STUDIES ON THE DEVELOPMENT OF F_1 HYBRIDS IN OKRA(Abelmoschus esculentus (L.) Moench) WITH HIGH YIELD AND RESISTANCE TO YELLOW VEIN MOSAIC VIRUS

Thesis submitted in partial fulfilment of the requirements for the degree of

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CERTIFICATE

This is to certify that the thesis entitled " **STUDIES ON THE DEVELOPMENT OF F₁ HYBRIDS IN OKRA (Abelmoschus esculentus (L.) Moench) WITH HIGH YIELD AND RESISTANCE TO YELLOW VEIN MOSAIC VIRUS** " *submitted in partial fulfilment of the requirements for the degree of* **Master of Science (Horticulture)** *to the* **Tamil Nadu Agricultural University, Coimbatore** *is a record of bona fide research work carried out by* **Ms . INDURANI .C** *under my supervision and guidance and that no part of this thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles or prizes and that the work has not been published in part or full in any scientific or popular journal or magazine.*

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Abstract

ABSTRACT

STUDIES ON THE DEVELOPMENT OF F1 HYBRIDS IN OKRA (Abelmoschus esculentus (L.) Moench) WITH HIGH YIELD AND RESISTANCE TO YELLOW VEIN MOSAIC VIRUS

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1999

A study was undertaken with seven genotypes in okra to develop F1 hybrids with high yield and resistance to yellow vein mosaic virus. A total of 33 F1 hybrids were developed successfully and studied during summer 1997 for yield, yield contributing traits and resistance to yellow vein mosaic virus. Among the hybrids MF-3 x OHD-1, MF-3 x Varsha Uphar, MF-3 x Arka Anamika, OHD-1 x Varsha Uphar, OHD-1 x Arka Anamika and Varsha Uphar x Arka Anamika expressed high mean performance as well as heterosis (diii estimate) for yield. Based on the yellow vein mosaic virus disease resistance, four parents were selected and crossed in a half diallel fashion in order to confirm their yield and resistance to yellow vein mosaic virus to study the combining ability, heterosis and gene action through graphic and genetic analysis.

The parent Varsha Uphar was adjudged as the best general combiner for individual fruit weight, yield per plant, phenol content in leaves and crude fibre content in fruits. The hybrids MF-3 x Varsha Uphar, MF-3 x Arka Anamika and Varsha Uphar x Arka Anamika were adjudged as the best specific combiner for number of fruits per plant, individual fruit weight and yield per plant.

Rank correlation studies indicated that parental array mean is dependable than the ***per se*** performance for the selection of best general combiners. The ***per se*** performance of the hybrids had significant correlation with ***sca*** effect of the hybrids for contributing traits like number of fruits per plant and individual fruit weight as well as yield per plant.

Gene action elicited through genetic and graphic analysis showed that there is preponderance of non-additive gene action for the characters like plant height at first flowering, individual fruit weight, fruit length, fruit girth, plant height at final harvest, yield per plant and protein content in fruits.

Association analysis revealed a strong and positive correlation between number of fruits per plant and yield of fruits per plant. The present study shows that both the parents should have resistance to yellow vein mosaic virus so that the resistance can be maintained in the hybrids thus synthesised. The present attempt has resulted in the development of two high yielding F1 hybrids with fair resistance to yellow vein mosaic virus viz., OHD-1 x Varsha Uphar and Varsha Uphar x Arka Anamika.

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Indurani. C.

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Introduction

1. INTRODUCTION

Bhendi or Okra (***Abelmoschus esculentus*** (L.) Moench) is a major vegetable crop grown throughout India for its green tender fruits during summer and rainy seasons. In India, it is widely cultivated in Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. Bhendi is valued for its tender and delicious fruits mainly in culinary preparations and to a limited extent in canning, dehydration and freezing. It has an average nutritive value (ANV) of 3.21 Kcal which is higher than that of tomato, eggplant and most of the cucurbits except bitter gourd (Grubben 1977).

There is a pressing demand for a suitable variety with high yield which can be achieved effectively by adopting proper breeding techniques. For this, the understanding of the genetic nature of quantitative traits of population is necessary.

In most of the developed varieties the average yield has been found to range between 8 and 10 t/ha. Besides this almost all the varieties recommended for cultivation are found to be either susceptible or tolerant to some extent to the important viral disease yellow vein mosaic which reduces the quality of the fresh vegetable. Hence developing varieties highly tolerant or resistant to yellow vein mosaic virus is to be given utmost attention.

Among the breeding methods selection from derivative population of a hybrid of genetically divergent parents would help to bring about significant improvement in yield. While an appreciable improvement in yield coupled with good amount of resistance can be achieved through the development of F_1 hybrids.

In the present study an attempt was therefore made to develope F_1 hybrids for yield and resistance to yellow vein mosaic virus with the following objectives :

1) To develop heterotic F_1 hybrids in combination with field resistance to yellow vein mosaic virus.

2) To estimate the general combining ability of parents for yield and component traits and to estimate the specific combining ability of hybrids for yield and component traits.

3) To get the information on the nature of gene action on the component characters and

4) To find out the direction and magnitude of association between yield and component characters.

Review of Literature

2. REVIEW OF LITERATURE

The work on variability, heritability, genetic advance, heterosis, heterobeltiosis, combining ability, correlation, path coefficient, gene action, and yellow vein mosaic virus resistance on bhendi have been reviewed here under.

2.1. VARIABILITY, HERITABILITY AND GENETIC ADVANCE

The success of any plant breeding programme is dependent on a very large degree of genetic variability in the available germplasm.

Padda ***et al.*** (1970) evaluated 21 varieties of bhendi and found that moderate to high heritability, genetic advance and GA as per cent of mean for the characters like seed per pod, yield per plant, mosaic infection and 1000 seed weight. They indicated that because of high heritable mechanism, significant improvement could be possible through selection for these characters. Singh ***et al.*** (1974) observed high GCV for fruit diameter, total sugars, crude fibre and yield per plant. According to Majumdar ***et al.*** (1974) the heritability estimates were high in respect of days to flower, weight of fruit and yield per plant.

Rao and Ramu (1975a) were of the opinion that pod girth was influenced more by environment than pod length and number of ridges. They found that heritability and genetic advance were high for pod length. Mahajan and Sharma (1979) observed high heritability estimates for number of fruits, fruit length and fruit diameter. Palaniveluchamy ***et al.*** (1983) found that plant height recorded the highest estimates of heritability and genetic advance.

According to El-Maksound *et al.* (1984a) high heritability values were recorded for earliness of flowering, number of fruits per plant and fruit weight. Korla and Sharma (1984) reported that traits like plant height, first fruit setting node, number of fruits and yield per plant exhibited moderate to high heritability and genetic advance.

Reddy *et al.* (1985) reported that high genetic advance and heritability were noted for fruit yield per plant, branch number and plant height indicating that these characters are governed by additive gene effects. Singh (1986) indicated that heritability estimates were higher in the F_2 than the F_1 except for number of days to flowering. Yadav (1986) reported that plant height, yield per plant and number of seeds per pod showed high genotypic coefficients of variation, heritability and expected genetic advance. Number of pods per plant and length of pods gave moderately high genotypic coefficients of variation and high heritability.

Balakrishnan and Balakrishnan (1988) studied the variability in bhendi. They reported that number of fruits per plant and yield per plant exhibited high phenotypic and genotypic coefficient of variations. The heritability, genetic advance and genetic advance as a percentage of mean was high for number of fruits per plant, fruit weight and yield per plant.

Vijay and Manohar (1990) reported that number of pods per plant, number of branches per plant and pod yield per plant were reported to have high genotypic coefficient of variation as compared to other components. Number of ribs per pod, number of branches per plant and plant height had maximum heritability and genetic advance as per cent of mean together.

Ariyo (1990) observed relatively high genotypic coefficient of variation and heritability estimates for height of flowering, edible fruit length, final plant height, number of seeds per pod and length of mature fruits. Patel and Dalal (1992) noticed that days to first flowering and number of branches per plant were highly influenced by the environment.

According to Gondane and Lal (1994) medium to high heritability was found to be associated with high genetic advance in respect of primary branches and leaves per plant. Meghwal and Khandelwal (1994) reported high heritability coupled with high GA for plant height, internodal distance fruit weight, number of nodes per plant and yield per plant.

Sood ***et al.*** (1995) reported that moderate heritability coupled with high to moderate genetic advance was recorded for the node at which first fruit set, plant height and nodes per plant. According to Lakshmi ***et al.*** (1996) yield per plant, number of fruits per plant and 100 seed weight had high genotypic coefficient of variation and genetic advance as per cent of mean. Plant height, number of seeds per fruit and 100 seed weight had maximum heritability.

Senthil Kumar (1996) reported that the characters plant height days to 50% flowering, fruit weight, seeds per fruit and 1000 seed weight exhibited high heritability estimates while fruit length and girth showed moderate to low heritability .

Panda and Singh (1997) reported that the characters like number of branches, number of pods and total pod yield per plant had higher genotypic as well as phenotypic coefficient of variation in both the environments. High heritability coupled with high genetic advance was observed for plant height, number of pods and total pod yield per plant which indicated that these characters are more reliable for improvement through selection.

2.2. HETEROSIS AND HETEROBELTIOSIS

Heterosis is a special genetic mechanism where in the genotypes when brought together in a specific pattern express their ability to exhibit a dramatic shift in particular characters.

Akram and Shafi (1971) found that F_1 hybrids had more tender fruits of better appearance than the parental average and three hybrids excelled the better parent. Akram *et al.* (1973) reported that among 16 combinations studied maximum heterobeltiosis of 31.33 per cent was observed in the cross T_1 x Indian in respect of yield per plant.

Jalani and Graham (1973) reported from a study of crosses between local and American varieties of Okra, that F_1 hybrids involving two Malaysian cultivars Local 5, Local 7 and two American cultivars viz., Emerald and Gold Coast exhibited positive heterosis for per cent germination, precocity of flowering, plant height and yield. It was observed by them that the size of heterosis may be due to initial advantage conferred by the hybrid embryo which tended to be heavier and longer than those of the parents.

Rao and Raj (1974) found 10 hybrids out yielded the standard variety Pusa Sawani by 10-14 per cent. Singh *et al.* (1975) reported that out of 24 crosses, eight showed hybrid vigour for earliness over the earlier parents. The heterosis ranged from +0.01 to +3.23 per cent where as five hybrids exhibited heterosis over the superior parents for plant height ranging from +14.29 to +32.11 per cent. The heterosis over the better parent for fruit length was between +0.31 to +14.27 per cent. Only two crosses exhibited heterosis for fruit length over the best parent. Maximum heterosis of +52.27 per cent over the better parent and +32.71 per cent over the best parent was recorded by the cross 7107 x FC.

Sharma and Mahajan (1978) evaluated 64 F_1 hybrids in a line x tester analysis and reported that eight showed significant heterosis for early flowering. The highly heterotic hybrid was Dark green x Pusa Sawani. Six crosses were found to be highly heterotic for fruit length. Nine crosses exhibited significant heterosis over the better parent for yield.

Elangovan (1979) in a line x tester analysis reported significant heterosis for yield and yield components. A number of hybrids showed negative heterosis for fruit length. Highest positive heterosis of +8.13 per cent over the better parent was observed for fruit width. Thaker ***et al.*** (1982) reported that in 21 crosses involving 7 parents the percentage increase over the better parent was the highest for fruit yield per plant followed by number of fruits per plant and fruit length.

Changan and Shukla (1986) reported that out of 30 cross combinations, 18 showed heterosis over the mid parent and 14 over the better parent. Poshiya and Shukla (1986a) found in a 7 x 7 diallel cross that heterosis was the highest for number of pods per plant and yield per plant. The high heterosis for yield was attributed mainly to many pods per plant.

Vijay and Manohar (1986) reported that heterosis over the better parent calculated for 11 yield related characters in 45 ***Abelmoschus esculentus*** F_1 hybrids derived from 10 lines showed that the highest values for pod yield was seen in Pusa Sawani x Clemson Spineless and Pusa Sawani x IC 8911, and these two crosses together with Pusa Sawani x Sel 6-1 and Sel 6-1 x Summer beauty showed the highest heterobeltiosis for days to 50% flowering.

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Shukla and Gautam (1990) reported that the cross IC 52392 x Pusa Sawani manifested high heterosis as well as high inbreeding depression. Mandal and Das (1991) reported that in a diallel set of 8 parents of okra 28 F_1 hybrids (excluding reciprocals) showed that the maximum heterosis over better parent (+52.38 per cent) was seen for the yield per plant followed by number of fruits per plant. The crosses Punjab Padmini x Sel. 10 and EMS 8 x Sel. 4 showed high heterosis for yield and most of its components.

Chavadhal and Malkhandale (1994) studied the heterosis for yield and yield components in 36 F_1 hybrids involving 9 parents. The study revealed that the hybrid selection 2-2 x Assam TRO could be selected for exploitation of hybrid vigour. Lakshmi ***et al.*** (1995) studied the heterosis in 8 parents and 28 hybrids. The highest heterosis over better parent for yield was observed in Tadikonda local x PB No. 58.

Singh ***et al.*** (1996) has given information on heterobeltiosis in 8 varieties and their F_1 hybrids. The best performing hybrids were Pusa Makhmali x Parbhani Kranti Pusa Sawani x Parbhani Kranti, Pusa Makhmali x P5 and Parbhani Kranti x Punjab 7 which gave +103.2, +88.1, +87.1 and +84.1 per cent higher marketable yield than the best parents (Punjab Padmini) respectively. More and Patil (1997) reported that over all mean heterosis over mid and better parent was highest for fruit yield per plant. The average inbreeding depression for fruit yield per plant and other characters were similar to that of heterosis but low in magnitude. Wankhade ***et al.*** (1997) reported from his studies that the F_1 hybrid Vaishali Vadhu x Local Akola was identified as an outstanding for fruits per plant, yield per plant and 7 other character to be exploited commercially for higher gain.

2.3 Combining ability

A number of genetic analysis including diallel have been employed in okra to study the combining ability. General combining ability refers to the average performance of a line in a series of crosses where as specific combining ability is the deviation from the performance predicted on the basis of general combining ability. ~~General~~ specific combining ability was due to non-additive gene effect.

Swamy Rao (1977) in a line x tester analysis observed that for the days to flowering, the general combining ability ranged from -2.77 to +2.63 and *sca* effects from -3.83 to +3.82. Among all the parents, Seven Dhari was a good general combiner for earliness while AE 107 was a good general combiner for number of fruits.

Kulkarni ***et al.*** (1978) studied the combining ability in a 6x6 diallel population. They observed that Pusa Sawani x White Velvet exhibited significant negative ***sca*** effect for days to flowering Seven Dhari x Dwarf green registered significant positive values for tallness which was result of average combiners. Similarly maximum number of pods was obtained in Seven Dhari x Dwarf green as a result of the combination of average combiners.

In a combining ability study on okra through diallel analysis Swamy Rao and Ramu (1978) observed that the highest ***sca*** effect was expressed by a hybrid which had a combination of good combiners. It was reported that yield was not under the influence of non additive gene action since parents with positive and negative ***gca*** effect had produced hybrids with positive ***sca*** effect.

Partap and Dhankar (1980) in a 7 parental diallel analysis found that in the crosses producing higher yield per plant one of the parents was found to be the best general combiner. They also observed that crosses with high *sca* effect involved good x good, good x poor and poor x poor combiners.

Elangovan ***et al.*** (1981) reported that 14 lines and 4 testers were employed in this study. They reported that for testing the combining ability use of four testers appeared to be quite adequate. The ratio of *GCA:SCA* indicated the preponderance of non-additive gene action. High specific combining ability effect was expressed in hybrids involving high x high or high x medium or low x low combiners.

Thakar ***et al.*** (1981) in a combining ability analysis found that ***gca*** effect was high for fruit length in EC 68475 and for fruit length and weight in IC 18960. Singh and Singh (1984) reported from a partial diallel involving 20 strains of Okra that Pusa Sawani was the best general combiner for 7 traits and 7121 was best for 8 traits. Pusa Sawani is resistant to yellow vein mosaic virus a major disease of Okra and it is considered that this variety might proved to be useful donor of resistance in breeding programmes,later it was found to be susceptible.

In a half diallel cross of 7 varieties of Okra Poshiya and Shukla (1986a) found that *sca* effects were significant for fruit yield per plant and ***gca*** effects were significant for days to 50% flowering, fruit length and number of fruits per plant and nodes. New sln x AE 91 was reported to be the most promising combination for the improvement of yield.

Vijay and Manohar (1986) calculated the combining ability from a 10 x 10 diallel excluding reiprocals. They observed that the crosses Pusa Sawani x Clemson Spineless and P_1 x PC 8911 were noted for pod yield and most of the yield components except for pod length. ***sca*** was significant of highly significant for all characters.

Veeraragavathatham and Irulappan (1991) carried out the combining ability analysis through a 7x7 full diallel analysis using 7 parents. The *gca* variance was significant for most of the traits when compared to *sca* variance indicating the preponderance of additive gene action. Rank correlation studies indicated that parental *per se* for the selection of good general combiner. Hence the choice of hybrid combination based on array mean is a better index rather than parental *per se* and heterosis may be considered as appropriate.

Veeraragavathatham and Irulappan (1991a) in another study about the performance of parents and hybrids for certain biometric traits in okra observed that 3 cross combinations were observed to be the best among the 42 combinations based on the mean performance for yield and certain other component traits.

Mandal and Das (1992) studied the combining ability in a 8x8 diallel crosses in okra. From the *gca* estimates of the parents Pusa Sawani was found to be good combiner for yield and most of the other characters. Punjab Padmini x Sel.10 cross showed the best *sca* effect for yield per plant.

Vasline (1993) studied the combining ability for 15 parents and 36 hybrids from a 12 line x 3 tester cross of bhendi. The parent lines AE 110 and AE 158 were good general combiners for a combination of traits. The hybrid Pusa Sawani x Co 2 was promising based on *sca* effects and *per se* performance.

Chavadhal and Malkhandale (1994) reported the combining ability in okra for 9 parents and 36 F_1 hybrids. They observed that the parents P_1, P_2 and P_3 were good general combiners for yield and its components. The study revealed the high *sca* effect in hybrid involving high x high or high x medium combiners.

In a diallel analysis of 10 parents, Arora (1994) observed that the parents Pusa Sawani, Vaishali vadhu and Foam Barelley were good general combiners for most of the characters. The result indicated that both additive and non-additive genetic variances were important for all the characters. The non-additive component was more for yield and fruit weight and additive component was predominant for rest of the characters. However development of F_1 hybrids is possible wherever feasible, otherwise progeny selection is suggested.

Lakshmi ***et al.*** (1995) studied the combining ability on a diallel analysis in okra involved 8 parents and 28 hybrids. Estimates of ***sca*** showed that best cross combination for yield was Parbhani kranti x Arka Abhay followed by PB No.58 x Punjab padmini.

Sivakumar ***et al.*** (1995) gave information on combining ability on 7 yield components in bhendi. Among the parents Punjab 7 was the best general combiner for fruit yield and number of fruits per plant. Non-additive gene action appeared to be important for number fruits, individual fruit weight, length, length-girth ratio and fruit yield.

Wankhade ***et al.*** (1995) reported that of the 12 parents, Vaishali Vadhu and Local Akola were found best general combiners and they exhibited significant ***gca*** effects for five and 4 characters respectively. The crosses P_1xP_3, P_2xP_6, P_2xP_7, P_4xP_{12}, P_5xP_{12} showed significant ***sca*** effects for five characters including yield and fruits per plant indicating scope for exploitation of heterosis.

Genetics of earliness, yield and fruit characters in okra was studied by Wankhade ***et al.*** (1995). Dominant alleles were present in more number than recessive alleles in all the characters studied except ridges on fruit and these dominant alleles were associated with negative effects.

Singh *et al.* (1996) reported about the combining ability on 9 yield components in 8 lines and their F_1 hybrids. The best specific combinations were Punjab Padmini x Punjab 7, Punjab 7 x P_5 and Punjab Padmini x P_5 for total yield, plant height, fruit length and marketable yield.

2.4 Correlation and path coefficient

Correlation analysis help in the evaluation of relationship existing between yield and its components along with the interrelationship among yield components. In most of the breeding programme the plants are selected based on the yield alone but this is not a reliable one because yield is a complex factor controlled by several factors.

Path coefficient analysis is helpful in partitioning the correlation into components due to direct and indirect effects and also permits critical examination of specific factors that provide a given correlation.

Rao and Ramu (1975a) found that fruit length had significant positive correlation with yield where as fruit girth and number of ridges on the fruit had negative but non-significant correlation. Rao and Ramu (1975b) observed that yield per plant exhibited significant and positive association with number of fruits, number of nodes per plant and plant height.

Elangovan (1979) recorded significant positive correlation for the characters like number of branches, earliness, number of fruits, fruit length and width with yield. Plant height also exhibited significant positive correlation with number of fruits.

Arumugam (1977) found in a study on the F_1, F_2 and back cross progenies of interspecific crosses of bhendi that horticultural traits like fruit quality, number of fruits and earliness showed no association with resistance to yellow vein mosaic and suggested the possibilities of isolating resistant recombinant with desirable horticultural traits. Mahajan and Sharma (1979) observed that yield had a positive and significant association with plant height, number of fruits per plant and fruit length.

Partap *et al.* (1979) studied interrelationship and path analysis in 21 F_1 hybrids and 7 parents. They found that number of flowers and fruits per branches and per plant, length and weight of fruits had significant positive correlation with yield.

Elangovan *et al.* (1980) studied the correlation analysis and reported that it is significant to note that hundred seed weight did not show any significant association either positive or negative with yield and its components indicating that increased yield in bhendi.

SriRamachandramurthy and Bavaji (1980) observed correlation and path coefficient analysis in bhendi. Phenotypic correlations were found to be smaller than genotypic correlations. Among the different characters studied fruit number followed by days to flowering were found to have high direct effect on yield.

El-maksoud *et al.* (1984b) reported positive association between plant height, fruit weight and fruit length and indicated that selection for short stature could lead to reduced yield. Later flowering was positively associated with more fruits per plant and larger fruits.

Reddy *et al.* (1985) found that fruit yield had significant positive correlation with plant height, number of branches and number of fruits. Number of fruits had the highest positive effect on fruit yield.

Poshiya and Shukla (1985) studied correlation coefficient between *per se* performance, array mean and general combining ability effects in okra. It was concluded that selection may be practised on the basis of F_1 performance and combining ability effects.

Yadav (1986) reported that the characters like plant height, yield per plant and number of seeds per pod showed high genotypic coefficients of variation, plant height number of pods per plant and pod length showed significant positive correlation with yield.

Mishra *et al*.(1990) observed that yield showed positive and significant association with pods per plant, pod weight, pod length and plant height. Singh *et al* (1990) reported that fruit yield was positively correlated with fruit length, fruit diameter, number of fruits per plant and fruit weight. Path analysis studies conducted by Balakrishnan and Balakrishnan (1990) revealed that number of fruits per plant and the fruit weight are the direct and positive contributory characters to yield per plant due to high direct effect.

Jeyapandi and Balakrishnan (1990) reported that the fruit yield in bhendi is directly dependent on the traits viz., plant height, fruit length, fruit weight and number of fruits per plant. Shukla (1990) reported that days to first flowering number of nodes per plant, fruits per plant and average fruit weight had high contribution towards yield.

Vijay and Manohar (1990) conducted correlation and path analysis studies in okra. Pod yield per plant showed high positive significant correlation with number of pods per plant, height at first fruiting node and plant height. Path analysis revealed positive direct effect on pod yield per plant and number of pods per plant height at first fruiting node, plant height, internodal distance and days to 50 per cent flowering. Since the regression of these characters are governed by additive gene effects suggesting directly their use as selection criterion.

Singh *et al.* (1990) revealed that number of fruits per plant, fruit weight, fruit length and fruit diameter are the important yield components and therefore major emphasis should be given for these characters while making selection in okra. Fageria *et al.*(1992) reported that fruit yield had significant positive association with days to 50% flowering, plant height, nodes per plant, fruits per plant, fruit length, fruit diameter, days to seed maturity, seeds per fruit, 100 seed weight and seed weight.

Mishra and Singh (1992) studied the correlation and path coefficient of green fruit yield and its components in 18 cultivars of okra. Yield per plant was positively and significantly associated with fruits per plant, fruit weight, fruit length, plant height and fruit girth. Path analysis revealed that fruit length and number of fruits per plant were most important variables. Patel *et al.*(1993) conducted association studies in okra. Plant height was significantly correlated with first fruiting node, inter nodal length and days to first flowering. So the characters like plant height, number of pods per plant and days to first flowering are the important yield contributing characters. Dash and Mishra (1995) reported that fruit yield per plant was positively correlated with number of branches per plant fruit length, first girth, fruit weight, number of seeds per fruit and weight per fruit.

Gondane *et al.* (1995) conducted an investigation on interrelationship and path coefficient of 11 quantitative characters using 50 genotypes of okra. Based on the path coefficient analysis the weight of edible pod and number of pods per plant were found to be the most important variables contributing towards yield. Hence, for the improvement of okra crop there should be a compromise with in these traits. Sood *et al.*(1995) recorded that nodes per plant, duration of availability of edible pods. Plant height and pod length had positive and strong correlations with yield. Chandra deo *et.al.* (1996) conducted correlation and path analysis, studied and suggested that selection for number of pods per plant, length of pod and plant height is important to evolve high yielding varieties of okra.

Lakshmi *et al.*(1996) reported that yield per plant showed high positive significant correlation with number of fruits per plant, number of nodes per plant and number branches per plant. Path analysis revealed positive direct effect on yield per plant through number of pods per plant, pod weight, number of nodes per plant and number of seeds per pod.

Correlation and path coefficient analysis in okra was conducted by Subhasini *et.al.* (1996). Number of days taken for first pod setting showed significant negative correlation with yield per plant. Based on path coefficient analysis of number of pods per plant, number of fruits per plant and pod weight were found to be the most important variables.

Yadav (1996) reported that estimation of correlation coefficient exhibited significant positive relation with plant height with number of nodes for first pod apperance, length of pods, number of seeds per pod and yield per plant. Path analysis indicated that length of the fruit had the maximum direct effect on fruit yield improvement of plant followed by number of pods per plant. Hence improvement of plant populations or varieties can be made through these characters.

2.5. GENE ACTION

The variances due to general and specific combining ability give an indication of type of gene action involved. The significance of ***gca*** effect variance indicates the additive gene action, and the significance of ***sca*** effect indicates the non-additive gene action.

The gene action on yield and yield components are reported below

No.	Character	Additive gene action	Non-additive gene action
1.	Days to flowering	Kulkarni ***et al.*** (1976) Swamy Rao (1977) Elangovan (1979) Partap and Dhankar (1980) Partap ***et al.*** (1982)	Kulkarni ***et al.*** (1976) Swamy Rao and Sathyavathi (1977) Sharma and Mahajan (1978) Partap and Dhankar (1980) Nirmal Singh ***et al.*** (1995)
2.	Plant height	Swamy Rao and Sathyavathi (1977) Partap and Dhankar (1980) Reddy ***et al.*** (1985) Veeraragavathatham and Irulappan (1990)	Kulkarni ***et al.*** (1976) Swamy Rao (1977) Sharma and Mahajan (1978) Elangovan (1979) Veeraragavathatham and Irulappan (1990) Nirmal Singh ***et al.*** (1995)
3.	Number of fruits per plant	Swamy Rao (1977) Swamy Rao and Sathyavathi (1977) Sharma and Mahajan (1978) Partap and Dhankar (1980) Veeraragavatham and Irulappan (1990)	Sharma and Mahajan (1978) Elangovan (1979) Thakar ***et al.*** (1981) Veeraragavathatham and Irulappan (1990) Nirmal Singh ***et al.*** (1995)
4.	Fruit length	Sharma and Mahajan (1978) Veeraragavatham and Irulappan (1990)	Elangovan (1979) Veeraragavathatham and Irulappan (1990) Nirmal Singh ***et al.*** (1995)

5.	Fruit girth per width	Veeraragavatham and Irulappan (1990)	Sharma and Mahajan (1978) Veeraragavathatham and Irulappan (1990)
6.	Fruit weight	Thaker ***et al.*** (1981) Wankhade ***et al.*** (1995)	Sharma and Mahajan (1978) Nirmal Singh ***et al.*** (1995) Wankhade ***et al.*** (1995)
7.	Yield	Partap and Dhankar (1980) Thaker ***et al.*** (1981) Reddy ***et al.*** (1985)	Elangovan (1979) Nirmal Singh ***et al.*** (1995)
8.	Yellow vein mosaic incidence	Veeraragavatham and Irulappan (1990)	-

Arumugam (1977) through a genetic analysis of the F_1, F_2 and backcross of interspecific hybrids of ***Abelmoschus*** reported that the resistance to yellow vein mosaic was controlled by one group of genes with additive effect exhibiting as high as 69-98 per cent narrow sense heritability. Further it was also emphasized the role of modified gene in enhancing the susceptibility of the progenies.

Partap ***et al.***(1982) reported that in okra through a component of variation analysis evaluated 28 okra genotypes of a 7 parental diallel set. They observed that the variance due to D estimate was significant for all the characters excepting disease incidence and sugar content for fruits. The magnitude of dominance components was higher than the additive for all the characters except days to 50 per cent flowering and first fruiting node. The positive values of h^2 suggested the dominance to be in positive direction. For the characters first fruiting node and days to 50 per cent flowering, high heritability coupled with additive gene action indicated that simple selection would be effective to select early genotypes. Involvement of both additive and non-additive gene action suggested the use of recurrent selection for their improvement.

Sharma and Dhillon (1983) were studying the genetics of resistance to yellow vein mosaic virus in interspecific crosses of bhendi and found that the resistance was controlled by two complimentary dominant genes with additive effect.

Reddy ***et.al.***(1985) reported that plant height had high direct and indirect effects on yield while branch number had an indirect effect selection for these two characters is seen as the most effective method for improving yield. Randhawa (1989) studied the genetics of economic characters in the intervarietal cross of okra. He reported that most of the characters showed partial to complete dominance except for yield per plant, which displayed over dominance.

Veeraragavathatham and Irulappan (1990) reported in the genetic analysis of okra that among both additive and non-additive gene action, the additive genes played significant role in yellow vein mosaic incidence.

Nirmal Singh ***et al.***(1995) observed that ambi-directional dominance was observed in all the characters except days to first fruiting and average fruit weight. The role of environment in the expression of three characters namely node at which first flower appears, days to first fruiting and average fruit weight was also observed. The predominance of non-additive genetic variance for all the characters under study including total yield per plant may be exploited by developing F_1 hybrids in okra.

Wankhade ***et al.*** (1995) reported in the genetics of earliness, yield and fruit characters in okra that dominant alleles were present in more number than recessive alleles in all the characters studied except ridges on fruit and these dominant alleles were associated with negative effects.

2.6. YELLOW VEIN MOSAIC VIRUS RESISTANCE

Arumugam and Muthukrishnan (1978) screened bhendi cultivars for resistance to yellow vein mosaic disease. A total of 181 cultivars were screened and all of them proved susceptible to the disease both under controlled and field conditions. The delayed symptoms exhibited by 5 accessions were found to be non-heritable and their hybrids were susceptible recording the reaction grade of 3.0.

Sharma and Dhillon (1983) studied the genetics of resistance to yellow vein mosaic virus in the interspecific crosses of Okra. The resistance in ***Abelmoschus manihot*** (L.) ***medicus*** ssp. ***manihot*** a cultivated type from Ghana seems to be of a symptomless carrier type. It was found to be controlled by two complementary dominant genes in the crosses of ***Abelmoschus esculentus*** and ***A. manihot*** ssp. ***manihot***. The gene estimates based on the simple additive dominance model suggested the preponderance of additive gene effects. The negative association between the node at which virus appeared first and virus index suggests that earlier the expression of virus the higher would be the intensity of virus. Therefore the relationship could advantageously be used as an index for screening germplasm.

Sharma and Sharma (1984) reported that only a line of ***A. manihot*** ssp. ***manihot*** from Ghana was resistant. Although it proved to be a symptomless carrier of virus in grafting tests, this species is regarded as a good source for incorporating resistance into susceptible ***A. esculentus*** cultivars.

Sharma and Sharma (1984) studied the breeding for yellow vein mosaic virus resistance and reported that a high degree of symptomless carrier type of resistance to YVM virus was identified in ***A. esculentus*** var. EC 31830 from Ghana. A plant carrying this resistance was identified in the open pollinated F_2 of Pusa Sawani x EC 31830. This was crossed with the F_1 Pusa Sawani x EC 31830, following controlled pollination. This was advanced to F_8 with further selection. This had field tolerance to the virus and was rated 70-80 Per cent tolerance at different sites. Limited inheritance studies revealed that tolerance is probably controlled by two dominant complimentary genes is under polygenic control.

Nerkar and Jambhale (1985) reported that the wild taxa ***A. tetraphyllus, A. manihot*** and ***A. manihot*** subsp. manihot were crossed reciprocally with ***A. esculentus*** cv. Pusa Sawani. The F_1s were partially or totally sterile. All three wild taxa were resistant and were shown to be symptomless carriers. Resistance in each of the other 2 taxa was controlled by a single dominant gene. Nine resistant lines were obtained which bred true for agronomic characters and fruit quality.

Jambhale and Nerkar (1986) studied the performance of yellow vein mosaic resistant variety `Parbhani kranti'. Four resistant lines derived from cross of ***A. esculentus*** x ***A. manihot*** showed only 4.09 - 19.37 per cent of plants affected with the virus. Parbhani kranti derived from the same material did not show any symptoms of virus infection and gave higher yields of marketable fruit than the susceptible ***A. esculentus*** varieties Sel.22 and Pusa Sawani, the latter being the recurrent parent of Parbhani Kranti.

Khan and Mukhopadhyay (1986) studied the screening of okra varieties tolerant to YVM virus of five varieties screened under field conditions Sl-1 showed the lowest incidence of infection (24.36 per cent) and gave the highest yields (40.36 q/ha).

Madhusoudanan and Nazeer (1986) reported about the origin of `quinean type' of okra. Inter crossing between soudanien okra susceptible to ***Hibiscus esculentus*** yellow vein mosaic virus, and a quinean type was successful but due to the difference in chromosome number of the parents the hybrid exhibited abnormal meiosis, leading sterility and so incorporation of the resistant gene into soudanien was hindered. The origin of quinean okra through natural hybridization between ***Hisbiscus esculentus*** and ***A. manihot*** was suggested.

Arora *et al.*(1992) reported that these were the differences observed among the 157 advanced germplasm lines and 7 cultivars/hybrids evaluated in-the field for reactions to okra yellow vein mosaic bigeminivirus over 2 years. Incidence was the highest in Pusa Makhmali compared with only 0.64 per cent in the most resistant line EMS 8, out of the advanced generations 36 individual plant selections of Punjab Padmini and 39 of EMS-8 remained free from the virus. Evaluation of selected verities of okra for yield and resistance to yellow vein mosaic was done by sally K. Mathew *et al.*(1993). Among 7 varieties Selection 4 and Arka Anamika were promising in yield and performance.

Sharma *et al.*(1993) analysed the performance of okra cultivars in relation to yellow vein mosaic virus and yield. Among 8 varieties evaluated Punjab Padmini and Punjab 7 gave higher yield and were also highly resistant to yellow vein mosaic virus. Another high yielding variety which carried resistance to yellow vein mosaic was Parbhani Kranti. While Pusa Sawani and Pusa Makhmali proved highly susceptible to yellow vein mosaic virus.

Arora (1995) reported that PAU is ahead in evolving okra virus resistant varieties. Punjab Padmini, Punjab-7, Punjab-8 these varieties has got medium to high degree of resistance to yellow vein mosaic virus. Rajmony *et al.*(1995) studied the resistance to yellow mosaic virus in bhendi in Kerala and reported that among several species ***Abelmoschus tetraphyllus***, ***Abelmoschus manihot*** ssp. ***teraphyllus***, ***Abelmoschus ficulneus***, ***Abelmoschus moschatus*** and ***Hibiscus huegeli*** were resistant to virus in southern region of Kerala. Among the cultivated types Arka Anamika, Parbhani Kranti and Vijai were found to be tolerant to the virus.

Srivastava ***et al*** (1995) reported that among 12 varieties screened Varsha Uphar and HRB-55 were free from the disease. Arka Anamika showed moderate resistance to yellow vein mosaic virus at Karnal. Sangar (1997) reported that Arka Anamika was highly resistant, Arka Abhay resistant and Parbhani Kranti and V6 were moderately resistant to the disease. The other varieties tested were either susceptible or highly susceptible to yellow vein mosaic virus.

Sannigrahi and Choudhury (1998) reported that among 7 cultivars evaluated for growth and yield characteristics and virus resistance Arka Anamika and Arka Abhay were the most suitable yellow vein mosaic virus resistant okra cultivars for commercial cultivation in Assam, compared with Pusa Sawani a popular but highly yellow vein mosaic virus susceptible cultivar.

2.7. QUALITITATIVE PARAMETERS

2.7.1. Phenol content in leaves

Accumulation of phenolic compounds in host parasite reaction is the general phenomenon of resistance and breakdown of these compounds determined the degree of resistance. (Farkas and Kirlay (1962) and Sindhan and Parashar (1984)). Tomato varieties resistant to bacterial wilt (Kao and Hsiao, 1980) and root rot nematodes (Narayana and Reddy, 1980) were also shown to have higher phenol content than susceptible varieties.

Singh and Abidi (1988) also reported high phenol content in cultivars of tomato which showed high disease resistance with the phenol content ranging from 514 mg/100 g to 933 mg/100 g. Sudha (1991) observed that the field resistant lines had remarkably higher amounts of phenol than the commercial varieties. The phenol content was highest in L-12 at the rate of 61.44 µg/g. Sarma ***et al.*** (1995) reported that increase in phenol content makes the variety resistant to yellow vein mosaic virus incidence.

2.7.2. Crude fibre content in fruits

Sivagama Sundari (1991) reported about the crude fibre content in bhendi fruits. She opined that as the regression line passed through the origin for crude fibre content. This suggested the role of complete dominance. Sathiyamurthy (1997) in his studies on gamma ray induced mutations in bhendi reported that the gamma irradiation had no significant influence on the crude fibre content.

Materials and methods

3. MATERIALS AND METHODS

The present study was carried out at the college orchard, Horticultural College and Research institute, Tamil Nadu Agricultural University, Coimbatore which is situated at 11°N latitude and 77°E longitude and at an elevation of 426.6 m above mean sea level. The evaluation was done during February –May and July – October, 1998. The Materials used and methodology followed are presented below.

3.1. MATERIALS

The details of the parents chosen for the study given in Annexure I are as follows :

(P_1) MF_1, (P_2) MF_2, (P_3) MF_3 - three mosaic free mutants derived from induced mutagenesis of Parbhani Kranti and (P_4) OHD-1, (P_5) OHD-2 - double cross hybrid derivatives of the following crossing pattern evolved at Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore.

AE 974 x Arka Abhay — (Best general Combiner for yield) (Sel. 4) → F_1 HY 13 (Sel. 4)

AE 974 x Arka Anamika — (Sel. 10) → F_1 HY 15

HY 13 x HY 15

↓

F_1

↓ Selected from the segregating population

F_2 → F_3 → F_4 → F_5 → F_6

↓

Two single plants parents were selected from F_6 population as OHD-1 and OHD-2.

(P_6) Arka Anamika-evolved at IIHR Bangalore by inter-specific hybridisation using ***Abelmoschus tetraphyllus*** var. ***tetraphyllus***. followed by back cross breeding.

(P_7) Varsha Uphar-evolved at Haryana Agricultural University, Hisar. Evolved by pedigree selection of Lam selectionlx Parbani Kranti, resistant to YVMV in rainy season in Harayana zone 6 and 4.

These genotypes were used as parents for developing F_1 hybrids.

3.2. METHODS

The parents were maintained by selfing continuously for six generations.

3.2.1. Selfing techniques

The flower buds likely to open on the following day were selected and the carolla end was covered with butter paper cover.

3.2.2. Crossing techniques

The flower buds which are likely to open on the next day, were selected between 4-6 pm for emasculation. A circular cut was given around the fused calyx including epicalyx at about 1 mm from its base, then the corolla was removed gently without injuring the gynoecium and all the anthers were removed. The emasculated flowers were immediately bagged with butter paper covers. Similarly the flower buds of male parents from which the pollen grains have to be collected were also bagged.

On the next day between 6 to 8 a.m, the butter paper covers were removed and the dehisced anthers were collected from the previously bagged flowers of the male parents and it was gently rubbed on the stigma. The pollinated flowers were then rebagged and labelled.

Plate 1. Field view of the experiment

Plate 4. Promising parents

a. OHD-1

b. VARSHA UPHAR

c. ARKA ANAMIKA

3.3. FIELD PLOT TECHNIQUE

3.3.1. Evaluation of Hybrids and Parents

During the first season attempts were made to produce 42 F_1 hybrids using 7 parents. A total number of 33 hybrids were developed successfully and these 33 F_1 hybrids were raised along with 7 parents in a randomized block design with 2 replications. The seeds were sown at a spacing of 45 cm x 30 cm and along the border Pusa Sawani was raised as a yellow vein mosaic virus susceptible check variety. The yield and yield contributing characters including yellow vein mosaic virus incidence were studied during the first season. Yellow vein mosaic virus incidence was given more importance i.e. the resistant plants were grafted with yellow vein mosaic virus infected scion of Pusa Sawani. After 15 days of inoculation the incidence was observed. The resistant varieties were free from mosaic even after inoculation.

Resistance was again confirmed by screening under milar cages. All the 33 hyrbids were raised in pots. The milar cages were prepared with transparency sheets and muslin cloth and kept over the potted plants. The white flies (Bemisia tabaci) were collected from brinjal plant and also from susceptible Pusa Sawani in a test tube in early morning hours. The insects were allowed from the test tube to fly inside the milar cage. The healthy plants were observed for mosaic incidence. Six hybrids were found to be resistant to yellow vein mosaic virus. From the 33 hybrids, six hybrids with high yield and resistance to yellow vein mosaic were selected and again raised in the second season along with their parents (P_1 (MF-3), P_2 (OHD-1), P_3 (Varsha Uphar) and P_4 (Arka Anamika) in a randomized block design with 3 replications in a half diallel design. Pusa Sawani was used as border row. Data on the following traits were recorded on 10 randomly selected plants in each replication, the mean values were arrived at and subjected to the following statistical analysis.

Plate 3. Artificial inoculation of yellow vein mosaic incidence

2

iii. Increase in the F_1 over the best parent

$$diii = \frac{F_1 - Bp}{Bp} \times 100$$

Where, F_1 = Mean value of the hybrid

$$Mp = \text{Mean of mid parental value } \frac{P_1 + P_2}{2}$$

P_1 and P_2 = are mean value of first and second parents.

Br = Mean of better parental value.

Bp = Mean of highest parental value.

3.5.2. Partial Diallel Analysis

The first step in the statistical analysis was to test the null hypothesis to show that there was no genetic difference among the genotypes under study. This was worked out by randomized block design (Singh and Chaudhary, 1979).

Analysis of variance (ANOVA Table)

Source	df	Expected mean square
Block (b)	(r-1)	$\sigma^2 e + g\,\sigma^2 b$
Genotypes (g)	(g-1)	$\sigma^2 e + r\,\sigma^2 g$
Error (e)	(r-1) (g-1)	$\sigma^2 e$

From the AV table genotypic and phenotypic variability parameters and heritability estimates were worked out.

Where

$$Sg = \frac{1}{2P} \Sigma i \, (Xi. \times X.i)^2 - \frac{2}{P^2} X^2..$$

$$Ss = \frac{1}{2} \sum_i \sum_j Xij \, (Xij \times Xji) \frac{1}{2P} \Sigma i \, (Xi. + X.i)^2 + \frac{1}{P^2} X^2...$$

$$Me^1 = \frac{Me}{b}$$

Where Me is the experimental error mean square for the randomized block design, b is the number of blocks.

General and **specific combining ability** were estimated as follows

$$gi = \frac{1}{2P} (Xi. \times X.i) - \frac{1}{P^2} X..$$

$$sij = \frac{1}{2} (Xij \times ji) - \frac{1}{2P} (Xi. + X.i + Xj. + X.j) + \frac{1}{P^2} X..$$

$$Var\ gi = \frac{P-1}{2P^2} \sigma^2 e$$

$$Var\ (Sij) = \frac{1}{2P^2} (P^2 - 2P + 2) \sigma^2 e$$

3.5.4. Hayman's approach

The following 2 procedures were adopted in the present study to understand the gene action from the data.

1. Graphic analysis (Hayman, 1954)

2. Genetic analysis (Hayman, 1954)

3.5.4.1. Graphic analysis

The graphic as proposed by Jinks and Hayman (1953) and Hayman (1954) was followed by the variances and covariances listed below were calculated.

Vr	=	Variance of r^{th} array
Wr	=	The covariance between non-recurring parents and the offspring of r^{th} array
Wr'	=	The covariance between the array means and the offspring of r^{th} array
V_0L_0	=	Variance of the parents.
V_0L_1	=	The variance of the means of the arrays..
V_1L_1	=	Mean variance of arrays.
W_0L_1	=	The mean covariance between the parents and arrays.
$(ML_1\text{-}ML_0)$	=	The difference between the mean of parents and the mean of these n^2 progenies.
E	=	Expected environmental component of variation with VrWr and WrWr' calculated graphs were constructed for all the characters studied for VrWr and WrWr'.

The limiting parabola for the VrWr graph was constructed with the formula

$$Wr^2 = Vr \times V_0L_0$$

The correlation between Wr + Vr and Yr were worked out.

Test of hypothesis

The validity of the hypothesis postulated by Hayman (1954 a) was tested by t^2 test.

$$t^2 = \frac{(n-2)}{n} \quad \frac{Var.Vr - Var.Wr}{Var.Vr \times Var.\ Wr - Cov^2(Vr.\ Wr)}$$

t^2 was tested against the 'F' value with 4 and (n-2) degrees of freedom. Significant t^2 indicates the failure of atleast one of the hypothesis postulated.

The regression (b) of covariance (Wr) on variance (Vr) and its standard error was calculated as

$$b = \frac{\text{Cov. (Wr'Vr)}}{\text{Var. Vr}}$$

$$\text{Standard error (b)} = \frac{\sqrt{\text{(Var.Wr} - \text{Cov. Wr'Vr)}}}{\text{Var. Vr (n-2)}}$$

3.5.4.2. Genetic analysis (Components of variance)

The genetic components D, F, H_1, H_2 and h^2 were estimated as described by Hayman (1954 a) using the second degree statistics and error mean squares.

D = Component of variation due to additive effects of the genes

H_1 = Components of variation due to dominance effects of the genes

H_2 = The proportion of dominance variance due to positive and negative effects of genes.

h^2 = Dominance effects expressed as the algebric sum over all loci in heterozygous phase.

F = Mean value of Fr over arrarys.

E = Expected environmental variation.

These parameters were calculated using the following formulae.

$$\hat{D} = V_0L_0 - \hat{E}$$

$$\hat{F} = V_0L_0 - 4W_0L_01 - 2(n-2)\,\hat{E}/n$$

$$\hat{H}_1 = V_0L_0 - 4\,W_0L_01 + V_1L_1 - 3(n-2)\,\hat{E}/n$$

$$\hat{H}_2 = 4V_1L_1 - 4V_0L_1 - \frac{2(n^2-1)}{n^2}\hat{E}$$

$$\hat{h}^2 = 4(ML_1 - ML_0)2 - 4(n-1)E/n^2.$$

$$E = \frac{\text{Sum of squares of blocks} + \text{Sum of squares of replication x progeny}}{\text{Degrees of freedom for both}} / \text{Number of replications}$$

Standard error $S^2 = \frac{1}{2}\,Var\,(Wr\text{-}Vr)$.

The significance of each of these genetic parameters was tested using the respective standard error.

The genetic parameters thus calculated were employed for the computation of proportional value mentioned below.

$$\left[\frac{\hat{H}_1}{\hat{D}}\right]^{1/2} = \text{Mean degree of dominance}$$

$$\left[\frac{\hat{H}_2}{4\hat{H}_1}\right] = \text{The proportion of genes with positive and negative effects in the parents.}$$

$$\frac{(4\hat{D}\hat{H}1)^{1/2} + F}{(4\hat{D}\hat{H}1)^{1/2} - F} = \text{The proportion of dominant and recessive genes in the parents. (KD/KR)}$$

$$\frac{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{2}H_2 - \frac{1}{2}F}{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{4}H_2 - \frac{1}{2}F + E} = \text{Narrow sense Heritability}$$

$$\frac{\hat{h}^2}{\hat{H}_2} = \text{Number of groups of genes which control the character and exhibit dominance.}$$

Correlation

Simple correlations were worked out following the methods of Panse and Sukhatme (1957). Genotypic correlations were computed following the methods of Johnson *et al.* (1955).

3.6. QUALITATIVE ANALYSIS

3.6.1. Phenol content in leaves

The phenol content in the leaf sample were estimated as per the procedure suggested by Malick and Singh (1980).

3.6.2. Carbohydrate content in fruits

The total carbohydrates in the fruits of bhendi were estimated by anthrone method as per the procedure suggested by Hedge and Hofreiter (1962).

3.6.3. Protein content in fruits

Protein content in the fruits was estimated as per the procedure suggested by Lowry *et al.* (1951).

3.6.4. Crude fibre content in fruits

Fruits were collected randomly at vegetable maturity (7th day after flowering) and used for crude fibre estimation as per the procedure suggested by Maynard (1970).

Experimental results

4. EXPERIMENTAL RESULTS

The investigation was carried out with sevěn parents of bhendi and based on the performance in the first season (Feb-May) parents and their hybrids with better yield and resistance to Yellow vein mosaic virus were again raised during second season (July – October) and analysed for combining ability and were subjected to genetic analysis in a half-diallel design. The experimental results are as follows.

4.1. ANALYSIS OF VARIANCE (I SEASON)

The analysis of variance was calculated for 14 characters under study. The variance due to the genotypes was significant for all the characters at one per cent level (Table 1).

4.2. MEAN PERFORMANCE OF PARENTS AND HYBRIDS

Mean performance of parents and hybrids were recorded and values are given in table 2.

4.2.1. Plant height at first flower bud appearance

Among the seven parents the plant height at first flower bud appearance ranged from 12.38 cm in P_2 to 18.0 cm in P_3.

Among the 33 hybrids the range for plant height at first flower bud appearance ranged from 11.35 cm in P_7 x P_1 to 22.84 cm in P_5 x P_2. The plant height at first flower bud appearance was also more in the hybrids P_5 x P_6, P_5 x P_4 and P_4 x P_6.

TABLE –1 ANALYSIS OF VARIANCE

Source	d.f.	S.S	M.S	F
1. Plant height at first flower bud appearance				
Replication	1	4.255	4.255	3.404
Genotypes	39	425.099	10.899	8.69**
Error	39	48.92	1.25	
2. Yellow vein mosaic incidence (per cent)				
Replication	1	0.385	0.385	0.129
Genotypes	39	28427.382	728.907	244 .28**
Error	39	116.371	2.983	
3. Node at which first symptom of yellow vein mosaic appeared				
Replication	1	0.083	0.083	0.309
Genotypes	39	477.879	12.253	45.45**
Error	39	10. 514	0.269	
4. Number of fruits /plant				
Replication	1	8.639	8.639	4.459
Genotypes	39	1217. 971	31. 23	16.12**
Error	39	75. 552	1.937	
5. Individual fruit weight (g)				
Replication	1	11. 333	11.333	8.547
Genotypes	39	345. 315	8.854	6.68**
Error	39	51. 71	1.326	

(Contd...

TABLE –1 (Contd…

Source	d.f.	S.S	M.S	F
6. Fruit length (cm)				
Replication	1	0.014	0.014	0.038
Genotypes	39	124 . 587	3.195	8.70**
Error	39	14.269	0.366	
7. Fruit girth (cm)				
Replication	1	0.206	0.206	3.169
Genotypes	39	22.772	0.584	8.99**
Error	39	2.534	0.065	
8. Plant height at final harvest (cm)				
Replication	1	0.321	0.321	0.131
Genotypes	39	5332 . 941	136 . 742	55. 67**
Error	39	95.796	2.456	
9. Number of branches /plant				
Replication	1	0.001	0.001	0.0005
Genotypes	39	323.130	8.285	4.57**
Error	39	70.762	1.814	
10. yield /plant (g)				
Replication	1	2433 . 659	2433 . 659	7.489
Genotypes	39	428692 . 611	10992 . 118	33. 83**
Error	39	12669 . 567	324 . 861	

(Contd…

TABLE – 1 (Contd...

Source	d.f.	S.S	M.S	F
11. Phenol content in leaves (mg / g)				
Replication	1	0.001	0.001	5.0
Genotypes	39	0.894	0.023	93.15**
Error	39	0.009	0.0002	
12. Carbohydrate content in fruits (per cent)				
Replication	1	0.043	0.043	0.171
Genotypes	39	26. 078	0.669	2.66**
Error	39	9.808	0.251	
13. Protein content in fruits (per cent)				
Replication	1	0.011	0.011	0.500
Genotypes	39	6.513	0.167	7.490**
Error	39	0.868	0.022	
14. Crude fibre content in fruits (per cent)				
Replication	1	0.017	0.017	0.029
Genotypes	39	395 . 823	10.149	17. 68**
Error	39	22.385	0.574	

* Significance at 5 per cent level
** Significance at 1 per cent level

4.2.2. Yellow vein mosaic incidence

Among the parents P_5 recorded the maximum incidence of 56.4 per cent. While P_3, P_4, P_6 and P_7 did not record any mosaic incidence. The hybrids involving the above parents also did not record any mosaic incidence. Among the hybrids $P_5 \times P_1$ recorded the maximum incidence of 58.9 per cent followed by $P_5 \times P_2$ recorded 57.3 per cent. The parents P_3, P_4, P_6 and P_7 and the hybrids involving these parents were found to be tolerant to yellow vein mosaic virus.

4.2.3. Node at which yellow vein mosaic incidence appeared

Among the parents which exhibited the symptoms, P_2 recorded the lowest number of node (4.50) at which the first symptom of yellow vein mosaic virus appeared. This was followed by P_1 (5.3). The parent P_5 exhibited the yellow vein mosaic virus at the highest mean node number (6.7). The parents P_3, P_4, P_6 and P_7 did not record yellow vein mosaic symptom. The hybrids involving the above parents also did not record any yellow vein mosaic symptom.

4.2.4. Number of fruits per plant

Among the seven parents the number of fruits per plant ranged from 19.3 in P_1 to 25.18 in P_4.

The range for this character among the 33 hybrid was from 18.2 in $P_1 \times P_2$ to 34.53 in $P_3 \times P_7$. The hybrids involving the parents P_3 and P_4 produced more number of fruits. The hybrid $P_4 \times P_7$ ranked second with 34.51 number of fruits per plant.

4.2.5. Individual fruit weight

The parent P_7 recorded maximum fruit weight (17.67 g) among the seven parents. Whereas the parent P_1 recorded minimum fruit weight (15.67 g).

Among the hybrids the minimum fruit weight was recorded by the cross P_2 x P_1 (9.87 g) and the maximum fruit weight was recorded by the cross P_7 x P_6 (19.48 g). The crosses P_4 x P_5 (18.33 g), P_7 x P_3 (18.9 g) and P_7 x P_6 (19.48 g) recorded more fruit weight than the hybrid mean value (18.21 g).

4.2.6. Fruit length

Among the seven parents the fruit length was maximum (15.65 cm) in P_4, while minimum fruit length was recorded (12.68 cm) in P_5.

The hybrid P_6 x P_5 recorded the maximum fruit length (18.55 cm), while the minimum fruit length was recorded by the P_5 x P_1 (13.01 cm). The crosses involving the parents P_6 and P_7 produced more fruit length than the other parents.

4.2.7. Fruit girth

The fruit girth ranged from 5.85 cm in P_5 to 6.33 cm in P_6. The parental mean showed the value of 6.19 cm whereas the hybrid mean showed the value of 6.72 cm. Among the 33 hybrids the highest value for fruit girth was recorded by the hybrid P_3 x P_4 (6.91 cm) followed by P_4 x P_7 (6.71 cm). The lowest value was recorded by the hybrid P_2 x P_5 (5.31 cm).

4.2.8. Plant height at final harvest

The final height of the plant among the seven parents ranged from 81.5 cm in P_1 to 109.5 cm in P_7 the mean being 98.99 cm.

Among the 33 hybrids the plant height ranged from 89.58 cm in P_1 x P_4 to 128.9 cm in P_3 x P_7 and P_7 x P_6. The mean being 105.7 cm hybrids involving the parents P_7 and P_3 produced more plant height than the other hybrids.

TABLE - 2 MEAN PERFORMANCE OF PARENTS AND HYBRIDS (SEASON I)

Genotypes	First flowering height (cm)	Yellow vein mosaic incidence (%)	Node at which mosaic appears	No. of fruits/plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)
Parents							
P_1	12.90	34.8	5.3	19.30	15.67	15.08	6.15
P_2	12.38	41.1	4.5	20.32	16.67	14.70	5.95
P_3	18.00	-	-	19.40	15.68	15.35	6.30
P_4	15.02	-	-	25.18	15.76	15.63	6.45
P_5	16.45	56.4	6.7	22.78	16.33	12.68	5.85
P_6	15.07	-	-	23.03	16.26	14.25	6.33
P_7	14.35	-	-	24.98	17.67	15.40	6.32
Mean	14.88	44.1	5.5	23.70	16.29	14.73	6.19
Hybrids							
$P_1 \times P_2$	13.08	42.20	4.2	18.20	12.20	13.09	6.15
$P_1 \times P_3$	13.09	40.36	3.3	21.60	11.67	13.10	6.00
$P_1 \times P_4$	13.07	32.28	5.8	20.49	13.73	15.02	5.49
$P_1 \times P_6$	11.90	18.50	4.7	21.50	16.67	15.32	5.41
$P_1 \times P_7$	13.65	19.30	7.0	20.60	17.70	13.25	6.01
$P_2 \times P_1$	13.65	49.20	6.3	30.56	9.87	14.64	6.15
$P_2 \times P_5$	13.47	33.90	2.9	28.13	12.40	14.20	5.31
$P_3 \times P_1$	12.81	20.90	4.0	23.56	15.50	14.35	6.10
$P_3 \times P_2$	13.68	38.30	5.3	32.39	14.93	13.76	5.63
$P_3 \times P_4$	14.90	-	-	32.29	13.93	16.65	6.91
$P_3 \times P_5$	17.52	35.60	4.7	23.75	16.13	16.13	6.08
$P_3 \times P_6$	17.05	-	-	30.26	17.15	15.95	5.81
$P_3 \times P_7$	17.09	-	-	34.53	17.25	16.95	5.99

- Incidence not seen

TABLE - 2 (Contd..)

Genotypes	First flowering height (cm)	Yellow vein mosaic (%)	Mosaic node	No. of fruits/plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)
Hybrids							
P_4 x P_1	11.87	19.10	3.3	25.37	14.88	15.45	5.98
P_4 x P_2	13.87	26.50	6.0	30.21	16.00	14.64	5.82
P_4 x P_5	13.57	28.30	5.3	32.21	18.33	14.97	6.13
P_4 x P_6	13.01	-	-	27.04	17.13	16.01	6.58
P_4 x P_7	17.54	-	-	34.51	18.13	16.65	6.71
P_5 x P_1	13.22	58.90	5.3	23.03	14.33	13.01	5.35
P_5 x P_2	13.95	57.30	3.8	25.02	14.01	14.64	6.02
P_5 x P_3	22.84	29.80	3.7	25.91	15.10	14.97	6.05
P_5 x P_4	16.88	47.90	5.0	26.53	14.91	15.60	5.85
P_5 x P_6	18.04	28.30	2.9	25.02	14.90	14.27	6.09
P_5 x P_7	19.72	29.42	5.3	26.33	15.66	15.33	5.25
P_6 x P_3	17.29	-	-	21.11	15.86	15.85	6.12
P_6 x P_4	15.03	-	-	28.17	14.60	18.33	5.83
P_6 x P_5	17.33	27.20	2.9	24.09	15.38	18.55	6.10
P_6 x P_7	15.40	-	-	25.17	15.90	15.09	5.39
P_7 x P_1	16.07	21.82	6.0	26.97	18.13	14.65	5.85
P_7 x P_3	11.35	-	-	24.12	18.90	16.50	6.35
P_7 x P_4	13.30	-	-	22.44	15.31	18.81	5.55
P_7 x P_5	12.98	20.30	4.7	28.09	16.13	14.90	5.69
P_7 x P_6	13.91	-	-	32.63	19.48	16.68	6.53
Mean	14.75	32.97	4.51	26.42	18.21	15.89	6.72
SEd	1.120	1.727	0.519	1.392	1.151	0.605	0.255
CD (0.05)	2.270	3.494	1.050	2.815	2.33	1.23	0.516

TABLE - 2 (Contd..)

Genotypes	Plant height at final harvest (cm)	No. of branches/ plant	Yield/plant (g)	Phenol (mg/g)	Carbohydrate (%)	Protein (%)	Crude fibre (%)
Parents							
P_1	81.50	4.5	252.3	0.28	6.4	1.60	13.50
P_2	90.52	5.0	290.4	0.29	5.6	1.90	14.81
P_3	95.30	5.5	374.4	0.40	7.0	2.20	11.82
P_4	89.70	5.0	408.4	0.39	4.8	2.41	12.33
P_5	90.50	4.1	353.1	0.20	6.8	2.33	12.56
P_6	105.90	6.0	397.6	0.44	6.2	1.98	14.90
P_7	109.50	5.8	462.4	0.44	6.8	2.73	8.75
Mean	98.99	5.12	362.66	0.35	6.23	2.16	12.67
Hybrids							
$P_1 \times P_2$	90.60	5.5	242.26	0.18	6.20	1.9	12.80
$P_1 \times P_3$	98.60	4.5	257.60	0.28	6.80	1.6	13.40
$P_1 \times P_4$	89.58	5.0	267.33	0.20	7.00	2.1	13.00
$P_1 \times P_6$	99.10	6.1	380.57	0.29	6.30	2.0	13.20
$P_1 \times P_7$	89.60	6.0	448.13	0.30	6.70	1.9	13.10
$P_2 \times P_1$	90.50	4.8	289.41	0.19	5.95	1.9	15.59
$P_2 \times P_5$	82.70	3.9	389.10	0.25	7.20	2.1	17.33
$P_3 \times P_1$	99.40	4.8	302.20	0.26	7.30	2.3	16.69
$P_3 \times P_2$	95.38	5.8	391.60	0.32	6.70	2.0	14.56
$P_3 \times P_4$	109.10	5.3	492.40	0.40	6.74	1.9	13.13
$P_3 \times P_5$	120.10	4.9	379.10	0.24	6.80	1.6	14.44
$P_3 \times P_6$	123.70	5.9	490.13	0.40	6.92	1.8	12.33
$P_3 \times P_7$	128.90	5.8	491.84	0.41	6.98	2.3	13.30

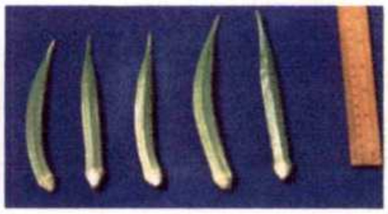
TABLE - 2 (Contd...)

Genotypes	Plant height at final harvest (cm)	No. of branches /plant	Yield/ plant (g)	Phenol (mg/g)	Carbohydrate (%)	Protein (%)	Crude fibre (%)
Hybrids							
P_4 x P_1	119.50	5.10	379.80	0.19	5.40	1.90	13.20
P_4 x P_2	129.13	5.80	420.11	0.30	5.60	2.00	12.10
P_4 x P_5	116.20	5.30	440.11	0.20	6.80	1.50	14.00
P_4 x P_6	125.90	5.30	490.10	0.43	6.73	1.94	13.20
P_4 x P_7	128.00	5.10	511.80	0.43	6.80	2.30	12.90
P_5 x P_1	99.50	5.90	380.00	0.19	6.80	1.60	17.19
P_5 x P_2	89.80	4.80	353.10	0.31	6.40	2.80	15.06
P_5 x P_3	95.25	3.90	350.70	0.21	6.80	2.00	14.56
P_5 x P_4	109.61	4.00	361.25	0.29	5.81	1.50	13.19
P_5 x P_6	98.20	4.40	362.97	0.23	6.93	1.94	12.90
P_5 x P_7	100.00	4.30	412.97	0.14	6.90	2.40	12.40
P_6 x P_3	125.42	5.80	357.60	0.44	1.80	1.80	11.94
P_6 x P_4	116.90	4.90	328.20	0.41	2.61	2.61	12.30
P_6 x P_5	120.30	5.30	311.50	0.23	2.20	2.20	12.93
P_6 x P_7	124.85	4.40	491.20	0.48	2.20	2.20	8.75
P_7 x P_1	119.50	4.20	479.10	0.25	2.50	2.50	10.94
P_7 x P_3	113.50	4.70	453.84	0.41	2.20	2.20	8.12
P_7 x P_4	110.10	3.90	420.40	0.40	2.30	2.30	11.44
P_7 x P_5	121.30	3.50	499.80	0.40	2.70	2.70	10.31
P_7 x P_6	128.90	4.90	522.90	0.48	2.80	2.80	8.75
Mean	105.70	4.71	398.79	0.36	6.63	2.10	12.68
SEd	1.567	1.347	18.024	0.016	.502	0.149	0.758
CD (0.05)	3.170	2.725	36.457	0.032	1.014	.302	1.532

Plate 2. Fruit characters of the hybrids in season I

MF-1× MF-2

MF-1× MF-3

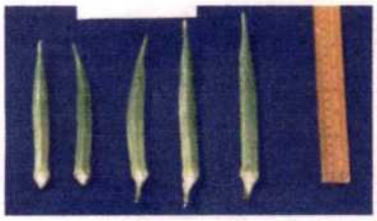


MF-1× OHD-1

MF-1× A.A

MF-1 × V.U

MF-2× MF-1



MF-2× OHD-2

MF-3× MF-1

MF-3 × MF-2

MF-3× OHD-1

MF-3× OHD-2

MF-3× A.A

MF-3× V.U

OHD-1× MF-1

OHD-1× MF-2

OHD-1× OHD-2

OHD-1 × A.A

OHD-1× V.U

OHD-2 × MF-1

OHD-2× MF-2

OHD-2× MF-3

OHD-2 × OHD-1

OHD-2 ×A.A

OHD-2× V.U

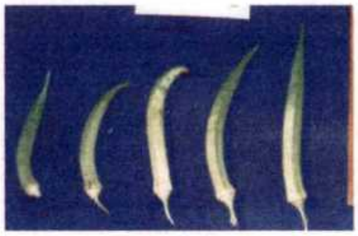
A.A×MF-3

A.A×OHD-1

A.A ×OHD-2

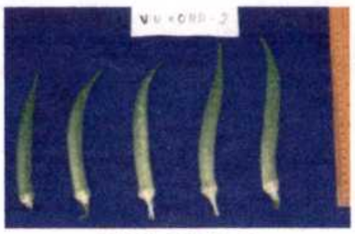
A.A× V.U

V.U× MF-1



V.U× MF-3

V.U ×OHD-1



V.U ×OHD-2

V.U× A.A

4.2.9. Number of branches per plant

Among the 7 parents the number of branches ranged from 4.1 in P_5 to 6.0 in P_6.

Among the 33 hybrids the number of branches ranged from 6.1 in P_1 x P_6 to 3.5 in P_7 x P_5. The hybrid mean was found to be lower than the parental mean.

4.2.10. Yield (g/plant)

The per plant yield ranged from 252.3 g in P_1 to 462.4 g in P_7. The parental mean was 362.66 g.

Among the 33 hybrids the hybrid P_7 x P_6 recorded the maximum yield of 522.9 g. The minimum yield was 242.26 g in P_1 x P_2. The hybrids involving the parents P_3, P_4, P_6 and P_7 recorded higher yield per plant.

4.2.11. Phenol content (mg/g of leaf tissue)

The phenol content among the 7 parents ranged from 0.20 mg/g in P_5 to 0.44 in P_6 and P_7. Among the 33 hybrids the phenol content ranged from 0.14 mg/g in P_5 x P_7 to 0.48 mg/g in P_7 x P_6 and P_6 x P_7. The hybrids involving the parents P_6 and P_7 recorded higher levels of phenol content.

4.2.12. Total carbohydrate in fruit (per cent)

Among the parents the total carbohydrate ranged from 4.8 per cent in P_4 to 7.0 per cent in P_3. The carbohydrate content among the 33 hybrids ranged from 1.8 per cent in P_6 x P_3 to 7.3 per cent in P_3 x P_1. The hybrids involving the parents P_3 and P_7 recorded more carbohydrate content.

4.2.13. Protein in fruit (per cent)

The protein content among the parents ranged from 1.6 in P_1 to 2.73 in P_7. The parental mean was 6.23 per cent. The protein content in the fruits among the hybrids ranged from 1.6 per cent in P_1 x P_3 and P_5 x P_1 to 2.8 per cent in P_7 x P_6 and P_5 x P_2.

4.2.14. Crude fibre in fruit (Per cent)

The crude fibre content among the 7 parents ranged from 8.75 per cent in P_7 to 14.9 per cent in P_6. Among the 33 hybrids the range for this character was from 8.12 per cent in P_7 x P_3 to 17.33 in P_2 x P_5. The hybrids P_7 x P_6, P_7 x P_5, P_7 x P_1, P_6 x P_5, P_3 x P_6, P_3 x P_7 recorded minimum crude fibre content.

4.3. HETEROSIS

The magnitude of heterosis for different characters were estimated as the performance of F_1 in comparison with the mid parent (di), better parent (dii) and the best parent (diii) and presented in tables 3 to 14.

4.3.1. Plant height at first flower bud appearance (Table 3)

The di estimates ranged from -26.63 to +58.47 per cent. Thirteen out of 33 hybrids exhibited positive heterosis. The highest di estimate of +58.47 per cent was recorded by the hybrid P_5 x P_2. The positive and significant heterosis values ranged from +6.57 per cent in P_2 x P_1 to +58.47 per cent in P_5 x P_2.

The range of heterobeltiosis was between -34.08 in P_3 x P_7 to +38.89 per cent in P_5 x P_2 and it was found that eighteen crosses exhibited significant negative heterobeltiosis.

TABLE - 3 HETEROSIS (PER CENT) FOR PLANT HEIGHT AT FIRST FLOWER BUD APPEARANCE

Hybrids	di	dii	diii
$P_1 \times P_2$	+ 3.44	+ 1.36	-27.36**
$P_1 \times P_3$	- 15.37**	- 27.3**	- 27.36**
$P_1 \times P_4$	- 6.38	- 12.98**	- 27.39**
$P_1 \times P_6$	- 14.89**	- 21.01**	- 33.89**
$P_1 \times P_7$	+ 0.17	- 4.88	- 24.19**
$P_2 \times P_1$	+ 6.57	+ 4.42	- 25.17**
$P_2 \times P_5$	- 11.15*	- 22.13**	- 28.86**
$P_3 \times P_1$	- 14.69**	- 26.78**	- 26.78**
$P_3 \times P_2$	- 1.58	- 16.94**	- 16.94**
$P_3 \times P_4$	- 21.14**	- 27.67**	- 27.67**
$P_3 \times P_5$	- 1.03	- 5.31	- 5.31
$P_3 \times P_6$	+ 3.10	- 5.31	- 5.31
$P_3 \times P_7$	- 26.63**	- 34.08**	- 34.08**
$P_4 \times P_1$	- 0.68	- 7.69	- 22.97
$P_4 \times P_2$	- 1.06	- 9.75*	- 24.69**
$P_4 \times P_5$	- 12.89**	- 16.66**	- 23.86**
$P_4 \times P_6$	+ 16.60**	+ 16.43**	- 2.56
$P_4 \times P_7$	- 9.96*	- 11.98**	- 26.56**
$P_5 \times P_1$	- 4.96	- 15.20**	- 22.53**
$P_5 \times P_2$	+ 58.47**	+ 38.89**	+ 26.89**
$P_5 \times P_3$	- 1.99	- 6.22	- 6.22
$P_5 \times P_4$	+ 14.67**	+ 9.7**	+ 0.22
$P_5 \times P_6$	+ 25.13**	+ 19.88**	+ 9.58*
$P_5 \times P_7$	+ 12.28**	+ 5.11	- 3.97
$P_6 \times P_3$	+ 15.65**	+ 6.22	+ 6.22
$P_6 \times P_4$	+ 15.17**	+ 15.00**	- 3.75
$P_6 \times P_5$	- 1.78	- 5.90	- 14.03**
$P_6 \times P_7$	+ 14.04**	+ 11.32*	- 6.83
$P_7 \times P_1$	- 16.68**	- 20.88**	- 38.94**
$P_7 \times P_3$	- 17.76**	- 26.11**	-26.11**
$P_7 \times P_4$	- 11.60*	- 13.58**	- 27.89**
$P_7 \times P_5$	- 18.87**	- 23.87**	- 30.44**
$P_7 \times P_6$	+ 25.31**	+ 9.9**	+ 19.85**

* Significance at 5 per cent level

** Significance at 1 per cent level

The diii estimate was maximum in the hybrid P_5 x P_2 (+26.89 per cent). Twenty hybrids exhibited significant standard heterosis in the negative direction. The positive standard heterosis values ranged from +0.22 in P_5 x P_4 to +26.89 per cent in P_5 x P_2.

4.3.2. Number of fruits per plant (Table 4)

The relative heterosis for number of fruits per plant ranged from -16.57 per cent (P_7 x P_4) to +75.78 per cent in P_2 x P_1. The positive significant heterosis ranged from +14.86 per cent in P_4 x P_5 to +75.78 per cent in P_2 x P_1. The negative significant heterosis was reported in only one cross P_4 x P_4 (-16.57 per cent).

The heterobeltiosis ranged from -0.53 in P_6 x P_5 to +65.82 per cent in P_3 x P_2. Only 4 hybrids exhibited significant heterobeltiosis in the negative direction.

The standard heterosis ranged from -21.18 in P_1 x P_7 to +21.59 per cent in P_3 x P_2 and P_3 x P_4. Only 6 crosses recorded significant standard heterosis in the negative direction.

4.3.3. Individual fruit weight (Table 5)

Among the 33 crosses only one cross P_7 x P_6 recorded significant positive heterosis. The heterosis ranged from -1.12 per cent (P_5 x P_4) to +25.56 per cent (P_7 x P_6). Twenty crosses recorded significant heterosis in the negative direction.

Three crosses recorded heterobeltiosis over the better parent and this ranged from +1.36 per cent in P_4 x P_6 to +12.00 per cent in P_7 x P_6. The negative heterobeltiosis ranged from -6.09 per cent in P_5 x P_4 to -36.35 per cent in P_1 x P_3.

TABLE - 4 HETEROSIS (PER CENT) FOR NUMBER OF FRUITS PER PLANT

Hybrids	di	dii	diii
$P_1 \times P_2$	+ 17.71*	+ 10.94	- 21.14**
$P_1 \times P_3$	+ 15.71	+ 7.49	- 21.18**
$P_1 \times P_4$	+ 0.62	- 18.04**	- 18.04**
$P_1 \times P_6$	+ 5.89	- 11.84	- 16.62**
$P_1 \times P_7$	- 2.00	- 19.82**	- 20.74**
$P_2 \times P_1$	+ 75.78**	+ 65.64**	+ 17.78**
$P_2 \times P_5$	+ 27.09**	+ 11.30	+ 5.26
$P_3 \times P_1$	+ 34.73**	+ 25.16**	- 8.29
$P_3 \times P_2$	+ 68.40**	+ 65.82**	+ 21.59**
$P_3 \times P_4$	+ 40.30**	+ 21.59**	+ 21.59**
$P_3 \times P_5$	+ 10.94	- 1.52	- 6.87
$P_3 \times P_6$	+ 10.94	- 1.52	- 6.87
$P_3 \times P_7$	+ 51.10**	+ 31.59**	+ 3.09**
$P_4 \times P_1$	+ 22.77**	+ 0.00	+ 0.00
$P_4 \times P_2$	+ 27.57**	+ 9.12	+ 9.12
$P_4 \times P_5$	+ 14.36*	+ 11.25	+ 11.25
$P_4 \times P_6$	+ 0.06	- 2.66	- 2.66
$P_4 \times P_7$	- 9.36	- 9.87	- 9.87
$P_5 \times P_1$	+ 24.07**	+ 3.30	- 2.31
$P_5 \times P_2$	+ 20.27**	+ 5.33	-0.39
$P_5 \times P_3$	+ 15.82*	+ 2.81	- 2.77
$P_5 \times P_4$	+ 8.55	+ 5.61	+ 5.61
$P_5 \times P_6$	+ 3.69	+ 3.69	- 1.94
$P_5 \times P_7$	+ 4.98	+ 2.71	+ 1.58
$P_6 \times P_3$	- 3.11	- 13.99*	- 18.66**
$P_6 \times P_4$	- 1.78	- 4.40	- 4.40
$P_6 \times P_5$	- 0.53	- 0.53	+ 5.94
$P_6 \times P_7$	+ 1.43	- 0.77	- 1.90
$P_7 \times P_1$	+ 28.31**	+ 4.98	+ 3.78
$P_7 \times P_3$	+ 20.68**	+ 5.04	+ 3.84
$P_7 \times P_4$	- 16.57**	- 17.05**	- 17.05**
$P_7 \times P_5$	- 6.91	- 8.98	- 9.97
$P_7 \times P_6$	+ 20.27	+ 5.83	+ 0.42

* Significance at 5 per cent level

** Significance at 1 per cent level

TABLE – 5 HETEROSIS (PER CENT) FOR INDIVIDUAL FRUIT WEIGHT

Hybrids	di	dii	diii
$P_1 \times P_2$	- 17.46**	- 17.46**	- 35.77**
$P_1 \times P_3$	- 33.41**	- 36.35**	- 45.68**
$P_1 \times P_4$	- 8.87*	- 12.58**	- 31.97**
$P_1 \times P_6$	+ 2.85	+ 2.47	- 19.67**
$P_1 \times P_7$	- 4.01	- 14.65**	- 14.65**
$P_2 \times P_1$	- 38.27**	- 38.27**	- 51.96**
$P_2 \times P_5$	- 24.84**	- 25.36**	- 40.88**
$P_3 \times P_1$	- 18.92**	- 22.50**	- 33.85**
$P_3 \times P_2$	- 17.61**	- 21.25**	- 32.79**
$P_3 \times P_4$	- 21.82**	- 28.17**	- 38.70**
$P_3 \times P_5$	- 4.67	- 7.95*	- 21.44**
$P_3 \times P_6$	- 14.99**	- 18.45**	- 30.40**
$P_3 \times P_7$	- 24.66**	- 30.18**	- 30.18**
$P_4 \times P_1$	- 7.24	- 11.01*	- 30.75**
$P_4 \times P_2$	- 11.83**	- 15.42**	- 34.18**
$P_4 \times P_5$	- 9.81*	- 14.34**	- 31.92**
$P_4 \times P_6$	+ 3.18	+ 1.36	- 22.68**
$P_4 \times P_7$	- 2.23	- 16.17**	- 16.17**
$P_5 \times P_1$	- 7.63	- 8.59*	- 27.35**
$P_5 \times P_2$	- 10.25*	- 11.19**	- 29.41**
$P_5 \times P_3$	- 10.16*	- 13.24**	- 25.96**
$P_5 \times P_4$	- 1.12	- 6.09	- 25.36**
$P_5 \times P_6$	- 8.09	- 8.72*	- 27.45**
$P_5 \times P_7$	- 12.62**	- 21.58**	- 21.58**
$P_6 \times P_3$	- 5.83	- 9.66*	- 22.90**
$P_6 \times P_4$	- 3.22	- 7.48	- 27.47**
$P_6 \times P_5$	- 5.60	- 6.25	- 25.48**
$P_6 \times P_7$	- 13.92**	- 23.22**	- 23.22**
$P_7 \times P_1$	- 24.49**	- 32.86**	- 32.86**
$P_7 \times P_3$	- 27.55**	- 32.86**	- 32.86**
$P_7 \times P_4$	- 16.89**	- 28.74**	- 28.74**
$P_7 \times P_5$	- 20.59**	- 28.74*	- 28.74**
$P_7 \times P_6$	+ 25.56**	+ 12.00**	+ 12.00**

* Significance at 5 per cent level
** Significance at 1 per cent level

The highest standard heterosis over the best parent was expressed by P_7 x P_6 (+12.00 per cent). The negative significant standard heterosis ranged from -14.65 per cent in P_1 x P_7 to -51.96 per cent in P_2 x P_1.

4.3.4. Fruit length (Table 6)

Ten hybrids exhibited positive heterosis over mid parent and the remaining twenty three hybrids exhibited negative heterosis for fruit length. The positive heterosis ranged from +0.35 per cent (P_6 x P_3) to + 22.01 per cent (P_5 x P_7). The negative heterosis ranged from -0.50 per cent (P_7 x P_5) to -13.97 per cent (P_1 x P_3).

The highest dii estimate was recorded by P_5 x P_7 (+11.96 per cent). The negative heterobeltiosis ranged from -0.40 per cent (P_1 x P_6) to -19.94 per cent (P_5 x P_4). Only two crosses recorded positive heterobeltiosis over the better parent.

The positive standard heterosis ranged from +2.56 per cent (P_7 x P_6) to 8.56 per cent (P_5 x P_7). The negative significant standard heterosis ranged from -3.10 per cent (P_1 x P_6) to -19.94 per cent (P_5 x P_4).

4.3.5. Fruit girth (Table 7)

The di value for fruit girth ranged from -26.94 per cent (P_6 x P_4) to +9.36 per cent (P_7 x P_6). Among the 33 crosses twenty five crosses exhibited significant heterosis in the negative direction.

The dii value ranged from -30.34 per cent (P_6 x P_5) to +1.12 per cent (P_3 x P_5). Twenty nine crosses have recorded significant heterobeltiosis in the negative direction.

TABLE - 6 HETEROSIS (PER CENT) FOR FRUIT LENGTH

Hybrids	di	dii	diii
P_1 x P_2	- 12.11**	- 18.20**	- 15.89**
P_1 x P_3	- 13.97**	- 14.78**	- 16.89**
P_1 x P_4	- 1.29	- 3.10	- 3.10
P_1 x P_6	+ 2.40	- 0.40	- 4.06
P_1 x P_7	- 12.40**	- 12.69**	- 15.34**
P_2 x P_1	- 4.85	- 6.04	- 9.49*
P_2 x P_5	+ 5.42	- 1.84	- 7.80
P_3 x P_1	- 5.69	- 6.52	- 8.34*
P_3 x P_2	- 10.70*	- 12.58**	- 14.28**
P_3 x P_4	- 11.24**	- 12.11**	- 12.11**
P_3 x P_5	+ 0.86	- 7.92	- 9.71*
P_3 x P_6	- 5.73	- 9.09	- 10.86**
P_3 x P_7	- 7.11	- 7.62	- 9.42
P_4 x P_1	- 5.97	- 7.70	- 7.70
P_4 x P_2	- 5.96	- 8.82*	- 8.82*
P_4 x P_5	+ 1.68	- 7.99*	- 7.99*
P_4 x P_6	- 8.83*	- 12.91**	- 12.91**
P_4 x P_7	- 7.02	- 8.48*	- 8.48*
P_5 x P_1	- 5.73	-13.23**	- 16.42**
P_5 x P_2	+ 1.00	- 5.95	- 11.66**
P_5 x P_3	+ 2.11	- 6.78	- 8.59*
P_5 x P_4	- 11.53*	- 19.94**	- 19.94**
P_5 x P_6	+ 4.88	- 0.91	- 9.78*
P_5 x P_7	+ 22.01**	+ 11.96**	+ 8.56*
P_6 x P_3	+ 0.35	- 3.23	- 5.11
P_6 x P_4	-13.61**	- 17.48**	- 17.48*
P_6 x P_5	- 1.39	- 6.84	- 15.18**
P_6 x P_7	- 0.19	- 3.23	- 6.17
P_7 x P_1	- 6.78	- 7.08	- 9.90*
P_7 x P_3	- 11.86**	- 12.35**	- 14.06**
P_7 x P_4	- 10.11*	- 11.47**	- 11.47**
P_7 x P_5	- 0.50	- 8.70*	- 11.47**
P_7 x P_6	+ 9.09*	+5.77	+ 2.56

* Significance at 5 per cent level
** Significance at 1 per cent level

TABLE - 7 HETEROSIS (PER CENT) FOR FRUIT GIRTH

Hybrids	di	dii	diii
$P_1 \times P_2$	- 8.34*	- 10.08*	- 15.85**
$P_1 \times P_3$	- 20.56**	- 20.72**	- 25.51**
$P_1 \times P_4$	- 7.10	- 8.23*	- 14.11**
$P_1 \times P_6$	- 16.73**	- 19.40**	- 19.40**
$P_1 \times P_7$	- 15.94**	- 19.19**	- 24.38**
$P_2 \times P_1$	- 12.37**	- 14.03**	- 19.55**
$P_2 \times P_5$	- 8.98*	- 9.81*	- 18.79**
$P_3 \times P_1$	- 16.46**	- 16.63**	- 21.66**
$P_3 \times P_2$	- 11.90**	- 13.73**	- 18.94**
$P_3 \times P_4$	- 20.65**	- 21.77**	- 26.49**
$P_3 \times P_5$	+ 4.27	+ 1.12	- 4.98
$P_3 \times P_6$	- 14.24**	- 16.83**	- 16.83**
$P_3 \times P_7$	- 15.36**	- 18.80**	- 23.70**
$P_4 \times P_1$	- 11.84**	- 12.90**	- 18.49**
$P_4 \times P_2$	- 14.27**	- 14.88**	- 22.26**
$P_4 \times P_5$	- 6.30	- 7.85	- 15.85**
$P_4 \times P_6$	- 18.66**	- 22.19**	- 22.19**
$P_4 \times P_7$	- 8.75*	- 11.24**	- 18.94**
$P_5 \times P_1$	- 9.79*	- 12.34**	- 17.96**
$P_5 \times P_2$	- 15.53**	- 16.35**	- 24.68**
$P_5 \times P_3$	- 7.41	- 10.20*	- 15.62**
$P_5 \times P_4$	- 6.05	- 7.60	- 15.62**
$P_5 \times P_6$	- 18.40**	- 23.17**	- 23.17**
$P_5 \times P_7$	- 7.26	- 8.29	- 19.02**
$P_6 \times P_3$	- 10.43**	- 13.13**	- 13.13**
$P_6 \times P_4$	- 26.94**	- 30.11**	- 30.11**
$P_6 \times P_5$	- 26.01**	- 30.34**	- 30.34**
$P_6 \times P_7$	- 13.33*	- 19.25**	- 19.25**
$P_7 \times P_1$	- 6.04*	- 9.68**	- 15.47**
$P_7 \times P_3$	- 9.17*	- 12.85**	- 18.11**
$P_7 \times P_4$	- 6.54	- 9.09*	- 16.98**
$P_7 \times P_5$	- 11.93**	- 12.91**	- 23.09**
$P_7 \times P_6$	+ 9.36*	- 15.55**	- 15.55**

* Significance at 5 per cent level
** Significance at 1 per cent level

Plate 5. Hybrid combinations free from yellow vein mosaic

a. MF-3 × OHD-1
b. MF-3 × VARSHA UPHAR
c. MF-3 × ARKA ANAMIKA
d. OHD-1 × VARSHA UPHAR
e. OHD-1× ARKA ANAMIKA
f. VARSHA UPHAR × ARKA ANAMIKA

The diii value ranged from -30.34 per cent (P_6 x P_5) to -4.98 per cent (P_3 x P_5). All the crosses have recorded standard heterosis over the best parent in the negative direction.

4.3.6. Plant height at final harvest (Table 8)

Among the 33 crosses the positive heterosis over the mid parent ranged from +0.49 per cent (P_7 x P_3) to +7.90 per cent (P_4 x P_7). The heterosis in the negative direction ranged from -0.30 per cent (P_5 x P_2) to -13.72 per cent (P_6 x P_5). Only three crosses have exhibited significant heterosis in the negative direction.

The dii value ranged from -17.10 per cent (P_6 x P_5) to +6.33 per cent (P_4 x P_7). P_1 x P_3 (-6.69), P_1 x P_4 (-5.94), P_4 x P_1 (-7.31), P_4 x P_2 (-7.72) and P_5 x P_6 (-7.35) have recorded significant heterosis in the negative direction.

The diii estimate ranged from -18.26 per cent (P_6 x P_5) to +4.73 per cent (P_3 x P_6). Only one cross P_7 x P_6 (+5.76 per cent) recorded significant standard heterosis over the best parent.

4.3.7. Number of branches per plant (Table 9)

The di estimate for number of branches per plant ranged from -21.60 per cent (P_6 x P_7) to +19.98 per cent. The heterosis in the negative direction ranged from -1.96 per cent (P_6 x P_5) to -26.48 per cent (P_4 x P_6).

Eight crosses out of 33 recorded heterobeltiosis over the better parent in the positive direction. The dii estimate ranged from -4.41 per cent (P_2 x P_1) to -29.10 per cent (P_1 x P_7) in the negative direction. The lowest heterobeltiosis was

TABLE - 8 HETEROSIS (PER CENT) FOR PLANT HEIGHT AT FINAL HARVEST

Hybrids	di	dii	diii
P_1 x P_2	+ 4.47	+ 1.74	- 4.40
P_1 x P_3	- 1.28	- 6.60**	- 6.69**
P_1 x P_4	- 2.89	- 5.94*	- 10.63**
P_1 x P_6	+ 0.19	- 4.66	- 6.00*
P_1 x P_7	+ 1.47	- 3.10	- 5.19*
P_2 x P_1	- 0.62	- 3.23	- 9.07**
P_2 x P_5	- 1.61	- 3.23	- 9.07**
P_3 x P_1	+ 3.86	- 1.83	- 1.83
P_3 x P_2	+ 5.63*	+ 2.45	+ 2.45
P_3 x P_4	+ 3.63	+ 1.04	+ 1.04
P_3 x P_5	+ 7.21**	+ 2.32	+ 2.32
P_3 x P_6	+ 5.47*	+ 4.73	+ 4.73
P_3 x P_7	- 0.43	- 1.50	- 1.50
P_4 x P_1	- 4.31	- 7.31**	- 11.94**
P_4 x P_2	- 7.21**	- 7.72**	- 12.33**
P_4 x P_5	+ 1.42	- 0.79	- 5.74*
P_4 x P_6	- 2.63	- 4.40	- 5.74*
P_4 x P_7	+ 7.90**	+ 6.33*	+ 4.04
P_5 x P_1	+ 1.02	0.00	- 9.13**
P_5 x P_2	- 0.30	- 1.94	- 7.86**
P_5 x P_3	+ 0.51	- 4.08	- 4.08
P_5 x P_4	- 5.28*	- 7.35**	- 11.97**
P_5 x P_6	+ 3.46	- 0.60	- 1.99
P_5 x P_7	+ 3.98	+ 0.27	- 1.89
P_6 x P_3	+ 1.26	+ 0.55	+ 0.55
P_6 x P_4	- 1.68	- 3.47	- 4.83*
P_6 x P_5	- 13.72**	- 17.10**	- 18.26**
P_6 x P_7	+ 2.64	+ 2.25	+ 0.82
P_7 x P_1	+ 2.41	- 2.20	- 4.31
P_7 x P_3	+ 0.49	- 0.59	- 0.59
P_7 x P_4	+ 6.07*	- 4.53	+ 2.28
P_7 x P_5	+ 7.54**	+ 3.73	+ 1.50
P_7 x P_6	+ 6.16*	+ 5.76 *	+ 4.27

* Significance at 5 per cent level

** Significance at 1 per cent level

TABLE - 9 HETEROSIS (PER CENT) FOR NUMBER OF BRANCHES PER PLANT

Hybrids	di	dii	diii
P_1 x P_2	- 13.18*	- 17.65**	- 30.35**
P_1 x P_3	- 10.08	- 14.71*	- 27.86**
P_1 x P_4	- 13.44*	- 21.24**	- 27.11**
P_1 x P_6	- 16.31**	- 24.22**	- 29.10**
P_1 x P_7	- 19.38**	- 29.10**	- 29.10**
P_2 x P_1	+ 0.78	- 4.41	- 19.15**
P_2 x P_5	+ 4.64	+ 3.42	- 10.45*
P_3 x P_1	- 3.57	- 8.53	- 22.64**
P_3 x P_2	- 11.76*	- 11.76*	- 25.37**
P_3 x P_4	+ 6.74	+ 2.15	- 5.47
P_3 x P_5	+ 1.73	+ 0.55	- 12.94**
P_3 x P_6	+ 8.92	+ 3.70	- 2.99
P_3 x P_7	+ 12.96	+ 10.45*	+ 10.45*
P_4 x P_1	- 2.51	- 11.29*	- 17.91**
P_4 x P_2	- 7.30	- 11.29*	- 17.91**
P_4 x P_5	- 20.84**	- 23.39**	- 29.10**
P_4 x P_6	- 26.48**	- 26.88**	- 31.59**
P_4 x P_7	- 19.90**	- 22.89**	- 22.89**
P_5 x P_1	- 7.21	- 12.96*	- 24.63**
P_5 x P_2	- 20.07**	- 21.00**	- 31.59**
P_5 x P_3	- 5.54	- 6.64	- 19.15**
P_5 x P_4	- 8.35	- 11.29*	- 17.91**
P_5 x P_6	- 11.63*	- 14.92**	- 20.40**
P_5 x P_7	- 14.68**	- 20.40**	- 20.40**
P_6 x P_3	+ 9.23	+ 3.99	- 2.71
P_6 x P_4	- 17.12**	- 17.58**	- 22.89**
P_6 x P_5	- 1.96	+ 5.61	- 11.69*
P_6 x P_7	- 21.60**	- 24.13**	- 24.13**
P_7 x P_1	+ 0.42	- 11.69*	- 11.69*
P_7 x P_3	- 12.37*	- 19.13**	- 19.13**
P_7 x P_4	- 9.56	- 12.91**	- 12.94**
P_7 x P_5	- 6.65	- 12.94**	- 12.91**
P_7 x P_6	+ 19.98**	+ 12.71**	+ 12.71**

* Significance at 5 per cent level
** Significance at 1 per cent level

recorded by (+0.55 per cent) the cross P_3 x P_5 in the positive direction. The highest heterobeltiosis was recorded by the cross P_7 x P_6 (+12.71 per cent).

The diii estimate ranged from -31.59 per cent (P_5 x P_2 and P_4 x P_6) to +12.71 per cent (P_7 x P_6). Only two crosses P_3 x P_7 (10.45) and P_7 x P_6 (12.71) recorded significant standard heterosis.

4.3.8. Yield of fruits per plant (Table 10)

Among the 33 crosses eight crosses had recorded negative heterosis. The positive heterosis ranged from +0.49 per cent (P_3 x P_1) to +52.22 per cent (P_7 x P_6). The negative heterosis ranged from –1.80 per cent (P_5 x P_7) to -20.29 per cent (P_6 x P_5).

The dii estimate ranged from -31.93 per cent (P_1 x P_4) to +39.97 per cent (P_7 x P_6). Ten crosses have recorded significant heterosis in the negative direction. The diii estimate for yield per plant ranged from -43.38 per cent (P_2 x P_1) to +39.97 per cent (P_7 x P_6). The lowest heterosis was recorded by P_7 x P_3 (+10.04 per cent). Twenty two hybrids have recorded significant heterosis in the negative direction.

4.3.9. Phenol content in leaves (Table 11)

The di estimate for phenol content ranged from -63.64 per cent (P_5 x P_4) to P_7 x P_6 (+24.39 per cent). The lowest negative heterosis was recorded by P_6 x P_7 (-1.08 per cent). The dii estimate ranged from -72.84 per cent (P_5 x P_4) to +19.19 per cent (P_7 x P_6). The crosses P_5 x P_2 (+4.55), P_6 x P_4 (+7.95) and P_7 x P_6 (+19.19) have recorded positive heterobeltiosis.

TABLE - 10 HETEROSIS (PER CENT) FOR YIELD OF FRUITS PER PLANT

Hybrids	di	dii	diii
$P_1 \times P_2$	- 10.71**	- 15.01**	- 51.79**
$P_1 \times P_3$	- 17.95**	- 25.04**	- 53.55**
$P_1 \times P_4$	- 19.56**	- 31.93**	- 49.62**
$P_1 \times P_6$	+ 10.76**	- 9.77**	- 26.50**
$P_1 \times P_7$	+ 24.78**	- 5.64 **	- 5.64**
$P_2 \times P_1$	+ 4.87	- 0.18	- 43.38**
$P_2 \times P_5$	+ 10.32**	- 2.37	- 28.09**
$P_3 \times P_1$	+ 0.49	- 8.20*	- 43.11**
$P_3 \times P_2$	+ 33.17**	+ 27.52**	- 20.98**
$P_3 \times P_4$	+ 34.49**	+ 25.17**	+ 24.15**
$P_3 \times P_5$	+ 11.11**	+ 2.30	- 24.66**
$P_3 \times P_6$	+ 20.05	+ 12.01**	+ 18.32**
$P_3 \times P_7$	+ 37.22**	+ 11.13**	+ 11.13**
$P_4 \times P_1$	+ 15.85**	- 1.96	- 27.43**
$P_4 \times P_2$	+ 29.44**	+ 14.31**	- 15.39**
$P_4 \times P_5$	- 6.46*	- 6.69*	- 30.93**
$P_4 \times P_6$	+ 26.52**	+ 20.74**	+ 1.64
$P_4 \times P_7$	+ 29.75**	+ 24.51**	+ 24.51**
$P_5 \times P_1$	+ 22.88**	+ 4.20	- 23.26**
$P_5 \times P_2$	+ 8.45*	- 4.02	- 29.31**
$P_5 \times P_3$	+ 5.04	- 3.29	- 28.77**
$P_5 \times P_4$	+ 0.76	+ 0.51	- 25.61**
$P_5 \times P_6$	- 6.48*	- 10.96**	- 27.47**
$P_5 \times P_7$	- 1.80	- 14.74**	- 14.74**
$P_6 \times P_3$	+ 30.54**	+ 14.92**	- 6.38**
$P_6 \times P_4$	+ 10.79**	+ 5.73*	- 13.87**
$P_6 \times P_5$	- 20.29**	- 24.11**	- 38.18**
$P_6 \times P_7$	+ 31.54**	+ 19.35**	+ 19.35**
$P_7 \times P_1$	+ 28.09**	- 3.13	- 3.13
$P_7 \times P_3$	+ 11.09**	+ 10.04**	+ 10.04**
$P_7 \times P_4$	+ 12.16**	- 2.41	- 2.41
$P_7 \times P_5$	+ 10.70**	- 3.89	- 3.89
$P_7 \times P_6$	+ 52.22**	+ 39.97**	+ 39.97**

* Significance at 5 per cent level
** Significance at 1 per cent level

TABLE - 11 HETEROSIS (PER CENT) FOR PHENOL CONTENT IN LEAVES

Hybrids	di	dii	diii
P_1 x P_2	- 24.49**	- 13.48**	- 62.24**
P_1 x P_3	- 18.57**	- 33.72**	- 41.84**
P_1 x P_4	- 42.22**	- 51.85**	- 60.20**
P_1 x P_6	- 18.31**	- 34.09**	- 40.82**
P_1 x P_7	- 21.05**	- 38.78**	- 38.78**
P_2 x P_1	- 6.12	- 14.81**	- 53.06**
P_2 x P_5	+ 14.29**	+ 9.09	- 51.02**
P_3 x P_1	- 22.86**	- 37.21**	- 44.90**
P_3 x P_2	- 1.54	- 25.58**	- 34.69**
P_3 x P_4	- 5.39	- 8.14**	- 10.39**
P_3 x P_5	- 23.81**	- 44.19**	- 51.02**
P_3 x P_6	- 6.90	- 7.95**	- 17.35**
P_3 x P_7	- 14.13**	- 19.39**	- 19.39**
P_4 x P_1	- 45.19**	- 54.32**	- 62.24**
P_4 x P_2	- 7.20	- 28.40**	- 40.82**
P_4 x P_5	- 35.54**	- 51.85**	- 60.20**
P_4 x P_6	+ 2.06	- 1.14	- 11.22**
P_4 x P_7	- 5.03	- 13.27**	- 13.27**
P_5 x P_1	- 55.32**	- 61.11**	- 78.57**
P_5 x P_2	+ 9.52	+ 4.55	- 53.06**
P_5 x P_3	- 39.68**	- 55.81**	- 61.22**
P_5 x P_4	- 63.64**	- 72.84**	- 77.55**
P_5 x P_6	- 32.81**	- 51.14**	- 56.12**
P_5 x P_7	- 53.62**	- 67.35**	- 67.35**
P_6 x P_3	- 6.90*	- 7.95**	- 17.35**
P_6 x P_4	+ 12.43**	+ 7.95**	- 3.06
P_6 x P_5	- 31.25**	- 50.00**	- 55.10**
P_6 x P_7	- 1.08	- 6.12*	- 6.12*
P_7 x P_1	- 46.05**	- 50.16**	- 58.16**
P_7 x P_3	- 6.52*	- 12.24*	- 12.24**
P_7 x P_4	- 13.97**	- 21.43**	- 21.43**
P_7 x P_5	- 43.48**	- 60.20**	- 60.20**
P_7 x P_6	+ 24.39**	+ 19.19**	+ 19.19**

* Significance at 5 per cent level
** Significance at 1 per cent level

The standard heterosis recorded was from -77.55 per cent (P_5 x P_4) to +19.19 per cent (P_7 x P_6). The lowest negative heterosis was recorded by the cross P_6 x P_4 (-3.06 per cent).

4.3.10. Carbohydrate content in fruits (Table 12)

The di estimate ranged from -16.20 per cent (P_5 x P_3) to +23.77 per cent (P_1 x P_4). Nineteen crosses showed heterosis over the mid parent in the positive direction. The dii estimate ranged from -18.11 per cent (P_4 x P_1) to +8.66 per cent (P_1 x P_4). Twenty five crosses showed heterobeltiosis in the negative direction. The cross P_5 x P_2 exhibited lowest heterosis in the positive direction +0.85 per cent.

Lowest standard heterosis was exhibited by the cross P_1 x P_3 (+0.44 per cent). The highest standard heterosis was exhibited by the cross P_3 x P_1 (+6.50 per cent). Four crosses have exhibited standard heterosis in the positive direction.

4.3.11. Protein content in fruits (Table 13)

Among the 33 crosses eleven crosses have recorded positive heterosis. It ranged from +1.08 in P_4 x P_1 to +16.54 in P_7 x P_6. The negative heterosis value recorded was -0.23 per cent (P_4 x P_2) to -28.43 per cent (P_4 x P_7).

The dii estimate ranged from -31.86 per cent (P_1 x P_7 and P_4 x P_7) to +12.03 per cent in P_7 x P_6. The standard heterosis value exhibited was from -42.91 per cent (P_1 x P_3) to +12.03 per cent (P_7 x P_6). Except P_7 x P_2 all the crosses showed significant heterosis in the negative direction.

TABLE - 12 HETEROSIS (PER CENT) FŎR CARBOHYDRATE CONTENT IN FRUITS

Hybrids	di	dii	diii
P_1 x P_2	- 1.17	- 7.09	- 12.85*
P_1 x P_3	+ 3.66	+ 0.44	+ 0.44
P_1 x P_4	+ 23.77**	+ 8.66	+ 1.92
P_1 x P_6	- 3.20	- 4.72	- 10.64*
P_1 x P_7	+ 0.00	- 2.96	- 3.25*
P_2 x P_1	+ 2.251	- 3.62	- 9.60
P_2 x P_5	+ 1.08	- 6.00	- 9.75
P_3 x P_1	+ 9.91	+ 6.50	+ 6.50
P_3 x P_2	+ 9.22	- 0.30	- 0.30
P_3 x P_4	+ 4.32*	- 10.86	- 10.86*
P_3 x P_5	- 11.83*	- 13.59*	- 13.59*
P_3 x P_6	+ 0.62	- 3.99	- 3.99
P_3 x P_7	+ 3.70	+ 3.55	+ 3.55
P_4 x P_1	- 6.73	- 18.11**	- 23.19**
P_4 x P_2	+ 8.95	+ 1.25	- 16.40**
P_4 x P_5	- 2.65	- 15.38**	- 18.70**
P_4 x P_6	+ 9.95	- 2.11	- 11.08*
P_4 x P_7	- 2.16	- 16.30**	- 16.54**
P_5 x P_1	- 0.39	- 1.54	- 5.47
P_5 x P_2	+ 8.44	+ 0.85	- 3.18
P_5 x P_3	- 16.20**	- 17.87**	- 17.87**
P_5 x P_4	+ 16.90**	+ 1.62	- 2.44
P_5 x P_6	+ 5.45	+ 2.62	- 1.48
P_5 x P_7	- 5.51	- 7.26	- 7.53
P_6 x P_3	- 5.57	- 9.90	- 9.90
P_6 x P_4	+ 11.42	- 0.81	- 9.10
P_6 x P_5	- 5.14	- 7.69	- 11.37**
P_6 x P_7	- 1.40	- 5.78	- 6.06
P_7 x P_1	+ 0.08	- 2.89	- 3.18
P_7 x P_3	- 5.18	- 5.32	- 5.32
P_7 x P_4	+ 12.55*	- 3.70	- 3.99
P_7 x P_5	- 7.92	- 9.63	- 9.90
P_7 x P_6	+ 2.56	+ 2.00	+ 2.29

* Significance at 5 per cent level
** Significance at 1 per cent level

TABLE - 13 HETEROSIS (PER CENT) FOR PROTEIN CONTENT IN FRUITS

Hybrids	di	dii	diii
P_1 x P_2	+ 4.08	- 0.27	- 31.86**
P_1 x P_3	- 18.64**	- 26.54**	- 42.91**
P_1 x P_4	- 3.73	- 18.53**	- 26.34**
P_1 x P_6	+ 9.86	+ 5.41	- 28.18**
P_1 x P_7	- 16.19**	- 31.86**	- 31.86**
P_2 x P_1	- 1.55	- 5.66	- 35.54**
P_2 x P_5	- 6.80	-12.53*	- 31.86**
P_3 x P_1	+ 15.49**	+ 4.27	- 18.97**
P_3 x P_2	- 1.64	- 7.58	- 28.18**
P_3 x P_4	- 18.95**	- 24.64**	- 31.86**
P_3 x P_5	- 24.26**	- 24.35**	- 41.07**
P_3 x P_6	- 11.11*	- 16.59**	- 35.17**
P_3 x P_7	- 19.17**	- 28.18**	- 28.18**
P_4 x P_1	+ 1.08	- 14.46**	- 22.65**
P_4 x P_2	- 0.23	- 12.42**	- 20.81**
P_4 x P_5	- 10.28*	- 16.50**	- 24.49**
P_4 x P_6	+ 7.32**	+ 5.91	- 14.92**
P_4 x P_7	- 28.43**	- 31.86**	- 31.86**
P_5 x P_1	+ 2.23	- 7.80	- 28.18**
P_5 x P_2	- 1.76	- 7.80	- 28.18**
P_5 x P_3	- 28.05**	- 28.13**	- 44.10**
P_5 x P_4	- 22.54**	- 27.90	- 34.81**
P_5 x P_6	+ 5.93	- 0.71	- 22.65**
P_5 x P_7	- 2.69	- 13.44**	- 13.44**
P_6 x P_3	- 16.41**	- 21.56	- 39.04**
P_6 x P_4	+ 11.50*	- 2.24	- 11.60**
P_6 x P_5	+ 8.45	+ 1.65	- 20.81**
P_6 x P_7	- 4.93	- 20.07*	- 20.07**
P_7 x P_1	+ 13.25**	- 7.92*	- 7.92**
P_7 x P_3	- 12.75**	- 22.47**	- 22.47**
P_7 x P_4	- 14.89**	- 18.97**	- 18.97**
P_7 x P_5	- 0.62	- 11.60	- 11.60**
P_7 x P_6	+ 16.54**	+ 12.03**	+ 12.03**

* Significance at 5 per cent level
** Significance at 1 per cent level

TABLE - 14 HETEROSIS (PER CENT) FOR CRUDE FIBRE CONTENT IN FRUITS

Hybrids	di	dii	diii
P_1 x P_2	- 4.41	- 6.10	- 26.57**
P_1 x P_3	- 13.36*	- 24.0*	- 24.00
P_1 x P_4	- 6.79	- 10.91	- 26.29**
P_1 x P_6	- 3.68	- 6.43	- 25.14**
P_1 x P_7	+ 20.97*	- 1.14	- 25.43**
P_2 x P_1	+ 5.78	+ 3.91	- 18.74**
P_2 x P_5	+ 19.81**	+ 15.26*	- 2.46
P_3 x P_1	+ 2.61	- 10.00	- 10.00
P_3 x P_2	- 7.84	- 17.89**	- 17.89**
P_3 x P_4	+ 0.47	- 8.20	- 8.20
P_3 x P_5	- 13.53*	- 20.17**	- 20.17**
P_3 x P_6	- 13.87*	- 22.49**	- 22.49**
P_3 x P_7	+ 10.88	- 18.03**	- 18.03**
P_4 x P_1	- 6.94	- 11.05	- 26.40**
P_4 x P_2	+ 3.39	+ 0.55	- 16.80**
P_4 x P_5	- 3.14	- 4.22	- 18.94**
P_4 x P_6	+ 1.37	+ 0.31	- 17.51**
P_4 x P_7	+ 15.99	+ 8.46	- 24.26**
P_5 x P_1	+ 21.39**	+ 14.79	- 2.86
P_5 x P_2	+ 11.84	+ 7.60	- 8.94
P_5 x P_3	- 15.48**	- 21.97**	- 21.97**
P_5 x P_4	- 8.23*	- 9.25	- 23.20**
P_5 x P_6	- 22.56**	- 24.68**	- 36.26**
P_5 x P_7	- 19.00*	- 6.85	- 21.17**
P_6 x P_3	- 17.97**	- 26.17**	- 26.17**
P_6 x P_4	- 13.55**	- 14.99**	- 29.66**
P_6 x P_5	- 12.11	- 14.52**	- 27.66**
P_6 x P_7	- 14.82	- 31.93**	- 45.54**
P_7 x P_1	+ 6.05	- 13.33	- 34.63**
P_7 x P_3	- 29.24**	- 47.69**	+ 47.69**
P_7 x P_4	+ 7.50	- 15.16*	- 29.80**
P_7 x P_5	- 1.96	- 23.26**	- 35.06**
P_7 x P_6	- 8.38	- 26.79**	- 41.43**

* Significance at 5 per cent level
** Significance at 1 per cent level

4.3.12. Crude fibre content in fruits (Table 14)

The heterosis recorded was -29.24 per cent (P_7 x P_3) to +20.97 per cent (P_1 x P_7). The lowest value +0.47 per cent was recorded by P_3 x P_4. The dii estimate ranged from -47.69 (P_7 x P_3) to +15.26 per cent (P_2 x P_5). Only 4 crosses have recorded heterobeltiosis over the better parent.

In the standard heterosis estimate the value ranged from -45.54 per cent (P_6 x P_7) to -2.86 per cent (P_5 x P_1). All the 33 crosses have recorded standard heterosis in the negative direction for the crude fibre content in fruits.

4.4. Variability, Heritability and Genetic Advance

Phenotypic and genotypic variance, phenotypic and genotypic coefficients of variation, heritability, genetic advance and genetic advance as percent of mean were worked out for the eight different biometric traits and presented in Table 15.

Among the eight traits studied the phenotypic variance ranged from as low as +0.179 for fruit girth to +7604.38 in yield of fruits per plant. Plant height at final harvest exhibited the higher phenotypic variance (+54.77) but next to yield of fruits. The characters such as fruit girth and fruit length exhibited relatively lesser phenotypic variance.

The genotypic variance was also maximum in respect of yield per plant (+3638.197). The characters like plant height at final harvest, number of fruits per plant exhibited higher genotypic variance next to yield per plant. The estimate of genotypic variance was low for other characters.

TABLE - 15 VARIABILITY , HERITABILITY AND GENETIC ADVANCE

Characters	PV	GV	PCV	GCV	h2 (broad sense)	GA	GA as per cent of mean
Plant height at first flower bud appearance	3.581	3.216	13.530	12.820	89.800	3.500	25.030
Number of fruits/plant	17.475	14.779	16.670	15.330	84.580	7.280	29.040
Fruit weight	8.473	5.615	18.910	15.390	66.280	3.970	25.810
Fruit length	0.964	0.460	6.650	4.600	47.780	0.970	6.550
Fruit girth	0.179	0.118	8.00	6.500	65.970	0.580	10.870
Plant height at final harvest	54.700	23.727	4.950	3.26	43.320	6.600	4.420
Number of branches /plant	4.479	3.430	11.800	10.330	76.630	3.340	18.620
Yield /plant	7604.380	3638.197	24.090	16.660	47.840	85.930	23.740

In terms of coefficient of variation, the phenotypic and genotypic coefficients of variation were relatively higher for yield of fruits per plant (24.09 and 16.66) next to yield per plant highest GCV was exhibited by fruit weight and number of fruits per plant.

The broad sense heritability was the highest for plant height of first flower bud appearance (89.80) while it was the least for the plant height at final harvest. It was moderate for the characters such as number of branches (76.63), fruit weight (66.28), fruit girth (65.97), yield of fruits per plant (47.84), fruit length (47.18) and plant height at final harvest (43.32).

The character yield of fruits per plant exhibits highest genetic advance (85.93) and moderate genetic advance as per cent of mean (23.74). Lower GA was exhibited by the characters fruit girth, fruit length and number of branches.

Number of fruits per plant exhibited maximum GA as per cent of mean (29.04) followed by fruit weight (25.81) other characters like plant height, fruit length and fruit girth exhibited low to moderate GA as per cent of mean.

4.5. Partial diallel analysis

Based on the performance of parents and hybrids during first season not only for yield but also for resistance/tolerance to yellow vein mosaic disease the following four parents were chosen and crossed in a partial diallel fashion.

I season	Genotype	Redesignated parent number in II season
P_3	MF-3	P_1
P_4	OHD-1	P_2
P_7	Varsha Uphar	P_3
P_6	Arka Anamika	P_4

TABLE – 16 MEAN PERFORMANCE OF PARENTS AND HYBRIDS (SEASON II)

Genotypes	Plant height at first flower bud appearance	Number of fruits/ Plant	Individual fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Plant height at final harvest (cm)
P1	13.10	20.50	18.68	14.10	5.41	98.50
P2	14.45	26.78	16.76	14.65	5.98	103.30
P3	12.95	26.98	19.10	15.20	6.10	106.30
P4	13.59	25.03	17.88	13.89	5.31	104.12
Mean	13.52	24.82	18.10	14.46	5.70	103.05
P1*P2	13.32	30.29	18.69	14.75	5.49	99.50
P1×P3	13.10	31.16	17.89	15.20	5.98	104.30
P1×P4	13.38	30.53	17.61	14.98	6.01	108.80
P2×P3	13.95	32.03	17.59	15.32	5.72	104.32
P2×P4	13.08	29.94	18.38	14.89	5.99	108.12
P3×P4	12.98	32.01	18.92	15.98	6.12	109.40
Mean	13.35	30.99	18.26	15.19	5.89	105.74
SE	**0.257**	**1.366**	**0.897**	**0.543**	**0.153**	**5.294**
CD(0.05)	**0.504**	**2.679**	**1.759**	**1.064**	**0.299**	**10.377**

(Contd...

TABLE – 16 (Contd…)

Genotypes	**Number of branches/ plant**	**Yield/plant (cm)**	**Phenol**	**Carbohydrate**	**Protien**	**Crude fibre**
P1	5.10	394.80	0.41	6.70	2.30	13.23
P2	4.91	429.40	0.40	6.50	2.10	12.50
P3	5.31	484.40	0.47	6.80	2.60	8.75
P4	5.28	428.80	0.46	6.40	2.00	9.15
Mean	5.15	434.35	0.44	6.60	2.38	10.90
P1*P2	5.10	502.40	0.47	6.80	2.50	12.09
P1×P3	5.32	501.94	0.46	6.50	2.30	10.18
P1×P4	4.98	498.33	0.46	6.70	2.60	10.78
P2×P3	5.46	531.80	0.42	6.70	2.80	11.48
P2×P4	5.29	510.21	0.47	6.40	2.40	9.09
P3×P4	5.23	549.90	0.48	6.90	2.80	8.79
Mean	5.28	515.76	0.46	6.70	2.57	10.40
SE	**0.881**	**6.787**	**0.009**	**0.403**	**0.228**	**1.092**
CD(0.05)	**1.726**	**11.304**	**0.019**	**0.789**	**0.447**	**2.141**

TABLE - 17 HETEROSIS (PER CENT) FOR YIELD OF FRUITS /PLANT (SEASON II)

Hybrids	di	dii	d iii
$P_1 \times P_2$	+38.50**	+28.97**	+26.15**
$P_1 \times P_3$	+39.22**	+12.33**	+12.33**
$P_1 \times P_4$	+21.00**	+13.09**	+18.02**
$P_2 \times P_3$	+30.15**	+25.53**	+25.53**
$P_2 \times P_4$	+28.12**	+21.04**	+2.69**
$P_3 \times P_4$	+53.22**	+41.97**	+41.97**

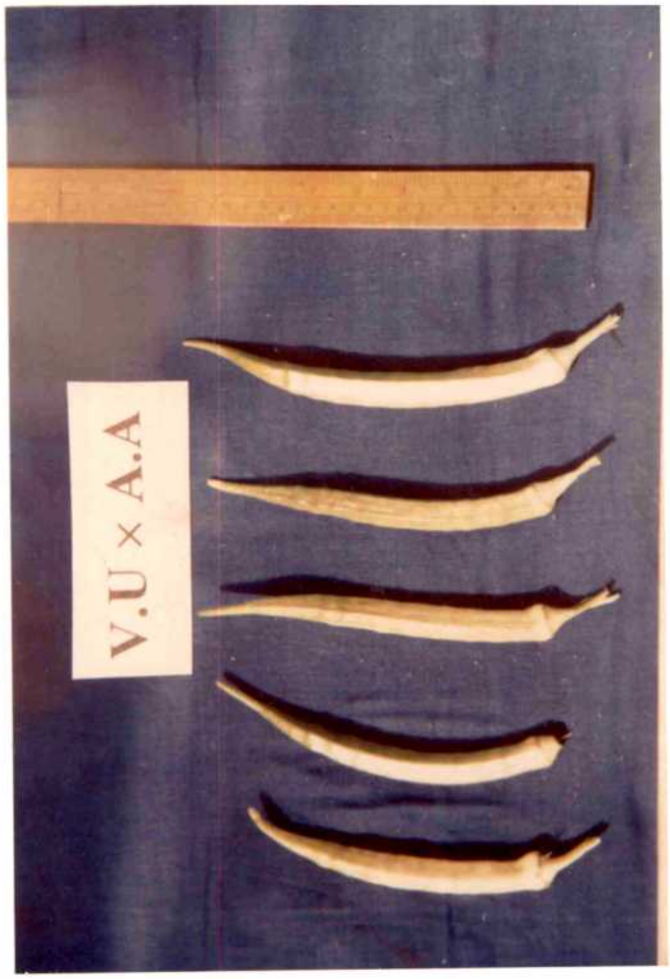
* Significant at 5 per cent level
** Significant at 1 per cent level

Plate 6. Promising hybrid combinations

a. VARSHA UPHAR × ARKA ANAMIKA

b. OHD-1 × VARSHA UPHAR

a



b

Mean performance of the parents and hybrids in season II (Table 16) indicated that the parents and hybrids performed better than the parents and hybrids in season I. The heterosis for yield in season II (Table 17) showed that all the 6 hybrids recorded positive and significant heterosis.

The data collected were subjected to combining ability analysis, genetic analysis and graphic analysis with respect to yield and component traits as well as qualitative traits, so as to identify promising cross combination for yield and resistance/tolerance to yellow vein mosaic, the results are as follows.

4.6. COMBINING ABILITY ANALYSIS

The combining ability analysis was carried out for 12 characters and the results are presented in tables 18 to 24.

4.6.1. Combining ability variances (Table 18)

The variance of general combining ability (*GCA*) was significant for yield of fruits per plant while the variances of *GCA* for other traits were non-significant.

The variance of specific combining ability (*SCA*) of the crosses showed significance for the characters like yield of fruits per plant, number of branches, crude fibre content in fruits, plant height at first flowering and plant height at final harvest (Table 18). The other characters like fruit length, fruit girth, phenol content in leaves, carbohydrate and protein content in fruits showed non-significant *SCA* variance.

The *GCA/SCA* ratio was less than 1.0 for all the traits. The highest being fruit girth (0.365) and it was lowest for the character plant height at final harvest (0.004).

TABLE – 18 ANALYSIS OF VARIANCE FOR COMBINING ABILITY

Mean squares

SOURCE	df	Plant height at first flower bud appearance	Number of fruits /plant	Individual Fruit weight	Fruit length	Fruit girth	Plant height at final harvest
GCA	3	0.600^{NS}	1.244^{NS}	1.063^{NS}	0.070^{NS}	0.111^{NS}	0.179^{NS}
SCA	6	3.549*	12.567*	8.071*	0.611^{NS}	0.305^{NS}	46.733*
Error	18	0.022	0.622	0.268	0.098	0.008	9.344
GCA/SCA		0.169	0.099	0.132	0.115	0.365	0.004

Mean squares

SOURCE	df	Number of branches /plant	Yield/ Plant	Phenol	Carbohydrate	Protein	Crude fibre
GCA	3	1.059^{NS}	338.337**	0.00004^{NS}	0.038^{NS}	0.0013^{NS}	0.169^{NS}
SCA	6	3.295*	3465.63**	0.009^{NS}	0.288^{NS}	0.105^{NS}	7.715**
Error	18	0.258	15.356	0.0001	0.054	0.017	0.398
GCA/SCA		0.321	0.098	0.0477	0.132	0.012	0.022

* Significance at 5 per cent level

** Significance at 1 per cent level

4.6.2. General combining ability effects (*gca*) and specific combining ability effects (*sca*)

The estimates of ***gca*** for the parents and ***sca*** for the hybrids are presented for 12 characters in the tables 19 to 24. Rank correlations between ***gca*** effects and parental arraymeans, parental performance and ***gca*** effects and ***per se*** performance of hybrids and ***sca*** effects were estimated and persented in Tables 25 and 26.

4.6.2.1. Plant height at first flowering (Table 19)

The ***gca*** of the parents ranged from -0.878 in P_4 to +0.961 in P_2 (Table 19). The ***gca*** was significant and positive in P_1 and P_2, whereas it was significant and negative in P_3 and P_4.

The ***sca*** of the crosses ranged from -2.346 in P_1 x P_4 to +2.108 in P_2 x P_3. The ***sca*** was positive and significant in P_1 x P_2, P_2 x P_4, P_3 x P_4 and P_2 x P_3. But the ***sca*** was negative and significant in P_1 x P_3 and P_1 x P_4. All the hybrids showed significant ***sca*** for this character. The crosses involving P_2 showed positive and significant ***sca***.

Rank correlation (Table 25) between parental array means and ***gca*** effects, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.2. Number of fruits per plant (Table 19)

The ***gca*** of the parents for this trait ranged from -1.686 in P_2 to +0.872 in P_3. Except the parent P_2 all the other parents P_1, P_2 and P_4 showed positive ***gca*** effect in which that of P_4 was non-significant (Table 19).

The ***sca*** effect for this character in the hybrids ranged from -4.215 in P_1 x P_2 to +4.597 in P_1 x P_4. The hybrids P_1 x P_3, P_1 x P_4 and P_3 x P_4 alone exhibited positive

TABLE - 19 ESTIMATES OF gca OF PARENTS (DIAGONAL), AND sca OF HYBRIDS FOR PLANT HEIGHT AT FIRST FLOWER BUD APPEARANCE AND NUMBER OF FRUITS / PLANT

Plant height at first flower bud appearance

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	+0.197**	+0.915**	-1.545**	-2.346**	gca (gi) 0.052	1.058	1.392
P2.		+0.961**	+2.108**	+1.107**	(gi-gj) 0.086		
P3			-0.279**	+0.380**	sca (sij) 0.094	2.592	3.409
P4				-0.878**	(sij-skl) 0.171		

Number of fruits/plant

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	+0.642*	-4.215**	+3.870**	+4.597**	gca (gi) 0.279	1.383	1.817
P2		-1.686**	-1.586**	-1.169*	(gi-gj) 0.455		
P3			+0.872**	0.150^{NS}	sca (sij) 0.499	3.091	4.063
P4				$+0.172^{NS}$	(sij-skl) 0.911		

* Significance at 5 per cent level ** Significance at 1 per cent level
NS Non significance

significant ***sca*** that of the hybrid P_3 x P_4 was non-significant. Wherever the parent P_2 was involved it resulted in negative ***sca*** in the hybrids for this characters.

Rank correlation (Table 25) between parental array means and ***gca*** effects, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.3. Individual fruit weight (Table 20)

The ***gca*** of the parents for individual fruit weight ranged from -1.233 in P_1 to +0.942 in P_3. All the four parents showed significant ***gca*** effect. The parents P_2 and P_3 recorded positive and significant ***gca***, whereas the parents p_1 and P_4 showed negative significant ***gca***.

Rank correlation (Table 25) between parental array means and ***gca*** effects, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.4. Fruit length (Table 20)

Among the parents the ***gca*** ranged from -0.208 in P_1 to +0.421 in P_3. The parent P_3 alone showed positive and significant ***gca***.

The ***sca*** effect of the hybrids ranged from -1.131 in P_1 x P_3 to 1.047 in P_1 x P_4. The hybrid P_2 x P_3 showed non-significant positive ***sca*** whereas all the other hybrids showed significant ***sca*** effect. The parent P_3 as female exhibited either negative or non-significant ***sca*** effect.

TABLE - 20 ESTIMATES OF gca OF PARENTS (DIAGONAL), AND sca OF HYBRIDS FOR INDIVIDUAL FRUIT WEIGHT AND FRUIT LENGTH

Individual fruit weight

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	-1.233**	+3.543**	-4.162**	+0.247^NS	gca (gi) 0.183	0.347	0.456
P2		+0.807**	-2.215**	+0.477^NS	(gi-gj) 0.299		
P3			+0.942**	-0.911*	sca (sij) 0.328	0.775	1.019
P4				-0.516*	(sij-skl) 0.598		

Fruit length

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	-0.208^NS	+0.442*	-1.131**	1.047**	gca (gi) 0.111	0.175	0.230
P2		-0.196^NS	0.016^NS	0.451*	(gi-gi) 0.181		
P3			+0.421**	0.437*	sca (sij) 0.198	0.392	0.516
P4				-0.017^NS	(sij-ski) 0.362		

* Significance at 5 per cent level ** Significance at 1 per cent level
NS Non significance

Rank correlation (Table 25) between parental array means and ***gca*** effects, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.5. Fruit girth (Table 21)

The ***gca*** among the parents ranged from - 0.465 in P_1 to + 0.035 in P_4. P_2 and P_3 showed positive and significant ***gca***, whereas the parent P_4 showed positive and non-significant ***gca*** among the four parents.

The ***sca*** effect among the hybrids ranged from -0.590 in P_2 x P_3 to +0.759 in P_1 x P_2. Except P_1 x P_2 all the hybrids P_1 x P_4, P_2 x P_4, P_2 x P_3 and P_3 x P_4 showed negative and significant ***sca*** effect. The non-significant and negative ***sca*** was exhibited by the hybrid P_1 x P_3.

Rank correlation (Table 25) between parental array mean and ***gca*** effect, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and non-significant (Table 26)

4.6.2.6. Plant height at final harvest (Table 21)

The ***gca*** among the parents ranged form -1.026 in P_2 to + 1.869 in P_3. All the 4 parents showed non significant ***gca*** for this character.

The ***sca*** effect ranged from -9.174 in P_2 x P_3 to 9.913 in P_1 x P_4. The hybrids P_1 x P_3 and P_1 x P_4 showed positive and significant ***sca*** effect, whereas the hybrids P_1 x P_2, P_2 x P_4, and P_3 x P_4 showed positive and non-significant ***gca*** for this character.

TABLE -21 ESTIMATES OF gca OF PARENTS (DIAGONAL) , AND sca OF HYBRIDS FOR FRUIT GIRTH AND PLANT HEIGHT AT FINAL HARVEST

Fruit girth

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	-0.465**	+0.759**	-0.023^{NS}	-0.337**	gca (gi) 0.031	0.065	0.086
P2		-0.333**	-0.590**	-0.158*	(gi-gj) 0.051		
P3			-0.097**	-0.483**	sca (sij) 0.056	0.146	0.192
P4				+0.035^{NS}	(sij-skl) 0.102		

Plant height at final harvest

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	-0.818^{NS}	+0.413^{NS}	5.785**	9.913**	gca (gi) 1.081	6.330	8.320
P2		-1.026^{NS}	-9.174**	0.920^{NS}	(gi-gj) 1.765		
P3			1.869^{NS}	1.259^{NS}	sca (sij) 1.933	14.155	18.604
P4				-0.026^{NS}	(sij-skl) 3.530		

* Significance at 5 per cent level ** Significance at 1 per cent level
NS Non significance

Rank correlation (Table 25) between parental array mean and ***gca*** effect, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and non-significant (Table 26)

4.2.6.7. Number of branches per plant (Table 22)

The ***gca*** among the parents for the character number of branches per plant ranged from -1.253 in P_1 to + 1.223 in P_2. The parents P_3 and P_4 showed non-significant ***gca*** for this character.

Among the hybrids the ***sca*** ranged from -2.836 in P_3 x P_4 to +0.418 in P_1 x P_3. The hybrids P_2 x P_3, P_2 x P_4 and P_3 x P_4 showed negative and significant ***sca*** effect. The hybrids P_1 x P_2 and P_1 x P_3 showed non-significant ***sca***.

Rank correlation (Table 25) between parental array means and ***gca*** effects, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.8. Yield of fruits per plant (Table 22)

Among the parents ***gca*** ranged from -17.805 in P_1 to + 20.066 in P_3. The parents P_1 and P_2 showed significant and negative ***gca***, whereas the parents P_3 and P_4 showed significant positive ***gca***.

The ***sca*** among the hybrids ranged from -51.834 in P_1 x P_2 to +77.177 in P_1 x P_4. The hybrids P_2 x P_4, P_1 x P_3, P_2 x P_3 and P_3 x P_4 showed significant and negative ***sca*** whereas the hybrid P_1 x P_4 showed positive and significant ***sca***.

TABLE - 22 ESTIMATES OF gca OF PARENTS (DIAGONAL), AND sca OF HYBRIDS FOR NUMBER OF BRANCHES / PLANT AND YIELD / PLANT

Number of branches / plant

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	-1.253**	-0.609^{NS}	+0.418^{NS}	+0.778*	gca (gi) 0.180	1.653	1.858
P2		+1.223**	-1.057**	-1.497**	(gi-gj) 0.294		
P3			+0.312^{NS}	-2.836**	sca (sij) 0.322	1.145	1.192
P4				-0.332^{NS}	(sij-skl) 0.587		

Yield / plant

Parents	P1	P2	P3	P4	SE	CD 5%	CD 1%
P1	-17.805**	-51.834**	-38.677**	+77.177**	gca (gi) 1.385	18.631	25.059
P2		-13.387**	-42.605**	-9.148**	(gi-gj) 2.262		
P3			+20.066**	-44.834**	sca (sij) 2.478	40.843	53.450
P4				+11.126**	(sij-skl) 4.525		

* Significance at 5 per cent level ** Significance at 1 per cent level

NS Non significance

However the mean performance was better in combinations like P_2 x P_3 and P_3 x P_4 even though they exhibited negative ***sca*** effects. The parental ***per se*** was not significantly related to ***gca***.

Rank correlation (Table 25) between parental array means and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.9. Phenol content in leaves (Table 23)

The ***gca*** among the parents ranged from -0.000 in P_2 to + 0.007 in P_4. P_2 and P_3 showed non-significant ***gca***. Whereas P_1 and P_4 showed significant ***gca***.

The ***sca*** among the hybrids ranged from -0.037 in P_2 x P_4 to 0.001 in P_3 x P_4. Except P_1 x P_2 and P_3 x P_4 all the hybrids showed negative and significant ***sca***. Whereas P_1 x P_2 and P_3 x P_4 showed non-significant ***sca***.

Rank correlation (Table 25) between parental array means and ***gca*** effects parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and significant (Table 26).

4.6.2.10. Carbohydrate content in fruits (Table 23)

The ***gca*** for the trait ranged from -0.281 in P_4 to + 0.225 in P_3. The parents P_3 and P_4 showed significant ***gca***, whereas the parents P_1 and P_2 showed non-significant ***gca***.

TABLE - 23 ESTIMATES OF gca OF PARENTS (DIAGONAL), AND sca OF HYBRIDS FOR PHENOL CONTENT AND CARBOHYDRATE CONTENT

Phenol content

Parents	P1	P2	P3	P4	SE	CD	
						5%	1%
P1	-0.009**	-0.004^{NS}	-0.026**	-0.008*	gca (gi) 0.002	0.006	0.008
P2		-0.000^{NS}	-0.028**	-0.037**	(gi-gj) 0.003		
P3			0.002^{NS}	+0.001^{NS}	sca (sij) 0.003	0.014	0.016
P4				0.007**	(sij-skl) 0.006		

Carbohydrate content

Parents	P1	P2	P3	P4	SE	CD	
						5%	1%
P1	-0.042^{NS}	+0.067^{NS}	+0.373*	+0.146^{NS}	gca (gi) 0.082	0.321	0.422
P2		+0.098	0.070^{NS}	-1.127**	(gi-gl) 0.134		
P3			0.225*	0.145^{NS}	sca (sij) 0.147	0.717	0.943
P4				-0.281**	(sij-ski) 0.268		

* Significance at 5 per cent level ** Significance at 1 per cent level

NS Non significance

Among the hybrids the ***sca*** ranged from -1.127 in P_2 x P_4 to +0.373 in P_1 x P_3. The hybrids P_1 x P_3 and P_2 x P_4 showed significant ***sca***, whereas the hybrids P_1 x P_2, P_1 x P_4, P_2 x P_3 and P_3 x P_4 showed non-significant positive ***sca***.

Rank correlation (Table 25) between parental array mean and ***gca*** effect, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and non-significant (Table 26)

4.6.2.11. Protein content in fruits (Table 24)

The ***gca*** among the parents ranged from - 0.550 to + 0.040 in P_2. All the 4 parents showed non-significant ***gca*** for this character.

The ***sca*** among the hybrids ranged from -0.418 in P_2 x P_3 to +0.1 in P_3 x P_4. The hybrids P_1 x P_3, P_1 x P_4 and P_2 x P_3 showed significant and negative ***sca*** where as the hybrids P_2 x $P_4$and P_3 x P_4 showed though positive ***sca*** effects they were non-significant.

Rank correlation (Table 25) between parental array mean and ***gca*** effect, parental ***per se*** and ***gca*** effects and ***per se*** performance of the hybrids and their corresponding ***sca*** effects were all positive and non-significant (Table 26)

4.6.2.12. Crude fibre content in fruits (Table 24)

Among the parents the ***gca*** ranged from -0.490 in P_2 to +0.643 in P_1. The parents P_1 and P_3 showed positive and significant ***gca***, whereas the parents P_2 and P_4 showed negative ***gca*** for this character.

TABLE – 24 ESTIMATES OF gca OF PARENTS (DIAGONAL), AND sca OF HYBRIDS FOR PROTEIN CONTENT AND CRUDE FIBRE CONTENT

Protein content

Parents	P1	P2	P3	P4	SE	CD	
						5%	1%
P1	-0.055^{NS}	-0.158^{NS}	-0.290**	-0.347**	gca (gi) 0.047	0.055	0.0658
P2		+0.040^{NS}	-0.418**	+0.095^{NS}	(gi-gl) 0.076		
P3			+0.005^{NS}	+0.100^{NS}	sca (sij) 0.083	0.146	0.201
P4				+0.009^{NS}	(sij-skl) 0.152		

Crude fibre content

Parents	P1	P2	P3	P4	SE	CD	
						5%	1%
P1	+0.643**	+3.552**	+0.600^{NS}	-0.285^{NS}	gca (gi) 0.223	0.195	0.430
P2		-0.490*	+3.100**	+1.371**	(gi-gl) 0.364		
P3			0.066**	+0.212^{NS}	sca (sij) 0.399	0.393	0.585
P4				-0.219^{NS}	(sij-skl) 0.728		

* Significance at 5 per cent level ** Significance at 1 per cent level
NS Non significance

TABLE -25 RANK CORRELATION COEFFICIENT r(s) BETWEEN *gca* EFFECT AND ARRAY MEAN AND BETWEEN *gca* EFFECTS AND PARENTAL *per se* PERFORMANCE

Character	r(s)	
	gca vs array mean	gca vs parental per se performance
Plant height at first flower bud appearance	+ 1. 000**	+0. 821*
Number of fruits/plant	+0. 964**	+0. 964**
Fruit weight	+0. 660NS	+0. 964**
Fruit length	+1. 000**	+0. 857*
Fruit girth	+0. 643NS	+0. 696NS
Plant height at final harvest	+1. 000**	+0.500NS
Number of branches /plant	+1. 000**	+0. 889**
Yield /plant	+0. 964**	+0. 750NS
Phenol content	+0. 978**	+0. 969**
Carbohydrate content	+0. 660**	+0. 669NS
Protein content	+1. 000**	+0. 525NS
Crude fibre content	+1. 000**	+0. 964**

* Significant at 5 per cent level
** Significant at 1 per cent level
NS Non significant

TABLE - 26 RANK CORRELATION COEFFICIENT r(s) BETWEEN *per se* PERFORMANCE OF THE HYBRIDS AND *sca* EFFECTS

Character	Rank correlation coefficient r(s)
Plant height at first flower bud appearance	+0. 498*
Number of fruits/plant	+0. 863**
Fruit weight	+0. 549**
Fruit length	+0. 492**
Fruit girth	+0. 398NS
Plant height at final harvest	+0. 168NS
Number of branches /plant	+0. 638**
Yield /plant	+0. 643**
Phenol content	+0. 498*
Carbohydrate content	+0. 293NS
Protein content	+0. 302NS
Crude fibre content	+0. 494*

* Significant at 5 per cent level
** Significant at 1 per cent level
NS Non significant

The *sca* among the hybrids ranged from -0.285 in P_1 x P_3 to +3.552 in P_1 x P_2. The hybrids P_1 x P_3, P_1 x P_4 and P_3 x P_4 showed non-significant *sca*. The hybrids P_1 x P_2, P_2 x P_3 and P_2 x P_4 showed significant *sca*.

Rank correlation (Table 25) between parental array means and *gca* effects parental *per se* and *gca* effects and *per se* performance of the hybrids and their corresponding *sca* effects were all positive and significant (Table 26).

4.7. t^2 TEST HYPOTHESIS

To test the validity of the assumption the t^2 test was carried out (Table 27). Among the characters studied, for three traits viz., height of plant at first flowering, fruit girth and yield per plant showed significance indicating the failure of the hypothesis for these characters. The other characters showed non-significant t^2 values indicating the validity of the assumptions for them.

4.8. GRAPHIC ANALYSIS

Information was elicited on gene action for twelve characters from the VrWr graphs. Variances of the array. (Vr), covariances between the parents and their progenies in each array (Wr) were computed from the half diallel table (Table 28). The VrWr graphs were drawn where in (a) slope and position of regression line upon which the points representing the parental arrays fall and (b) the distribution of these points along the regression line (Table 29).

In order to test the validity of the assumptions, the significance of the deviation of the regression values from unity and from zero for VrWr regression tested.

TABLE - 27 ESTIMATES OF t^2, b, SEb, b-0 /SEb AND 1- b/SEb

Characters	t^2	b	SEb	b-0/SEb	1-b/SEb
Plant height at first flower bud appearance	14.533*	0.373	0.110	3.404**	5.711**
Number of fruits/plant	2.892	0.839	0.083	10.117**	1.939
Individual fruit weight	0.0001	0.444	0.641	0.693	0.868
Fruit length	0.222	0.205	0.495	0.414	1.604
Fruit girth	78.107**	-0.117	0.055	-2.104	20.136**
Plant height at final harvest	0.209	0.469	0.436	1.076	1.216
Number of branches /plant	0.011	0.796	0.379	2.098	0.534
Yield/plant	45.028**	0.004	0.074	0.049	13.519**
Phenol content	0.055	0.448	0.526	0.852	1.050
Carbohydrate content	0.245	0.916	0.129	7.127**	0.651
Protein content	1.782	0.447	0.252	1.771	2.194
Crude fibre content	-3.145	-0.403	1.984	-0.203	0.707

* Significant at 5 per cent level
** Significant at 1 per cent level

The tests of significance have revealed that the VrWr regression significantly deviated from zero for the three characters viz., plant height at first flowering, number of fruits per plant and carbohydrate content. The deviation from zero was not significant for the remaining nine characters.

The characters like plant height at first flowering, fruit girth, and yield per plant deviated significantly from unity for VrWr regression.

4.8.1. Plant height at first flowering

In the VrWr graph (Fig 1(the regression line intercept the Y axis below the point of origin. The slope of the regression line was less than unity ($b = 0.373 \pm 0.110$).

The array pionts P_1, P_2, P_3 and P_4 were distributed above the regression line. The array point P_3 was distributed below the origin. All the array points were below the unit slope. The array point P_1 was the farthest and P_3 was the nearest to the origin, while P_2 was scattered towards the centre.

4.8.2. Number of fruits per plant

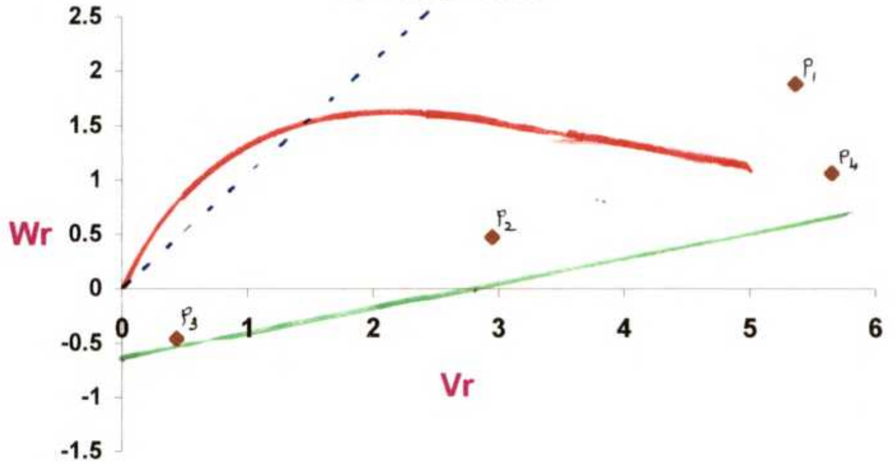
The regression line in the VrWr graph intercepted the y ordinate above the point of origin (Fig 2.). The slope of the regression was less than unity ($b = 0.839 \pm 0.083$).

The array points P_1, P_2, P_3 and P_4 were scattered above the regression line. All the array points were scattered above the unit slope. The array point P_3 was nearest to the origin, while P_1 was farthest to the origin.

VrWr GRAPH

FIG 1. PLANT HEIGHT AT FIRST FLOWER BUD APPEARANCE

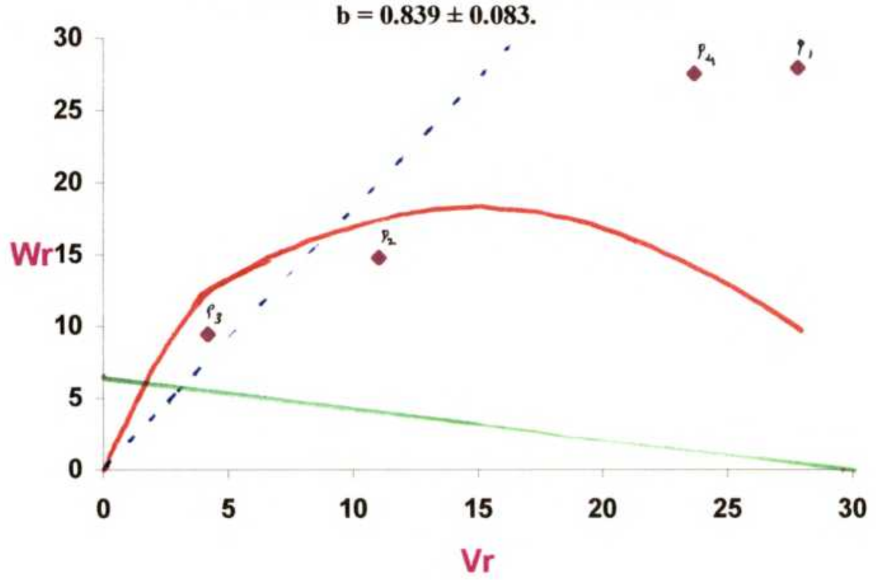
$b = 0.373 \pm 0.110$



VrWr GRAPH

FIG 2. NUMBER OF FRUITS / PLANT

$b = 0.839 \pm 0.083$.



4.8.3. Individual fruit weight

In the VrWr graph (Fig 3) the regression line intercepted the Y ordinate below the point of origin. The slope of the regression line was less than unity ($b = 0.444 \pm 0.641$).

The array point P_1 alone was above the origin, while the array points P_2, P_3 and P_4 were below the origin. The array points P_1, P_2, P_3 and P_4 were scattered away from the regression line. All the array points were above the unit slope. The regression line was almost parallel to the Y axis. The array point P_2 was nearer to the origin.

4.8.4. Fruit length

The regression line intercepted the Y axis below the origin. The slope of the regression line was less than unity ($b = 0.205 \pm 0.495$).

The array points P_1, P_2, P_3 and P_4 were scattered below the regression line. All array points were found below the unit slope. The point P_2 was nearer to the origin, while P_1, P_3 and P_4 were farthest from the origin P_1, P_2 and P_4 remained below the X axis. P_3 was towards the centre of the VrWr graph (Fig. 4).

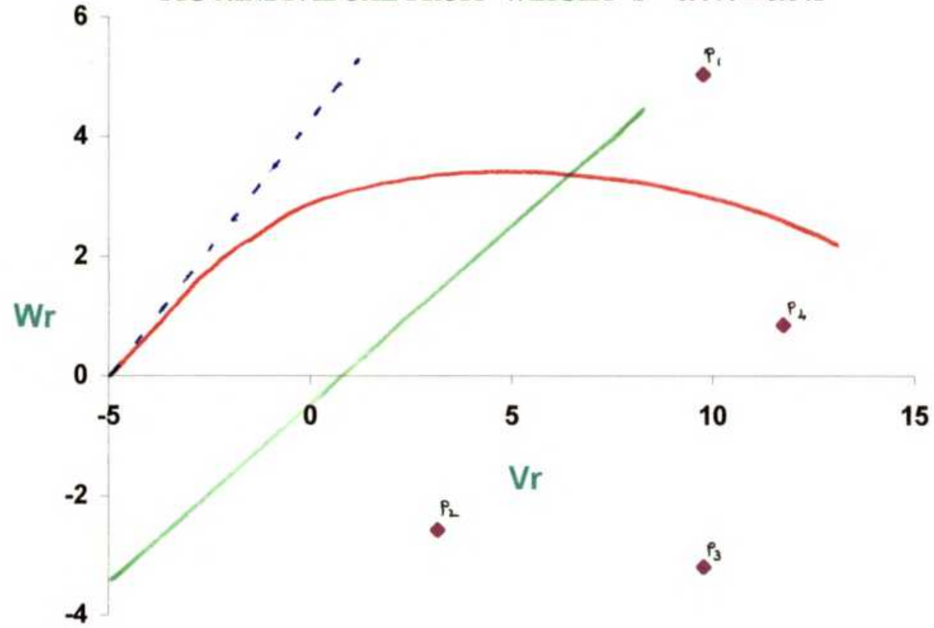
4.8.5. Fruit girth

The regression line intercepted the Y axis above the point of origin (Fig. 5.). The slope of regression line was less than unity and negative ($b = -0.117 \pm 0.055$).

The array points P_1, P_2, P_3 and P_4 were scattered above the regression line. But all the array points were found below the unit slope. P_1 was closer to the unit slope. The array points P_1 and P_3 were found closer to the point of origin while P_2 and P_4 were found far away from the point of origin below the X axis.

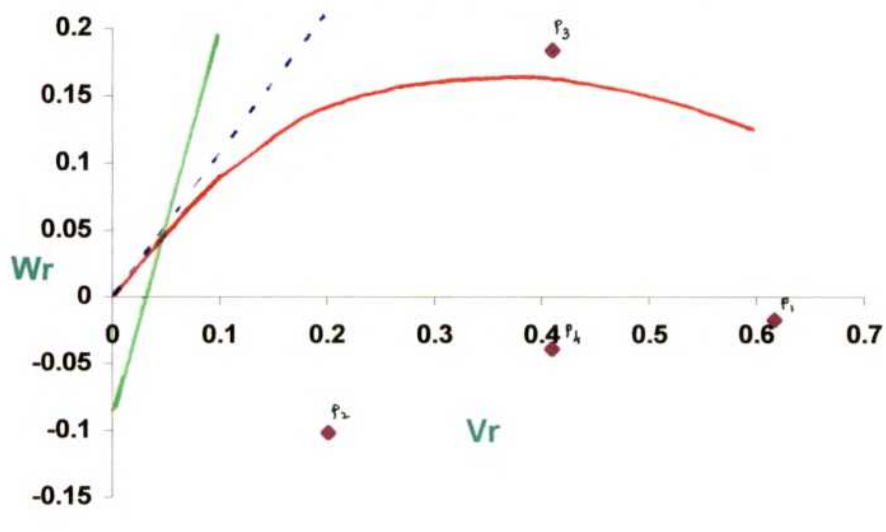
VrWr GRAPH

FIG 3.INDIVIDUAL FRUIT WEIGHT b = 0.444 ± 0.641



VrWr GRAPH

FIG 4.FRUIT LENGTH b = 0.205 ± 0.495



4.8.6. Plant height at final harvest

The regression line of VrWr graph intercepted the Y axis just below the origin (Fig. 6). The slope of the regression line was less than unity (b = 0.469 ± 0.436).

The array points P_1, P_2, P_3 and P_4 were found above the regression line. The array points P_1, P_2 and P_4 were scattered above the unit slope while the array point P_3 was found below the unit slope just below the X axis. The array point was found closer to the origin. While the array point P_2 and P_4 were found to be away from the point of origin.

4.8.7. Number of branches per plant

The regression the intercept the Y axis below the point of origin. The slope of the line was less than unity (b = 0.796 ± 0.379).

All the array points P_1, P_2, P_3 and P_4 were scattered below the regression line below the X axis. The unit slope was found above the array points. The array point P_2 was nearer to the origin while the array point P_3 was far away from the origin. The array point P_1 was closer to the regression line (Fig. 7).

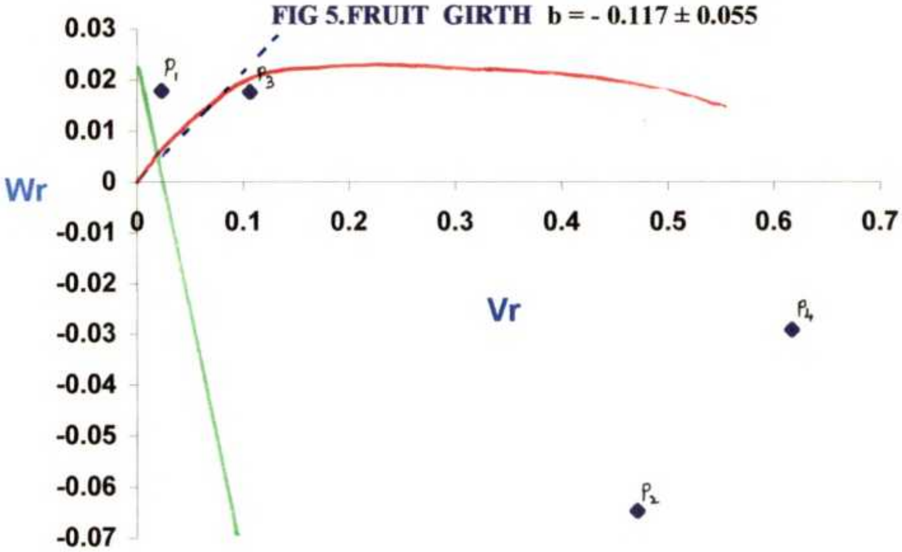
4.8.8. Yield of fruits per plant

The regression line intercepted the Y axis above the point of origin. The slope of the regression line was less than unity (b = 0.004 ± 0.074).

The array points P_1, P_2 and P_4 were above the regression line while the array point P_3 was below the regression line. The array point P_2 was above the unit slope. Where as the array points P_1, P_3 and P_4 were found below the unit slope. The point P_2 was nearer to the origin while the point P_4 was far away to the point of origin.

VrWr GRAPH

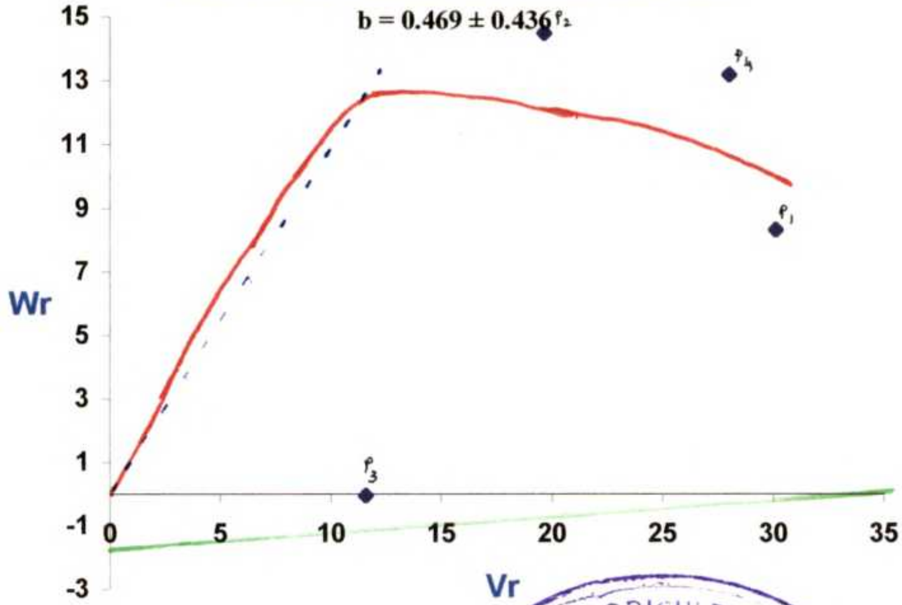
FIG 5.FRUIT GIRTH b = - 0.117 ± 0.055



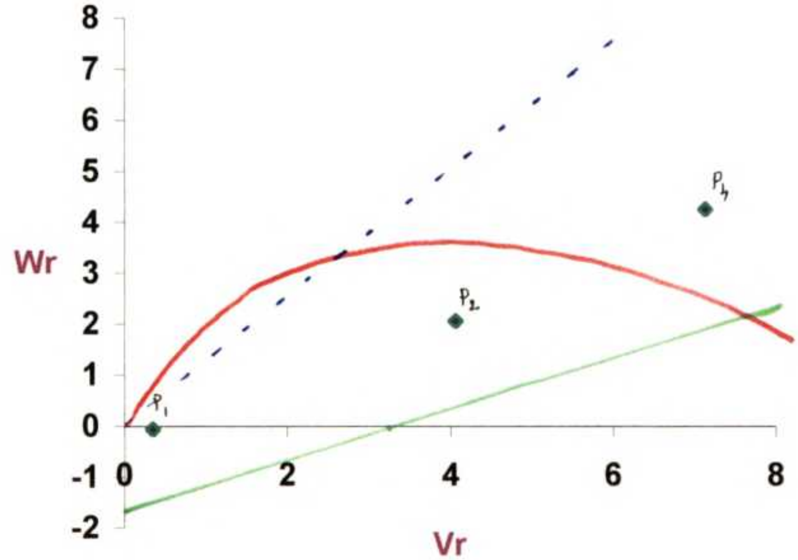
VrWr GRAPH

FIG.6 PLANT HEIGHT AT FINAL HARVEST

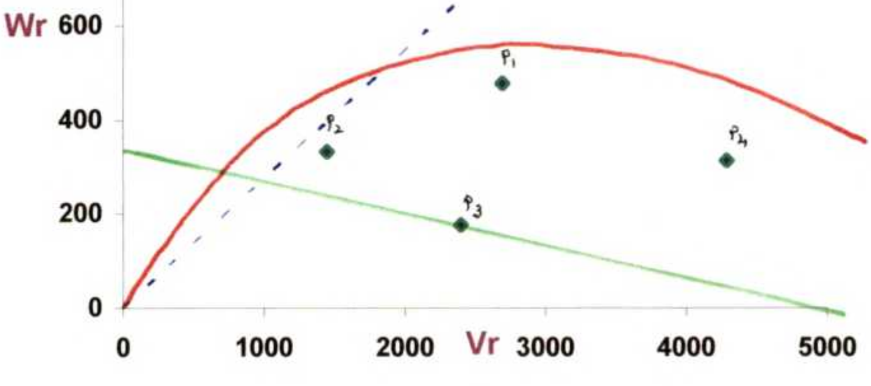
b = 0.469 ± 0.436



VrWr GRAPH
FIG 7. NUMBER OF BRANCHES PER PLANT
b = 0.796 ± 0.379



VrWr GRAPH
FIG 8. YIELD PER PLANT b = 0.004 ± 0.074



4.8.9. Phenol content in leaves

The regression line lies almost on the X axis."It is very much closer to the X axis. The slope of the regression line was less than unity (b = 0.448 ± 0.526) (Fig. 9).

All the array points P_1, P_2, P_3 and P_4 lies on the X axis. All the array points lies below the unit slope. All the array points are nearer to the origin. There is no much deviation from the point of origin.

4.8.10. Carbohydrate content in fruits

In the VrWr graph (Fig. 10). The regression line intercepted the Y axis just above the origin. The slope of the regression line was less than unity. (b = 0.916 ± 0.129).

The array points P_2, P_3 and P_4 scattered above the regression line while the array point P_1 lies below the regression line. The array points P_1 , P_2 and P_4 lies below the unit slope.

4.8.11. Protein content in fruits

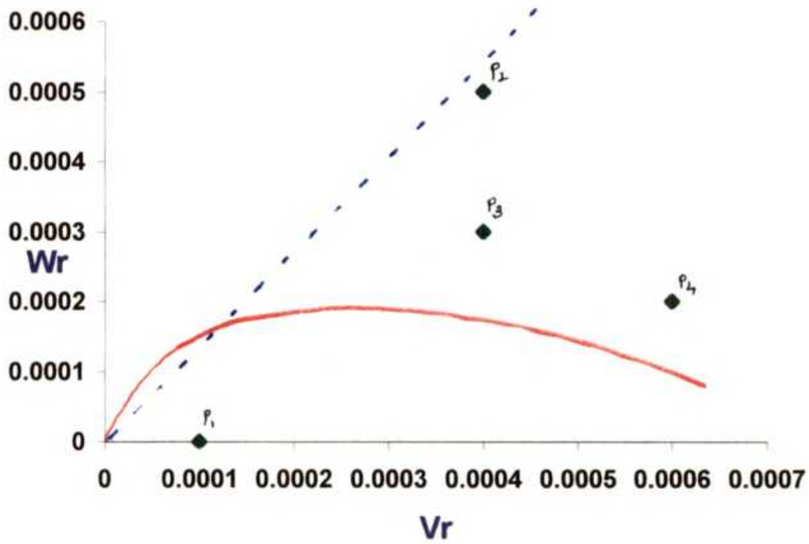
The regression line intercepted the Y axis just below the point of origin. (Fig. 11). The slope of the regression line was less than unity (b = 0.447 ± 0.252).

The array points P_2 was nearer to the origin. While the array point P_3 was far away from the point of origin. The array point P_4 was scattered towards the centre of the VrWr graph. All the array points are below the regression line. All the array points are also below the unit slope.

VrWr GRAPH

FIG 9. PHENOL CONTENT IN LEAVES

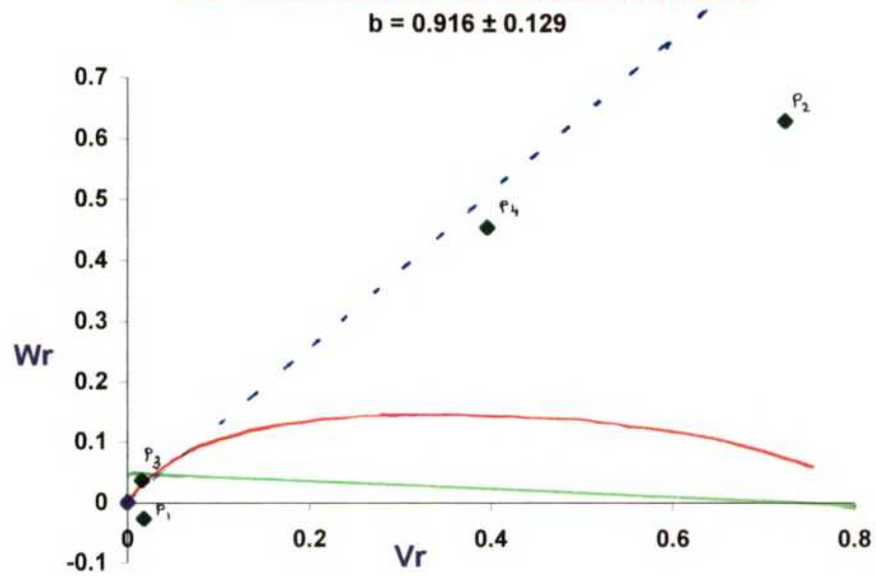
b = 0. 448 ± 0. 526



VrWr GRAPH

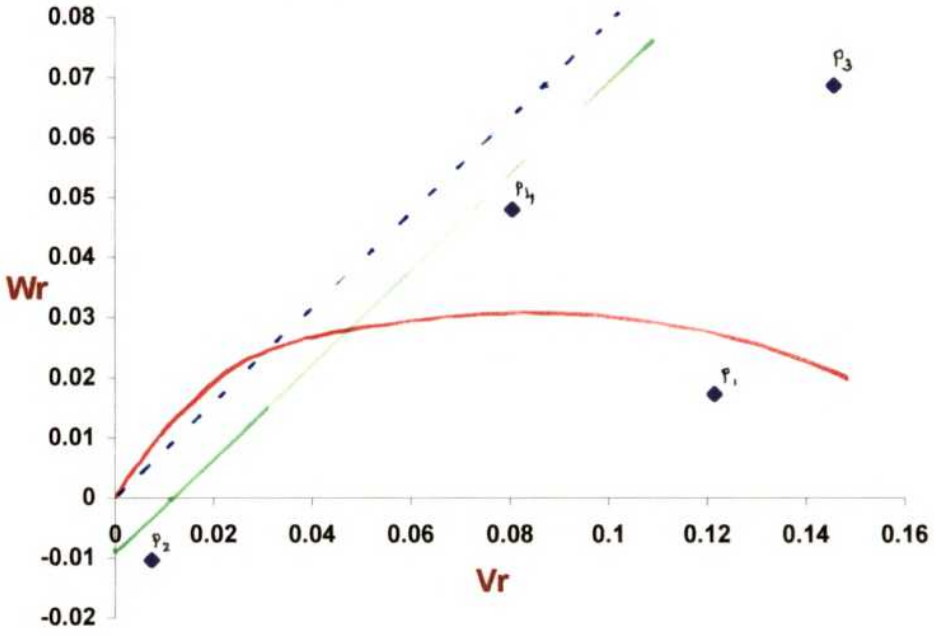
FIG 10.CARBOHYDRATE CONTENT IN FRUITS

b = 0.916 ± 0.129



VrWr GRAPH

FIG 11. PROTEIN CONTENT b = 0.447 ± 0.252



VrWr GRAPH

FIG 12.CRUDE FIBRE b = - 0.403 ± 1.984

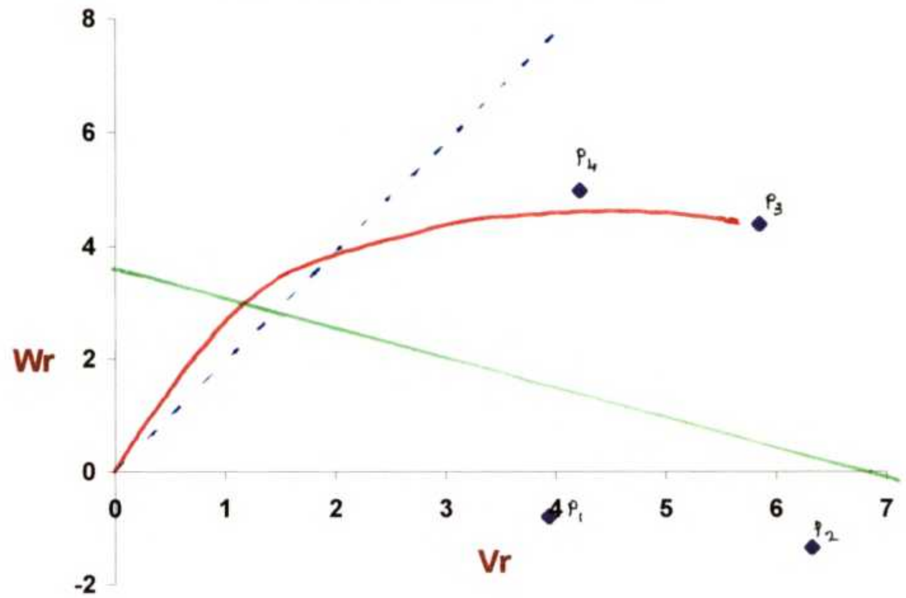


TABLE - 28 ESTIMATE OF VARIANCES (Vr) AND COVARIANCES (Wr) OF ARRAYS FOR F_1

Characters	P_1		P_2		P_3		P_4	
	Vr	Wr	Vr	Wr	Vr	Wr	Vr	Wr
Plant height at first flower bud appearance	5.370	1.876	2.955	0.469	0.437	-0.461	5.657	1.059
Number of fruits /plant	27.853	27.957	11.0.68	14.795	4.217	9.427	23.710	27.552
Individual fruit weight	9.771	5.033	3.186	-2.572	9.789	-3.194	11.766	0.846
Fruit length	0.617	-0.018	0.202	-0.102	0.411	0.184	0.409	-0.039
Fruit girth	0.024	0.018	0.472	-0.165	0.107	0.018	0.617	-0.029
Plant height at final harvest	30.153	8.346	28.063	13.179	11.596	-0.061	19.679	14.482
Yield/plant	2697.861	-476.20	1451.990	331.577	2400.086	176.074	4289.881	311.856
Phenol	0.0001	0.0000	0.0004	0.0005	0.0004	0.0003	0.0006	0.0002
Carbohydrate	0.018	-0.027	0.725	0.629	0.016	0.036	0.396	0.454
Protein	0.122	0.017	0.008	-0.010	0.146	0.069	0.081	0.048
Crude fibre	3.941	-0.807	6.323	-1.349	5.851	4.385	4.223	4.982

TABLE - 29 ESTIMATES OF Y INTERCEPT (a) AND SLOPE (b) OF FITTING REGRESSION LINE (wr = a + b vr) AND STANDARD ERROR OF b VALUES

Characters	VrWr a	VrWrb
Plant height at first flower bud appearance	-0.610	+0.373 ± 0.110
Number of fruits/plant	+5.909	+0.839 ±0.083
Fruit weight	-3.802	+0.444 ± 0.641
Fruit length	-0.078	+0.205 ± 0.495
Fruit girth	+0.021	-0.117 ± 0.055
Plant height at final harvest	-1.519	+0.469 ± 0.436
Number of branches /plant	-1.728	+0.796 ± 0.379
Yield /plant	+314.143	+0.004 ± 0.074
Phenol content	+0.0001	+0.448 ± 0.526
Carbohydrate content	+0.008	+0.916 ± 0.129
Protein content	-0.009	+0.447 ± 0.2522
Crude fibre content	+3.851	-0.403 ± 1.984

TABLE - 30 ESTIMATES OF VARIANCES AND COVARIANCES FOR F_1

Characters	$V_0 L_0$	$W_0 L_{01}$	$V_1 L_1$	$V_0 L_1$	$(ML_1-ML_0)^2$
Plant height at first flower bud appearance	1.504	0.736	3.605	0.549	1.666
Number of branches	40.402	19.933	16.712	10.021	7.304
Individual fruit weight	3.398	0.028	8.628	1.895	0.679
Fruit length	0.116	0.006	0.409	0.112	0.018
Fruit girth	0.177	-0.015	0.305	0.014	0.098
Plant height at final harvest	13.822	8.987	22.373	6.273	21.352
Number of branches/plant	3.144	0.998	3.427	0.691	1.899
Yield/plant	223.507	324.057	2709.955	899.112	561.550
Phenol	0.001	0.0003	0.0004	0.0002	0.0004
Carbohydrate	0.582	0.273	0.289	0.133	0.178
Protein	0.037	0.031	0.089	0.028	0.0003
Crude fibre	6.465	1.803	5.084	1.803	0.795

4.8.12. Crude fibre content in fruits

The regression line intercepted the Y axis far away from the origin (Fig. 12). The slope of the regression line was less than unity and negative. (b= -0.403 ± 1.984)

The array points P_1 and P_2 are below the regression line while the array points P_3 and P_4 are above the regression line. The array point P_1 was nearer to the point of origin where as the point P_3 was far away from the point of origin. The points P_3 and P_4 were scattered above the unit slope.

4.9. GENETIC ANALYSIS

The estimates of genetic parameters by splitting the components of variation is presented in table 31 and the ratios of genetic parameters in the table 32.

4.9.1. Plant height at first flowering

The components of variation due to dominance H_1 (12.569), proportion of dominance due to positive and negative genes H_2 (11.895) and net dominant effect h^2 (6.540) were found to be significant and positive, whereas the additive component D, dominance F and environmental component were non-significant.

Among the ratios of genetic parameters $(H_1/D)^{1/2}$ (3.063) was found to be more than one. $(H_2/4H_1)$ was (0.237) less than 0.25 indicating the unequal distribution of alleles. The proportion of dominant and recessive genes as indicated by the ratio

$$\frac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F}\left(\frac{KD}{KR}\right)$$

was less than one (0.976). The gene groups that controlled this was evidenced by the ratio h^2/H_2 was found to be 0.549. which is less than one. The narrow sense heritability was found to be low (25.21 per cent).

4.9.2. Number of fruits per plant

The additive component D, components of variation due to dominance H_1, H_2 and h^2 were positive and significant whereas the parameters environmental effect, dominance F registered non-significance.

The genetic parameters ratios revealed that the mean degree of dominance $(H_1/D)^{1/2}$ was found to be less than one, the groups of gene controlling this character h^2/H_2, and the KD/KR ratio was found to be more than one. The narrow sense heritability was high as 73.69 per cent.

4.9.3. Individual fruit weight

The component of variation H_1, and H_2 were significant. The other parameters like D, F, h^2 and E registered non-significance.

Among the genetic parameters $(H_1/D)^{1/2}$ and KD/KR was found to be more than one. $H_2/4H_1$ (0.178) was not equal to 0.250. h^2/H_2 was also less than one (0.098). The narrow sense heritability was 35.53 per cent.

4.9.4. Fruit length

The parameters H_1 and H_2 were significant while the other parameters registered non-significance. $(H_1/D)^{1/2}$ and KD/KR was found to be more than one $(H_1/D)^{1/2}$ was found to be more (6.619). The ratios h^2/H_2 and allelic distribution $H_2/4H_1$ registered less than one and 0.25 respectively. The narrow sense heritability per cent was 37.55.

4.9.5. Fruit girth

All the 6 genetic parameters registered non-significance for this character. The ratios of genetic parameters $(H_1/D)^{1/2}$ and KD/KR was found to be more than one.

$H_2/4H_1$ (0.200) was not equal to 0.250, and h^2/H_2 was not equal to one. The narrow sense heritability was as low as 8.25 per cent.

4.9.6. Plant height at final harvest

The genetic parameters H_1 and H_2, h^2 and E were significant for this character. D and F was found to be non-significant. The ratio $(H_1/D)^{1/2}$ and h^2/H_2 was found to be more than one. $H_2/4H_1$ (0.253) was found to be equal to 0.250 indicating the equal distribution or alleles for this character. KD/KR was less than one. The narrow sense heritability was high 35.46 per cent.

4.9.7. Number of branches per plant

The genetic parameters D, H_1, H_2 and h^2 was found to be positive and significant. The other parameters F, E was found to be non-significant. The ratios of genetic parameters $((H_1/D)^{1/2}$ and KD/KR was found to be more than one. $H_2/4H_1$ and h^2/H_2 was found to be less than 0.250 and one respectively. The narrow sense heritability was 30.83 per cent.

4.9.8. Yield of fruits per plant

Both D and F were not significant. But the components H_1 and H_2 were higher than D and significant.

The mean degree of dominance $(H_1/D)^{1/2}$ (8.307) was found to be more than one. $H_2/4H_1$ was not equal to 0.250. KD/KR and h^2/H_2 was less than one. The narrow sense heritability was found to be high (48.95 per cent).

4.9.9. Phenol content in leaves

The genetic parameters F, H_1 and H_2 was found to be significant and positive.

The ratios of genetic parameters $(H_1/D)^{1/2}$ and KD/KR was found to be more than one. h^2/H_2 was negative and not equal to one (-0.145). The narrow sense heritability was high (55.53 per cent).

4.9.10. Carbohydrate content in fruits

The components F, H_1, H_2 and h^2 was significant and positive. The other components D and F were non-significant.

The ratios $(H_1/D)^{1/2}$, KD/KR and h^2/H_2 was found to be more than one. But $H_2/4H_1$ was equal to 0.250. This character recorded more narrow sense heritability (60.35 per cent).

4.9.11. Protein content in fruits

H_1 and H_2 were positive and significant while the other components D, F, h^2, and E were non-significant. The ratio $(H_1/D)^{1/2}$ was found to be more than one. While KD/KR and h^2/H_2 were not equal to one. $H_2/4H_1$ (0.229) was not equal to 0.250. The narrow sense heritability was 45.45 per cent.

4.9.12. Crude fibre content in fruits

The genetic parameters D, H_1, and H_2 were found to be positive and significant. While the other parameters F, h^2 and E were found to be non-significant.

The ratio of genetic parameters $(H_1/D)^{1/2}$ and KD/KR was more than one. $H_2/4H_1$ and h^2/H_2 were not equal to 0.250 and one respectively. The narrow sense heritability was 20.43 per cent.

TABLE - 31 ESTIMATES OF GENETIC PARAMETERS FOR F_1

Characters	D ± SE(D)	F ± SE(F)	H_1 ± SE(H_1)
Plant height at first flower bud appearance	1.339 ± 1.243	-0.101 ± 3.192	12.569 ± 3.612
Number of branches	39.612** ± 1.727	0.284 ± 4.436	25.545** ± 5.020
Individual fruit weight	3.249 ± 3.149	6.534 ± 8.089	37.424** ± 9.153
Fruit length	0.035 ± 0.142	0.127 ± 0.364	1.528** ± 0.412
Fruit girth	0.077 ± 0.252	0.313 ± 0.648	1.206 ± 0.733
Plant height at final harvest	6.768 ± 5.462	-15.357 ± 14.033	49.731** ± 15.878
Number of branches/plant	2.799* ± 1.315	1.951 ± 3.379	11.997** ± 3.823
Yield/plant	138.442 ± 934.263	-934.277 ± 2400.166	9554** ± 2715.800
Phenol content	0.0005** ± 0.0001	0.0001 ± 0.0001	0.0007** ± 0.0001
Carbohydrate content	0.552** ± 0.054	0.041 ± 0.139	0.569** ± 0.157
Protein content	0.031 ± 0.031	-0.055 ± 0.081	0.255* ± 0.092
Crude fibre content	6.413**± 2.924	5.666 ± 7.513	19.460** ± 8.501

(contd...)

TABLE - 31 (contd...)

Characters	$H_2 \pm SE(H_2)$	$h^2 \pm SE(h^2)$	$E \pm SE(E)$
Plant height at first flower bud appearance	11.895**± 3.334	6.540** ± 2.253	0.163 ± 0.556
Number of branches	25.186** ± 4.634	28.621** ± 3.131	0.790 ± 0.772
Individual fruit weight	26.634** ± 8.449	2.606 ± 5.709	0.149 ± 1.408
Fruit length	1.029* ± 0.381	0.013 ± 0.257	0.081 ± 0.063
Fruit girth	0.964 ± 0.677	0.319 ± 0.457	0.100 ± 0.113
Plant height at final harvest	50.289** ± 14.657	80.118** ± 9.904	7.054** ± 2.443
Number of branches/plant	10.252** ± 3.529	7.341** ± 2.385	0.345 ± 0.588
Yield/plant	7073.241** ± 2506.892	2182.402 ± 1693.957	85.065 ± 417.815
Phenol content	0.0005** ± 0.0001	-0.0001 ± 0.0001	0.0001± 0.0001
Carbohydrate content	0.562** ± 0.145	0.687** ± 0.098	0.029 ± 0.024
Protein content	0.233** ± 0.085	-0.003 ± 0.057	0.006 ± 0.014
Crude fibre content	17.884** ± 7.847	3.141 ± 5.303	0.052 ± 1.308

* Significance at 5 per cent level ** Significant at 1 per cent level

TABLE - 32 RATIOS OF GENETIC PARAMETERS FOR F_1

Characters	$(H_1/D)^{1/2}$	$H_1/4H_1$	KD/KR	h^2/H_2	Heritability (NS) per cent
Plant height at first flower bud appearance	3.063	0.237	0.976	0.549	25.21
Number of branches	0.803	0.245	1.009	1.136	73.69
Individual fruit weight	3.395	0.178	1.843	0.098	35.53
Fruit length	6.619	0.168	1.757	0.012	37.55
Fruit girth	3.947	0.200	3.106	0.331	8.250
Plant height at final harvest	2.711	0.253	0.409	1.593	35.46
Number of branches/plant	2.070	0.214	1.405	0.716	30.83
Yield/plant	8.307	0.185	0.422	0.309	48.95
Phenol content	1.190	0.179	1.141	-0.145	55.53
Carbohydrate content	1.016	0.247	1.076	1.223	60.35
Protein content	2.866	0.229	0.526	-0.014	45.45
Crude fibre content	1.742	0.230	1.694	0.176	20.43

4.10. ASSOCIATION ANALYSIS (Table 33)

Genotypic correlations were computed to find out the degree of direction of association between yield and characters viz., plant height at first flowering, fruit length, fruit girth, fruit weight, number of fruits per plant, number of branches and plant height at final harvest. The inter relation among the component characters was also estimated.

The characters plant height at first flowering, fruit length, fruit girth, fruit weight, number of fruits per plant, number of branches and plant height showed positive and significant association with yield (Table 33). The correlation coefficient between fruit girth and plant height was the highest (0.973),number of fruits per plant and plant height showed the next highest correlation coefficient (0.813).

The intercorrelation among the characters revealed that the genotypic correlation for fruit weight and number of branches was positive and significant (0.684). Number of fruits per plant and yield was positive and significant (0.630). The intercorrelation among the characters fruit girth and plant height was strong (0.973).

TABLE - 33 GENOTYPIC CORRELATION MATRIX

Characters	Plant height at first flower bud appearance	Number of fruits/ Plant	Individual fruit weight	Fruit length	Fruit girth	Plant height at final harvest	Number of branches/ plant	Yield/plant
Plant height at first flower bud appearance	_	-0.318	+0.564	-0.169	+0.428	-0.111	-1.071	+0.087
Number of fruits/plant		_	-0.566	+0.421	+0.046	+0.095	+0.343*	+0.408*
Individual fruit weight			_	+0.088	-0.638*	+0.276	+0.973**	-0.121
Fruit length				_	-0.714*	+0.684*	+0.007	-0.118
Fruit girth					_	-0.183	+0.813**	+0.630*
Plant height at final harvest						_	+0.036	+0.536
Number of branches/ plant							_	+0.143
Yield/plant								_

* Significant at 5 per cent level ** Significant at 1 per cent level

Discussion

5. DISCUSSION

Okra (*Abelmoschus esculentus* (L.) Moench). is classified as often cross pollinated crop. However repeated selfing could succeed in maintenance of homozygosity of the genotypes for most of the traits. Such an attempt would help to develop inbreds which can be used in hybridization programme for development of heterotic hybrids.

In the present investigation,seven parental genotypes maintained at Department of Olericulture, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore were crossed in all possible combinations. Three mosaic free mutants viz., MF-1 (P_1), MF-2(P_2) and MF-3 (P_3) derived from induced mutagenesis of Parbhani Kranti, identified at Department of Olericulture, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. OHD-1 (P_4) and OHD-2 (P_5) which are the double cross hybrid derivatives evolved at Department of Olericulture, Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore. These two showed low magnitude of yellow vein mosaic virus incidence. Arka Anamika, released from the Indian Institute of Horticultural research, Bangalore, resistant to yellow vein mosaic virus and high yielding was used as P_6. Varsha Uphar, evolved at Haryana Agricultural University, Hisar which is found to be resistant to yellow vein mosaic virus disease and high yielding was used as P_7.

A total of 33 hybrids were successfully evolved after meeting with failure of seed setting in a few combinations. These 33 hybrids were studied in the first season (Feb-May) for yield and incidence of yellow vein mosaic virus disease.

5.1. PERFORMANCE OF PARENTS AND HYBRIDS

Flowering at a shorter height is an indication of earliness which is a desirable character in Okra for getting early and consequently high yields. The hybrid P_3 x P_6 has recorded lower plant height. The hybrid P_3 x P_7 exhibited the highest plant height at flowering. The overall mean of the hybrids was lower than that of the parents, there by indicating the tendency of `earliness' which is a desirable trait in the hybrids. Elangovan (1979) has reported earliness in hybrids, upholding the present results. Sivagama Sundari (1991) has also reported earliness in hybrids in bhendi.

Yellow vein mosaic incidence was more in the parent P_5 while it was lowest in the parent P_1. The yellow vein mosaic incidence was nil in the parents P_3, P_4, P_6 and P_7 and the hybrids involving these parents viz P_3 x P_4, P_3 x P_6, P_3 x P_7, P_4 x P_6, P_4 x P_7, P_7 x P_6. Sharma and Dhillon (1983) studied the genetics of resistance to yellow vein mosaic and found that the resistance was controlled by two complementary dominant genes with additive effect. Resistance in Arka Anamika was supported by Sally K. Mathew ***et al.*** (1993), Rajmony ***et al.*** (1995) and Sangar (1997). Observation on the node at which yellow vein mosaic symptom appeared revealed that among the two parents P_5 and P_2, the parent P_5 exhibited the symptom at maximum node number (6.7). The minimum node number was recorded in the parent P_2 (4.5). A higher node number indicates later infection and less effect on yield. This results coincides with the results of Sharma and Dhillon (1983) and Veeraragavathatham (1989). It was interesting to note that the hybrids involving the parents P_3, P_4, P_6 and P_7 did not show any symptom of yellow vein mosaic incidence. The resistance of the parents MF-3, OHD-1, Varsha Uphar and Arka Anamika was confirmed by graft inoculation from the susceptible scion of Pusa Sawani and also by the artificial inoculation with white flies for yellow vein mosaic incidence. Sannigrahi and Choudhury (1998) also reported that the hybrid produced by Arka Anamika did not show any symptom.

The parents as well as the hybrids exhibited wide variation for number of fruits per plant. Three hybrids P_2 x P_1, P_3 x P_2 and P_3 x P_4 exceeded the best parent significantly. These hybrids also showed high heterosis of +17.78 per cent, +21.59 per cent and +21.59 per cent respectively over the best parent. Such a high heterosis for this important yield contributing trait was reported in bhendi by Elangovan (1979), Thaker *et al.* (1982), Poshiya, Shukla (1986a), Veeraragavathatham (1989), Shukla and Gautam (1990), Sivagama Sundari (1991) and More *et al.* (1997). This may be due to the multiplicative interaction of the parents (Elangovan, 1979). Further the parents were from diverse origin leading to the high heterozygosity in the hybrids. As yield is a complex trait and the ultimate objective of any breeding program is increase in the heterosis of such identifiable contributing trait can strengthen the exploitation of hybrid vigour in this crop. Such a view is also shared by Elangovan (1979), Singh and Singh (1979), Veeraragavthatham (1989), Sivagama Sundari (1991) and Chavadhal *et al.* (1994). Further, the overall performance of hybrids is significantly greater than the parents for this trait, thus strengthening the possibilities of exploiting hybrid vigour.

Individual fruit weight is yet another character contributing directly to the yield. Both the parents and hybrids exhibited wider variation for this trait in the present study. The hybrid P_7 x P_6 recorded significantly higher fruit weight than the best parent and in this cross, both the parents were the highest for this trait. This is further exemplified that cross registered significant positive diii value (Sivagama Sundari, 1991). Such an increase in fruit weight can be attributed to the conglomeration of favourable genes in the hybrids.

There was not much variation between the parents and hybrids for fruit length and fruit girth, although two hybrids exceeded the best parent for fruit length. The general reduction in fruit length can be associated with the increase in number of fruits per plant, as they are negatively linked characters (Elangovan, 1979 and Sivagama Sundari, 1991). While, most of the hybrids exhibited negative heterosis for fruit length and fruit girth, P_7 x P_6 recorded positive and significant values for both length and girth which further exemplifies the potentiality of hybrid vigour for these characters in Okra (Thaker *et al.*, 1982 Sivagama Sundari, 1991 and More and Patil, 1997) Veeraragavathatham (1989) observed negative diii estimates for both fruit length and fruit girth, while Shukla and Gautam (1990) observed both negative and positive diii estimates for fruit length and high positive estimates for fruit girth.

The plant height at final harvest showed wide differences both in parents and hybrids. Some hybrids were taller than the tallest parent P_7. Further most of the hybrids showed negative diii estimates. The mean expression for this trait was the highest in P_7 while it was the lowest in P_1. The higher heterosis for this character indicated the presence of non-additive gene action. Veeraragavathatham (1989) has reported highest plant height in three hybrids. Chavadhal and Malkhandale (1994) reported the same results.

Number of branches per plant was of diverse nature in both the parents as well as in the hybrids. Except the hybrids P_7 x P_6 and P_3 x P_7, all the hybrids showed negative and significant heterosis.

Phenol content in the leaves indicates the degree of resistance to yellow vein mosaic virus. The phenol content was more in the parent P_7. The hybrid mean was higher than the parental mean implying more degree of resistance in the hybrids than the parents. The hybrid P_7 x P_6 exhibited positive and significant negative heterosis. While almost all the hybrids exhibited significant negative heterosis. The same was reported by Sarma ***et al.*** (1995).

Carbohydrate content in the fruits showed negative and non-significant diii estimate. Only 2 hybrids P_1 x P_3 and P_1 x P_4 showed positive heterosis for this character, but again they are non-significant.

There was not much variation seen among the parents and hybrids for protein content in the fruits. P_7 x P_6 was the only hybrid showed positive and significant heterosis. While all the other hybrids recorded significant heterosis in the negative direction.

The crude fibre content was found to vary much in both the parents and hybrids. All the hybrids exhibited negative and significant negative heterosis which is a desirable attribute for this character, as it is responsible for fruit quality. Elangovan (1979), Sheela *et al.* (1988) and Sivagama Sundari (1991) are also of the opinion that negative heterosis for crude fibre content is a desirable quality improving factor in this crop.

P_7 was the best parent yielded 462.40 g/plant, followed by P_4 (408.40 g/plant) and P_6 (397.60 g/plant). The nine hybrids, P_7 x P_6 (522.90 g/plant) P_4 x P_7 (511.80 g/plant), P_7 x P_5 (499.80 g/plant), P_3 x P_4 (492.40 g/plant), P_3 x P_7 (491.84 g/plant), P_6 x P_7 (491.20 g/plant) P_3 x P_6 (490.13 g/plant), P_4 x P_6 (490.10 g/plant) and P_7 x P_1 (479.10 g/plant) recorded higher yields than the best parent. It can be seen that in all the above hybrids one or both of the parents were high yielders. Even among these hybrids the high x high parental combination of P_7 x P_6 and P_4 x P_7 topped the others. This is in line with the findings of Elangovan *et al.* (1981), Vijay and Manohar (1986) and Sivagama Sundari (1991) in bhendi.

On the other hand, P_7 which ranked first among the parents, P_4 and P_6 which ranked second and third among the parents is involved as one of the parents in three heterotic hybrids. This may be due to epistatic gene action as reported by Swamy Rao (1977). The parent P_7, P_4 and P_6 involved in the top hybrids indicating their potentiality as good general combiners. The parents P_3 is involved in three high yielding hybrids. All these parents P_7, P_6 and P_4 are involved either as male or female parents in the above hybrids thus suggesting their versatile nature in the production of F_1 hybrids. The present results coincided with the results of Sivagama Sundari (1991) and Singh *et al.* (1996).

The general mean performance of the hybrids (398.79 g) was greater than that of the parents (362.66 g/plant) indicating the possibility of exploiting hybrid vigour in this crop. Singh and Singh (1979), Vijay and Manohar (1986), Veeraragavathatham (1989), Sivagama Sundari (1991) observed similar results lending support to the present findings. When the hybrids were analysed interms of heterosis,only the above 6 hybrids expressed positive diii values. Elangovan (1979), Veeraragavathatham (1989), Sivagama Sundari (1991) have also reported high standard heterosis in okra. Wankhade *et al.* (1997) has also reported significant heterosis over standard variety for yield upholding the present results.

From the results of the first season trial, the genotypes MF-3, OHD-1, Varsha Uphar and Arka Anamika have been selected as parents suitable for developing F_1 hybrids with better yield and high level of resistance to yellow vein mosaic virus.

To study the combining ability and gene action,these genotypes were crossed in a half diallel fashion, with following redesignated parent number.

MF-3	- P_1
OHD-1	- P_2
Varsha Uphar	- P_3
Arka Anamika	- P_4

From the results it was evident that the above parents recorded good mean performance for yield and other yield contributing traits in season II. All the hybrids raised in season II showed positive and significant heterosis value for yield.

5.2. Validity of assumptions

The assumption in a diallel was developed by Hayman (1954 b) are

i) diploid segregation

ii) homozygous parents

iii) no multiple allelism

iv) no linkage and

v) no epistasis

The validity of these assumptions were examined as follows.

The cultivars of okra have two genomes, one comprising of 29 chromosomes, referred as `T genome' as they are homologous with ***Abelmoscnus tuberculatus*** and another with 36 chromosomes, called `Y' genome, inherited from the primitive ***Abelmoscnus esculentus***. Due to the amphidiploidy nature arising out in such a combination, the crop behaves like a true diploid forming a complete set of bivalents without any abnormality in meiosis. Further, intervarietal crosses never posed any problem, thus upholding the assumption of diploid segregation.

In the analysis of array variances, covariances and genetic analysis the means of the direct crosses were used as suggested by Hayman (1954 a). Care was taken to achieve homozygosity in the parents by selfing over 6 successive generations, the assumptions of no epistasis, no multiple allelism and uncorrelated gene distribution could not be clearly assessed in the present study as it was difficult to evaluate these independently. Kempthorne (1956) considered the assumptions of absence of multiple allelism to be of little consequence and also that of independent gene distribution on estimates of gene frequency. Crumpacker and Allard (1962) opined that the effects on partial failure of certain of these assumptions seemed unlikely to be large enough to disturb the genetic analysis of the data.

A perusal of analysis of variance for combining ability showed that the variance associated with general combining ability was significant for yield of fruits per plant. The variance due to ***SCA*** was significant for the 7 characters like plant height at first flowering, number of fruits per plant individual fruit weight, number of branches per plant, plant height at final harvest, yield per plant and crude fibre content. However the mean squares for ***SCA*** was larger than those for ***GCA***. Similarly the estimated component of variance of ***SCA*** was larger than that of ***GCA*** for every character. Further the ratio of ***GCA/SCA*** revealed the preponderance of non-additive gene action for inheritance of all the characters. A similar view in okra was shared by Sharma and Mahajan (1978), Elangovan (1979), Singh and Singh (1979), Vijay and Manohar (1986), Sivagama Sundari (1991), Nirmal Singh ***et al.*** (1995) and More and Patil (1997).

The parent P_4 showed high negative ***gca*** for plant height at first flower bud appearance, but its mean performance indicated a greater height. On the other hand P_2 flowered at a taller height however its ***gca*** was the highest. Such evidences reflect that ***per se*** performance did not relate to the ***gca*** for this character.

The high negative ***gca*** of the parent P_4 is expressed in the positive ***sca*** in the hybrid $P_2 \times P_4$ and $P_3 \times P_4$ and negative ***sca*** in the hybrid $P_1 \times P_4$. Among the hybrids of P_4, the ***sca*** was positive in 2 hybrids and but as negative in the hybrid $P_1 \times P_4$. Similarly the parent P_1 showed positive ***gca*** effect while its hybrids showed high negative and significant ***sca*** indicating the role of both dominant and additive genes controlling this trait. One of the parents expressed negative and significant ***gca*** while the hybrids exhibited positive and significant ***sca*** indicating the possible role of cytoplasmic genes in this character.

The parental performance and ***gca*** were in agreement for number of fruits per plant with P_1 and P_3 with more fruits and having higher ***gca***. Swamy Rao (1977), Elangovan (1979), Veeraragavathatham (1989) and Sivagama Sundari (1991) also observed a similar trend for this trait. On the other hand the ***per se*** performance of the hybrids are not reflecting their ***sca***. This is exemplified that P_1 x P_2 and P_3 x P_4 which ranked fourth and third for this trait exhibited the lowest and non-significant ***sca*** of -4.215 and +0.150 respectively. The combination P_2 x P_4 recorded negative and significant ***sca*** recorded low number of fruits. The higher sca in a hybrid does not necessarily imply that the hybrid should perform well, as the ***sca*** represents deviation from the mean ***gca*** effects of its parents. Such instances have also been reported by Veeraragavathatham (1989) and Sivagama Sundari (1991) for fruit number. This clearly indicates that a conclusion cannot be arrived at by taking either ***per se*** performance or ***gca*** or ***sca*** in isolation for a successful heterosis breeding and this view is shared by Elangovan (1979) and Sivagama Sundari (1991).

Individual fruit weight is yet another important yield component in bhendi. In the present study the parents varied widely in fruit weight. The mean expression and combining ability of the parents coincided well indicating the predominant role of additive gene in the control of this character. Analysis of variance for combining ability indicated that non-additive gene action also plays a role as indicated by significant variance due to *SCA*. All the parents showed significant ***gca*** effect whereas the two hybrids involving P_4 (Arka Anamika) as male parent showed non-significant ***sca*** effect. The low x low general combiners resulted in a low ***sca*** hybrids revealed additive x additive genetic interaction (P_1 x P_4). The hybrids P_1 x P_2 and P_1 x P_3 a high x low combinations expressed excellent heterotic effects due to the dominance created through the better parent. Srivatsava *et al.* (1979) and Sivagama Sundari (1991) observed that the parents with such divergent mean performance always result in good hybrids, thus upholding the present result.

The variances due to *SCA* and *GCA* are non-significant for fruit length and fruit girth. The performance of the parents for fruit length and fruit girth were in total disagreement with their ***gca***. The hybrids P_1 x P_2 and P_1 x P_4 produced positive and significant ***sca*** although both the parents had negative ***gca*** for fruit length. Similarly for fruit girth the parents with positive ***gca*** resulted in hybrids with negative ***sca***. These indicated the role of non-additive gene action in fruit length and fruit girth. Elangovan (1979) observed that the ***per se*** performance and ***gca*** of the parents are correlated. Veeraragavathatham (1989) and Sivagama Sundari (1991) reported non-additive genes to control fruit length and fruit girth giving supporting evidence to the present investigation.

In the character plant height at final harvest, the performance of the hybrids was not in full agreement with their ***gca***. Parents with low and non-significant ***gca*** produced hybrids with high and significant ***sca***. Low x low combinations of P_1 and P_4, produced hybrids with high ***sca*** indicating inter allelic interaction of complementary nature for this character. When the ***per se*** performance and ***sca*** of the hybrids were analysed together it was interesting to note that the hybrids ranking high in mean performance like P_1 x P_3, P_2 x P_3 and P_1 x P_4 all exhibited significant and high ***sca*** indicating interaction of high order for this character, such results may also arise out of mutual cancellation of gene effects as opined by Swamy Rao (1977). Veeraragavathatham (1989) indicated the role of modifying factors from cytoplasm in controlling plant height, though it could not be confirmed in the present investigation as the mating was done only in partial diallel and reciprocal difference of a hybrid combination could not be assessed perfectly.

The mean performance and ***gca*** are in partial agreement for the character number of branches per plant. The ***SCA*** variance is significant indicating the action of additive and non-additive genetic interaction. A low x low combination hybrid P_3 x P_4 resulted in a high mean expression indicating an inter allelic interaction. The hybrids P_2 x P_3 and P_2 x P_4 representing high x low combinations expressed excellent heterotic effects due to the dominance created through the better parent. Srivatsava ***et al.*** (1979) observed that the parents with such divergent mean performance always result in good hybrids thus upholding the present result.

The ***GCA*** and ***SCA*** variances showed nonsignificant for phenol content. The ***per se*** of parents was not in full agreement with ***gca***. The hybrids P_2 x P_4, P_2 x P_3, P_1 x P_3 and P_1 x P_4 representing low x low combinations resulted in high ***sca*** hybrids suggesting the role of inter-allelic interaction.

The non-significant ***GCA*** and ***SCA*** variances showed the action of non-additive gene action in controlling the carbohydrate content. The parents P_1 and P_2 showed non-significant ***gca*** and ***sca*** of the hybrid P_1 x P_2 also was found to be non-significant parents. Parents with low ***gca*** resulted in hybrids with low ***sca*** indicating the role of additive genes for this character.

The ***per se*** performance of the parents was not in full agreement with ***gca*** in most cases for protein content but in contrast the performance of the hybrids was in agreement with their ***sca*** in most cases. All the parents showed non-significant ***gca*** for protein content. The hybrids P_2 x P_3, P_1 x P_4 and P_1 x P_3 produced negative and significant ***sca*** although the parents P_1, P_2, P_3 and P_4 had positive and non-significant ***gca*** thus indicating the role of dominance for this character.

The mean performance and ***gca*** of the parents for crude fibre content coincide. Similarly the performance of most the hybrids also reflect their sca. Further the behaviour of the hybrids was also predictable based on the ***gca*** of the parents thus indicating a strong additive gene action for crude fibre content. The present result corroborate with the results of Sivagama Sundari (1991).

The ***gca*** of the parents P_2, P_3 and P_4 were well correlated with *per se* performance. Swamy Rao (1977) was of the opinion that parental performance is a good indication of ***gca*** of the parents. But the parent which had higher parental means showed relatively low ***gca*** although positive and significant indicating that P_4 was relatively poor combiner.

The high ***gca*** of the parents P_2, P_3 and P_4 is also expressed in the high ***sca*** of the hybrids P_2 x P_3 and P_3 x P_4, thus emphasizing an additive x additive type of interaction. Swamy Rao and Ramu (1978), Elangovan (1979), Elangovan *et al.* (1981), Veeraragavathatham (1989) and Sivagama Sundari (1991) also found that the parents with high ***gca*** product hybrids with high ***sca*** which is in line with the present findings. The hybrids involving P_1 as female parent and P_3 as male parent expressed negative and significant ***sca*** for many characters, although both the parents had positive and significant ***gca***. This indicated the complimentary gene action which played a predominant role in controlling this character (Basak and Dana, 1971). On the contrary hybrids with P_3 as male parent exhibited positive and significant ***sca*** thus bringingout the dominant genes in the parent. The parent P_4 produced hybrids with positive significant ***sca*** although they had negative and non-significant ***gca*** for many characters like number of fruits per plant, fruit length, plant height at final harvest and number of branches per plant, thus bringing out. the complementation of favoruable genes. Veeraragavathatham (1989), Sivagama Sundari (1991). Mandal and Das (1992), Wankhade *et al.* (1994) and Lakshmi *et al.* (1995) also reported similar results.

In conclusion, based on heterosis and combining ability, it is possible to exploit the hybrid vigour through heterosis breeding considering the behaviour of traits like number of fruits per plant and individual fruit weight, the two most important yield contributing traits. The other characters directly linked with yield such as fruit length and fruit girth also suggest hybridity in this crop. However when yield per plant was considered, both dominant and additive x additive type of gene action were seen in considerable proportion, besides the other gene actions. Further the heterosis was appreciable in all the 6 hybrids, but it was more in the hybrids P_3 x P_4 (Varsha Uphar x Arka Anamika), P_2 x P_3 (OHD-1 x Varsha Uphar) and P_2 x P_4 (OHD-1 x Arka Anamika).

5.3. GRAPHIC ANALYSIS

The regression coefficient (b) was less than unity for all the characters, indicating the presence of epistasis. The `Y' intercept was positive for number of fruits per plant, fruit girth, yield per plant, carbohydrate and crude fibre content implying partial dominance. Graphical representation had confirmed this type of gene action.

Scattering of array points above the regression line and parabola differentiated the parent genetically.

The regression line indicated the over dominance suggesting the importance of non-additive factors for the character plant height at first flower bud appearance. The parent P_3 is more dominant occupying the position nearer to the origin. The parent P_2 is having equal frequency of dominant and recessive genes occupied the intermediate position.

The Y intercept is positive for number of fruits per plant cutting the Y axis above the origin implying the presence of partial dominance. The parents P_2 and P_3 are dominant for this character and the parents P_4 and P_1 are recessive as indicated by the array points.

For the character fruit weight the regression line indicating the presence of over dominance. The parents P_1, P_4 and P_3 are recessive and the parent P_2 is distributed with equal frequency for dominant and recessive genes which occupied the intermediate position.

The regression line for fruit length showed over dominance as the line cutting the Y intercept below the origin. The array points indicating that P_1, P_3 and P_4 are with recessive genes for this character and the parent P_2 is distributed with equal frequency for dominant and recessive genes for fruit length.

For the character fruit girth the regression line implies the presence of partial dominance as it touches the Y axis above the origin. The parents P_2 and P_4 are with recessive genes and the parents P_1 and P_3 are with dominant genes which are located near the origin.

Plant height graph indicated the presence of over dominance. The parents P_4, P_2 and P_1 are with recessive genes and the parent P_1 is with dominant genes for plant height.

For number of branches per plant the regression line indicating the presence of over dominance as it cuts Y axis below the origin. The parent P_3 is with recessive genes and the parents P_1, P_2 and P_4 are distributed with equal frequencies of dominant and recessive genes which occupied the intermediate position.

For the character phenol content in leaves the regression line passes through the point of origin implying the action of complete dominance. The regression line touches the X axis. All the array points of the parents P_1, P_2, P_3 and P_4 are with dominant genes.

The regression line cuts the Y axis above the point of origin indicated the action of partial dominance for carbohydrate content in fruits. The parents P_2 and P_4 are farthest from the origin indicating the parents are with recessive genes and the parents P_1 and P_3 are with dominant gene action.

The regression the cutting the Y axis below the origin shows the presence of over dominance for protein content in fruits. P_1, P_3 and P_4 are with recessive genes and P_2 is with dominant genes for this character.

VrWr graph for crude fibre content in fruits indicated the presence of partial dominance. The parents P_1, P_2, P_3 and P_4 are distributed in the middle area suggesting equal frequency of dominant and recessive genes.

The regression line for the important character yield per plant indicated the presence of partial dominance. P_2 and P_3 are with dominant genes and P_1 and P_4 are with equal frequencies of dominant and recessive genes for yield per plant.

These results were in concordance with the resluts of Veeraragavathatham (1989) and Sivagama Sundari (1991).

5.4. GENETIC ANALYSIS

The estimates of additive genetic variance was positive and significant for the characters like number of fruits per plant, number of branches per plant, phenol, carbohydrate and crude fibre content indicating high transmissibility in the progeny. Therefore direct selection will be of much use for such characters. (Srivatsava ***et al.***, 1979 and Sivagama Sundari, 1991). The F value is not significant for all the 12 characters implying less of dominant alleles in the parents. The estimates of H_1 (components of variation due to dominance) and H_2 (proportion of dominance due to positive and negative genes) showed the preponderance of non-additive gene action for all the characters except for fruit girth. The mean degree of dominance $(H_1/D)^{1/2}$ estimate was more than unity for all the characters except for number of fruits per plant and this may be due to over dominance or repulsive phase linkage bias (Srivatsava ***et al.***, 1979).

The ratio of total dominant to recessive alleles

$$\frac{(4DH_1)^{1/2} + F}{(4DH_1)^{1/2} - F} \quad \left[\frac{KD}{KR}\right]$$

pooled over all of the parents also indicated the prevalence of dominance over recessive for all the characters except for the characters like plant height at first flowering, plant height at final harvest, yield per plant and protein content which showed the KD/KR values less than one indicate the prevalence of recessive over dominant alleles, which is in agreement with the findings of Veeraragavathatham (1989) and Sivagama Sundari (1991). The distribution of positive and negative alleles were unequal for all the characters except for the characters like number of fruits per plant, plant height at final harvest and carbohydrate content as indicated by $H_2/4H_1$ which is less than 0.25 for these traits. This asymmetrical distribution of alleles would have been the result of constant selection for these characters.

The h^2/H_2 ratio indicated the preponderance of dominant alleles for number of fruits per plant, plant height at final harvest and carbohydrate content and recessive alleles for rest of the characters.

Heritability estimates in the narrow sense was moderate for plant height at first flowering, fruit weight, fruit length, plant height at final harvest, number of branches per plant and crude fibre content.

The low heritability estimates was shown by the character fruit girth. The rest of the characters viz., number of fruits per plant, yield per plant. phenol content in leaves carbohydrate and protein content in fruits had high heritability in the narrow sense where in pedigree selection will be possible (Srivatsava *et al.*, 1979 and Sivagama Sundari, 1991) from inter varietal hybrids in the later generation.

5.5. ASSOCIATION ANALYSIS

In any crop improvement programme, a knowledge on the association of characters is of significant importance since it contributes indirectly to the success of selection.

In the present investigation a strong positive association existed for yield with number of fruits per plant. Singh *et al.* (1974), Elangovan *et al.* (1981), Reddy *et al.* (1985), Veeraragavathatham (1989), Sivagama Sundari (1991), Patel *et al.* (1993), Gondane *et al.* (1995) and Lakshmi *et al.* (1996) also observed a strong linkage between yield and number of fruits per plant.

The other characters like fruit length, number of branches and plant height at first flowering were positive and non-significant with yield.

When the inter association of contributing characters were analysed, it was found that fruit girth is significantly associated with number of fruits per plant and plant height at final harvest similarly. The fruit weight is significantly associated with number of fruits per plant and number of branches per plant. Number of fruits per plant is positively and significantly associated with plant height at final harvest Reddy (1985), Veeraragavathatham (1989), Sivagama Sundari (1991), Fageria *et al.* (1992), Senthilkumar (1996) and Sathiyamurthy (1997) also observed such interrelationship lending support to the present findings.

Interestingly, high significant and positive correlation exists between the characters fruit girth and plant height at final harvest followed by the characters number of fruits per plant and plant height at final harvest and such relationships are rather unusual. To conclude, the present study suggests that number of fruits per plant, fruit weight, fruit girth, number of branches per plant and plant height at final harvest should be considered together as primary yield determining components in okra.

5.6. BREEDING VALUE OF PARENTS AND HYBRIDS

Identification of the superior inbreds and realization of higher productivity in the recombinants are considered the primary objective in any crop improvement programme. This objective could be realised by evaluation of the parents for their potentialities and combining ability for yield and various yield components. High variability with high mean is desirable because of the occurrence of greater frequency of desirable segregants which could be fixed. Improvement of quantitative and qualitative characters could be effective only when potential variability exist in the experimental population. The *GCA* variance was the maximum for yield per plant. The *SCA* variance was also the maximum for yield per plant. The parents P_3 and P_4 recorded high mean and high *gca* for yield per plant. The hybrids involving P_1, P_2, P_3 and P_4 expressed higher heterotic effects. Therefore the parents with high *gca* and high mean would serve as desirable parents in a crossing programme for recombination of favourable genes.

The result from the present investigation indicated that gene action was additive, dominance and epistatic of varying magnitude, the degree of dominance being more with most of the economic attributes. As such superior lines or transgressive segregants could be isolated form the F_2 population of the present study.

Though the heterotic expression is not very much pronounced the possibility of combining favourable alleles for traits like number of fruits there by yield along with resistance to yellow vein mosaic virus (Since the character is controlled by complementary genes with additive effect) is much more when we go in for development of F_1 hybrids. Both the parents should have resistance to YVMV so that the resistance can be maintained in the hybrid thus synthesised. The present attempt has resulted in the development of such hybrids like OHD-1 x Varsha Uphar and Varsha Uphar x Arka Anamika

Summary

6. SUMMARY

Investigations were carried out with seven genotypes of okra (***Abelmoschus esculentus*** (L.) Moench), namely MF-1, Mf-2, MF-3, OHD-1, OHD-2, Arka Anamika and Varsha Uphar. Four parents found to be resistant to yellow vein mosaic virus were selected. They were (MF-3, OHD-1 Varsha Uphar and Arka Anamika). Half diallel analysis was employed and 6 hybrids and their parents were evaluated. The heterosis, general combining ability of the parents, specific combining ability of the hybrids, genetic parameters and correlation coefficients were estimated for the traits such as plant height at first flower bud appearance, number of fruits per plant, individual fruit weight, fruit length, fruit girth, plant height at final harvest, number of branches per plant, yield per plant, phenol content in leaves, carbohydrate, protein and crude fibre content in fruits at vegetable maturity. The salient findings are summarised below.

1. The parents chosen were found to have high genetic variability in most of the traits.

2. The hybrids performed better than the parents in either of the desirable direction for all the characters except for number of branches and carbohydrate content in fruits, wherein the parents performed well.

3. The parents MF-3, OHD-1 and Arka Anamika performed well for fruit weight, fruit length, fruit girth, yield and phenol content in leaves.

4. The parent Varsha Uphar was adjudged as the best general combiner for the characters like fruit weight, yield per plant, high phenol content in leaves and low crude fibre content in fruits. The hybrids MF-3 x Varsha Uphar, MF-3 x Arka Anamika, OHD-1 x Varsha Uphar and Uphar x Arkra Anamika were adjudged as the best specific combiners for number of fruits per plant, individual fruit weight and yield per plant.

5. The hybrids namely MF-3 x OHD-1, MF-3 x Varsha Uphar and Varsha Uphar x Arka Anamika recorded positive diii estimate (heterosis over the best parent) of +21.59 per cent, + 3.09 per cent and + 0.42 per cent respectively for number of fruits per plant.

6. For individual fruit weight the heterosis over the best parent was positive in Varsha Uphar x Arka Anamika which recorded + 12.00 per cent.

7. The hybrids namely Varsha Uphar x Arka Anamika and OHD-2 x Varsha Uphar recorded positive diii estimate (heterosis over the best parent) for fruit length.

8. The hybrids MF-3 x OHD-1, MF-3 x Arka Anamika, MF-3 x Varsha Uphar, OHD-1 x Arka Anamika, OHD-1 x Varsha Uphar and Varsha Uphar x Arka Anamika expressed high mean performance and heterosis with high diii estimate for yield (+ 24.15 per cent, + 18.32 per cent, + 11.13 per cent, + 1.64 per cent, + 24.51 per cent and + 39.97 per cent respectively) druing the first season.

9. The parents MF-3, OHD-1, Varsha Uphar and Arka Anamika were found to be resistant to yellow vein mosaic even after artificial inoculation through white flies. The hybrids of these parents did not show any symptom even after artificial inoculation of virus by grafting method.

10. In the second season the highest mean performance was recorded by Varsha Uphar x Arka Anamika (549.90 g/plant) and OHD-1 x Varsha Uphar (531.80 g/Plant). They also exhibited highest heterosis over best parent (diii) for yield per plant viz., + 41.97 per cent and + 25.53 per cent respectively.

11. Combining ability analysis during second season revealed that the mean squares due to ***GCA*** to ***SCA*** of the crosses were significant for seven characters suggesting the importance of both additive and non-additive gene action.

12. The ratio of GCA to SCA was less than unity for all the characters suggesting the preponderance of non-additive gene action for inheritance of all the characters.

13. Significant SCA variances for the seven characters indicated that the character expression is influenced by non-additive gene action.

14. Significant ***SCA*** of the crosses were due to combinations of high x high, high x low or low x low ***gca*** parents for individual fruit weight, plant height at final harvest, number of branches per plant and yield per plant indicating additive x additive, additive x dominant and dominant x dominant types of interactions.

15. The ***per se*** performances of the parents donot truly reflect the ***gca*** for the characters like plant height at first flower bud appearance, fruit length, fruit girth, plant height at final harvest, phenol content in leaves, protein content in fruits, suggesting the involvement of some modifiers in the expression of these traits.

    The ***per se*** performance of the parents truly reflects the ***gca*** for number of fruits per plant. Individual fruit weight, crude fibre content and yield per plant.

16. From the t^2 hypothesis partial failure of the assumption was observed for the traits like plant height at first flowering, fruit girth and yield of fruits per plant.

17. From the graphic analysis over-dominance was suggested for plant height at first flower bud appearance, individual fruit weight, fruit length, plant height at final harvest, number of branches per plant and protein content in fruits. Complete

dominance was suggested for phenol content in leaves. Partial dominance was suggested for the characters like number of fruits per plant, fruit girth, yield per plant carbohydrate and crude fibre content in fruits.

18. Predominance of additive genes was evident for number of fruits per plant, number of branches per plant, phenol content in leaves carbohydrate and crude fibre content in fruits.

19. There was unequal distribution of positive and negative alleles for all the characters except for number of fruits per plant, plant height at final harvest and carbohydrate content in fruits. Prevalence of dominance to recessive alleles was observed for all the characters except for plant height at first flower bud appearance, plant height at final harvest, yield per plant and protein content in fruits.

20. There was positive and significant correlation for yield with number of fruits per plant. Inter correlations between fruit girth and number of fruits per plant, fruit weight and number of fruits per plant, fruit weight and number of branches per plant were significant. Number of fruits per plants is positive and significantly associated with plant height at final harvest.

21. The mechanism of resistance to yellow vein mosaic disease may be attributed to the high level of endogenous phenolics.

22. Due to the involvement of non-additive gene action for plant height at first flower bud appearance, individual fruit weight, fruit length, fruit girth, plant height at final harvest, yield per plant and protein content in fruits, heterosis breeding is suggested for the improvement of these characters.

23. Based on two season trial two hybrid combinations viz., Varsha Uphar x Arka Anamika and OHD-1 x Varsha Uphar have been adjudged as superior in respect of yield per plant and resistance to yellow vein mosaic disease. However, these two combinations have to be tried in larger area of land so as to assess their exact yield potential. They have to be subjected to high level of inoculum of yellow vein mosaic virus to confirm their resistance/tolerance by testing in hotspots of this particular viral disease.

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*** Originals not seen.**

Appendices

Appendix – I Source of germplasm

Genotype	Source
P_1 – MF-1	Mosaic free mutant derived from induced mutagenesis of Parbhani Kranti identified at HC & RI , TNAU Coimbatore
P_2 – MF-2	Mosaic free mutant derived from induced mutagenesis of Parbhani Kranti identified at HC & RI , TNAU Coimbatore
P_3 – MF-3	Mosaic free mutant derived from induced mutagenesis of Parbhani Kranti identified at HC & RI , TNAU Coimbatore
P_4 – OHD-1	Double cross hybrid derivatives evolved at HC & RI ,TNAU Coimbatore
P_5 – OHD-2	Double cross hybrid derivatives evolved at HC & RI ,TNAU Coimbatore
P_6 – ARKA ANAMIKA	Interspecific hybridisation using Abelmoschus manihot ssp.tetraphyllus var. tetraphyllus followed by backcross breeding evolved at IIHR - Bangalore
P_7 – VARSHA UPHAR	Evolved at Hariyana Agricultural University Hisar

APPENDIX 2. WEATHER DATA FOR THE CROPPING PERIODS

Month	Days	Standard week	Maximum temperature (°C)	Minimum temperature (°C)	RH (%) 07.22h	RH (%) 14.22h	Rainfall (mm)
Feb.98	5-11	6	31.2	22.0	84	48	-
	12-18	7	31.7	20.6	81.8	43.0	-
	19-25	8	34.3	20.8	83.0	40.0	-
	26-4	9	35.0	22.0	83.1	32.1	-
Mar.	5-11	10	35.0	21.1	84.1	36.1	-
	12-18	11	34.8	21.2	83.1	31.8	-
	19-25	12	36.4	21.4	80.1	27.3	-
	26-1	13	36.3	25.1	77.7	38.1	-
April	2-8	14	35.6	24.2	83.7	36.3	63.0
	9-15	15	36.4	24.9	78.8	39.0	-
	16-22	16	37.4	25.8	79.1	37.8	-
	23-29	17	36.8	24.2	80.1	42.3	33.0
May	30-6	18	36.3	24.8	80.1	39.0	2.0
July	16-22	29	32.2	23.0	84	56	2.5
	23-29	30	39.2	22.6	79	61	22.0
	30-5	31	39.6	23.4	67	58	5.5
August	6-12	32	29.0	22.1	87	65	6.0
	13-19	33	31.3	21.9	88	51	2.5
	20-26	34	31.5	22.9	72	49	7.5
	27-2	35	32.5	23.0	78	45	1.0
Sep.	3-9	36	32.9	23.1	85	47	-
	10-16	37	33.0	22.9	83	47	13.7
	17-23	38	32.6	22.1	80	49	28.0
	24-30	39	32.8	22.1	79	39	-
Oct.	1-7	40	33.3	22.5	81	47	41.5
	8-14	41	31.1	22.8	82	51	52.5
	15-21	42	30.8	22.2	86	54	18.6
	22-28	43	30.1	22.2	92	62	81.0
Nov	29-4	44	29.6	22.1	89	68	136.0