also confirmed the resistance of *A. tetraphyllus* wall., which was used earlier by Dutta (1984) for developing YVMV resistant lines Sel-4 and Sel-10. Lowest level of virus infection was recorded for Punjab-7 and Parbhani Kranti by Singh *et al.* (1993). Sharma *et al.* (1993) also confirmed the resistance of Parbhani Kranti to okra YVMV. Handa and Gupta (1993) inferred the tolerance nature of Parbhani Kranti to YVMV of okra. Mathew *et al.* (1993) recorded lowest incidence of YVMV in Sel-4 and Arka Anamika in their tribal. Dhankhar *et al.* (1996c) reported out of 20 parents and their 51 hybrids, only parent Parbhani Kranti and 11 hybrids with high level of resistance to YVMV. Poopathi *et al.* (1996) recorded no incidence of this disease in Parbhani Kranti and AROH-2. Fugro and Rajput (1999) using a partial diallel mating system involving nine genotypes, developed 36 F_1 hybrids, of which Sel-4 x Parbhani Kranti, Pusa Sawani x Punjab-7, Sel-4 x Bo-1, Sel-4 x Punjab-7 and Sel-4 x Sel-10 were free from YVMV infection. Nath *et al.* (1999) observed minimum disease incidence (4.44%) in

Parbhani Kranti and Arka Abhay at 90 days after sowing. Singh and Singh (2000) inferred that Parbhani Kranti was moderately resistant to YVMV. Deo *et al.* (2000) annunciated that Parbhani Kranti and its hybrid Parbhani Kranti x HRB-9-2 were highly resistant to YVMV. Rattan and Bindal (2000) in their programme to develop okra hybrids resistant to YVMV found that lines 407, 409, 417, 430 were completely resistant.

2.3.3 Genetics of YVMV resistance

Singh *et al.* (1962) reported that two recessive alleles at two loci conferred resistance to YVMV. Thakur (1976) stated that the resistance in an inter specific crosses involving *A. esculentus* cv Pusa Sawani and *A. manihot* ssp *manihot* cv Ghana was governed by two complementary dominant genes. This was supported by Sharma and Dhillon (1983). According to them, some of the plants in F_1 hybrids and in resistant parent Ghana were not completely resistant and the characteristic symptoms of virus appeared either on the top or on the new shoot growth quite late in the season. There fore, the possibility that the resistance to YVMV in *A. manihot* ssp *manihot* conditioned by polygenes cannot be ruled out. But, Nerkar and Jambhale (1985) reported a single dominant gene for resistance to YVMV in A. *manihot.*

Materials and Methods

MATERIALS AND METHODS

This research work was conducted in the vegetable research farm of Department of Olericulture, College of Horticulture, Kerala Agricultural University, Thrissur. The experimental site is located at an altitude of 22.5 m above MSL. The farm experiences a typical warm humid tropical climate. The experiment was conducted in two seasons, July - October 2000 and May - August 2001.

The experiment consisted of two parts.

A) Raising lines (females) and testers (males) for the production of F_1 seeds

B) Evaluation of F_1 hybrids along with their parents to assess the combining ability, estimate of heterosis and resistance to YVMV

3.1 Details of genotypes used for the experiment

The materials for the study comprised of 17 genotypes of okra (*Abelmoschus esculentus* (L.) Moench) maintaining at Department of Olericulture, of which two genotypes showing consistently high level of resistance to YVMV were used as testers. The list of parental genotypes (lines and Testers) and hybrids are given in Table 1 and 2 respectively.

3.2 Production of F_1 hybrid seeds

The 15 lines and two testers were raised in the vegetable plot during July - October 2000. Agronomic practices were followed as per the package of practices recommended by KAU (1996). To obtain F_1 hybrid seeds, the two tester plants were crossed with the lines as per the crossing technique given by Giriraj and Rao (1973).

Table 1. Source information of parents

Sl.No.	Accession number	Code number	Source	Name if a variety	Mode of evolution
	Lines				
1	AE-198	L_1	KAU, Vellanikkara	Aruna	Pure line selection
2	AE-202	L_2	KAU, Vellanikkara	Salkeerthi	,,
3	AE-210	L_3	Vellayani	Kiran	,,
4	AE-211	L_4	Mannarghat		,,
5	AE-214	L_5	Palaghat		,,
6	AE-219	L_6	Thrissur		,,
7	AE-238	L_7	KAU, Vellanikkara		*A. esculentus* x *A. caillei* derivative
8	AE-260	L_8	Ernakulam		Pure line selection
9	AE-264	L_9	Idukki		,,
10	AE-265	L_{10}	Thrissur		,,
11	AE-275	L_{11}	Kodungallore		,,
12	AE-279	L_{12}	Palaghat		,,
13	AE-280	L_{13}	Nenmara		,,
14	AE-282	L_{14}	Kollankodu		,,
15	AE-287	L_{15}	Kaipamangalam		*A. esculentus* x *A. caillei* derivative
	Tester				
1	AE-285	T_1	KAU, Vellanikkara		*A. esculentus* x *A. caillei* derivative
2	AE-190	T_2	Parbhani	Parbhani Kranti	*A. esculentus* x *A. manihot* derivative

Table 2. Hybrid combinations

F_1 hybrids	Code number	F_1 hybrids	Code number
AE-198 x AE-285	L_1 x T_1	AE-260 x AE-190	L_8 x T_2
AE-198 x AE-190	L_1 x T_2	AE-264 x AE-285	L_9 x T_1
AE-202 x AE-285	L_2 x T_1	AE-264 x AE-190	L_9 x T_2
AE-202 x AE-190	L_2 x T_2	AE-265 x AE-285	L_{10} x T_1
AE-210 x AE-285	L_3 x T_1	AE-265 x AE-190	L_{10} x T_2
AE-210 x AE-190	L_3 x T_2	AE-275 x AE-285	L_{11} x T_1
AE-211 x AE-285	L_4 x T_1	AE-275 x AE-190	L_{11} x T_2
AE-211 x AE-190	L_4 x T_2	AE-279 x AE-285	L_{12} x T_1
AE-214 x AE-285	L_5 x T_1	AE-279 x AE-190	L_{12} x T_2
AE-214 x AE-190	L_5 x T_2	AE-280 x AE-285	L_{13} x T_1
AE-219 x AE-285	L_6 x T_1	AE-280 x AE-190	L_{13} x T_2
AE-219 x AE-190	L_6 x T_2	AE-282 x AE-285	L_{14} x T_1
AE-238 x AE-285	L_7 x T_1	AE-282 x AE-190	L_{14} x T_2
AE-238 x AE-190	L_7 x T_2	AE-287 x AE-285	L_{15} x T_1
AE-260 x AE-285	L_8xT_1	AE-287 x AE-190	L_{15} x T_2

A flower bud that was going to open the next morning was chosen between 4 PM and 6 PM for emasculation. A circular cut was made around the fused calyx including the epicalyx with a blade at 1 cm from its base. Later the corolla was removed gently without causing injury to the gynoecium. With a fine forceps, all the anthers were removed and excised calyx was replaced at its original position and covered with butter paper bag. On the emasculated flower, pollen grains collected from a tester flower which was bagged pervious day, were applied on the stigma next day morning between 7 to 8.30 am. The calyx cap was replaced after pollination. Then pollinated flowers were covered with butter paper bag. Seeds were collected after the pods fully dried and before shattering.

3.3 Evaluation of F_1 hybrids

F_1 hybrids along with their parents were evaluated during May - August 2001. Thirty F_1 hybrids along with 15 lines and two testers obtained from crossing programme were evaluated in a Randomized Completely Block Design (RCBD) with two replications. The spacing adopted was 60 x 45 cm. Fifteen plants were raised in each genotype in each replication in the plot size of 4.05 m^2. The gross plot size was 400 m^2. Cultural practices were adopted according to the package of practices recommended by KAU (1996). No plant protection measures were taken as it would reduce the vector population and there by hinder the natural epiphytotic condition.

3.3.1 Screening for resistance to YVMV

Genotypes were screened for resistance to YVMV by providing sufficient amount of field inoculum of virus by planting highly susceptible check around the field and in between rows. Observations on disease incidence and disease severity were recorded.

3.3.2 Artificial inoculation of YVMV

Resistance of disease free F_1 hybrids and parents in field condition were further confirmed by artificial inoculation through insect vector white flies and grafting techniques suggested by Capoor and Varma (1950) and Salehuzzaman (1985) and Fugro and Rajput (1999).

3.3.2.1 Transmission by grafting techniques

Healthy genotypes which were found resistant in the field trials were subjected to artificial inoculation by two grafting methods. In the first method, healthy genotypes were grafted with diseased plants by approach grafting method (Plate 1a) and in second case, the scion from the diseased plant was grafted on the healthy genotype by wedge grafting method (Plate 1b).

The grafted portions were tied with thread and covered with moistened cotton. Grafted seedlings were covered with wetted polythene cover to keep humidity. Wrapped cotton and polythene covers were moistened daily till the graft union had taken place. Inoculated plants were observed daily for two months for symptom expression.

3.3.2.2 Transmission through white fly vectors

White flies collected from fields were reared in the insect proof cages. Ten white flies after pre-acquisition fasting for 30 minutes were released on each diseased plants for acquisition of virus using a micro cage. After an hour of acquisition feeding, micro cage along with the viruliferous white flies was removed carefully from the

Plate 1

Plate 1a

Plate 1b

Plate 1c

diseased plant and fixed on the healthy genotype seedlings (Plate 1c) to be evaluated for the resistance. After 12 hours of inoculation feeding period, white flies were removed and the inoculated plants were sprayed with the insecticide (Dimethoate). Inoculated plants were kept under observation for two months for symptom expression.

3.3.2.3 Rating for YVMV

Observations on disease incidence and disease severity were recorded on 90 days after sowing. Disease severity was scored using 0-5 scale suggested by Deo *et al.* (2000).

Grade	Per cent leaves infected
0	Absent
1	<25% leaves (mild)
2	25-50% leaves
3	51-75% leaves
4	75-90% leaves
5	>90% leaves

Per cent Disease Severity (PDS) was calculated using the formula given below.

$$PDS = \frac{\text{Sum of all numerical ratings}}{\text{Total number of leaves observed}} \times \frac{100}{\text{Maximum disease grade}}$$

Per cent Disease Incidence (PDI) was calculated by using the formula given below.

$$PDI = \frac{\text{Number of plants infected}}{\text{Total number of plants}} \times 100$$

Based on the per cent disease incidence and disease severity, coefficient of infection

(CI) was calculated as suggested by Datar and Mayee (1981)

$$CI = \frac{\text{Per cent Disease Incidence} \times \text{Per cent Disease Severity}}{100}$$

Based on the CI the genotypes were categorized into five groups as shown below.

CI	Category
0-4	Highly Resistant (HR)
4.1-9	Resistant (R)
9.1-19	Moderately Resistant (MR)
19.1-39	Moderately Susceptible (MS)
39.1-69	Susceptible (S)
69.1-100	Highly Susceptible (HS)

3.4 Observations

Five plants were randomly selected and tagged individually before flowering from each replication for recording the observations. The following observations were recorded.

3.4.1 Quantitative characters

3.4.1.1 Plant height (cm)

The height of the plant was measured from the base of the plant to tip at the time of last harvest.

3.4.1.2 Internodal length (cm)

The length of the internode between 6^{th} and 7^{th} node of the plant was measured at the time of last harvest.

3.4.1.3 Number of primary branches

The number of primary branches per plant was counted at the time of last harvest.

3.4.1.4 Petiole length (cm)

Length of petiole of seventh leaf of each plant was measured at the time of last harvest.

3.4.1.5 Days to flowering

In each observation plant, date of opening of the first flower was recorded and the number of days from sowing to flowering was worked out.

3.4.1.6 Duration of flowering

Number of days between the first flowering and last flowering was calculated.

3.4.1.7 First fruiting node

The node at which first fruit was developed was noted and expressed in numbers.

3.4.1.8 Fruit length (cm)

Three fruits were harvested from each observation plant at seven days after flowering and the fruit length was measured from basal cap to the tip of fruit.

3.4.1.9 Fruit girth (cm)

Three fruits were harvested from each observation plant at seven days after flowering and the circumference of the fruit was recorded at the point of maximum bulging.

3.4.1.10 Number of fruits per plant

Total number of fruits in each plant was noted and was expressed in numbers.

3.4.1.11 Crop duration

Time taken for last harvest from sowing was recorded separately.

3.4.1.12 Yield per plant (g)

The weight of the fruits harvested from each plant was calculated.

3.4.2 Fruit quality characters

3.4.2.1 Mucilage content (%)

Twenty-five gm fresh fruit sample was taken, with that 100 ml of distilled water was added and kept for 24 hours. Then it was filtered through a muslin cloth into a flask. Fifty ml of alcohol was added to the flask and then it was filtered through a pre weighed filter paper. The filtrate along with the filter paper was dried and weighed. The percentage of the mucilage content was calculated by the formula given below.

$$\text{Percentage of mucilage} = \frac{B - A}{\text{Weight of the sample taken}} \times 100$$

B – Weight of the filter paper with mucilage

A – Weight of the filter paper alone

3.4.2.2 Calcium content (%)

Calcium content of the fruit was analysed as per the method given by Bhargava and Raghupathi (1993).

3.4.2.3 Vitamin A content (IU/100g)

Vitamin A content of the fruit was analysed as per the method of AOAC (1970).

3.4.2.4 Magnesium content (%)

Magnesium content of the fruit was analysed as per the method given by Bhargava and Raghupathi (1993).

3.4.3 Qualitative characters

Leaf characters like colour of the leaf base, colour of the leaf vein and leaf lobing were recorded from seventh leaf of each plant.

Flower characters such as flower colour and purple throat at corolla were also noted at the time of anthesis.

Fruit characters such as fruit pubescence, fruit colour and number of ridges on fruits were noted at the time of harvesting maturity.

3.5 Statistical Analysis

3.5.1 Combining ability analysis

The data collected on each characters were subjected to an analysis of variance appropriate for line x tester model (Kempthorne, 1957). The mean squares due to different sources of variation as well as their genetic expectations were estimated as detailed below.

Source	Df	MS	Expectations of mean squares
Lines	(l-1)	M_1	EMS + r(Cov.F.S. - 2 Cov.H.S.) + rt (Cov.H.S.)
Testers	(t-l)	M_2	EMS + r(Cov.F.S. - 2 Cov.H.S.) + rl (Cov.H.S.)
Line x Tester interaction	(l-l) x (t-l)	M_3	EMS + r(Cov.F.S. - 2 Cov.H.S.)
Error	(r-l) x (lt-l)	M_4	EMS
Total	rlt-l		

where, r = number of replications

l = number of lines and

t = number of testers

From the expectations of mean squares, the covariance of full sibs (Cov.F.S.) and that of half sibs (Cov.H.S.) were estimated as follows.

$$\text{Cov. H.S.} = \frac{(M_1 - M_3) + (M_2 - M_3)}{r\,(l + t)}$$

$$\text{Cov. F.S.} = \frac{(M_1 - M_4) + (M_2 - M_4) + (M_3 - M_4)}{3r} - \frac{6r\,(\text{Cov.H.S.}) - r\,(l + t)\,\text{Cov.H.S.}}{3r}$$

Using the above parameters, the combining ability variances were calculated as given below.

Variance due to general combining ability = σ^2 GCA = Cov.H.S.

Variance due to specific combining ability = σ^2 SCA = Cov.F.S. - 2 Cov.H.S.

3.5.1.1 Estimation of combining ability effects

The combining ability effects were estimated following the model as given below.

$$X_{ijk} = \# + g_i + g_j + s_{ij} + r_k + e_{ijk}$$

Where,

#	=	Population mean
g_i	=	*gca* effects of i^{th} line
g_j	=	*gca* effects of j^{th} tester
s_{ij}	=	*sca* effects of ij^{th} combination
r_k	=	replication effect
e_{ijk}	=	error associated with ijk^{th} observation
i	=	number of lines
j	=	number of testers
k	=	number of replications

The individual effects were estimated as follows:

i) Mean = # = $\frac{X...}{rlt}$

ii) gca effects of lines = $g_i = \frac{X_i..}{rt} - \frac{X...}{rlt}$

iii) gca effects of testers = $g_j = \frac{X_{.j.}}{rl} - \frac{X...}{rlt}$

iv) sca effects of hybrids = $s_{ij} = \frac{X_{ij}.}{r} - \frac{X_i..}{rt} - \frac{X_{.j.}}{rl} + \frac{X...}{rlt}$

where,

x . . . = total of all hybrid combinations

x_i . . = total of i^{th} line over t testers and r replications

$x_{.j.}$ = total of j^{th} tester over l lines and r replications

$x_{ij.}$ = total of the hybrid between i^{th} line and j^{th} tester over r replications

The significance of combining ability effects was tested by 't' test

3.5.2 Estimation of heterosis

From the date collected for the quantitative and fruit quality characters, heterosis was estimated by the method proposed by Briggle (1963) and Hayes *et al.* (1965).

$$\text{Relative heterosis } (d_i) = \frac{F_1 - MP}{MP} \times 100$$

$$\text{Heterobeltiosis } (d_{ii}) = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Standard heterosis } (d_{iii}) = \frac{F_1 - SV}{SV} \times 100$$

where,

F_1 = Mean performance of hybrid

MP = Arithmetic mean of two parents involved in each cross

BP = Mean performance of better parent involved in the cross

SV = Mean performance of standard variety

To test the significance of relative heterosis, standard error was calculated by the formula given below.

$$SE = \sqrt{\frac{3/2\sigma^2 e}{r}}$$

To test the significance of heterobeltiosis and standard heterosis, standard error was calculated using formula given below.

$$SE = \sqrt{\frac{2\sigma^2 e}{r}}$$

where, $\sigma^2 e$ - error mean square

r - number of replication

Results

RESULTS

Results of the present investigation are presented under the following heads.

1. Evaluation of F_1 hybrids and parents for YVMV resistance
2. *Per se* performance of parents and hybrids
3. Estimation of combining ability
4. Estimation of heterosis
5. Evaluation of qualitative traits

4.1 Evaluation of F_1 hybrids and parents for YVMV resistance

The reaction of F_1 hybrids and parents to YVMV is given in Table 3. Among the parents L_7 and L_{15} were found highly resistant. Even though L_{15} showed a mild infection of 0.08 per cent of coefficient of infection, L_7 was completely free of disease. Among the hybrids L_7 x T_2, L_{10} x T_2 were completely free of infection and 11 other hybrids viz.,L_{15} x T_2, L_{11} x T_2, L_9 x T_1, L_7 x T_1, L_3 x T_2, L_1 x T_1, L_6 x T_2, L_9 x T_2, L_4 x T_2, L_{14} x T_1, L_5 x T_2 were also categorized as highly resistant as coefficient of infection values ranged from 0.17 to 3.52 respectively. The hybrids, L_{13} x T_2, L_5 x T_1, L_2 x T_2, L_{14} x T_2, L_{15} x T_1, L_8 x T_2, L_2 x T_1 and L_{12} x T_2 were resistant to YVMV with coefficient of infection of 4.5 to 8.25.

Moderately resistant hybrids were L_3 x T_1, L_4 x T_1, L_{12} x T_1, L_1 x T_2 and L_8 x T_1. The testers T_1 and T_2 were also moderately resistant to YVMV. The lines L_{14}, L_{12}, L_3, L_4, L_9 and L_2 and hybrids L_6 x T_1, L_{11} x T_1, L_{10} x T_1 and L_{13} x T_1 were moderately susceptible to YVMV.

Table 3. Evaluation of okra genotypes for resistance to YVMV

Genotypes	Coefficient of Infection	Disease Reaction
L_7	0.00	HR
L_{15}	0.08	HR
T_1	11.15	MR
T_2	15.05	MR
L_{14}	25.50	MS
L_{12}	27.60	MS
L_3	30.00	MS
L_4	32.00	MS
L_9	34.00	MS
L_2	34.50	MS
L_1	40.00	S
L_5	40.30	S
L_{13}	41.90	S
L_6	42.00	S
L_8	44.00	S
L_{11}	48.00	S
L_{10}	49.80	S
L_7xT_2	0.00	HR
$L_{10}xT_2$	0.00	HR
$L_{15}xT_2$	0.17	HR
$L_{11}xT_2$	0.22	HR
L_9xT_1	0.38	HR
L_7xT_1	0.63	HR
L_3xT_2	0.87	HR
L_1xT_1	1.20	HR
L_6xT_2	1.76	HR
L_9xT_2	2.08	HR
L_4xT_2	3.20	HR
$L_{14}xT_1$	3.34	HR
L_5xT_2	3.52	HR
$L_{13}xT_2$	4.50	R
L_5xT_1	4.60	R
L_2xT_2	5.76	R
$L_{14}xT_2$	6.16	R
$L_{15}xT_1$	6.16	R
L_8xT_2	6.50	R
L_2xT_1	7.30	R
$L_{12}xT_2$	8.25	R
L_3xT_1	11.40	MR
L_4xT_1	13.05	MR
$L_{12}xT_1$	15.00	MR
L_1xT_2	16.38	MR
L_8xT_1	19.00	MR
L_6xT_1	20.30	MS
$L_{11}xT_1$	22.80	MS
$L_{10}xT_1$	29.60	MS
$L_{13}xT_1$	32.60	MS

HR - Highly Resistant
R - Resistant
MR - Moderately Resistant
MS - Moderately Susceptible
S - Susceptible

All the other parental lines such as L_1, L_5, L_{13}, L_6, L_8, L_{11} and L_{10} were susceptible to YVMV.

4.1.1 Artificial inoculation of YVMV

Artificial inoculation of YVMV by grafting and vector transmission methods did not show any symptoms of YVMV disease on inoculated plants which indicated that genotypes L_7 and hybrids L_7 x T_2 and L_{10} x T_2 were completely resistant to YVMV.

4.2 *Per se* performance of parents and hybrids

The *per se* performance of parents and hybrids are presented in Tables 4 and 5 respectively.

4.2.1 Plant height

Hybrids recorded maximum plant height of 200.70 cm compared with 153.38 cm of the parents. Among the parents, L_5 recorded the maximum plant height (187.36 cm) and L_8 recorded the least (79.07 cm). Among the hybrids, the tallest was L_9 x T_1 (263.95 cm) and the hybrid L_{13} x T_1 showed the shortest stature (152.54 cm).

4.2.2 Internodal length

Among the hybrids and parents, parents showed the short internodal length of 4.19 cm than the hybrids (4.20 cm). Out of 17 parents, L_8 had the shortest internodal length (3.42 cm) and longest internodal length was recorded in L_3 and L_{14} (5.03 cm). Among the 30 hybrids, shortest and longest internodal length were recorded in L_7 x T_1 (3.40 cm) and L_2 x T_2 (5.68 cm) respectively.

4.2.3 Number of primary branches

For this character, parents exhibited maximum value (1.71) compared with hybrids (1.43). Out of 17 parents, the maximum number of branches was recorded in

Table 4. *Per se* performance of parents

Parents	Plant height (cm)	Inter nodal length (cm)	Number of primary branches	Petiole length (cm)	Days to flowering (days)	Duration of flowering (days)	First fruiting node	Fruit length (cm)	Fruit girth (cm)	No. of fruits/ plant	Crop duration (days)	Yield/ plant (grams)	Mucilage content (%)	Calcium content (%)	Vit. A content (IU/100gm)	Mg content (%)
L_1	185.53*	4.92	1.30	39.29*	46.70	60.30	8.20	11.89*	5.59	19.50	114.00	376.10*	0.25*	0.11	1306.30*	0.04
L_2	159.61	4.55	1.70	29.98	48.20	50.10	8.20	9.67	5.26	15.30	105.30	265.10	0.65	0.14	1075.82	0.08*
L_3	144.53	5.03	2.30	28.24	48.00	56.10	8.40	7.96	4.93	14.30	111.10	176.50	0.61	0.14	1086.86	0.05
L_4	178.20*	4.08	1.10	29.98	45.90*	51.40	7.30	11.97*	5.69	19.30	104.30	309.20	0.51	0.16	991.30	0.06
L_5	187.36*	4.68	3.40*	31.85	47.80	48.90	9.00	12.71*	6.20*	17.90	103.70	334.00*	0.31*	0.21*	716.13	0.03
L_6	102.45	3.92	1.60	25.97	47.70	51.30	8.90	6.82	7.29*	13.50	106.00	166.50	0.20*	0.07	896.84	0.05
L_7	166.54*	3.45*	0.80	28.75	47.00	60.40	8.30	12.17*	5.92*	18.00	114.40	274.00	0.55	0.16	1452.32*	0.08*
L_8	79.07	3.42*	1.80	29.58	47.60	45.00	7.40	7.78	5.64	14.00	99.60	239.90	0.33*	0.12	831.16	0.09*
L_9	162.54	4.50	0.60	29.96	45.40*	56.40	6.80*	13.21*	5.57	18.50	108.80	301.00	0.45	0.16	1031.68	0.07
L_{10}	184.70*	4.43	2.50	32.30	54.40	46.80	8.00	11.10*	5.14	11.50	108.20	176.10	0.37*	0.14	1178.17	0.03
L_{11}	182.45*	3.75	0.70	33.88*	47.50	54.30	6.60*	10.34	5.41	19.20	108.80	291.40	0.69	0.18*	830.51	0.06
L_{12}	97.04	4.22	2.40	35.58*	56.00	46.70	8.40	8.75	5.16	14.00	109.70	190.00	0.43	0.10	1208.27	0.05
L_{13}	83.54	3.92	2.40	32.14	54.50	51.00	8.00	7.27	7.02*	15.70	112.50	240.60	0.41	0.18*	865.57	0.07
L_{14}	176.87*	5.03	2.70	27.75	46.60	55.10	7.40	10.52	5.74	19.90*	108.70	346.50*	0.38*	0.16	849.72	0.06
L_{15}	184.37*	3.46*	2.00	29.83	46.20*	56.80	8.50	11.80*	5.58	22.50*	110.00	390.00*	0.44	0.15	1296.81*	0.06
T_1	158.86	3.64*	0.80	31.21	45.10*	52.65	8.40	12.81*	5.42	16.00	104.50	256.90	0.53	0.17*	1114.39	0.08*
T_2	173.79*	4.18	1.00	25.50	42.90*	62.65*	7.00*	11.09*	6.10*	23.00*	112.50	393.40*	0.46	0.15	1448.86*	0.07
Grand mean	153.38	4.19	1.71	30.69	48.09	53.27	7.93	10.46	5.74	17.18	108.36	278.07	0.45	0.15	1069.45	0.06
CD (5%)	10.93	0.45	1.02	2.34	1.52	7.38	0.85	0.24	0.13	2.48	7.55	53.54	0.07	0.02	205.69	0.02

* - significant at 5% level

Table 5. *Per se* performance of hybrids

Hybrids	Plant height (cm)	Inter nodal length (cm)	Number of primary branches	Petiole length (cm)	Days to flowering (days)	Duration of flowering (days)	First fruiting node	Fruit length (cm)	Fruit girth (cm)	No. of fruits/ plant	Crop duration (days)	Yield/ plant (grams)	Mucilage content (%)	Ca content (%)	Vit. A content (IU/100g)	Mg content
$L_1 \times T_1$	211.33	3.74*	1.40	31.51	47.50	57.10	8.20	14.89*	5.98	25.20	111.60	520.20*	0.42	0.18*	1121.72	0.07
$L_1 \times T_2$	181.29	4.56	0.80	31.55	44.70	58.60	7.20	12.31	5.54	18.00	110.30	351.50	0.54	0.13	893.86	0.06
$L_2 \times T_1$	201.45	4.86	1.40	30.78	45.00	66.80*	7.20	14.90*	6.22*	23.70	118.80	453.80	0.50	0.16	1193.97	0.08*
$L_2 \times T_2$	221.95*	5.68	1.50	32.69*	44.70	57.20	7.70	12.43	5.62	32.80*	108.90	627.30*	0.47	0.14	1224.39	0.05
$L_3 \times T_1$	212.70*	4.08	2.30	30.00	46.40	62.90	7.50	13.43	5.86	26.90*	116.30	468.50	0.68	0.18*	583.89	0.04
$L_3 \times T_2$	220.20*	4.11	2.20	27.99	45.10	60.10	7.60	15.41*	5.69	24.50	112.20	438.50	0.50	0.17*	1093.63	0.03
$L_4 \times T_1$	195.37	5.19	1.00	28.02	44.80	64.70	7.20	16.67*	5.61	21.80	116.50	388.70	0.42	0.19*	852.67	0.06
$L_4 \times T_2$	195.87	4.10	0.50	28.03	44.40	59.70	6.80	17.09*	6.11*	24.20	111.10	425.30	0.39*	0.17*	749.45	0.05
$L_5 \times T_1$	183.86	3.76	2.20	29.16	46.30	52.20	8.00	15.88*	6.32*	16.50	105.50	328.50	0.31*	0.15	835.28	0.05
$L_5 \times T_2$	199.37	4.22	3.00*	29.25	44.00*	60.10	7.20	13.78	5.63	24.00	111.10	482.20*	0.52	0.15	748.40	0.09*
$L_6 \times T_1$	211.20	3.69*	1.70	33.27*	46.20	58.00	8.20	13.63	6.78*	21.20	111.20	393.00	0.38*	0.10	1081.09	0.03
$L_6 \times T_2$	229.87*	4.72	2.90*	34.22*	45.90	61.70	7.80	14.23	6.04	33.60*	114.60	671.50*	0.34*	0.15	1109.94	0.06
$L_7 \times T_1$	191.87	3.40*	1.50	29.28	46.40	58.80	7.80	11.55	5.65	22.30	112.20	403.00	0.52	0.19*	1075.22	0.03
$L_7 \times T_2$	175.53	3.86	0.80	30.90	45.60	53.70	8.20	12.49	5.51	19.20	106.30	356.30	0.37*	0.14	1269.64*	0.07
$L_8 \times T_1$	182.95	4.00	1.10	31.99	46.90	52.30	8.50	13.15	6.12*	20.50	106.20	368.20	0.52	0.15	893.48	0.04
$L_8 \times T_2$	209.35	4.08	1.00	27.10	44.60	57.70	7.80	15.59*	5.96	18.50	109.30	346.80	0.44	0.14	1118.47	0.06
$L_9 \times T_1$	263.95*	3.88	2.00	32.29	42.60*	62.90	7.50	15.83*	6.45*	32.30*	112.50	614.60*	0.65	0.11	1203.24	0.07
$L_9 \times T_2$	220.20*	4.18	0.70	30.91	43.80*	59.70	6.90	17.41*	5.71	24.70	110.50	443.30	0.47	0.14	880.43	0.09*
$L_{10} \times T_1$	186.95	4.58	1.00	29.69	47.20	50.90	8.20	12.49	5.45	15.20	105.10	230.20	0.50	0.15	1145.80	0.06
$L_{10} \times T_2$	219.78*	4.79	0.70	34.34*	45.00	62.00	6.70	14.00	5.42	23.70	114.00	448.70	0.44	0.15	897.98	0.05
$L_{11} \times T_1$	206.75	4.25	1.10	29.11	45.60	62.70	7.60	15.47*	6.19*	26.50*	115.30	465.70	0.44	0.13	634.61	0.05
$L_{11} \times T_2$	187.92	4.21	0.70	28.68	45.90	58.30	7.30	17.06*	5.63	23.40	111.20	412.20	0.44	0.09	1276.51*	0.06
$L_{12} \times T_1$	214.20*	4.33	2.50*	30.75	48.50	53.20	7.50	12.56	6.50*	23.70	108.70	452.90	0.38*	0.13	1357.01*	0.08*
$L_{12} \times T_2$	185.87	3.68*	1.10	24.03	46.10	50.70	6.80	15.36*	6.12*	17.20	103.80	302.90	0.51	0.17*	1663.35*	0.05
$L_{13} \times T_1$	152.54	3.70*	0.50	33.35*	54.20	54.10	8.00	8.56	5.96	16.50	115.10	280.40	0.38*	0.20*	1160.10	0.05
$L_{13} \times T_2$	193.24	4.11	1.20	29.36	46.50	61.00	6.70	12.48	6.55*	21.70	114.50	433.60	0.46	0.17*	1002.83	0.08*
$L_{14} \times T_1$	201.60	3.71*	1.60	29.30	45.80	61.40	7.60	12.35	6.27*	22.60	114.20	429.70	0.37*	0.19*	965.71	0.07
$L_{14} \times T_2$	186.04	4.47	1.90	31.58	43.20*	62.20	7.00	12.95	5.81	24.60	112.60	467.00	0.38*	0.18*	842.80	0.05
$L_{15} \times T_1$	199.87	4.58	1.00	28.28	45.80	61.80	7.20	13.87	6.06	23.00	114.60	425.40	0.48	0.15	1028.42	0.05
$L_{15} \times T_2$	178.04	3.56*	1.50	31.20	45.60	61.40	7.50	15.39*	5.86	19.50	114.00	368.50	0.44	0.12	1123.73	0.04
Grand mean	200.70	4.20	1.43	30.29	45.81	58.80	7.51	14.11	5.95	22.92	111.61	426.61	0.46	0.15	1034.25	0.06
CD (5%)	10.93	0.45	1.02	2.34	1.52	7.38	0.85	0.24	0.13	2.48	7.55	53.34	0.07	0.02	205.69	0.02

L_5 (3.40), where as it was lower in L_9 (0.60). Among the hybrids, the number of branches was highest in L_5 x T_2 (3.00), but it was minimum in L_4 x T_2 and L_{13} x T_1 with the value of 0.50.

4.2.4 Petiole length

Hybrids recorded shorter petiole length of 30.29 cm compared with 30.69 cm of the parents. Lengthy petiole was observed in the parent L_1 (39.29 cm) and shortest was observed in T_2 (25.50 cm). Hybrids L_{10} x T_2 and L_{12} x T_2 showed maximum (34.34 cm) and minimum (24.03 cm) petiole lengths for this trait respectively.

4.2.5 Days to flowering

Hybrids were early in flowering (45.81 days) than their parents (48.09 days). The earliest flowering was observed in parent T_2 (42.90 days) while L_{12} (56 days) was late in flowering. The hybrid L_9 x T_1 showed the earliness in flowering with the recorded value of 42.60 days. It was maximum in L_{13} x T_1 cross combination (54.20 cm).

4.2.6 Duration of flowering

Hybrids flowered for more number of days (58.80 days) than their parents (53.27 days). Long duration of flowering was found in T_2 (62.65 days) and short duration was in L_8 (45 days). Hybrid L_2 x T_1 showed 66.80 days of flowering and 50.70 days of flowering was recorded in L_{12} x T_2.

4.2.7 First fruiting node

Hybrids started fruiting from the lower node (7.51) than their parents (7.93). L_{11} was the line, which flowered in lowest node (6.60) and L_5 was flowered in the highest node (9.00). Lowest node for flowering was observed in the hybrids L_{10} x T_2 and L_{13} x T_2 with the value of 6.70 and highest node in the hybrid L_8 x T_1.

4.2.8 Fruit length

Hybrids produced lengthy fruits (14.11 cm) than their parents (10.46 cm). The fruit length among parents ranged from 6.82 cm (L_6) to 13.21 (L_9). The hybrid L_9 x T_2 recorded the highest fruit length (17.41 cm). The lowest was recorded in L_{13} x T_1 with the value of 8.56 cm.

4.2.9 Fruit girth

For this character, hybrids recorded maximum value (5.95 cm) than their parents (5.74 cm). The fruit girth was maximum in L_6 (7.29 cm) and lowest fruit girth (4.93 cm) was exhibited by parent L_3. Among the hybrids, L_6 x T_1 exhibited the highest fruit girth (6.78 cm) and the lowest value was recorded in the hybrid L_{10} x T_2 (5.42 cm).

4.2.10 Number of fruits per plants

More number of fruits were produced by the hybrids (22.92) than their parents (17.18). The maximum number of fruits was recorded in T_2 (23.00) whereas it was lowest in L_{10} (11.50) among the parents. Among the hybrids, the number of fruits per plant was highest in L_6 x T_2 (33.60) but it was minimum in L_{10} x T_1 with the value of 15.20.

4.2.11 Crop duration

Crop duration was more for the hybrids (111.61 days) than their parents (108.36 days). Among the 17 parents, maximum duration was observed in L_7 with 114.40 days. Minimum was observed in L_8 with 99.60 days. Among the hybrids, 118.80 days of duration was observed in L_2 x T_1 and 103.80 days of duration was observed in L_{12} x T_2 which were maximum and minimum respectively.

4.2.12 Yield per plant

Among the parents and hybrids, hybrids were the highest yielder (426.61 g) than their parents (278.07 g). Among the 17 parents, the highest yield of 393.40 g was recorded in T_2. It was minimum in the parent L_6 with the recorded value of 166.50 g. The cross combination of L_6 x T_2 recorded the highest yield per plant (671.50 g). The lowest value was found in L_{10} x T_1 with 230.20 g.

4.2.13 Mucilage content

For mucilage content, parents exhibited lower values (0.45%) than the hybrids (0.46%). Maximum mucilage content was observed in L_{11} (0.69%) and minimum was in L_6 (0.20%). Among the hybrids, lowest mucilage content was observed in L_5 x T_1 (0.31%) and highest mucilage content was in L_3 x T_1 (0.68%).

4.2.14 Calcium content

Calcium content was equal in both the parents and hybrids (0.15%). Among the parents, the range of calcium content was from 0.07 per cent in L_6 to 0.21 per cent in L_5. Hybrid with high calcium content was L_{13} x T_1 (0.20%) and low calcium content was L_{11} x T_2 (0.09%).

4.2.15 Vitamin A content

Hybrids showed lower values (1034.25 IU/100g) than their parents (1069.45 IU/100g) for Vitamin A content. Among the parents, it was found to be high in L_7 with 1452.32 IU per 100 g. The lowest value was recorded in case of L_5 (716.13 IU/100 g). Among the hybrids, L_{12} x T_2 registered the highest vitamin A content (1663.35 IU/100 g) and it was found to be lowest in L_3 x T_1 (583.89 IU/100 g).

4.2.16 Magnesium content

For magnesium content also, parents and hybrids exhibited equal values (0.06%). Among the parents, the highest value was recorded in L_8 (0.09%), whereas it was lowest in L_5 and L_{10} (0.03%). Among the hybrids, highest value was recorded in L_9 x T_2 (0.09%). The hybrids, L_3 x T_2, L_5 x T_2, L_6 x T_1 and L_7 x T_1 showed lowest value of 0.03 per cent for this trait.

4.3 Estimation of combining ability

The character wise estimates of *gca* effects of parents and *sca* effects of hybrids are presented in the Tables 6 and 7 respectively.

4.3.1 Plant height

Among the 17 parents, 13 exhibited significant *gca* effects for this trait. The parent L_9 recorded the highest *gca* effect of 41.37, whereas L_{13} recorded the least (-27.81). Among the 30 hybrid combinations, 14 hybrids recorded positive significant *sca* effects and 14 hybrids showed negative significant *sca* effects. The highest *sca* effects were recorded in L_9 x T_1 (21.47). The lowest value was found in L_9 x T_2 (-21.47).

4.3.2 Internodal length

Eleven parents exhibited significant *gca* effects of which four were positive and seven were negative. Minimum negative *gca* effects was shown by L_7 (-0.57) and maximum positive *gca* effects was shown by L_2 (1.07). The highest *sca* effects was

Table 6. Estimates of *gca* effects of parents

Parents	Plant height	Inter nodal length	Number of primary branches	Petiole length	Days to flowering	Duration of flowering	First fruiting node	Fruit length	Fruit girth
L_1	-4.39**	-0.05	-0.33*	1.24**	0.29	-0.95	0.19	-0.51**	-0.19**
L_2	11.00**	1.07**	0.02	1.45**	-0.96**	3.20*	-0.06	-0.44**	-0.03
L_3	15.75**	-0.11	0.82**	-1.29**	-0.06	2.70	0.04	0.31**	-0.18**
L_4	-5.08**	0.44**	-0.68	-2.26**	-1.21**	3.40*	-0.51**	2.77**	-0.09**
L_5	-9.09**	-0.21**	1.17**	-1.08**	-0.66*	-2.65	0.09	0.72**	0.02
L_6	19.83**	0.00	0.87**	3.46**	0.24	1.05	0.49**	-0.18**	0.46**
L_7	-17.00**	-0.57**	-0.28	-0.20	0.19	-2.55	0.49**	-2.09**	-0.37**
L_8	-4.55**	-0.16*	-0.38*	-0.74	-0.06	-3.80**	0.64**	0.26**	0.09**
L_9	41.37**	-0.17*	-0.08	1.31**	2.61**	2.50	-0.31	2.51**	0.13**
L_{10}	2.66	0.48**	-0.58**	1.73**	0.29	-2.35	-0.06	-0.86**	-0.52**
L_{11}	-3.37*	0.03	-0.53**	-1.39**	-0.06	1.70	-0.06	2.16**	-0.04*
L_{12}	-0.67	-0.20*	0.37*	-2.90**	1.49**	-6.85**	-0.36	-0.15**	0.36**
L_{13}	-27.81**	-0.30**	-0.58**	1.07**	4.54**	-1.25	-0.16	-3.59**	0.30**
L_{14}	-6.88**	-0.11	0.32*	0.15	-1.31**	3.00*	-0.21	-1.46**	0.09**
L_{15}	-11.75**	-0.13	-0.18	-0.55	-0.11	2.80	-0.16	0.52**	0.01
T_1	0.40	-0.09**	0.06	0.17	0.80**	-0.14	0.23**	-0.42**	0.14**
T_2	-0.40	0.09**	-0.06	-0.16	-0.80**	0.14	-0.23**	0.42**	-0.14**
SE gi	1.65	0.08	0.16	0.40	0.30	1.44	0.19	0.04	0.02
SE gj	0.44	0.02	0.04	0.11	0.08	0.38	0.05	0.01	0.01

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

Contd.

Table 6. Continued

Parents	No. of fruits/ plant	Crop duration	Yield/ plant	Mucilage content	Calcium content	Vitamin. A content	Magnesium content
L_1	-1.32**	-0.66	9.24	0.02	0.00	-26.46	0.01**
L_2	5.33**	2.24	113.94**	0.03	0.00	174.93**	0.01**
L_3	2.78**	2.64	26.89*	0.14**	0.02**	-195.50**	-0.02**
L_4	0.08	2.19	-19.61	-0.05*	0.02**	-233.19**	0.00
L_5	-2.67**	-3.31*	-21.26*	-0.04*	0.00	-242.42**	0.01**
L_6	4.48**	1.29	105.64**	-0.10**	-0.03**	61.26	-0.01**
L_7	-2.17**	-2.36	-46.96**	-0.01	0.01*	138.18**	-0.01**
L_8	-3.42**	-3.86**	-69.11**	0.03	-0.01	-28.28	-0.01**
L_9	5.58**	-0.11	102.34**	0.10**	-0.03**	7.58	0.02**
L_{10}	-3.47**	-2.06	-87.16**	0.01	0.00	-12.36	0.00
L_{11}	2.03**	1.64	12.34	-0.01	-0.04**	-78.69*	0.00
L_{12}	-2.47**	-5.36**	-48.71**	-0.01	0.00	475.93**	0.01**
L_{13}	-3.82**	3.19*	-69.61**	-0.03	0.03**	47.21	0.01**
L_{14}	0.68	1.79	21.74*	-0.08**	0.03**	-130.00**	0.00
L_{15}	-1.67**	2.69	-29.66**	0.00	-0.01*	41.82	-0.01**
T_1	-0.39**	0.65	-11.76**	0.01	0.01**	-25.44**	0.00
T_2	0.39**	-0.65	11.76**	-0.01	-0.01**	25.44**	0.00
SE gi	0.49	1.47	10.45	0.02	0.005	36.02	0.004
SE gj	0.13	0.39	2.79	0.01	0.002	9.63	0.001

Table 7. Estimates of *sca* effects of hybrids

Hybrids	Plant height	Internodal length	Number of primary branches	Petiole length	Days to flowering	Duration of flowering	First fruiting node	Fruit length	Fruit girth
$L_1 \times T_1$	14.62**	-0.32**	0.24	-0.19	0.60	-0.61	0.27	1.71**	0.08**
$L_1 \times T_2$	-14.62**	0.32**	-0.24	0.19	-0.60*	0.61	-0.27	-1.71**	-0.08**
$L_2 \times T_1$	-10.65**	-0.32**	-0.11	-1.12**	-0.65*	4.94**	-0.48*	1.66**	0.16**
$L_2 \times T_2$	10.65**	0.32**	0.11	1.12**	0.65*	-4.94**	0.48*	-1.66**	-0.16**
$L_3 \times T_1$	-4.15*	0.07	-0.01	0.84*	-0.15	1.54	-0.28	-0.57**	-0.06**
$L_3 \times T_2$	4.15*	-0.07	0.01	-0.84*	0.15	-1.54	0.28	0.57**	0.06**
$L_4 \times T_1$	-0.65	0.63**	0.19	-0.17	-0.60*	2.64	-0.03	0.21**	-0.39**
$L_4 \times T_2$	0.65	-0.63**	-0.19	0.17	0.60*	-2.64	0.03	-0.21**	0.39**
$L_5 \times T_1$	-8.16**	-0.14	-0.46**	-0.21	0.35	-3.81**	0.17	1.47**	0.20**
$L_5 \times T_2$	8.16**	0.14	0.46**	0.21	-0.35	3.81**	-0.17	-1.47**	-0.20**
$L_6 \times T_1$	-9.74**	-0.43**	-0.66**	-0.64	-0.65*	-1.71	-0.03	0.12**	0.23**
$L_6 \times T_2$	9.74**	0.43**	0.66**	0.64	0.65*	1.71	0.03	-0.12**	-0.23**
$L_7 \times T_1$	7.77**	-0.14	0.29	-0.98*	-0.40	2.69	-0.43*	-0.05	-0.07**
$L_7 \times T_2$	-7.77**	0.14	-0.29	0.98*	0.40	-2.69	0.43*	0.05	0.07**
$L_8 \times T_1$	-13.60**	0.05	-0.01	2.28**	0.35	-2.56	0.12	-0.80**	-0.06**
$L_8 \times T_2$	13.60**	-0.05	0.01	-2.28**	-0.35	2.56	-0.12	0.80**	0.06**
$L_9 \times T_1$	21.47**	-0.06	0.59**	0.52	-1.40**	1.74	0.07	-0.37**	0.23**
$L_9 \times T_2$	-21.47**	0.06	-0.59**	-0.52	1.40**	-1.74	-0.07	0.37**	-0.23**
$L_{10} \times T_1$	-16.82**	-0.02	0.09	-2.49**	0.30	-5.41**	0.52**	-0.33**	-0.13**
$L_{10} \times T_2$	16.82**	0.02	-0.09	2.49**	-0.30	5.41**	-0.52**	0.33**	0.13**
$L_{11} \times T_1$	9.01**	0.11	0.14	0.05	-0.95**	2.34	-0.08	-0.37**	0.14**
$L_{11} \times T_2$	-9.01**	-0.11	-0.14	-0.05	0.95**	-2.34	0.08	0.37**	-0.14**
$L_{12} \times T_1$	13.76**	0.41**	0.64**	3.20**	0.40	1.39	0.12	-0.98**	0.05*
$L_{12} \times T_2$	-13.76**	-0.41**	-0.64**	-3.20**	-0.40	-1.39	-0.12	0.98**	-0.05*
$L_{13} \times T_1$	-20.75**	-0.12	-0.41	1.83**	3.05**	-3.31*	0.42*	-1.54**	-0.44**
$L_{13} \times T_2$	20.75**	0.12	0.41	-1.83**	-3.05**	3.31*	-0.42*	1.54**	0.44**
$L_{14} \times T_1$	7.38**	-0.29**	-0.21	-1.31**	0.50	-0.26	0.07	0.12**	0.09**
$L_{14} \times T_2$	-7.38**	0.29**	0.21	1.30**	-0.50	0.26	-0.07	-0.12**	-0.09**
$L_{15} \times T_1$	10.51**	0.60**	-0.31	-1.63**	-0.70*	0.34	-0.38*	-0.34**	-0.04*
$L_{15} \times T_2$	-10.51**	-0.60**	0.31	1.63**	0.70*	-0.34	0.38*	0.34**	0.04*
SE sij	1.65	0.08	0.16	0.40	0.30	1.44	0.19	0.04	0.02

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

Contd.

Table 7. Continued

Hybrid	No. of fruits/ plant	Crop duration	Yield/ plant	Mucilage content	Calcium content	Vitamin. A content	Magnesium content
$L_1 \times T_1$	3.99**	0.00	96.11**	-0.07**	0.02**	139.37**	0.01*
$L_1 \times T_2$	-3.99**	0.00	-96.11**	0.07**	-0.02**	-139.37**	-0.01*
$L_2 \times T_1$	-4.16**	4.30**	-74.99**	0.01	0.01	10.23	0.02**
$L_2 \times T_2$	4.16**	-4.30**	74.99**	-0.01	-0.01	-10.23	-0.02**
$L_3 \times T_1$	1.59**	1.40	26.76*	0.08**	0.00	-229.43**	0.01*
$L_3 \times T_2$	-1.59**	-1.40	-26.76*	-0.08**	0.00	229.43**	-0.01*
$L_4 \times T_1$	-0.81	2.05	-6.54	0.01	0.00	77.05*	0.00
$L_4 \times T_2$	0.81	-2.05	6.54	-0.01	0.00	-77.05*	0.00
$L_5 \times T_1$	-3.36**	-3.45*	-65.09**	-0.11**	0.00	68.88	-0.02**
$L_5 \times T_2$	3.36**	3.45*	65.09**	0.11**	0.00	-68.88	0.02**
$L_6 \times T_1$	-5.81**	-2.35	-127.49**	0.01	-0.03**	11.01	-0.01*
$L_6 \times T_2$	5.81**	2.35	127.49**	-0.01	0.03**	-11.01	0.01*
$L_7 \times T_1$	1.94**	2.30	35.11**	0.07**	0.02**	-71.77*	-0.02**
$L_7 \times T_2$	-1.94**	-2.30	-35.11**	-0.07**	-0.02**	71.77*	0.02**
$L_8 \times T_1$	1.39**	-2.20	22.46*	0.03	0.00	-87.05*	-0.01*
$L_8 \times T_2$	-1.39**	2.20	-22.46*	-0.03	0.00	87.05*	0.01*
$L_9 \times T_1$	4.19**	0.35	97.41**	0.08**	-0.02**	186.85**	-0.01*
$L_9 \times T_2$	-4.19**	-0.35	-97.41**	-0.08**	0.02**	-186.85**	0.01*
$L_{10} \times T_1$	-3.86**	-5.10**	-97.49**	0.02	0.00	149.35**	0.00
$L_{10} \times T_2$	3.86**	5.10**	97.49**	-0.02	0.00	-149.35**	0.00
$L_{11} \times T_1$	1.94**	1.40	38.51**	-0.01	0.01	-295.51**	0.00
$L_{11} \times T_2$	-1.94**	-1.40	-38.51**	0.01	-0.01	295.51**	0.00
$L_{12} \times T_1$	3.64**	1.80	86.76**	-0.07**	-0.02**	-127.74**	0.02**
$L_{12} \times T_2$	-3.64**	-1.80	-86.76**	0.07**	0.02**	127.74**	-0.02**
$L_{13} \times T_1$	-2.21**	-0.35	-64.84**	-0.05*	0.01	104.08**	-0.02**
$L_{13} \times T_2$	2.21**	0.35	64.84**	0.05*	-0.01	-104.08**	0.02**
$L_{14} \times T_1$	-0.61	0.15	-6.89	-0.01	0.00	86.89*	0.01*
$L_{14} \times T_2$	0.61	-0.15	6.89	0.01	0.00	-86.89*	-0.01*
$L_{15} \times T_1$	2.14**	-0.35	40.21**	0.01	0.01	-22.22	0.01*
$L_{15} \times T_2$	-2.14**	0.35	-40.21**	-0.01	-0.01	22.22	-0.01*
SE sij	0.49	1.47	10.45	0.02	0.007	36.02	0.005

recorded in L_4 x T_1 with the value of 0.63 and lowest *sca* effects was recorded in L_4 x T_2 with the value of -0.63.

4.3.3 Number of primary branches

The range of *gca* effects was from -0.68 to 1.17 which were shown by L_4 and L_5 respectively. Five parents showed positive significant *gca* effects for this trait. Among eight significant hybrid combinations, four hybrid combinations were positive. The *sca* effects with high value was shown by L_6 x T_2 (0.66) and low value was shown by L_6 x T_1 (-0.66).

4.3.4 Petiole length

Among 11 parents which showed significant *gca* effects, six were positive and five were negative. Highest positive *gca* effects was exhibited by L_6 with the value of 3.46 and lowest negative *gca* effects was exhibited by L_{12} with the value of -2.90. Eighteen hybrids showed significant *sca* effects for this trait. Hybrid L_{12} x T_1 showed highest positive *sca* effects (3.20) and hybrid L_{12} x T_2 showed lowest negative *sca* effects (-3.20).

4.3.5 Days to flowering

Among the 17 parents, nine parents exhibited significant *gca* effects for this trait. The parent L_{13} recorded the highest *gca* effect of 4.54, whereas L_{14} recorded the least (-1.31). Among the 30 hybrid combinations, eight hybrids recorded negative significant *sca* effects and eight hybrids showed positive significant *sca* effects. The highest *sca* effects was recorded in L_{13} x T_1 (3.05). The lowest value was found in L_{13} x T_2 (-3.05).

4.3.6 Duration of flowering

Five parents exhibited significant *gca* effects, of which L_2, L_4 and L_{14} were positive and other two were negative. Maximum positive *gca* effects was shown by L_4 (3.40) and minimum negative *gca* effects was shown by L_{12} (-6.85). The highest *sca* effects was recorded in L_{10} x T_2 with the value of 5.41 among four significant positive *sca* effects having hybrids. Lowest *sca* effects was recorded in L_{10} x T_1 with the value of -5.41.

4.3.7 First fruiting node

The range of *gca* effects was from -0.51 to 0.64 which were shown by L_4 and L_8 respectively. Two parents showed negative significant *gca* effects which were L_4 and T_2 for this trait. Among the 10 significant hybrid combinations, five were positive and five were negative. The *sca* effects with low value (-0.52) was shown by L_{10} x T_2 and high value was shown by L_{10} x T_1 (0.52).

4.3.8 Fruit length

All the 17 parents were having highly significant *gca* effects for this trait. Among them, eight were positive and nine were negative. Highest positive *gca* effects was showed by L_4 with the value of 2.77 and lowest negative *gca* effects was exhibited by L_{13} with the value of -3.59. Twenty-eight hybrids showed significant *sca* effects for this trait. Hybrid L_1 x T_1 showed highest positive *sca* effects (1.71) and hybrid L_1 x T_2 showed lowest negative *sca* effects (-1.71) for this trait.

4.3.9 Fruit girth

Among the 14 parents, which showed significant *gca* effects, seven were positive and seven were negative. The parent L_6 recorded the highest *gca* effect of

0.46, whereas L_{10} recorded the least (-0.52). All the 30 hybrid combinations showed significant *sca* effects for this trait with maximum value of 0.44 shown by L_{13} x T_2 and minimum value of -0.44 shown by L_{13} x T_1.

4.3.10 Number of fruits per plant

Fifteen parents exhibited significant *gca* effects, of which, six were positive and nine were negative. Maximum positive *gca* effects was shown by L_9 (5.58) and minimum negative *gca* effects shown by L_{13} (-3.82). The highest *sca* effects was recorded in L_6 x T_2 with the value of 5.81 and lowest *sca* effects was recorded in L_6 x T_1 with the value of -5.81.

4.3.11 Crop duration

The range of *gca* effects was from -5.36 in L_{12} to 3.19 in L_{13}. Among the four parents with significant *gca* effects, positive effect was shown by L_{13} only. Among six significant hybrid combinations, three were positive and three were negative. The *sca* effects with high value was shown by L_{10} x T_2 (5.10) and the low value was shown by L_{10} x T_1 (-5.10).

4.3.12 Yield per plant

Among the 14 parents, which showed significant *gca* effects, six were positive and eight were negative. Highest positive *gca* effects was exhibited by L_2 with the value of 113.94 and lowest negative *gca* effects was exhibited by L_{10} with the value of -87.16. Twenty-six hybrids showed significant *sca* effects for this trait. Hybrid L_6 x T_2 showed highest positive *sca* effects (127.49) and hybrid L_6 x T_1 showed lowest negative *sca* effects (-127.49).

4.3.13 Mucilage content

Six parents exhibited significant *gca* effects, of which three were negative and three were positive. Minimum negative *gca* effects was shown by L_6 (-0.10) and maximum positive *gca* effects was shown by L_3 (0.14). The highest *sca* effects was recorded in L_5 x T_2 with the value of 0.11 and lowest *sca* effects was recorded in L_5 x T_1 with the value of -0.11.

4.3.14 Calcium content

Among the 12 parents, which showed significant *gca* effects, six were positive and six were negative. Highest positive *gca* effects was exhibited by L_{13} and L_{14} with the value of 0.03 and lowest negative *gca* effects was exhibited by L_{11} with the value of -0.04. Ten hybrids showed significant *sca* effects for this trait. Hybrid L_6 x T_2 showed highest positive *sca* effects (0.03) and hybrid L_6 x T_1 showed highest negative *sca* effects (-0.03).

4.3.15 Vitamin A content

The range of *gca* effects was from -242.42 in L_5 to 475.93 in L_{12}. Ten parents showed significant *gca* effects, of which four were positive and six were negative. Among the 22 significant hybrid combinations, L_{11} x T_2 showed maximum *sca* effects of 295.51 and L_{11} x T_1 showed minimum *sca* effects of -295.51.

4.3.16 Magnesium content

Among the 11 parents, which showed significant *gca* effects for this trait, six were positive and five were negative. Highest positive *gca* effects was exhibited by L_9 with the value of 0.02 and lowest negative *gca* effects was exhibited by L_3 with the value of -0.02. Twenty-four hybrids showed significant *sca* effects for the trait, of which 12 were positive and 12 were negative. The range of *sca* effects was from -0.02 to 0.02. Lowest *sca* effects was shown by L_2 x T_2, L_5 x T_1, L_7 x T_1, L_{12} x T_2 and L_{13} x T_1. Highest *sca* effects was shown by L_2 x T_1, L_5 x T_2, L_7 x T_2, L_{12} x T_1 and L_{13} x T_2.

4.4 Estimation of heterosis

Hybrid vigour was estimated for 16 characters in 30 cross combinations and expressed in per cent over mid parent (Relative Heterosis), better parent (Heterobeltiosis) and standard parent (Standard Heterosis). AE-190 (Parbhani Kranti) was taken as standard parent. The character wise results are presented in Table 8.

4.4.1 Plant height

The heterosis over mid parent for this trait varied from -0.58 to 67.41 per cent in L_{15} x T_2 and L_{12} x T_1 respectively. Among the 30 hybrids, 27 showed significant and positive relative heterosis, where as one cross showed negative and non significant relative heterosis. Twenty-two hybrids showed positive and significant heterobeltiosis and it ranged from -3.98 to 62.39 per cent in L_{13} x T_1 and L_9 x T_1 respectively. Seven hybrids showed non-significant heterobeltiosis, of which four were negative. The heterosis over standard parent ranged from -12.33 (L_{13} x T_1) to 51.88 per cent (L_9 x T_1) for this trait, of which, 23 crosses showed significant positive standard heterosis and one cross showed significant negative standard heterosis.

4.4.2 Internodal length

Among the 30 hybrids, five hybrids showed significant negative relative heterosis and five hybrids showed significant positive relative heterosis and it ranged from -14.42 (L_{14} x T_1) to 34.46 per cent (L_4 x T_1) for this trait. The heterobeltiosis ranged from -11.96 to 42.58 per cent in L_{12} x T_2 and L_4 x T_1 respectively. Three

Table 8. Estimates of heterosis (Per cent)

Hybrid	Plant height			Internodal length			Number of primary branches		
	di	dii	diii	di	dii	diii	di	dii	diii
$L_1 \times T_1$	22.73**	13.91**	21.60**	-12.62**	2.75	-10.53	33.33	7.69	40.00
$L_1 \times T_2$	0.91	-2.29	4.31	0.22	9.09	9.09	-30.43	-38.46	-20.00
$L_2 \times T_1$	26.51**	26.21**	15.92**	18.68**	33.52**	16.27**	12.00	-17.65	40.00
$L_2 \times T_2$	33.14**	27.71**	27.71**	30.13**	35.89**	35.89**	11.11	-11.76	50.00
$L_3 \times T_1$	40.22**	33.89**	22.40**	-5.88	12.09	-2.39	48.39	0.00	130.00*
$L_3 \times T_2$	38.55**	26.70**	26.70**	-10.75*	-1.67	-1.67	33.33	-4.35	120.00*
$L_4 \times T_1$	15.93**	9.64**	12.42**	34.46**	42.58**	24.16**	5.26	-9.09	0.00
$L_4 \times T_2$	11.29**	9.92**	12.70**	-0.73	0.49	-1.91	-52.38	-54.55	-50.00
$L_5 \times T_1$	6.21*	-1.87	5.79	-9.62*	3.30	-10.05	4.76	-35.29*	120.00*
$L_5 \times T_2$	10.41**	6.41*	14.72**	-4.74	0.96	0.96	36.36	-11.76	200.00**
$L_6 \times T_1$	61.65**	32.95**	21.53**	-2.38	1.37	-11.72*	41.67	6.25	70.00
$L_6 \times T_2$	66.43**	32.27**	32.27**	16.54**	20.41**	12.92*	123.08**	81.25*	190.00**
$L_7 \times T_1$	17.93**	15.21**	10.40**	-4.09	-1.45	-18.66**	87.50	87.50	50.00
$L_7 \times T_2$	3.15	1.00	1.00	1.18	11.88	-7.66	-11.11	-20.00	-20.00
$L_8 \times T_1$	53.78**	15.16**	5.27	13.31*	16.96*	-4.31	-15.38	-38.89	10.00
$L_8 \times T_2$	65.59**	20.46**	20.46**	7.37	19.30**	-2.39	-28.57	-44.44	0.00
$L_9 \times T_1$	64.25**	62.39**	51.88**	-4.67	6.59	-7.18	185.71**	150.00*	100.00
$L_9 \times T_2$	30.94**	26.70**	26.70**	-3.69	0.00	0.00	-12.50	-30.00	-30.00
$L_{10} \times T_1$	8.83**	1.22	7.57*	13.51**	25.82**	9.60	-39.39	-60.00**	0.00
$L_{10} \times T_2$	22.61**	18.99**	26.46**	11.27*	14.59**	14.59**	-60.00**	-72.00**	-30.00
$L_{11} \times T_1$	21.15*	13.32**	18.97**	15.02**	16.76**	1.67	46.67	37.50	10.00
$L_{11} \times T_2$	5.50*	3.00	8.13*	6.18	12.27*	0.72	-17.65	-30.00	-30.00
$L_{12} \times T_1$	67.41**	34.84**	23.25**	10.11*	18.96**	3.59	52.25*	4.17	150.00**
$L_{12} \times T_2$	37.26**	6.95*	6.95*	-12.43**	-11.96*	-11.96*	-35.29	-54.17*	10.00
$L_{13} \times T_1$	25.86**	-3.98	-12.23**	-2.12	1.65	-11.48*	-68.75*	-79.17**	-50.00
$L_{13} \times T_2$	50.19**	11.19**	11.19**	1.48	4.85	-1.67	-29.41	-50.00*	20.00
$L_{14} \times T_1$	20.10**	13.98**	16.00**	-14.42**	1.92	-11.24*	-8.57	-40.74*	60.00
$L_{14} \times T_2$	6.11*	5.18*	7.05*	-2.93	6.94	6.94	2.70	-29.63	90.00
$L_{15} \times T_1$	16.46**	8.41**	15.01**	29.01**	32.37**	9.60	-28.57	-50.00	0.00
$L_{15} \times T_2$	-0.58	-3.43	2.45	-6.81	2.89	-14.83**	0.00	-25.00	50.00
SE	4.70	5.43	5.43	0.19	0.22	0.22	0.44	0.51	0.51
CD (5%)	9.47	10.93	10.93	0.39	0.45	0.45	0.88	1.02	1.02
CD (1%)	12.64	14.59	14.59	0.52	0.60	0.60	1.36	1.36	1.36

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

Contd.

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Table 8. Continued

Hybrid	Petiole length			Days to flowering			Duration of flowering		
	di	dii	diii	di	dii	diii	di	dii	diii
$L_1 \times T_1$	-10.61**	-19.80**	23.57**	3.49*	5.32**	10.72**	1.33	-5.41	-8.86
$L_1 \times T_2$	-2.61	-19.70**	23.73**	-0.22	4.20*	4.20*	-4.64	-6.39	-6.46
$L_2 \times T_1$	0.60	-1.38	20.71**	-3.54*	-0.22	4.90**	30.34**	27.48**	6.62
$L_2 \times T_2$	17.84**	9.04*	28.20**	-1.87	4.20*	4.20*	1.51	-8.63	-8.70
$L_3 \times T_1$	0.93	-3.88	17.65**	-0.32	2.88	8.16**	15.94**	12.12	0.40
$L_3 \times T_2$	4.17	-0.89	9.76*	-0.77	5.13**	5.13**	1.26	-3.99	-4.07
$L_4 \times T_1$	-8.42*	-10.22**	9.88*	-1.54	-0.67	4.43*	24.66**	23.47**	3.27
$L_4 \times T_2$	1.05	-6.50	9.92*	0.00	3.50	3.50	4.74	-4.63	-4.71
$L_5 \times T_1$	-7.52*	-8.45*	14.35**	-0.32	2.66	7.93**	3.06	-0.38	-16.68**
$L_5 \times T_2$	2.01	-8.16*	14.71**	-2.98*	2.56	2.56	7.80	-3.99	-4.07
$L_6 \times T_1$	16.37**	6.60	30.47**	-0.43	2.44	7.69**	11.86	10.69	-7.42
$L_6 \times T_2$	32.97**	31.77**	34.20**	1.32	6.99**	6.99**	8.34	-1.44	-1.52
$L_7 \times T_1$	-2.33	-6.18	14.82**	0.76	2.88	8.16**	4.26	-2.65	-6.15
$L_7 \times T_2$	13.92**	7.48	21.18**	1.45	6.29**	6.29**	-12.68*	-14.22*	-14.29*
$L_8 \times T_1$	5.25	2.50	25.45**	1.19	3.99*	9.32**	7.39	-0.19	-16.52**
$L_8 \times T_2$	-1.60	-8.38*	6.27	-1.44	3.96*	3.96*	7.25	-7.83	-7.90
$L_9 \times T_1$	5.57	3.46	26.63**	-5.86**	-5.54**	-0.70	15.62*	11.52	0.40
$L_9 \times T_2$	11.47**	3.17	21.22**	-0.79	2.10	2.10	0.34	-4.63	-4.71
$L_{10} \times T_1$	-6.50*	-8.08*	16.43**	-5.13**	4.66**	10.02**	2.62	-2.86	-18.75**
$L_{10} \times T_2$	18.82**	6.32	34.67**	-7.50**	4.90**	4.90**	13.35*	-0.96	-1.04
$L_{11} \times T_1$	-10.55**	14.08**	14.16**	-1.51	1.11	6.29**	17.53**	15.47*	0.08
$L_{11} \times T_2$	-3.40	-15.35**	12.47**	1.55	6.99**	6.99**	-0.26	-6.87	-6.94
$L_{12} \times T_1$	-7.92*	-13.58**	20.59**	-4.06**	7.54**	13.05**	7.37	1.53	-15.08*
$L_{12} \times T_2$	-21.32**	-32.46**	-5.76	-6.77**	7.46**	7.46**	-7.23	-19.01**	-19.07**
$L_{13} \times T_1$	5.29	3.76	30.78**	8.84**	20.18**	26.34**	4.64	3.24	-13.65*
$L_{13} \times T_2$	1.87	-8.65*	15.14**	-4.52**	8.39**	8.39**	7.39	-2.56	-2.63
$L_{14} \times T_1$	-0.61	-6.12	14.90**	-0.11	1.55	6.79**	14.23*	11.43	-2.00
$L_{14} \times T_2$	18.61**	13.80**	23.84**	-3.46*	0.70	0.70	5.69	-0.64	-0.72
$L_{15} \times T_1$	-7.34*	-9.39*	10.90*	0.33	1.55	6.76**	13.19*	8.80	-1.36
$L_{15} \times T_2$	12.78**	4.59**	22.35**	2.36	6.29**	6.29**	2.85	-1.92	-2.00
SE	1.01	1.64	1.64	0.65	0.75	0.75	3.18	3.67	3.67
CD (5%)	2.03	2.34	2.34	1.32	1.52	1.52	6.39	7.38	7.38
CD (1%)	2.71	3.13	3.13	1.76	2.03	2.03	8.53	9.85	9.85

Contd.

Table 8. Continued

Hybrid	First fruiting node			Fruit length			Fruit girth		
	di	dii	diii	di	dii	diii	di	Dii	diii
L_1 x T_1	-1.20	0.00	17.14**	20.57**	16.24**	34.27**	8.63**	6.98**	-1.97
L_1 x T_2	-5.26	2.86	2.86	7.14**	3.53**	11.00**	-5.22**	-9.18**	-9.18**
L_2 x T_1	-13.25**	-12.20*	2.86	32.56**	16.32**	34.36**	16.48**	14.76**	1.97
L_2 x T_2	1.32	10.00	10.00	19.75**	12.08**	12.08**	-1.06	-7.87**	-7.87**
L_3 x T_1	-10.71*	-10.71*	7.14	29.32**	4.84**	21.10**	13.24**	8.12**	-3.93**
L_3 x T_2	-1.30	8.57	8.57	61.78**	38.95**	38.95**	3.17**	-6.72**	-6.72**
L_4 x T_1	-8.28	-1.37	2.86	34.54**	30.13**	50.32**	0.99	-1.41	-8.03**
L_4 x T_2	-4.90	-2.86	-2.86	48.22**	42.77**	54.10**	3.65**	0.16	0.16
L_5 x T_1	-8.05	-4.76	14.29*	24.45**	23.97**	43.19**	8.78**	1.94	3.61**
L_5 x T_2	-10.00*	2.86	2.86	15.80**	8.42**	24.26**	-8.46**	-9.19**	-7.70**
L_6 x T_1	-5.20	-2.38	17.14**	38.87**	6.40**	22.90**	6.69**	-7.00**	11.15**
L_6 x T_2	-1.89	11.43	11.43	58.91**	28.31**	28.31**	-9.78**	-17.15**	-0.98
L_7 x T_1	-6.59	-6.02	11.43	-7.53**	-9.84**	4.15**	-0.35	-4.56**	-7.38**
L_7 x T_2	7.19	17.14**	17.14**	7.39**	2.63**	12.62**	-8.32**	-6.93**	-9.67**
L_8 x T_1	7.59	14.86*	21.43**	27.73**	2.65**	18.58**	10.67**	8.51**	0.33
L_8 x T_2	8.33	11.43	11.43	65.24**	40.58**	40.58**	1.53	-2.30*	-2.30*
L_9 x T_1	-1.32	10.29	7.14	21.68**	19.83**	42.74**	17.38**	15.80**	5.74**
L_9 x T_2	0.00	1.47	-1.43	43.29**	31.79**	56.99**	-2.14*	-6.39**	-6.39**
L_{10} x T_1	0.00	2.50	17.14**	4.52**	-2.46*	12.62**	3.22**	0.55	-10.66**
L_{10} x T_2	-10.67*	-4.29	-4.29	26.18**	26.13**	26.24**	-3.56**	-11.15**	-11.15**
L_{11} x T_1	1.33	15.15*	8.57	33.65**	20.77**	39.50**	14.31**	14.21**	1.48
L_{11} x T_2	7.35	10.61	4.29	59.22**	53.83**	53.83**	-2.17*	-7.70**	-7.70**
L_{12} x T_1	-10.71*	-10.71*	7.14	16.51**	-1.95*	13.26**	22.87**	19.93**	6.56**
L_{12} x T_2	-11.69*	-2.86	-2.86	54.84**	38.50**	38.50**	8.70**	0.33	0.33
L_{13} x T_1	-2.44	0.00	14.29*	-14.74**	-33.18**	-22.81**	-4.18**	-15.10**	-2.30*
L_{13} x T_2	-10.67*	-4.29	-4.29	35.95**	12.53**	12.54**	-0.15	-6.70**	7.38**
L_{14} x T_1	-3.80	2.70	8.57	5.87**	-3.59**	11.36**	12.37**	9.23**	2.79**
L_{14} x T_2	-2.78	0.00	0.00	19.85**	16.77**	16.77**	-1.86*	-4.75**	-4.75**
L_{15} x T_1	-14.79**	-14.29**	2.86	12.72**	8.27**	25.07**	10.18**	8.60**	-0.66
L_{15} x T_2	-3.23	7.14	7.14	34.47**	30.42**	38.77**	0.34	-3.93**	-3.93**
SE	0.37	0.42	0.42	0.10	0.12	0.12	0.05	0.06	0.06
CD (5%)	0.74	0.85	0.85	0.21	0.24	0.24	0.11	0.13	0.13
CD (1%)	0.98	1.14	1.14	0.27	0.32	0.32	0.15	0.17	0.17

Contd.

Table 8. Continued

Hybrid	Number of fruits per plant			Crop duration			Yield per plant		
	di	dii	diii	di	dii	diii	di	dii	diii
L_1 x T_1	41.97**	29.23**	9.57	2.15	-2.11	-0.8	64.36**	38.31**	32.23**
L_1 x T_2	-15.29**	-21.74**	-21.74**	-2.60	-3.25	-1.96	-8.64	-10.65	-10.65
L_2 x T_1	51.44**	48.13**	3.04	13.25**	12.82**	5.60	73.87**	71.18**	15.35*
L_2 x T_2	71.28**	42.61**	42.61**	0.00	-3.20	-3.20	90.52**	59.46**	59.46**
L_3 x T_1	77.56**	68.12**	16.96**	7.88*	4.68	3.38	116.20**	82.37**	19.09**
L_3 x T_2	31.37**	6.52	6.52	0.36	-0.27	-0.27	53.89**	11.46	11.46
L_4 x T_1	23.51**	12.95*	-5.22	11.59**	11.48**	3.56	37.33**	25.71**	-1.19
L_4 x T_2	14.42**	5.22	5.22	2.49	-1.24	-1.24	21.06**	8.11	8.11
L_5 x T_1	-2.65	-7.82	-28.26**	1.34	0.96	-6.22	11.19	-1.65	-16.50*
L_5 x T_2	17.36**	4.35	4.35	2.78	-1.24	-1.24	32.58**	22.57**	22.57**
L_6 x T_1	43.73**	32.50**	-7.83	5.65	4.91	-1.16	85.64**	52.98**	-0.10
L_6 x T_2	84.11**	46.09**	46.09**	4.90	1.87	1.87	139.86**	70.69**	70.69**
L_7 x T_1	31.18**	23.89**	-3.04	2.51	-1.92	-0.27	51.82**	47.08**	2.44
L_7 x T_2	-6.34	-16.52**	-16.52**	-6.30*	-7.08*	-5.51	6.77	-9.43	-9.43
L_8 x T_1	36.67**	28.12**	-10.87*	4.07	1.63	-5.6	48.23**	43.32**	-6.41
L_8 x T_2	0.00	-19.57**	-19.57**	3.06	-2.84	-2.84	9.52	-11.85	-11.85
L_9 x T_1	87.25**	74.59**	40.43**	5.49	3.40	0.00	120.33**	104.19**	56.23**
L_9 x T_2	19.04**	7.39	7.39	-0.14	-1.78	-1.78	27.68**	12.68	12.68
L_{10} x T_1	10.55	-5.00	-33.91**	-1.18	-2.87	-6.58	6.33	-10.39	-41.48**
L_{10} x T_2	37.39**	3.04	3.04	3.31	1.33	1.33	57.58**	14.06*	14.06*
L_{11} x T_1	50.57**	38.02**	15.22**	8.11*	5.97	2.49	69.87**	59.81**	18.38**
L_{11} x T_2	10.90*	1.74	1.74	0.50	-1.16	-1.16	20.39**	4.78	4.78
L_{12} x T_1	58.00**	48.13**	3.04	1.49	-0.91	-3.38	102.69**	76.29**	15.12*
L_{12} x T_2	-7.03	-25.22**	-25.22**	-6.57*	-7.73*	-7.73*	3.84	-23.00**	-23.00**
L_{13} x T_1	4.10	3.12	-28.26**	6.08*	2.31	2.31	12.72	9.15	-28.72**
L_{13} x T_2	12.14*	-5.65	-5.65	1.78	1.78	1.78	36.78**	10.22	10.22
L_{14} x T_1	25.91**	13.57*	-1.74	7.13*	5.06	1.51	42.43**	24.01**	9.23
L_{14} x T_2	14.69**	6.96	6.96	1.81	0.09	0.09	26.23**	18.71**	18.71**
L_{15} x T_1	14.48**	2.22	0.00	6.85*	4.18	1.87	31.52**	9.08	8.13
L_{15} x T_2	-14.29**	-15.22**	-15.22**	2.47	1.33	1.33	-5.92	-6.33	-6.33
SE	1.07	1.23	1.23	3.25	3.75	3.75	23.03	26.59	26.59
CD (5%)	2.15	2.48	2.48	6.54	7.55	7.55	46.37	53.54	53.54
CD (1%)	2.87	3.31	3.31	8.73	10.08	10.08	61.89	71.46	71.46

Contd.

Table 8. Continued

Hybrid genotype	Mucilage content			Calcium content			Vitamin A content		
	di	dii	diii	di	dii	diii	di	dii	diii
$L_1 \times T_1$	8.15	69.96**	-8.70	22.21**	0.78	20.00**	-7.32	-14.13	-22.58**
$L_1 \times T_2$	52.52**	116.94**	17.39*	-0.63	-12.33*	-13.33*	-35.11**	-38.31**	-38.31**
$L_2 \times T_1$	-15.72**	-5.93	8.70	1.72	-7.96	6.67	9.03	7.14	-17.59*
$L_2 \times T_2$	-15.69**	2.51	2.17	-3.35	-5.59	-6.67	-3.01	-15.49*	-15.49*
$L_3 \times T_1$	18.99**	27.94**	47.83**	12.39*	1.58	20.00**	-46.95**	-47.60**	-59.70**
$L_3 \times T_2$	-5.52	10.38	8.70	21.42**	18.46**	13.33*	-13.74*	-24.52**	-24.52**
$L_4 \times T_1$	-18.59**	-16.58	-8.70	10.82*	6.41	26.67**	-19.01	-23.48*	-41.15**
$L_4 \times T_2$	-18.26**	-13.88	15.22*	9.42	5.19	13.33*	-38.57**	-48.27**	-48.27**
$L_5 \times T_1$	-26.05**	0.16	-32.61**	-19.66**	-26.09**	0.00	-8.74	-25.05**	-42.35**
$L_5 \times T_2$	35.33**	67.20**	13.04	-16.71**	-28.65**	0.00	-30.86**	-48.35**	-48.35**
$L_6 \times T_1$	3.49	89.95**	-17.39*	-14.82*	-40.51**	-33.33**	7.51	-2.99	-25.38**
$L_6 \times T_2$	2.36	68.84**	-26.09**	33.99**	-1.69	0.00	-5.36	-23.39**	-23.39**
$L_7 \times T_1$	-4.03	-2.54	13.04	17.16**	11.10*	26.67**	-16.22*	-25.97**	-25.79**
$L_7 \times T_2$	-27.10**	-19.89*	-19.57*	-10.89*	-13.25*	-6.67	-12.47*	-12.58	-12.37
$L_8 \times T_1$	22.16**	60.06**	13.04	2.00	-12.71*	0.00	-8.15	-19.82*	-38.33**
$L_8 \times T_2$	13.30	35.67**	-4.35	-0.07	-8.16	-6.67	-1.89	-22.80**	-22.80**
$L_9 \times T_1$	32.86**	44.89**	41.30**	-34.43**	-36.52**	-26.67**	12.14	7.97	-16.95*
$L_9 \times T_2$	2.81	3.67	2.17	-10.24*	-14.43*	-6.67	-29.01**	-39.23**	-39.23**
$L_{10} \times T_1$	10.36	34.23**	8.70	-0.90	-11.79*	0.00	-0.04	-2.75	-20.92**
$L_{10} \times T_2$	5.97	18.33*	-4.35	4.82	0.58	0.00	-31.64**	-38.02**	-38.02**
$L_{11} \times T_1$	-26.84**	-16.27*	-4.35	-28.66**	-30.28**	-13.33*	-34.74**	-43.05**	-56.20**
$L_{11} \times T_2$	-23.41**	-4.37	-4.35	-44.78**	-50.01**	-40.00**	12.01	-11.90	-11.90
$L_{12} \times T_1$	-20.94**	-11.72**	-17.39*	-1.92	-23.72**	-13.83**	16.85*	12.31	-6.40
$L_{12} \times T_2$	15.03*	18.56*	10.87	40.10**	13.88*	13.33*	25.20**	14.80*	14.80*
$L_{13} \times T_1$	-18.60**	-7.12	-17.39*	9.81*	6.54	33.33**	17.18	4.10	-19.93**
$L_{13} \times T_2$	5.50	10.98	0.00	4.56	-5.98	13.33*	-13.34	-30.78**	-30.78**
$L_{14} \times T_1$	-20.02**	-4.81	-19.57*	11.08*	7.94	26.67**	-1.66	-13.34	-33.35**
$L_{14} \times T_2$	-10.98	-2.60	-17.39*	18.64**	12.71*	20.00**	-26.67**	-41.83**	-41.83**
$L_{15} \times T_1$	-1.34	8.72	4.35	-4.35	-11.18*	0.00	-14.70	-20.70*	-29.02**
$L_{15} \times T_2$	-3.11	-1.36	-4.35	-18.03**	-17.64**	-20.00*	-18.15**	-22.44**	-22.44**
SE	0.03	0.04	0.04	0.009	0.011	0.011	88.49	102.18	102.18
CD (5%)	0.06	0.07	0.07	0.019	0.020	0.020	178.13	205.69	205.69
CD (1%)	0.08	0.10	0.10	0.026	0.029	0.029	237.78	274.56	274.56

Contd.

Table 8. Continued

Hybrid	Magnesium content		
	di	dii	diii
L_1 x T_1	10.48*	17.69	0.00
L_1 x T_2	4.13	-17.19	-14.29
L_2 x T_1	-1.05	-0.06	14.29
L_2 x T_2	-30.70**	-36.03**	-28.57*
L_3 x T_1	-36.67**	-49.11**	-42.86**
L_3 x T_2	-56.34**	-62.20**	-57.14**
L_4 x T_1	-20.03*	-29.47*	-14.29
L_4 x T_2	-21.28*	-24.39*	-28.57*
L_5 x T_1	-20.84*	-45.03**	-28.57*
L_5 x T_2	67.27**	22.82*	28.57*
L_6 x T_1	-49.43**	-60.83**	-57.14**
L_6 x T_2	3.69	-13.84	-14.29
L_7 x T_1	-59.83**	-58.78**	-57.14**
L_7 x T_2	-9.71*	-15.44	0.00
L_8 x T_1	-47.54**	-48.03**	-42.86**
L_8 x T_2	-25.80**	-32.69**	-14.29
L_9 x T_1	-15.22*	-21.89*	0.00
L_9 x T_2	29.16**	30.17*	28.57*
L_{10} x T_1	1.75	-31.18**	-14.29
L_{10} x T_2	2.90	-26.68*	-28.57*
L_{11} x T_1	-27.67**	-39.05**	-28.57*
L_{11} x T_2	-9.38*	-17.26	-14.29
L_{12} x T_1	16.03*	-6.21	14.29
L_{12} x T_2	-21.44*	-31.53*	-28.57*
L_{13} x T_1	-39.20**	-43.37**	-28.57*
L_{13} x T_2	15.94*	18.26	14.29
L_{14} x T_1	-5.23	-20.12*	0.00
L_{14} x T_2	-19.56*	-26.53*	-28.57*
L_{15} x T_1	-24.21**	-36.09**	-28.57*
L_{15} x T_2	-43.48**	-48.36**	-42.86**
SE	0.007	0.008	0.008
CD (5%)	0.015	0.017	0.017
CD (1%)	0.019	0.022	0.022

hybrids showed negative heterobeltiosis for this trait, of which, one hybrid L_{12} x T_2 was significant. Six hybrids showed significant negative standard heterosis and five hybrids showed significant positive standard heterosis and ranged from -18.66 in L_7 x T_1 to 35.89 per cent in L_2 x T_1.

4.4.3 Number of primary branches

The range of relative heterosis for this trait was from -68.75 to 185.71 per cent in L_{13} x T_1 and L_9 x T_1 respectively. Among five hybrids, which showed significant relative heterosis, three were positive. The highest and lowest heterobeltiosis for this character were from L_9 x T_1 (150%) to L_{13} x T_1 (-79.17%) respectively. Two hybrids showed significant positive heterobeltiosis. The standard heterosis was also found significant in six hybrids, which were positive. L_5 x T_2 showed highest positive standard heterosis (200%) and L_4 x T_2 and L_{13} x T_1 showed lowest negative standard heterosis (-50%)for this trait.

4.4.4 Petiole length

The relative heterosis range was from -21.32 per cent in L_{12} x T_2 to 32.97 per cent in L_6 x T_2. Eight hybrids showed positive and significant relative heterosis. The heterobeltiosis was significant and towards positive side for four hybrids, whereas 13 hybrids showed negative significant heterobeltiosis. The positive significant standard heterosis was found in 28 hybrid combinations and it was highest in L_{10} x T_2 (34.67%). It was found to be lowest in L_{12} x T_2 with the value of -5.76 per cent.

4.4.5 Days to flowering

The relative heterosis for this trait was significant and negative for seven hybrids. The range was from -7.50 (L_{10} x T_2) to 8.84 per cent (L_{13} x T_1). Significant negative heterobeltiosis was found in one hybrid (L_9 x T_1). That was -5.54 per cent. The standard heterosis was negative in one hybrid (L_9 x T_1), which was not significant. It ranged from -0.70 in L_9 x T_1 to 26.34 per cent in L_{13} x T_1.

4.4.6 Duration of flowering

The range for the relative heterosis, heterobeltiosis and standard heterosis were from –12.68 to 30.34 per cent, -19.01 to 27.48 per cent and -19.01 to 6.62 per cent in L_2 x T_1 and L_7 x T_2, L_2 x T_1 and L_{12} x T_1 and L_2 x T_1 and L_{12} x T_1 respectively. The maximum significant positive heterosis was found in the hybrid L_2 x T_1 for all the three types of heterosis.

4.4.7 First fruiting node

The lowest significant negative relative heterosis and heterobeltiosis were found in the hybrid L_{15} x T_1 (-14.79 and -14.29% respectively). For standard heterosis, hybrid L_{13} x T_2 showed lowest significant negative heterosis (-4.29%). Relative heterosis for this trait ranged from -14.79 (L_{15} x T_1) to 8.33 per cent (L_8 x T_2). The range for heterobeltiosis and standard heterosis was -14.29 (L_{15} x T_1) to 17.14 (L_7 x T_2) and -4.29 (L_{13} x T_2 and L_{10} x T_2) to 21.43 per cent (L_8 x T_1) respectively.

4.4.8 Fruit length

All the 30 hybrids showed significant relative heterosis, of which, two were negative and 28 were positive. It ranged from –14.74 (L_{13} x T_1) to 65.24 per cent (L_8 x T_2). Heterobeltiosis also was significant in all the hybrids. The range of heterobeltiosis for this trait was from -33.18 (L_{13} x T_1) to 53.83 per cent (L_{11} x T_2). Out of 30 hybrids with significant heterosis, one hybrid showed significant negative heterosis of -22.81

per cent (L_{13} x T_1). Maximum and minimum standard heterosis were showed by L_9 x T_2 (56.99%) and L_{13} x T_1 (-22.81%) respectively.

4.4.9 Fruit girth

The relative heterosis ranged from -9.78 in L_6 x T_2 to 22.87 per cent in L_{12} x T_1. Fifteen hybrids showed positive and significant relative heterosis. The heterobeltiosis was significant and towards positive side for nine crosses, whereas 16 hybrids showed negative heterobeltiosis for this trait at significant level. The positive and significant standard heterosis was found in seven hybrids and it was highest in L_6 x T_1 (11.15%). It was found to be lowest in L_{10} x T_2 (-11.15%).

4.4.10 Number of fruits per plant

Among the 30 hybrids, 22 hybrids exhibited positive and significant heterosis over mid parent. The relative heterosis ranged from -15.29 (L_1 x T_2) to 87.25 per cent (L_9 x T_1) for this trait. The hybrids had shown heterobeltiosis value ranged from -25.22 in L_{12} x T_1 to 74.59 per cent in L_9 x T_1. Thirteen crosses showed positive and significant heterobeltiosis for this character. The significant and positive standard heterosis was found in five hybrids. The standard heterosis ranged from -33.91 (L_{10} x T_1) to 46.09 per cent (L_6 x T_2).

4.4.11 Crop duration

Relative heterosis for this trait was positively significant in seven hybrids. The lowest relative heterosis was registered in L_{12} x T_2 (-6.57%) and highest relative heterosis was found in L_2 x T_1 (13.25%). Positive and negative significant heterobeltiosis were shown by two hybrids each. Heterobeltiosis ranged from -7.73 per cent (L_{12} x T_2) to 12.82 per cent (L_2 x T_1). One hybrid L_{12} x T_2 showed significant negative standard heterosis for this trait with the value of -7.73 per cent. None showed positive standard heterosis for this trait.

4.4.12 Yield per plant

The maximum heterosis was shown by the hybrid L_6 x T_2 (139.86%) and minimum was shown by L_1 x T_2 (-8.64%) over mid parent. Twenty-two hybrids showed significant and positive relative heterosis. The heterosis over better parent ranged from -23.00 (L_{12} x T_2) to 104.19 per cent (L_9 x T_1). Sixteen crosses showed positive and significant heterobeltiosis. The positive significant standard heterosis was shown by 11 hybrids with maximum value of 70.69 in the hybrid L_6 x T_2. The standard heterosis was negative and significant for four hybrids. The lowest one was -41.48 exhibited by L_{10} x T_1.

4.4.13 Mucilage content

Six hybrids exhibited significant and positive heterosis over mid parent. Eleven hybrids exhibited significant and negative relative heterosis and it ranged from -27.10 (L_7 x T_2) to 52.52 per cent (L_1 x T_2). The highest value of heterobeltiosis was observed in L_9 x T_1 (22.67%). Out of 19 hybrids, which showed significant heterobeltiosis for this trait, only three were positive. The lowest heterobeltiosis value of -41.39 per cent showed by the hybrid L_5 x T_1. The standard heterosis range was from -32.61 in L_5 x T_1 to 47.83 per cent in L_3 x T_1. Three hybrids exhibited positive significant standard heterosis.

4.4.14 Calcium content

Positive and negative significant relative heterosis was shown by nine hybrids each. Relative heterosis ranged from -44.78 (L_{11} x T_2) to 40.10 per cent (L_{12} x

T_2). Heterobeltiosis for this trait was positively significant in four hybrids and negatively significant in 14 hybrids. The lowest heterobeltiosis was registered in L_{11} x T_2 (-50.01%) and highest positive heterobeltiosis was found in L_3 x T_2 (18.46%). Out of 18 hybrids which shown significant standard heterosis, 11 showed positive with highest value shown by L_{13} x T_1 (33.33%). Lowest standard heterosis was -40 per cent shown by L_{11} x T_2.

4.4.15 Vitamin A content

The maximum heterosis was shown by the hybrid L_{12} x T_2 (25.20%) and minimum was shown by L_3 x T_1 (-46.95%) over mid parent. Two hybrids showed significant and positive relative heterosis. They were L_{12} x T_2 and L_{12} x T_1. The heterosis over better parent ranged from -48.35 (L_5 x T_2) to 14.80 per cent (L_{12} x T_2). Only one hybrid L_{12} x T_2 showed positive and significant heterobeltiosis. The positive significant standard heterosis was shown by L_{12} x T_2. The standard heterosis was negative and significant for 22 hybrids. The lowest one was -59.70 per cent exhibited by L_3 x T_1.

4.4.16 Magnesium content

Relative heterosis for this trait was positively significant in five hybrids. The lowest relative heterosis was registered in L_7 x T_1 (-59.83%) and highest relative heterosis was found in L_5 x T_2 (67.27%). Positive significant heterobeltiosis was shown by two hybrids and 20 hybrids exhibited negative significant heterobeltiosis. Heterobeltiosis ranged from -62.20 in L_3 x T_2 to 30.17 per cent in L_9 x T_2. Two hybrids showed significant positive standard heterosis for this trait. Fifteen hybrids showed negative significant standard heterosis. It ranged from -57.14 in L_3 x T_2 and L_6 x T_1 to 28.57 per cent in L_5 x T_2 and L_9 x T_2.

4.5 Evaluation of qualitative traits

Results of the qualitative traits are given in Table 9.

4.5.1 Colour of the leaf base

Except L_2, L_5 and L_{14} all other lines and testers showed red colour leaf base. These three lines showed reddish green colour leaf base, when crossed with testers resulted with F_1s having reddish green colour leaf base.

4.5.2 Colour of leaf vein

Line 1 had the red colour veins. Other lines and testers had green colour veins. When L_1 crossed with testers yielded the F_1s with green colour leaf vein only.

4.5.3 Leaf lobing

Except L_1, L_6, L_9, L_{10}, L_{11}, L_{12} and L_{13}, other lines had shallow lobed (SL) leaves. Both testers had deeply lobed (DL) leaves. When SL x DL crosses encountered, resulted with deeply lobed leaves only.

4.5.4 Flower colour

Line 1 showed contrasting flower colour of yellow corolla with red veins on both sides. All other lines and testers showed yellow colour corolla. When L_1 crossed with testers, resulted with F_1s having yellow colour corolla with red veins only on out side of the corolla.

4.5.5 Purple throat at corolla

Lines L_2, L_3, L_5, L_9, L_{11} and L_{14} exhibited purple throat on inside of the corolla only. All other lines and testers exhibited the purple throat on both sides. When

Table. 9. Qualitative traits of parents and hybrids

Characters			L_1	L_2	L_3	L_4	L_5	L_6	L_7	L_8	L_9	L_{10}	L_{11}	L_{12}	L_{13}	L_{14}	L_{15}	Gene action
Colour of the leaf base	Lines→		R	RG	R	R	RG	R	R	R	R	R	R	R	R	RG	R	RG is dominant over R
	T_1	R	R	RG	R	R	RG	R	R	R	R	R	R	R	R	RG	R	
	T_2	R	R	RG	R	R	RG	R	R	R	R	R	R	R	R	RG	R	
Colour of the leaf vein	Lines→		R	G	G	G	G	G	G	G	G	G	G	G	G	G	G	Green vein is dominant over Red
	T_1	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	
	T_2	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	
Leaf lobing	Lines→		DL	SL	SL	SL	SL	DL	SL	SL	DL	DL	DL	DL	DL	SL	SL	DL is dominant over SL
	T_1	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	
	T_2	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	DL	
Flower colour	Lines→		YRV BoS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	YRVBoS is incompletely dominant over Yellow
	T_1	Y	YRVBaS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
	T_2	Y	YRVBaS	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Purple throat at Corolla	Lines→		BS	IO	IO	BS	IO	BS	BS	BS	IO	BS	IO	BS	BS	IO	BS	BS is dominant over IO
	T_1	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	
	T_2	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	BS	
Fruit pubescence	Lines→		D	D	D	D	SP	D	D	D	D	D	D	D	D	D	D	SP is dominant over D
	T_1	D	D	D	D	D	SP	D	D	D	D	D	D	D	D	D	D	
	T_2	D	D	D	D	D	SP	D	D	D	D	D	D	D	D	D	D	
Fruit colour	Lines→		R	LG	LG	LG	LG	LG	DG	LG	LG	LG	LG	LG	LG	LG	DG	LG is dominant over DG
	T_1	LG	RWGT	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	
	T_2	DG	RWGT	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	LG	DG	
No. of ridges on the fruit	Lines→		7	5	5	5	5	9	5	5	5	7	5	6	8	7	5	Five ridged fruit is dominant over multi ridged fruit
	T_1	5	6	5	5	5	6	7	5	5	5	7	5	6	8	7	5	
	T_2	5	7	5	5	5	5	7	5	5	5	6	5	6	7	7	5	

R - Red, RG - Reddish green, G - Green, Y - Yellow, YRVBoS - Yellow with Red vein on both sides of corolla, YRVBaS - Yellow with red vein on back side of corolla, DL - Deeply lobed, SL - Shallow lobed, BS - Both sides, IO - Inside only, D - Downy, SP - Slightly prickly, LG - Light green, DG - Dark green, RWGT - Red with green tinch the lines showing purple throat on inside of corolla only crossed with testers resulted with purple throat on both sides.

4.5.6 Fruit pubescence

Line 5 showed slightly prickly natured fruits. All others showed downy fruits only. When L_5 crossed with testers, resulted with F_1 having slightly prickly natured fruits only.

4.5.7 Fruit colour

Line 1 produced red coloured fruits, where as L_7, L_{15} and T_2 were having dark green (DG) colour fruits. Remaining lines and testers produced light green (LG) coloured fruits. When L_1 crossed with testers resulted with red fruits with green tinch. When DG x LG crosses encountered, resulted with light green fruits only.

4.5.8 Number of ridges on fruit

Lines L_1, L_6, L_{10}, L_{12}, L_{13} and L_{14} had more than five ridges on their fruits. Both the testers and other lines were five ridged. When multi ridged fruits crossed with five ridged fruits, the resultant progeny showed reduction in number of ridges towards five.

Discussion

DISCUSSION

The present study was carried out to evolve superior F_1 hybrids of okra combining resistance to YVMV by selecting suitable parents maintained in the germplasm of this crop in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Thrissur. The results obtained in the study is discussed under following heads below.

5.1 Analysis of variance

Significant amount of variability among parents was substantiated by ANOVA (Appendix I). Similarly for parents versus hybrids interaction provided adequacy for comparing the heterotic expression for all the traits except for internodal length, petiole length, mucilage content and vitamin A content. Partitioning of variance among the hybrids revealed that the mean squares due to lines was of greater magnitude than those due to testers for all characters except petiole length, duration of flowering, first fruiting node, number of fruits per plant, crop duration, yield per plant and vitamin A content. This revealed wide diversity among the lines for these traits and vice versa. The significance of variance due to L x T interaction showed the existence of variation among the hybrid populations for all traits except first fruiting node and crop duration as per Kempthorne, 1957.

5.2 Gene action

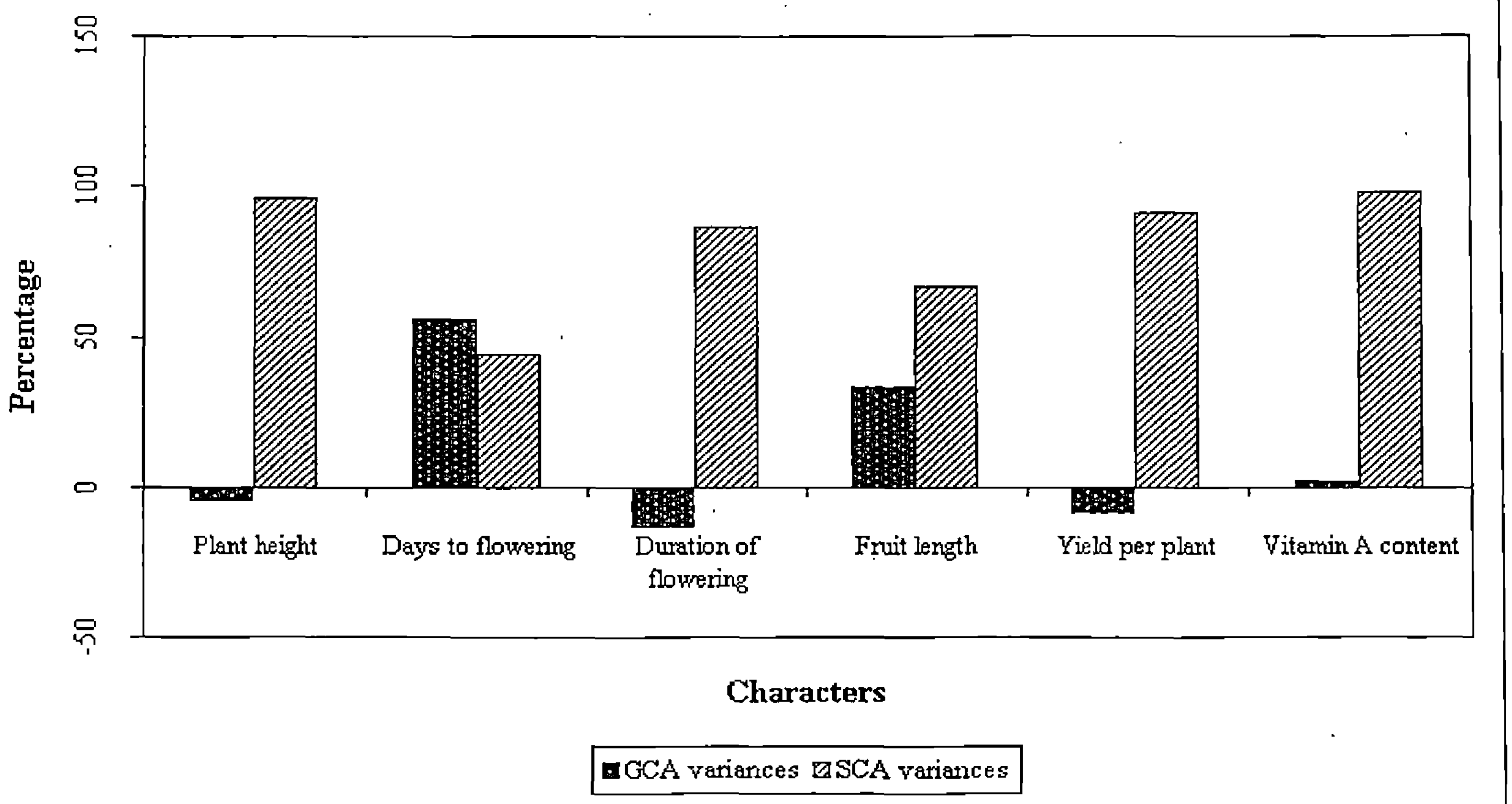
Successful and sound breeding methodology depends on the understanding of the gene action involved for the different characters. The relative estimates of variance due to SCA were higher than GCA variance for plant height, internodal length, number of primary branches, petiole length, duration of flowering, fruit length, fruit girth, number of fruits per plant, crop duration, yield per plant, mucilage content, calcium content, vitamin A content and magnesium content (Fig.1) indicating the preponderance of non-additive gene action in the inheritance of these characters (Appendix II). Similar findings were reported by Rao and Ramu (1975) for fruit girth, Singh and Singh (1984) for number of primary branches, Balachandran (1984) for vitamin A content, Korla *et al.* (1985) for mucilage content, Sivagamasundari *et al.* (1992a) for internodal length, Sivakumar *et al.* (1995) for number of fruits per plant, More and Patel (1997) for fruit length, Ahmed *et al.* (1997) for plant height and Singh and Sood (1999) for yield per plant. The predominance of non-additive gene action for these traits indicated the scope for exploitation of heterosis in improving these traits in okra.

There was a high additive gene action for days to flowering (Fig.1), first fruiting node. Similar findings were reported by Arumugam and Muthukrishnan (1979) for days to flowering and Korla *et al.* (1985) for first fruiting node. Pedigree method of breeding is the best for improvement of these traits in the segregating generations.

5.3 Evaluation of parents

To select reliable parents, the first and foremost step is to understand the genetic architecture of the selected parents for the desirable traits. The objective of a breeding programme will be fulfilled only when the parents selected based on the *per se* performance and *gca* effects. Therefore the parents selected in the study were assessed for their *per se* performance and general combining ability effects.

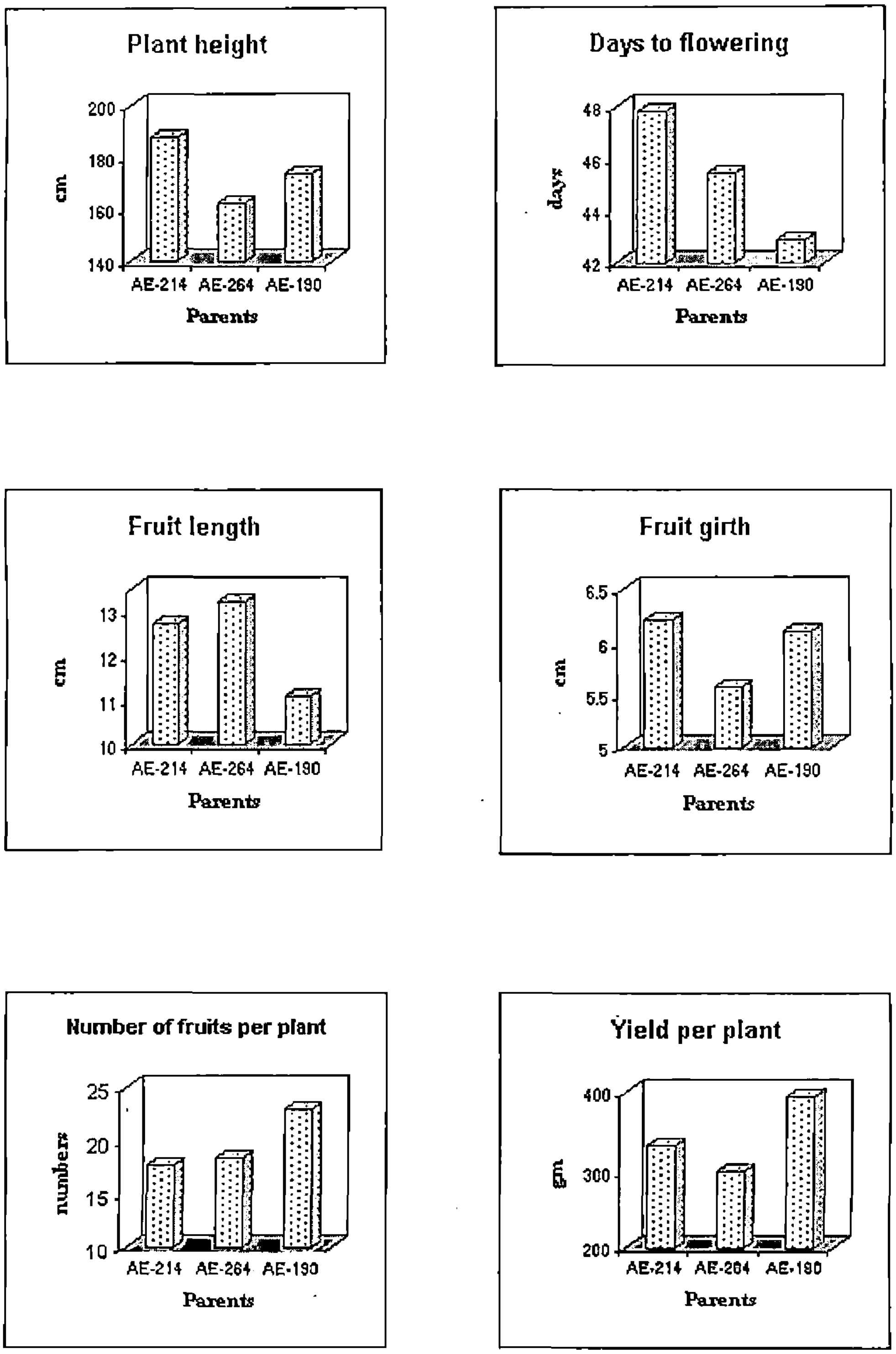
Fig. 1 Proportion of GCA and SCA variances



For a long time in breeding works, breeders chose the parents based on high *per se* performance alone. Among the parental materials studied (Table 4), the Line L_5 was superior for plant height, number of primary branches, fruit length, fruit girth, yield per plant, mucilage content and calcium content as it exhibited significantly increased mean values than the grand mean for these traits. Line 15 also had significantly superior mean values for plant height, internodal length, days to flowering, fruit length, number of fruits per plant, yield per plant and vitamin A content than grand mean. Line 1 also showed for plant height, petiole length, fruit length, yield per plant, mucilage content and vitamin A content. Likewise, Line 7 had for six different characters. Line 11 and L_{14} also had for four different characters different from each other. Among the two testers, T_2 showed significantly superior mean values for plant height, days to flowering, first fruiting node, fruit length, fruit girth, number of fruits per plant, yield per plant and vitamin A content. From the above result it can be concluded that L_5, L_{15} and T_2 were superior followed by L_1 and L_7.

Dhillon (1975) has pointed out that the combining ability of parents give useful information on the choice of parents in terms of expected performance of their progenies. Since *gca* effects are due to additive gene effects, it is fixable and useful for producing transgressive segregants (Sprague and Tatum, 1942). Parents were evaluated based on *gca* effects (Table 6). By and large, the present study revealed the *gca* effects on both direction - positive and negative for all the characters. Earlier workers Balachandran (1984), Sivagamasundari *et al.* (1992a), Sivakumar *et al.* (1995), Ahmed *et al.* (1997) reported similar such trend in okra. Significantly superior

Fig. 2. Mean performance of promising parents



gca effects were recorded by L_2 for plant height, petiole length, days to flowering, duration of flowering, number of fruits per plant, yield per plant, magnesium content and vitamin A content. Similarly L_9 was found to be good for plant height, internodal length, petiole length, fruit length, fruit girth, number of fruits per plant, yield per plant and magnesium content. Line 14 exhibited significant superior *gca* effects for number of primary branches, days to flowering, duration of flowering, fruit length, yield per plant, mucilage content and calcium content. Among the testers, T_2 exhibited significant superior *gca* effects for days to flowering, first fruiting node, fruit length, number of fruits per plant, yield per plant and vitamin A content. Nadarajan (1986) has pointed out that if a parent among the different available parents possessing significant *gca* effects for as many traits as possible, it is better earmarked for hybridization. Regarding the best combiners, L_2 (AE-202) and L_9 (AE-264) among lines and T_2 (AE-190) among testers can be justified as best general combiners.

The selection of parents based on *per se* performance alone might not hold well in producing superior progenies always (Prakash, 1987). Along with *per se* performance, combining ability has to be assessed while selecting parents (Kadambavanasundaram, 1980).

Chawla and Gupta (1983) stated that the parents with high *per se* performance as well as high *gca* effects could produce transgressive segregants in the F_2 as well as in the later generations. Hence, the parents were evaluated based on combining both the *per se* performance and the *gca* effects. From this, it can be understood that, the lines, L_5 (plant height, number of primary branches, fruit length, mucilage content and calcium content), L_9 (plant height, days to flowering, fruit length, number of fruits per plant and magnesium content), L_4 (days to flowering, duration of flowering, first fruiting node and fruit length), L_{13} (internodal length, fruit girth, crop duration and calcium content), L_2 and L_{14} for three different characters different from each other, L_7, L_8 and L_{15} for two different characters had high order of superiorities respectively for both *per se* and *gca* effects (Fig. 2). Among the testers, T_2 showed high order of superiority for both *per se* performance and *gca* effects for the characters such as plant height, days to flowering, duration of flowering, first fruiting node, fruit length, number of fruits per plant and yield per plant (Table 10). There fore multiple crosses involving the above said parents could be employed to get good segregants with all the desirable characters.

5.4 Evaluation of hybrids

The basic idea of hybridization programme is to combine the favourable genes present in the different parents into a single genotype. The hybrids, thus obtained can be utilised directly as F_1 hybrids to exploit hybrid vigour or forwarded to further generations to fix the desirable traits. The utilization of hybrid vigour will depend upon its genetic constitution. The genetic constitutions of hybrids are usually measured by the tools like *per se* performance, *sca* effects and heterosis per cent.

High *per se* performance was main criterion among the breeders for a long time (Kadambavanasundaram,1980). The *sca* effects are important criteria for evaluation of hybrids and it is the index to determine the usefulness of a particular cross combination in the exploitation of heterosis. Expression of heterosis even to a small magnitude for individual component is a desirable factor (Hatchcock and McDaniel, 1973). Scope for exploitation of heterosis will depend on its magnitude, the

Fig. 2. Mean performance of promising parents

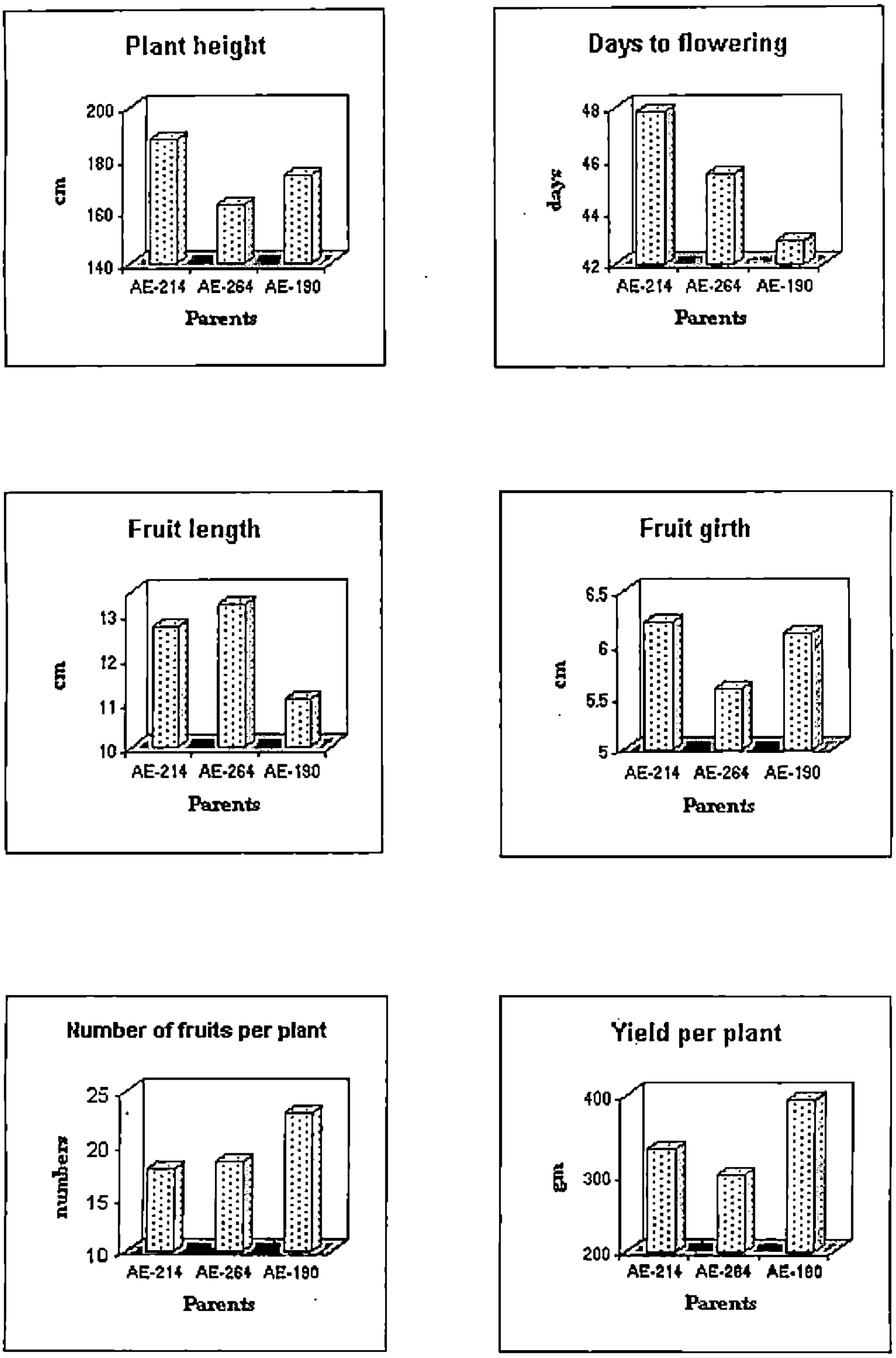


Table 10. Ranking of high status parents based on *per se* performance and *gca* effects

Characters	*Per se* performance	*gca* effects	*per se* performance and *gca* effects
Plant height	$L_5,L_1,L_{10},L_{15},L_{11},L_4,L_{14},L_7,T_2$	L_9,L_6,L_3,L_2	L_5,L_9,L_1,T_2
Internodal length	L_8,L_7,L_{15},T_1	$L_7,L_{13},L_5,L_{12},L_9,L_8,T_1$	L_7,L_8,L_{13},T_1
No. of primary branches	L_5	$L_5,L_6,L_3,L_{12},L_{14}$	L_5
Petiole length	L_1,L_{12},L_{11}	$L_6,L_{10},L_2,L_9,L_1,L_{13}$	L_1,L_6
Days to flowering	L_9,L_4,L_{15},T_2,T_1	L_{14},L_4,L_2,L_5,T_2	L_4,L_9,L_{14},T_2
Duration of flowering	T_2	L_4,L_2,L_{14}	L_4,T_2
First fruiting node	L_{11},L_9,T_2	L_4,T_2	L_{11},L_4,T_2
Fruit length	$L_9,L_5,L_7,L_4,L_1, L_{15},L_{10},T_1,T_2$	$L_4,L_9,L_{11},L_5,L_{15}, L_3, L_8,T_2$	L_9,L_4,L_5,T_2
Fruit girth	L_6,L_{13},L_5,L_7,T_2	$L_6,L_{12},L_{13},L_9,L_8,L_{14},T_1$	L_6,L_{13}
No. of fruits per plant	L_{15},L_{14},T_2	$L_9,L_2,L_6,L_3,L_{11},T_2$	L_{15},L_9,T_2
Crop duration	NIL	L_{13}	L_{13}
Yield per plant	$L_{15},L_1,L_{14},L_5,T_2$	$L_2,L_6,L_9,L_3,L_{14},T_2$	L_{14},L_{15},L_2,T_2
Mucilage content	$L_6,L_1,L_5,L_8,L_{10}, L_{14}$	L_6,L_{14},L_4,L_5	L_6,L_{14},L_5
Calcium content	L_5,L_{11},L_{13},T_1	$L_{13},L_{14},L_3,L_4,L_7,T_1$	L_{13},L_5,T_1
Vitamin A content	L_7,L_1,L_{15},T_2	L_{12},L_2,L_7,T_2	L_7,L_{12}
Magnesium content	L_8,L_2,L_7,T_1	$L_9,L_1,L_2,L_5,L_{12},L_{13}$	L_2,L_8,L_9

superiority of hybrids over standard variety, better parent and mid parent and biological feasibility for large scale production of hybrid seeds. Monoadelphous nature of bhendi flower makes the emasculation and pollination very easy. Availability of variation is more which favours exploitation of hybrid vigour. Number of seeds per fruit is comparatively more here.

Out of 30 hybrids , eight hybrids viz., L_9 x T_1, L_6 x T_2, L_2 x T_2 ,L_3 x T_2, L_9 x T_2, L_{10} x T_2, L_{12} x T_1 and L_3 x T_1 revealed significantly superior *per se* performance for plant height (Table 11). Among the 30 hybrids, 14 revealed positive and significant *sca* effects indicating the possibility of exploitation for the improvement of plant height (Table 12). Twenty hybrids recorded significant heterosis on all the three bases of heterosis (Relative heterosis, Heterobeltiosis and Standard heterosis) for plant height. (Table 13). The hybrid L_9 x T_1 had the highest heterosis value in all three bases followed by L_{12} x T_1 and L_{13} x T_1. Standard heterosis for this character was maximum in the hybrid L_9 x T_1. This sort of report was already given by Lal *et al.* (1975) and Mohamed *et al.*(1994). Among the hybrids, L_9 x T_1 excelled others by registering superior performance of *per se, sca* effects and the three bases of heterosis regarding plant height followed by L_{12} x T_1, L_6 x T_2 and L_{13} x T_2 (Table 14).

The *per se* performance for internodal length was negative and significant in seven out of 30 hybrids. Only one hybrid L_{12}x T_2 exhibited significantly superior negative heterosis for all the three bases for this trait. But high negative standard heterosis was given by the hybrid L_7 x T_1. Same type of report was presented by Lal *et al.* (1975) and Singh and Singh (1979). Seven hybrids were found to be good for internodal length, since they showed negatively significant *sca* effects. Among 30

Table 11. Selected hybrids with high *per se* performance

Sl. No.	Characters	Hybrids with high *per se* performance
1.	Plant height	L_9xT_1,L_6xT_2,L_2xT_2, L_3xT_2, L_9xT_2, $L_{10}xT_2$, $L_{12}xT_1$, L_3xT_1
2.	Internodal length	L_7xT_1, $L_{15}xT_2$, $L_{12}xT_2$, L_6xT_1, $L_{13}xT_1$, $L_{14}xT_1$, L_1xT_1
3.	No. of primary branches	L_5xT_2, L_6xT_2, $L_{12}xT_1$
4.	Petiole length	$L_{10}xT_2$, L_6xT_2, $L_{13}xT_1$, L_6xT_1, L_2xT_2
5.	Days to flowering	L_9xT_1, $L_{14}xT_2$, L_9xT_2, L_5xT_2
6.	Duration of flowering	L_2xT_1
7.	First fruiting node	NIL
8.	Fruit length	L_9xT_2, L_4xT_2, $L_{11}xT_2$, L_4xT_1, L_5xT_1, L_9xT_1, L_8xT_2, $L_{11}xT_1$, L_3xT_2, $L_{15}xT_2$, $L_{12}xT_2$, L_2xT_1, L_1xT_1
9.	Fruit girth	L_6xT_1, $L_{13}xT_2$, $L_{12}xT_1$, L_9xT_1, L_5xT_1, $L_{14}xT_1$, L_2xT_1, $L_{11}xT_1$, L_8xT_1, $L_{12}xT_2$, L_4xT_2
10.	No. of fruits per plant	L_6xT_2, L_2xT_2, L_9xT_1, L_3xT_1, $L_{11}xT_1$
11.	Crop duration	NIL
12.	Yield per plant	L_6xT_2, L_2xT_2, L_9xT_1, L_1xT_1, L_5xT_2
13.	Mucilage content	L_5xT_1, L_6xT_2, L_7xT_2, $L_{14}xT_1$, L_6xT_1, $L_{12}xT_1$, $L_{13}xT_1$, $L_{14}xT_2$, L_4xT_2
14.	Calcium content	$L_{13}xT_1$, L_4xT_1, L_7xT_1, $L_{14}xT_1$, L_1xT_1, L_3xT_1, $L_{14}xT_2$, L_3xT_2, L_4xT_2, $L_{12}xT_2$, $L_{13}xT_2$
15.	Vitamin A content	$L_{12}xT_2$, $L_{12}xT_1$, $L_{11}xT_2$, L_7xT_2
16.	Magnesium content	L_5xT_2, L_9xT_2, L_2xT_1, $L_{12}xT_1$, $L_{13}xT_2$

Table 12. Selected hybrids with superior *sca* effects

Sl. No.	Characters	Hybrids with superior *sca* effects
1.	Plant height	L_9xT_1, $L_{13}xT_2$, $L_{10}xT_2$, L_1xT_1, $L_{12}xT_1$, L_8xT_2, L_2xT_2, $L_{15}xT_1$, L_6xT_2, $L_{11}xT_1$, L_5xT_2, L_7xT_1, $L_{14}xT_1$, L_3xT_2
2.	Internodal length	L_4xT_2, $L_{15}xT_2$, L_6xT_1, $L_{12}xT_2$, L_1xT_1, L_2xT_1, $L_{14}xT_1$
3.	No. of primary branches	L_6xT_2, $L_{12}xT_1$, L_9xT_1, L_5xT_2
4.	Petiole length	$L_{12}xT_1$, $L_{10}xT_2$, L_8xT_1, $L_{13}xT_1$, $L_{15}xT_2$, $L_{14}xT_2$, L_2xT_2, L_7xT_2, L_3xT_1
5.	Days to flowering	$L_{13}xT_2$, L_9xT_1, $L_{11}xT_1$, $L_{15}xT_1$, L_2xT_1, L_6xT_1, L_1xT_2, L_4xT_1
6.	Duration of flowering	$L_{10}xT_2$, L_2xT_1, L_5xT_2, $L_{13}xT_2$
7.	First fruiting node	$L_{10}xT_2$, L_2xT_1, L_7xT_1, $L_{13}xT_2$, $L_{15}xT_1$
8.	Fruit length	L_1xT_1, L_2xT_1, $L_{13}xT_2$, L_5xT_1, $L_{12}xT_2$, L_8xT_2, L_3xT_2, L_9xT_2, $L_{11}xT_2$, $L_{15}xT_2$, $L_{10}xT_2$, L_4xT_1, L_6xT_1, $L_{14}xT_1$
9.	Fruit girth	$L_{13}xT_2$, L_4xT_2, L_9xT_2, L_6xT_1, L_5xT_1, L_2xT_1, $L_{11}xT_1$, $L_{10}xT_2$, $L_{14}xT_1$, L_1xT_1, L_7xT_2, L_3xT_2, L_8xT_2, $L_{12}xT_1$, $L_{15}xT_2$
10.	No. of fruits per plant	L_6xT_2, L_9xT_1, L_2xT_2, L_1xT_1, $L_{10}xT_2$, $L_{12}xT_1$, L_5xT_2, $L_{13}xT_2$, $L_{15}xT_1$, L_7xT_1, $L_{11}xT_1$, L_3xT_1, L_8xT_1
11.	Crop duration	$L_{10}xT_2$, L_2xT_1, L_5xT_2
12.	Yield per plant	L_6xT_2, $L_{10}xT_2$, L_9xT_1, L_1xT_1, $L_{12}xT_1$, L_2xT_2, L_5xT_2, $L_{13}xT_2$, $L_{15}xT_1$, $L_{11}xT_1$, L_7xT_1, L_3xT_1, L_8xT_1
13.	Mucilage content	$L_{13}xT_1$, L_1xT_1, L_7xT_2, $L_{12}xT_1$, L_3xT_2, L_9xT_2, L_5xT_1
14.	Calcium content	L_6xT_2, L_1xT_1, L_7xT_1, L_9xT_2, $L_{12}xT_2$
15.	Vitamin A content	$L_{11}xT_2$, L_3xT_2, L_9xT_1, $L_{10}xT_1$, L_1xT_1, $L_{12}xT_2$; $L_{13}xT_1$, L_8xT_2, $L_{14}xT_1$, L_4xT_1,L_7xT_2
16.	Magnesium content	L_2xT_1, L_5xT_2, L_7xT_2, $L_{12}xT_1$, $L_{13}xT_2$, L_1xT_1, L_3xT_1, L_6xT_2, L_8xT_2,L_9xT_2, $L_{14}xT_1$,$L_{15}xT_1$

Table 13. Selected hybrids with high heterosis on all three bases

Sl. No.	Characters	Selected hybrids with high heterosis on all three bases
1.	Plant height	L_9xT_1, $L_{12}xT_1$, L_3xT_1, L_6xT_1, L_2xT_2, L_3xT_2, L_8xT_2, L_9xT_2, $L_{10}xT_2$, L_2xT_1, L_1xT_1, $L_{13}xT_2$, $L_{11}xT_1$, $L_{14}xT_1$, L_7xT_1, $L_{15}xT_1$, L_4xT_2, L_4xT_1, $L_{12}xT_1$, L_5xT_2
2.	Internodal length	$L_{12}xT_2$
3.	No. of primary branches	L_6xT_2
4.	Petiole length	L_6xT_2, $L_{14}xT_2$, L_2xT_2, $L_{15}xT_2$
5.	Days to flowering	NIL
6.	Duration of flowering	NIL
7.	First fruiting node	NIL
8.	Fruit length	$L_{11}xT_2$, L_4xT_2, L_8xT_2, L_9xT_2, L_3xT_2, $L_{12}xT_2$, L_4xT_1, L_6xT_2, $L_{15}xT_2$, $L_{11}xT_1$, L_5xT_1, L_9xT_1, L_2xT_1, $L_{10}xT_2$, L_6xT_1, L_1xT_1, $L_{13}xT_2$, $L_{14}xT_2$, L_3xT_1, L_5xT_2, L_8xT_1, $L_{15}xT_1$, L_2xT_2, L_7xT_2, L_1xT_2
9.	Fruit girth	$L_{12}xT_1$, L_9xT_1, $L_{14}xT_1$
10.	No. of fruits per plant	L_6xT_2, L_9xT_1, L_3xT_1, L_2xT_2, $L_{11}xT_1$
11.	Crop duration	NIL
12.	Yield per plant	L_9xT_1, L_6xT_2, L_3xT_1, L_2xT_2, $L_{12}xT_1$, $L_{11}xT_1$, L_2xT_1, L_1xT_1, L_5xT_2, $L_{14}xT_2$, $L_{10}xT_2$
13.	Mucilage content	L_7xT_2, $L_{12}xT_1$
14.	Calcium content	L_3xT_2, $L_{12}xT_2$, $L_{14}xT_2$, L_7xT_1
15.	Vitamin A content	$L_{12}xT_2$
16.	Magnesium content	L_5xT_2, L_9xT_2

Table 14. Ranking high status hvbrids based on *ver se* verformance, *sca* effects and heterosis

Sl. No.	Characters	High status hybrids
1.	Plant height	L_9xT_1, $L_{12}xT_1$, L_6xT_2, $L_{13}xT_2$
2.	Internodal length	$L_{12}xT_2$, $L_{15}xT_2$, L_7xT_1
3.	No. of primary branches	L_6xT_2, L_5xT_2, $L_{12}xT_1$
4.	Petiole length	L_6xT_2, $L_{10}xT_2$, $L_{13}xT_2$
5.	Days to flowering	L_9xT_1,$L_{14}xT_2$, $L_{13}xT_2$
6.	Duration of flowering	L_2xT_1, $L_{10}xT_2$, L_4xT_1
7.	First fruiting node	L_2xT_1, $L_{15}xT_1$, $L_{10}xT_2$
8.	Fruit length	L_9xT_2, $L_{11}xT_2$, L_1xT_1, L_4xT_2
9.	Fruit girth	$L_{12}xT_1$, $L_{13}xT_2$, L_6xT_1, L_9xT_1
10.	No. of fruits per plant	L_6xT_2, L_2xT_2, L_9xT_1
11.	Crop duration	L_2xT_1, $L_{10}xT_2$
12.	Yield per plant	L_6xT_2, L_9xT_1, $L_{10}xT_2$, L_2xT_2, L_3xT_1, L_1xT_1
13.	Mucilage content	L_7xT_2, L_5xT_1, $L_{13}xT_1$, $L_{12}xT_1$
14.	Calcium content	L_7xT_1, L_3xT_2, $L_{12}xT_2$, L_6xT_2
15.	Vitamin A content	$L_{12}xT_2$, $L_{11}xT_2$
16.	Magnesium content	L_5xT_2, L_9xT_2, L_2xT_1

hybrids, L_{12} x T_2, L_{15} x T_2 and L_7 x T_1 excelled others in all three criteria such as *per se* performance, *sca* effects and heterosis on all the three bases.

Among the 30 hybrids, L_5 x T_2, L_6 x T_2 and L_{12} x T_1 showed significant *per se* performance for number of primary branches. Only one hybrid L_6 x T_2 showed significant positive heterosis for this trait. But high standard heterosis for this trait was expressed by L_5 x T_2. Rameshpathak and Syamal (1997) also reported same type of result. A total of four hybrids registered positively significant *sca* effects for this trait. The hybrids, L_6 x T_2, L_5 x T_2 and L_{12} x T_1 surpassed others in all the criteria viz., *per se* performance, *sca* effects and heterosis on all the three bases.

For petiole length, five hybrids showed significant *per se* performance. Nine hybrids showed significantly superior positive *sca* effect for this trait. Four hybrids exhibited significantly superior positive heterosis on all the three bases for this trait. Highest standard heterosis for this trait was shown by L_{10} x T_2. Among them, L_6 x T_2, L_{10} x T_2 and L_{13} x T_2 excelled others in all the three criteria.

Earliness is considered as desirable trait for supply the produce early in the market. Out of 30 hybrids, four have revealed significantly positive *per se* performance for the trait days to flowering. None of the hybrids exhibited significantly superior negative heterosis for all the three bases for this trait. A total of eight hybrids were found to be good for days to flowering, since they showed negatively significant *sca* effects. The hybrid L_9 x T_1 was the only hybrid expressed negative standard heterosis for this trait. But it was not a significant value. Comparing all the hybrids, L_9 x T_1 was the only hybrid exhibited negative heterosis on all the three bases. Among 30 hybrids, three hybrids viz., L_9 x T_1, L_{14} x T_2 and L_{13} x T_2 excelled others in the criteria such as *per se* performance and *sca* effects. These hybrids could be further evaluated for exploiting earliness in okra.

For the trait, duration of flowering, only one hybrid, L_2 x T_1 showed significantly superior *per se* performance and four hybrids viz., L_{10} x T_2, L_2 x T_1, L_5 x T_2 and L_{13} x T_2 showed significant positive *sca* effects. None of the hybrids exhibited significantly superior positive heterosis on all the three bases for this character. Highest standard heterosis was given by L_2 x T_1 that was not significant. But this is the hybrid which showed highest heterosis on the other two bases of heterosis. Among the hybrids, L_2 x T_1, L_{10} x T_2 and L_4 x T_1 registered superior performance of *per se* ,*sca* effects.

For first fruiting node, none showed significantly superior *per se* performance and none of the hybrids showed significantly superior negative heterosis on all the three bases. Highest negative standard heterosis was given by L_{10} x T_2 and L_{13} x T_2. But that was not a significant value. Five hybrids expressed significantly superior negative *sca* effects for this trait. Among 30 hybrids, L_2 x T_1 excelled others followed by L_{15} x T_1 and L_{10} x T_2.

Out of 30 hybrids, 13 registered significantly superior *per se* performance for fruit length. Twenty five hybrids revealed significantly superior heterosis on all the three bases for this trait. The hybrid L_9 x T_2 was the one which showed highest standard heterosis. Similar results were reported by Sheela *et al.* (1988) and Sivagamasundari *et al.*(1992b). Fourteen hybrids were found to show positive and significant *sca* effects for this trait. Among the hybrids, L_9 x T_2 excelled well others followed by L_{11} x T_2, L_4 x T_2 and L_1 x T_1.

Among the hybrids, 11 revealed significantly superior *per se* performance for fruit girth. Three hybrids (L_{12} x T_1, L_9 x T_1 and L_{14} x T_1) were found to be superior for heterosis on all the three bases for this trait. Highest significant standard heterosis was given by L_6 x T_1. Singh and Singh (1979) also reported same sort of report. A total of 15 hybrids revealed significantly superior *sca* effects. The hybrid, L_{12} x T_1 excelled others in all the three criteria. However, L_{13} x T_2 , L_6 x T_1 and L_9 x T_1 were also found to be superior on all the three criteria.

Five hybrids recorded significantly superior *per se* performance for number of fruits per plant. Five other hybrids also recorded significantly superior heterosis on all the three bases for this trait. The hybrid L_6 x T_2 expressed highest significant standard heterosis. More and Patel (1997) revealed similar result for this character. Thirteen hybrids showed positively significant *sca* effects for this trait. Among the hybrids, three hybrids excelled others in all the criteria . They are L_6 x T_2, L_2 x T_2 and L_9 x T_1, which have registered superior performance of *per se, sca* effects and also in all three bases of heterosis. So these hybrids can be utilized for future breeding programme.

For crop duration, none of the hybrids showed significantly superior *per se* performance. Three hybrids viz., L_{10} x T_2, L_2 x T_1 and L_5 x T_2 showed significantly superior positive *sca* effects. None of the hybrids exhibited positively significant heterosis on all the three bases. Hybrid L_2 x T_1 showed highest non significant heterosis. But it showed highest significant heterosis on the other two bases. Among the 30 hybrids, L_2 x T_1 and L_{10} x T_2 excelled others for this trait.

Out of 30 hybrids, five registered significantly superior *per se* performance and 11 hybrids have recorded significantly superior heterosis for all the three bases for yield per plant. L_6 x T_2 was the hybrid which showed highest significant standard heterosis for this trait. Singh and Singh (1979) also reported similar results for this character. A total of 13 hybrids exhibited significantly superior *sca* effects for yield per plant. Out of 30 hybrids, six hybrids viz., L_6 x T_2, L_9 x T_1, L_{10} x T_2, L_2 x T_2, L_3 x T_1 and L_1 x T_1 were superior to others for all the three criteria. There fore, these hybrids could be tried for concomitant performance in the future to exploit higher yield.

Among the 30 hybrids, nine have registered significant superior *per se* performance for mucilage content in the fruit. Two hybrids, L_7 x T_2 and L_{12} x T_1 exhibited significantly superior negative heterosis over all the three bases of heterosis. But L_5 x T_1 was the hybrid showed lowest significant standard heterosis for this trait. Seven hybrids exhibited significantly superior negative *sca* effects for this trait. The hybrids, L_7 x T_2, L_5 x T_1, L_{13} x T_1 and L_{12} x T_1 were excelled others for all the three criteria.

For calcium content, 11 hybrids showed significantly superior *per se* performance and five showed significantly superior *sca* effects. Four hybrids showed heterosis on all the three bases for this trait. The hybrid L_{13} x T_1 was the one which showed highest significant standard heterosis. Among the 30 hybrids, four were superior than others for all the three criteria. They were L_7 x T_1, L_3 x T_2, L_{12} x T_2 and L_6 x T_2. These hybrids lend scope for future utilization in breeding programme.

For Vitamin A content, four hybrids registered significantly superior *per se* performance. Eleven hybrids showed significantly superior positive *sca* effects for this

Plate 2

Plate 2a

Plate 2b

Plate 2c

Plate 3

Plate 3a

Plate 3b

Plate 3c

trait. One hybrid L_{12} x T_2 showed significant heterosis over all the three bases. This was the hybrid which showed highest heterosis on all the three bases. Among the 30 hybrids, L_{12} x T_2 and L_{11} x T_2 were superior to others for all the three criteria such as *per se* performance, *sca* effects and also in all three bases of heterosis. Therefore these hybrids could be utilized to increase the vitamin A content.

Out of 30 hybrids, five registered significant superior *per se* performance for magnesium content. Twelve hybrids showed significantly superior positive *sca* effects for this trait. But only two hybrids viz., L_5 x T_2 and L_9 x T_2 showed positive significant heterosis for this character. Both the hybrids expressed highest standard heterosis for this trait. Among the hybrids, L_5 x T_2, L_9 x T_2 and L_2 x T_1 registered superiority over other hybrids for all the three criteria.

As a whole none of the hybrids established its superiority for the entire traits in all the three criteria viz., *per se* performance, *sca* effects and heterosis on all the three bases (Relative heterosis, Heterobeltiosis and Standard heterosis).

However, the hybrid L_6 x T_2 (AE-219 x AE-190) (Plate 3a) could be sorted as the best among all hybrids, since it excelled others in all the three criteria of evaluation of hybrids for the traits viz., plant height, number of primary branches, petiole length, number of fruits per plant, yield per plant and calcium content. Next in the order was L_9 x T_1 (AE-264 x AE-285) (Plate 3b), L_{10} x T_2 (AE-265 x AE-190) and L_2 x T_1 (AE-202 x AE-285) (Plate 3c).

Even though in practical utility, the yield and its components are the basic and fore most important traits considered for yield improvement. Therefore for higher yield, the hybrid L_6 x T_2 (AE-219 x AE-190) was considered as the best followed by L_9 x T_1 (AE-264 x AE-285) and L_{10} x T_2 (AE-265 x AE-190) (Table 15)(Fig 3).

5.5 Evaluation of qualitative characters

Regarding the study on qualitative characters (Table 9), following trends had derived. Reddish green colour of the leaf base is dominant over the red colour leaf base. Green colour leaf vein is dominant over the red colour leaf vein.

Deeply lobed nature of the leaves is dominant over shallow lobed leaves. This result was confirmed by the report of Venkataramani (1952). Yellowish with red veins on both sides of corolla in flower is incompletely dominant over the yellow colour.

Purple throat at corolla on both sides is dominant over the purple throat at inside only. Kalia and Padda (1962) also confirmed this. Slightly prickly nature of the fruit is dominant over the downy fruits. This was confirmed by Sharma and Arora (1993). Fruit with light green colour is dominant over the fruits with dark green colour. Five ridged fruits were dominant over multi ridged fruits.

5.6 Evaluation of genotypes for resistance to YVMV

The prime objective of this work is to develop YVMV resistant hybrids. So the parents and hybrids were evaluated for their reaction to YVMV.

5.6.1 Evaluation of parents

Among the 15 lines evaluated based on the coefficient of infection (CI) two genotypes namely AE-238 (L_7) and AE-287 (L_{15}) showed highly resistant reaction to YVMV. Remaining genotypes were moderately susceptible to susceptible (Table 3). The disease free genotype AE-238 (Plate 2a) was tested by artificial inoculation

Table 15. Performance of promising hybrids

Promising hybrids	Mean values				
	Yield per plant (g)	Fruit length (cm)	Fruit girth (cm)	No. of fruits per plant	Resistance to YVMV
AE-219 x AE-190	671.50	14.23	6.04	33.60	HR
AE-264 x AE-285	614.60	15.83	6.45	32.30	HR
AE-265 x AE-190	448.70	14.00	5.42	23.70	HR
AE-202 x AE-285	453.80	14.90	6.22	23.70	R

Fig. 3. Performance of promising hybrids over standard check

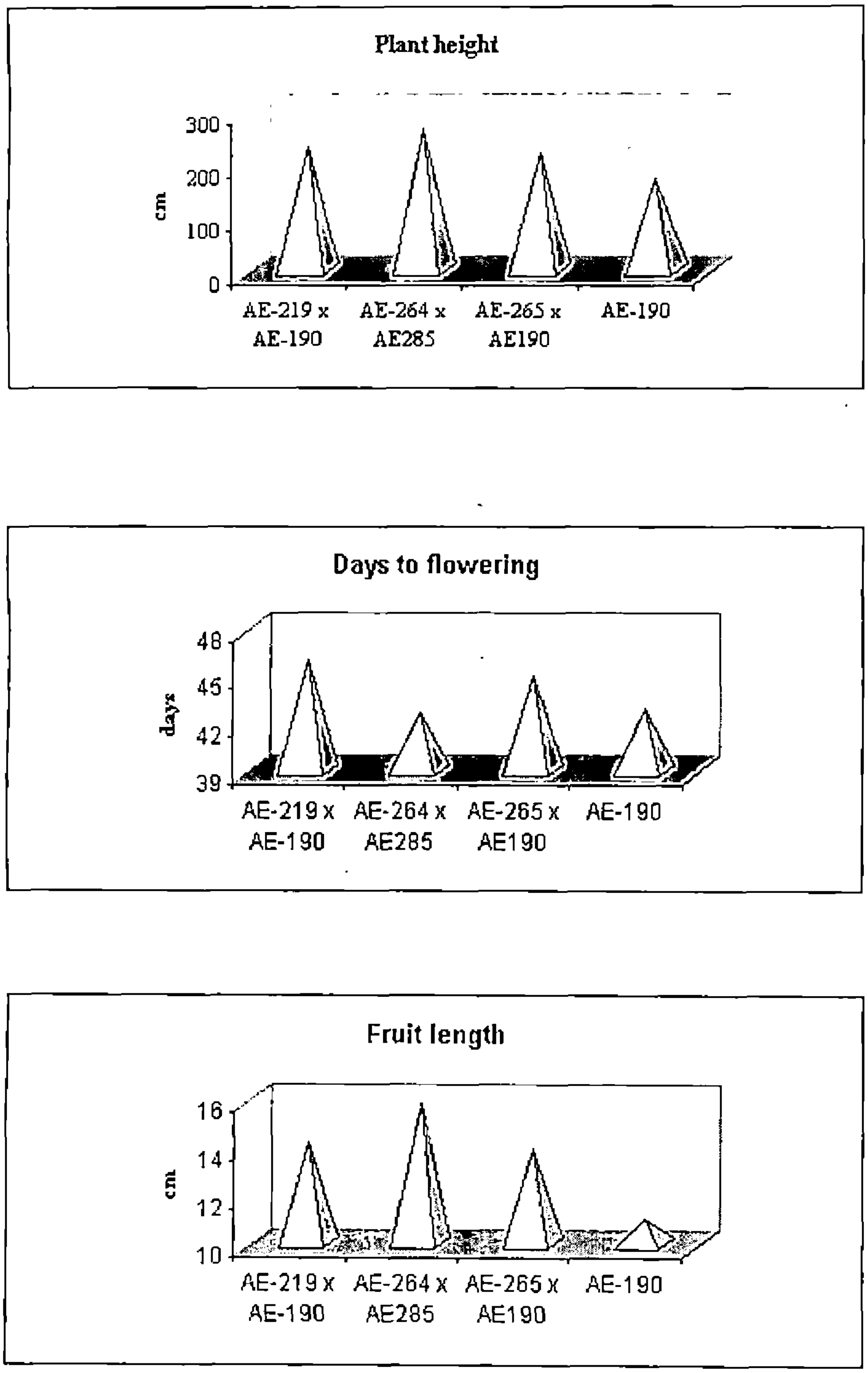
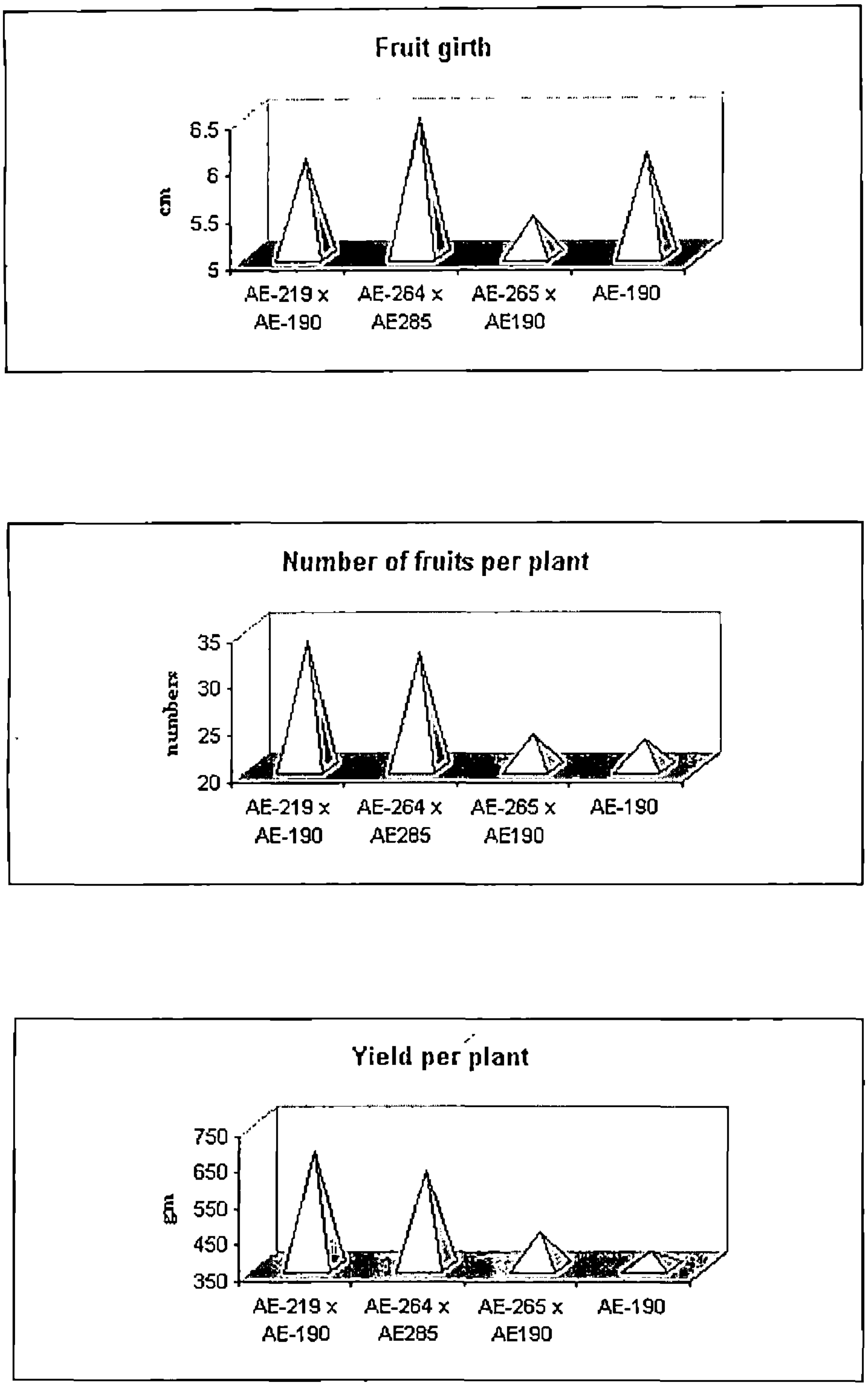


Fig. 3. Performance of promising hybrids over standard check



through grafting and vector transmission methods. It also confirmed the resistance reaction of this genotype. Hence, this genotype as well as AE-287 can be used as a potential parents for incorporation of disease resistance. Batra and Singh (2000) who conducted an experiment with 13 other genotypes also reported similar type of result. Moderately resistant reaction of the tester AE-190 was similar with the inference of Singh and Singh (2000). Resistance to YVMV rendered by AE-238 and AE-287 must be attributed to their origin out of the cross *A. esculentus* x *A. caillei* in which *A. caillei* is a source of resistance to YVMV.

5.6.2 Evaluation of hybrids

Among 30 hybrids, two viz. AE-238 x AE-190 (L_7 x T_2) (Plate 2b) and AE-265 x AE-190 (L_{10} x T_2) (Plate 2c) did not show any symptom in the field level and in grafting and vector transmission studies also. Other 11 hybrids were showed highly resistant reaction. Eight hybrids exhibited resistant reaction. Five other hybrids with moderate resistant reaction. Experiment conducted by Fugro and Rajput (1999) with 36 hybrids resulted similar type of result.

Line x tester analysis of parents and hybrids resulted with three top ranking hybrids(AE-219 x AE-190, AE-264 x AE-285 and AE-265 x AE-190). By comparing these hybrids with their disease reaction to YVMV, it can be concluded that AE-265 x AE-190 (L_{10} x T_2) as most superior hybrid (CI = 0). Next best hybrids with highly resistant reaction and superior yield were AE-264 x AE-285 (L_9 x T_1) followed by AE-219 x AE-190 (L_6 x T_2).

5.6.3 Inference on the genetics of resistance to YVMV

From this investigation, it can be concluded that two parents (AE-238 (L_7) and AE-287 (L_{15})) were highly resistant to YVMV. Among them one parent AE-238 did not show any symptom in field level and also in grafting and vector transmission studies. The cross involving this line with moderately resistant tester (AE-190) (T_1) resulted in disease free F_1 in field screening as well as grafting and vector transmission studies. Another hybrid involving that line (AE-238 x AE-285) (L_7 x T_1) showed highly resistant reaction to YVMV with coefficient of infection of 0.63. The parent AE-287 produced highly resistant hybrid when crossed with AE-190 and resistant hybrid when crossed with AE-285.

The hybrid AE-265 x AE-190 did not show any symptom in field screening, grafting and vector transmission studies. But its female parent was in susceptible category, which gave resistant hybrid with moderately resistant AE-190. Eleven other hybrids were also highly resistant to YVMV with varying levels of coefficient of infection. Then their parents also in different disease categories.

From the above inferences conclusion can be made towards the complex nature of resistance to YVMV involving major and minor genes with probably acting modifiers. Sharma and Dhillon (1983) also reported similar results that reaffirm the findings obtained in the present study. Hence, further study on the subsequent generations involving BC_1, BC_2, and F_2 are required to confirm the genetics of resistant reaction to YVMV in the parents selected for the present study.

Summary

SUMMARY

The investigations on "Development of yellow vein mosaic virus (YVMV) resistant hybrids in Okra (*Abelmoschus esculentus* (L.) Moench)" was carried out during 2000-01 at the Department of Olericulture, College of Horticulture, Thrissur to identify potential parents and superior F_1 hybrids having resistance to YVMV in Okra.

Fifteen lines viz., AE-198, AE-202, AE-210, AE-211, AE-214, AE-219, AE-238, AE-260, AE-264, AE-265, AE-275, AE-279, AE-280, AE-282 and AE-287 were crossed with two testers viz., AE-285 and AE-190 (Parbhani Kranti) in a line x tester mating design. The 17 parents and their 30 hybrids were evaluated for the quantitative traits such as plant height, internodal length, number of primary branches, petiole length, days to flowering, duration of flowering, first fruiting node, fruit length, fruit girth, number of fruits per plant, crop duration, yield per plant, quality traits such as mucilage content, calcium content, vitamin A content and Magnesium content and qualitative characters such as colour of the leaf base, colour of the leaf vein, leaf lobing, flower colour, purple throat at corolla, fruit pubescence, fruit colour and number of ridges on fruit and also they were evaluated for resistance to YVMV. Combining ability effects, heterosis were also worked out to select superior hybrids and parents.

The important findings of the present study are

1. The analysis of variance for all the characters studied was highly significant, which indicated wide variability among the parents and hybrids for these traits.
2. The SCA variance was greater in magnitude than the GCA variance for plant height, internodal length, number of primary branches, petiole length, duration of

flowering, fruit length, fruit girth, number of fruits per plant, crop duration, yield per plant, mucilage content, calcium content, vitamin A content and magnesium content indicating preponderance of non-additive gene action, whereas, preponderance of additive gene action was noticed for days to flowering and first fruiting node.

3. On the basis of *per se* performance, AE-214 (L_5) and AE-287 (L_{15}) excelled well among lines for most of the characters. AE-214 was superior for plant height (187.36 cm), number of primary branches (3.40), fruit length (12.71 cm), fruit girth (6.20 cm), yield per plant (334 g), mucilage content (0.31%) and calcium content (0.21%). AE-287 was superior for plant height (184.37 cm), internodal length (3.46 cm), days to flowering (46.2 days), fruit length (11.80 cm), number of fruits per plant (22.50), yield per plant (390 g) and vitamin A content (1296.81 IU/100 g) than grand mean. Among testers, AE-190 (T_2) excelled well for the characters such as plant height (173.79 cm), days to flowering (42.90 days), first fruiting node (7.00), fruit length (11.09 cm), fruit girth (6.10 cm), number of fruits per plant (23.00), yield per plant (393.40 g) and vitamin A content (1448.86 IU/100 g) than the other tester. So these three parents were found to be best among genotypes tried.

4. The line AE-202 (L_2) established good general combining ability values for plant height, petiole length, days to flowering, duration of flowering, number of fruits per plant, yield per plant, magnesium content and vitamin A content and AE-264 (L_9) for plant height, internodal length, petiole length, fruit length, fruit girth, number of fruits per plant, yield per plant and magnesium content. The tester

AE-190 (T_2) (days to flowering, first fruiting node, fruit length, number of fruits per plant, yield per plant and vitamin A content) was also found to have favourable *gca* effects and hence these parents can be used for recombination breeding.

5. Among the lines, AE-214 (L_5) for plant height, number of primary branches, fruit length, mucilage content and calcium content and AE-264 (L_9) for plant height, days to flowering, fruit length, number of fruits per plant and magnesium content showed good performance by registering high *per se* performance as well as high *gca* effects. Similarly among testers, AE-190 (T_2) (plant height, days to flowering, duration of flowering, first fruiting node, fruit length, number of fruits per plant and yield per plant) was the best performer. Hence, multiple crosses involving these parents may throw desirable segregants combing all the economic characters.

6. Based on the *per se* performance, *sca* effects and heterosis on all the three bases, the hybrids, AE-264 x AE-285 (L_9 x T_1), AE-279 x AE-285 (L_{12} x T_1), AE-219 x AE-190 (L_6 x T_2) and AE-280 x AE-190 (L_{13} x T_2) for plant height, AE-279 x AE-190 (L_{12} x T_2), AE-287 x AE-190 (L_{15} x T_2) and AE-238 x AE-285 (L_7 x T_1) for internodal length, AE-219 x AE-190 (L_6 x T_2), AE-214 x AE-190 (L_5 x T_2) and AE-279 x AE-285 (L_{12} x T_1) for number of primary branches, AE-219 x AE-190 (L_6 x T_2), AE-265 x AE-190 (L_{10} x T_2) and AE-280 x AE-190 (L_{13} x T_2) for petiole length, AE-264 x AE-285 (L_9 x T_1), AE-282 x AE-190 (L_{14} x T_2) and AE-280 x AE-290 (L_{13} x T_2) for days to flowering, AE-202 x AE-285 (L_2 x T_1), AE-265 x AE-190 (L_{10} x T_2) and AE-211 x AE-285 (L_4 x T_1) for duration of

flowering, AE-202 x AE-285 (L_2 x T_1), AE-287 x AE-285 (L_{15} x T_1) and AE-265 x AE-190 (L_{10} x T_2) for first fruiting node, AE-264 x AE-190 (L_9 x T_2), AE-275 x AE-190 (L_{11} x T_2), AE-198 x AE-285 (L_1 x T_1) and AE-214 x AE-190 (L_4 x T_2) for fruit length, AE-279 x AE-285 (L_{12} x T_1), AE-280 x AE-190 (L_{13} x T_2), AE-219 x AE-285 (L_6 x T_1) and AE-264 x AE-285 (L_9 x T_1) for fruit girth, AE-219 x AE-190 (L_6 x T_2), AE-202 x AE-190 (L_2 x T_2) and AE-264 x AE-285 (L_9 x T_1) for number of fruits per plant, AE-202 x AE-285 (L_2 x T_1) and AE-265 x AE-190 (L_{10} x T_2) for crop duration, AE-219 x AE-190 (L_6 x T_2), AE-264 x AE-285 (L_9 x T_1), AE-265 x AE-190 (L_{10} x T_2), AE-202 x AE-190 (L_2 x T_2), AE-210 x AE-285 (L_3 x T_1) and AE-198 x AE-285 (L_1 x T_1) for yield per plant, AE-238 x AE-190 (L_7 x T_2), AE-214 x AE-285 (L_5 x T_1), AE-280 x AE-285 (L_{13} x T_1) and AE-279 x AE-285 (L_{12} x T_1) for mucilage content, AE-238 x AE-285 (L_7 x T_1), AE-210 x AE-190 (L_3 x T_2), AE-279 x AE-190 (L_{12} x T_2) and AE-219 x AE-190 (L_6 x T_2) for calcium content, AE-279 x AE-190 (L_{12} x T_2) and AE-275 x AE-190 (L_{11} x T_2) for vitamin A content and AE-214 x AE-190 (L_5 x T_2), AE-264 x AE-190 (L_9 x T_2) and AE-202 x AE-285 (L_2 x T_1) for magnesium content excelled other hybrids.

7. Among the hybrids, on the basis of *per se* performance, *sca* effects and heterosis on the three bases (relative heterosis, heterobeltiosis and standard heterosis), three hybrids namely AE-219 x AE-190 (L_6 x T_2), AE-264 x AE-285 (L_9 x T_1) and AE-265 x AE-190 (L_{10} x T_2) could be acclaimed as the best crosses for most of the economic traits and could be used for further exploitation.

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8. The line AE-238 (L_7) and hybrids AE-238 x AE-190 (L_7 x T_2) and AE-265 x AE-190 (L_{10} x T_2) were found highly resistant with coefficient of infection of zero. They did not show any symptom in field screening, grafting and vector transmission studies. The parent can be used for incorporation of disease resistance.

9. Among top ranking three hybrids revealed by line x tester analysis, AE-265 x AE-190 (L_{10} x T_2) was the best hybrid as it did not show symptom in field screening (CI=0), grafting and vector transmission studies followed by AE-264 x AE-285 (L_9 x T_1) and AE-219 x AE-190 (L_6 x T_2).

10. Regarding the gene action for qualitative characters, reddish green colour of leaf base, green colour of leaf vein, deeply lobed nature of leaves, purple throat on both sides of corolla, slightly prickly nature of fruit, light green colour of fruit and five ridged nature of the fruits were dominant. Yellowish with red colour on both sides of corolla in flower is incompletely dominant.

11. Inferences on genetics of resistance to YVMV shows its complex nature involving probably major and minor genes with acting modifiers. Further generations are to be evaluated to confirm it.

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* Originals not seen

Appendices

Appendix – I. ANOVA for line x tester Analysis

Source of variation	Df	Mean Squares							
		Plant Height	Internodal length	No. of primary branches	Petiole length	Days to flowering	Duration of flowering	First fruiting node	Fruit length
Replication	1	10.553^{NS}	0.532^{**}	0.940^{NS}	1.324^{NS}	2.277^{NS}	0.106^{NS}	0.288^{NS}	0.00133^{NS}
Parents	16	2891.356^{**}	0.600^{**}	1.352^{**}	23.182^{**}	25.140^{**}	52.235^{**}	1.029^{**}	8.553^{**}
Lines	14	3234.214^{**}	0.639^{**}	1.329^{**}	22.393^{**}	22.973^{**}	46.473^{**}	1.019^{**}	8.847^{**}
Testers	1	222.898^{**}	0.292^{*}	0.040^{NS}	32.604^{**}	4.840^{**}	104.041^{**}	1.960^{**}	2.958^{**}
Lines Vs Testers	1	759.789^{**}	0.349^{*}	2.987^{**}	24.793^{**}	5.766^{**}	81.086^{*}	0.238^{NS}	10.033^{**}
Hybrids	29	862.491^{**}	0.519^{*}	0.939^{**}	10.216^{**}	8.180^{**}	35.249^{**}	0.493^{**}	7.672^{**}
Lines	14	1111.125^{NS}	0.620^{NS}	1.378^{*}	11.616^{NS}	9.850^{NS}	39.728^{NS}	0.436^{NS}	11.489^{*}
Testers	1	8.456^{NS}	0.444^{NS}	0.216^{NS}	1.662^{NS}	38.755^{**}	1.274^{NS}	3.266^{**}	10.823^{NS}
Lines x Testers	14	674.861^{**}	0.423^{**}	0.552^{**}	9.428^{**}	4.326^{**}	33.197^{*}	0.352^{NS}	3.629^{**}
Par Vs Hyb	1	48603.94^{**}	0.0052^{NS}	1.764^{*}	3.584^{NS}	112.64^{**}	662.75^{**}	3.757^{**}	288.306^{**}
Error	46	29.496	0.0498	0.256	1.356	0.569	13.443	0.179	0.0138

Contd.

* - Significant at 5% level , ** - Significant at 1% level , NS – Non significant

Appendix – I. Continued.

Source of Variation	Mean Squares							
	Fruit girth	No. of fruits per Plant	Crop duration	Yield per Plant	Mucilage content	Calcium content	Vitamin A Content	Magnesium Content
Replication	0.0027^{NS}	1.285^{NS}	3.419^{NS}	292.76^{NS}	0.00007^{NS}	0.00005^{NS}	5838.97^{NS}	0.000005^{NS}
Parents	0.787**	20.988**	32.512*	11166.86**	0.037**	0.0023**	99710.25**	0.00062**
Lines	0.867**	18.747**	32.578*	10713.54**	0.041**	0.0025**	9138**	0.00061**
Testers	0.462**	49.000**	64.000*	18632.28**	0.0055*	0.00069*	111873**	0.00021^{NS}
Lines Vs Testers	0.0009^{NS}	24.351**	0.094^{NS}	10048.06**	0.011**	0.0008*	204071.5**	0.00118**
Hybrids	0.252**	41.582**	27.119*	18393.96**	0.014**	0.0015**	102791.6**	0.00052**
Lines	0.271^{NS}	43.639^{NS}	30.446^{NS}	17017.93^{NS}	0.0155^{NS}	0.0021^{NS}	131455.7^{NS}	0.00048^{NS}
Testers	1.187^{NS}	9.138^{NS}	24.871^{NS}	8303.733^{NS}	0.0047^{NS}	0.0016^{NS}	38828.29^{NS}	0.00014^{NS}
Lines x Testers	0.166**	41.844**	23.951^{NS}	20490.81**	0.0128**	0.00085**	26888^{NS}	0.0006**
Par Vs Hyb	0.951**	713.613**	228.906**	478855.8**	0.0021^{NS}	0.0005*	26888^{NS}	0.00033*
Error	0.0041	1.517	14.075	707.364	0.0013	0.00012	10440.89	0.00007

* - Significant at 5% level , ** - Significant at 1% level , NS – Non significant

Appendix – II. Components of Additive & Non additive variance for biometrical traits

Sl. No	Variances → / Characters ↓	Covariance of half Sib	$\sigma^2 A$	Covariance of full Sib	$\sigma^2 D$	$\sigma^2 A / \sigma^2 D$	Gene Action
1.	Plant height	-6.77	-13.54	314.71	328.25	-0.04	NA
2.	Internodal length	0.0064	0.01	0.2001	0.19	0.05	NA
3.	No. of primary branches	0.0144	0.03	0.218	0.19	0.16	NA
4.	Petiole length	-0.1641	-0.33	3.858	4.19	0.08	NA
5.	Days to flowering	1.1751	2.35	4.203	1.85	1.27	A
6.	Duration of flowering	-0.7468	-1.49	8.177	9.67	-0.15	NA
7.	First fruiting node	0.0882	0.18	0.234	0.06	3.00	A
8.	Fruit length	0.4428	0.89	2.694	1.81	0.49	NA
9.	Fruit girth	0.0331	0.07	0.148	0.08	0.88	NA
10.	No. of fruits per plant	-0.9091	-1.82	18.296	20.11	-0.09	NA
11.	Crop duration	0.2181	0.44	5.189	4.75	0.09	NA
12.	Yield per plant	-460.58	-921.17	8957.8	9879.02	-0.09	NA
13.	Mucilage content	-0.00016	-0.0003	0.0052	0.005	-0.06	NA
14.	Calcium content	0.000058	0.00012	0.00049	0.00037	0.32	NA
15.	Vitamin A content	379.15	758.30	35751.6	34993.29	0.02	NA
16.	Magnesium content	-0.000017	0.00003	0.00024	0.00021	0.14	NA

A – Additive Gene action , NA – Non additive Gene action

DEVELOPMENT OF YELLOW VEIN MOSAIC VIRUS (YVMV) RESISTANT HYBRIDS IN OKRA [*Abelmoschus esculentus* (L.) Moench]

By

J. RAVI SANKAR

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

The investigations on "Development of yellow vein mosaic virus (YVMV) resistant hybrids in okra (*Abelmoschus esculentus* (L.) Moench)" was undertaken at the Department of Olericulture, College of Horticulture, Thrissur during the period of 2000-2001.

Fifteen lines viz., AE-198, AE-202, AE-210, AE-211, AE-214, AE-219, AE-238, AE-260, AE-264, AE-265, AE-275, AE-279, AE-280, AE-282 and AE-287 were crossed with two testers AE-285 and AE-190 (Parbhani Kranti) in line x tester mating design to produce 30 hybrids. These F_1 hybrids along with the parents were evaluated for several quantitative, fruit quality, qualitative characters and resistance to yellow vein mosaic virus. Among them, a parent AE-238 and two hybrids AE-238 x AE-190 and AE-265 x AE-190 were disease free in field screening, grafting and vector transmission studies.

The general combining ability of the parents, specific combining ability of the hybrids and heterosis (relative heterosis, heterobeltiosis and standard heterosis) were estimated. The best general combiners were AE-202, AE-264 and AE-190 which showed significant high *gca* effects for most of the traits among the traits studied. Based on the *per se* and *gca* effects, the parents AE-264, AE-214 and AE-190 were found as best for crossing.

Based on the *per se* performance, *sca* effects and heterosis on all the three bases, the hybrids AE-264 x AE-285 for plant height, AE-279 x AE-190 for internodal length, AE-219 x AE-190 for number of primary branches, AE-219 x AE-190 for petiole length, AE-264 x AE-285 for days to flowering, AE-202 x AE-285 for duration

of flowering, AE-202 x AE-285 for first fruiting node, AE-264 x AE-190 for fruit length, AE-279 x AE-285 for fruit girth, AE-219 x AE-190 for number of fruits per plant, AE-202 x AE-285 for crop duration, AE-219 x AE-190 for yield per plant, AE-238 x AE-190 for mucilage content, AE-238 x AE-285 for calcium content, AE-279 x AE-190 for vitamin A content and AE-214 x AE-190 for magnesium content excelled other hybrids.

Based on *per se* performance, *sca* effects and heterosis, hybrids AE-219 x AE-190, AE-264 x AE-285 and AE-265 x AE-190 were selected as top ranking hybrids. Among them AE-265 x AE-190 was not shown disease symptoms in field screening, grafting and vector transmission studies. So it was to be concluded as best hybrid having YVMV resistance.

Reddish green colour of leaf base, green colour of leaf vein, deeply lobed nature of leaves, purple throat on both sides of corolla, slightly prickly nature of fruit, light green colour of fruit and five ridged nature of fruit were dominant. Yellowish with red colour on both sides of corolla in flower is incompletely dominant. Resistance to YVMV may be complex in nature probably involving major and minor genes with acting modifiers. Further studies are required to confirm it.