BREEDING FOR RESISTANCE TO DISTORTION MOSAIC VIRUS IN BITTERGOURD

(Momordica charantia L.*)*

By

P. ARUNACHALAM

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680656
KERALA, INDIA

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DECLARATION

I hereby declare that this thesis entitled **"Breeding for resistance to distortion mosaic virus in bittergourd (*Momordica charantia* L.)"** is a bonafide record of research work done by me during the course of research and that this thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Vellanikkara
Date : 26.10.02

P. Arunachalam

CERTIFICATE

Certified that this thesis, entitled **"Breeding for resistance to distortion mosaic virus in bittergourd (*Momordica charantia* L.)"** is a record of research work done independently by **Mr. P. Arunachalam** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

26/10/07

Dr. V.V. Radhakrishnan
Chairman, Advisory Committee
Associate Professor
Department of Plant Breeding and Genetics
College of Horticulture
Kerala Agricultural University
Vellanikkara
Trichur, Kerala

Vellanikkara
Date : 26/10/07

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. P. Arunachalam,** a candidate for the degree of **Doctor of Philosophy in Agriculture,** agree that this thesis entitled **"Breeding for resistance to distortion mosaic virus in bittergourd (*Momordica charantia* L.)"** may be submitted by **Mr. P. Arunachalam,** in partial fulfillment of the requirement for the degree.

26/10/02

Dr. V.V. Radhakrishnan
Chairman, Advisory Committee
Associate Professor
Department of Plant Breeding and Genetics
College of Horticulture, Vellanikkara

26/10/02

Dr. K. Pushkaran
(Member, Advisory Committee)
Professor and Head
Dept. of Plant Breeding and Genetics
College of Horticulture
Vellanikkara

26/10/02

Dr. Achamma Oommen
(Member, Advisory Committee)
Professor
Dept. of Plant Breeding and Genetics
College of Horticulture
Vellanikkara

26/10/02

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

26/10/02

Dr. P.G. Sadhankumar
(Member, Advisory Committee)
Associate Professor
AICVIP
College of Horticulture
Vellanikkara

26/10/02

(EXTERNAL EXAMINER)
Dr. K. THIYAGARAJAN
PROF AND HEAD
DEPARTMENT OF RICE
TNAU, COIMBATORE

Dedicated to

my beloved mother

Smt. (Late) P. Dhanukodiammal

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P. Arunachalam

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Introduction

1. INTRODUCTION

Bittergourd (*Momordica charantia* L.) is one of the most important remunerative cucurbitaceous vegetable crops grown in Kerala. Kerala is producing 5.78 lakh t of vegetables from 75,941 ha with a productivity of 8 t ha^{-1}. It is also reported that 7 lakh t of vegetables are brought from neighbouring states annually for meeting the domestic requirement (Devadas, 1999). To compensate this deficit in consumer market it is inevitable to increase the production and productivity of the major vegetable crops of the state. But the incidence of pests and diseases are the most important production constraints of bittergourd cultivation (Jayapalan and Sushama, 2001). Among the various diseases, virus diseases are the major constraints for the bittergourd cultivation. There are two types of mosaic diseases infecting bittergourd *viz*., bittergourd mosaic and bittergourd distortion mosaic. Distortion mosaic virus is found to cause serious damage and severe loss to the crop. Very often this disease totally devastates the crop especially during summer (Mathew *et al.*, 1991).

There had been tremendous impetus shown by the plant breeders in culminating with high yielding genotypes to uplift the socio-economic conditions of the farmers in almost all the crops. Kerala Agricultural University has released three bittergourd varieties namely Priya, Preethi and Priyanka. However, they are susceptible to bittergourd distortion mosaic virus (BDMV). Chemical control measures are not effective against mosaic and also they cause health and environmental problems. Hence, resistant breeding is the only way to tackle this menace. Isolated attempts had been made to screen resistance source and transfer it into the cultivated high yielding varieties, but no fruitful results have been reported so far.

The present investigation is a premier attempt to screen out the source(s) of resistance and to incorporate the resistant gene, if any, to the high yielding varieties. Keeping these in view, an attempt was made with following objectives.

1. To identify the resistant source(s) against bittergourd distortion mosaic virus.
2. To assess the genetic diversity and variability in *Momordica charantia* L.
3. To estimate heritability and genetic advance for various quantitative traits.
3. To know the nature of character association.
4. To assess the heterosis and combining ability of parents.
5. To visualize the gene action for BDMV resistance, yield and yield attributing traits.

Review of Literature

2. REVIEW OF LITERATURE

The available literature in bittergourd mosaic disease and other aspects pertaining to this study in bittergourd are reviewed under the following topics.

2.1 Mosaic diseases in bittergourd

2.2 Genetic diversity

2.3 Genetic parameters

2.4 Combining ability

2.5 Heterosis

2.6 Gene action

2.7 Character association

2.1 Mosaic Diseases in Bittergourd

Bittergourd mosaic virus (BMV) reported first in India by Uppal (1933). The serological studies indicated that BMV is related to cucumber mosaic virus, pumpkin mosaic virus and snakegourd mosaic virus (Purushothaman, 1994). The BMV disease was characterized by presence of alternate light green and dark green patches (Nagarajan and Ramakrishnan, 1971) and transmitted by aphids (Purushothaman *et al.*, 1998).

Bittergourd distortion mosaic virus (BDMV) disease is different from bittergourd mosaic and it was characterized by typical mosaic, leaf curling, crinkling and severe stunting. The leaves were reduced in size and distorted. The internodal length of the vine very much reduced; the infected plants produce less flower bud. The fruits were deformed, rough and corky in texture (Giri and Mishra, 1986; Mathew *et al.*, 1991 and Pandey *et al.*, 1998).

The occurrence of BDMV disease in Kerala was first reported by Mathew *et al.* (1991). It became a major disease in many bittergourd growing pockets of Kerala especially during summer season. In an early-infected crop, the yield loss was 100 per cent.

Electron microscopic observation of infected leaf tip preparation revealed the presence of twinned germinate virus particles, measuring 19 x 30 nm (Pandey *et al.*, 1998). They further reported that the virus could be transmitted by sap, seed and through grafting. Mathew *et al.* (1991) reported that whitefly (*Bemisia tabaci* Genn.) could transmit BDMV. They also reported that the virus was transmitted to cucumber (*Cucumis sativus* L.) by *B. tabaci* but not to snake gourd (*Trichosanthes anguina* L.) and pumkin (*Cucurbita moschata*) on artificial inoculation.

Varietal response to bittergourd mosaic and bittergourd distortion mosaic was observed in *Momordica charantia*. Thakur *et al.* (1996a) evaluated 30 germplasm lines and reported that BG 14-4, BL 240, BG 14, HK 12 and Palwal Sel-1 were free from yellow mosaic virus caused by Zucchini yellow mosaic poty virus.

The varieties such as Priya, Co 1 and Arka Harit were found to be susceptible to bittergourd mosaic virus (Purushothaman, 1994). Doraisamy *et al.* (1998) reported that the indigenous germplasm accession IC 68324 was least susceptible to bittergourd mosaic virus. This was confirmed through a sap transmissible experiment under controlled condition. Lakshmanan *et al.* (1998) reported that 61 white medium, 87 green long, 177 green medium, IC 68234 and IC 45358 were least susceptible to 40 per cent infection. Out of 15 varieties tested for their reaction to bittergourd distortion mosaic virus, only two varieties *viz.*, ARBTH 1 and Pusa Do Mausami were found to be resistant (Pandey *et al.*, 1998). The high yielding variety Preethi was susceptible to distortion mosaic virus causing damage up to 100 per cent (Rekha, 1999).

2.2 Genetic Diversity

Ramachandran *et al.* (1981) studied the genetic diversity of 25 germplasm lines collected from different parts of Kerala State. The germplasm were grouped into 10 clusters, including three solitary clusters. The maximum cluster size with six genotypes was recorded in cluster II. Considerable diversity within and between clusters was noticed. Out of eight characters included in this analysis, yield per plant, fruits per plant, female flower per plant and length of fruits had contributed maximum towards divergence.

Thirteen varieties released from different states of India *viz*., Orissa, West Bengal, Kerala, Himachal Pradesh, Punjab, Tamil Nadu, Bihar and Delhi were grouped to six clusters based on 14 characters. There were four solitary clusters and the remaining two clusters consisted of five and six genotypes per cluster. The character 100 seed weight followed by number of seeds per fruit, yield per plant and seed to flesh ratio had contributed maximum to divergence (Parhi *et al.*, 1993).

Vahab and Gopalakrishnan (1993) studied 50 genotypes, varying in fruit size, shape, colour and bitterness. Based on 18 characters these genotypes were grouped into five clusters. There were one solitary cluster and the largest cluster contained nine genotypes. It was reported that geographical diversity was not reflected on genetic diversity.

2.3 Genetic Parameters

Srivastava and Srivastava (1976) studied 10 bittergourd genotypes for various genetic parameters. They found high heritability for number of fruits per plant and suggested selection for this trait, further they reported that fruit weight, fruit yield per plant were conditioned by additive gene action. High genetic coefficient of variation (GCV) and genetic advance were recorded in number of fruits per plant followed by yield per plant. Lowest value of GCV, heritability and genetic advance were recorded for number of male flower per plant.

In a study carried out in 20 bittergourd varieties by Singh *et al.* (1977), the maximum phenotypic coefficient variation (PCV) of 41.41%, GCV (38.98%) and GA as per cent of mean (76.1%) were recorded in number of fruits per plant followed by 36.88 per cent, 35.08 per cent and 69.03 per cent respectively in fruit yield per plant. Yield per plant showed broad sense heritability of 91.43 per cent followed by 89.86 per cent.

The highest PCV (39.88%), GCV (37.82%) and genetic advance (89.9%) for fruit yield per plant were recorded. The high heritability for fruits per plant (99.8%)

followed by yield per plant (99.74%) and 98.18 per cent for days to opening of female flower (Ramachandran and Gopalakrishnan, 1979).

Genetic parameters were studied in 21 varieties of bittergourd by Mangal *et al.* (1981). High estimates of heritability along with high genetic advance and genetic coefficient of variation were recorded for fruit yield, number of fruits, and fruit weight due to additive gene action. Days to first female flowers and leaf lobing exhibiting low genotypic and phenotypic coefficient of variation. Choudhury (1987) observed the highest PCV and GCV for yield per plant, fruits per plant and fruit weight. The lowest values were recorded for early female flower formation. Genetic advance was high for yield per plant.

Vahab (1989) observed maximum PCV for fruit weight (48.77%) followed by yield per plant (39.91%), number of fruits per plant (31.82%). Moderate PCV for fruit length (29.56%), female flowers per plant (27.37%). Similar trend was noticed for genotypic coefficient of variation. High heritability along with high genetic gain were noticed for fruit weight, number of fruits and yield per plant.

Ram *et al.* (1997) recorded significant genetic variability for days to anthesis of 50 per cent male and female flowers, fruit length, fruit diameter, fruits per plant and yield per plant.

Genetic parameters were studied in seven parents and 21 hybrids by Prasad (2000). The maximum PCV recorded in fruit yield per plant (29.83%) followed by fruit weight (26.82%) and fruit length (25.05%). Low values of PCV were observed for days to male flower (12.3%) and days to female flower (13.18%). Fruit yield recorded GCV of 29.18 per cent followed by fruit weight (26.74%). Heritability values were high in fruit weight (99.0%) followed by days to first female flower (96.2%), fruit yield (95.7%) and fruit girth (95.7%). Genetic advance was high in fruit yield (58.73%) followed by fruit weight (54.93%). Puddan (2000) noticed high heritability with high genetic advance for first female flower appearance, fruit length, fruit girth and fruit weight.

2.4 Combining Ability

2.4.1 Days to first female flowering

Pal *et al.* (1983) reported that Monsoon Miracle, China and Holly Green as the best general combiners and the crosses Monsoon Miracle and Holly Green and the Largest x Prince as the best specific combinations. The hybrids MDU 1 x MC 55, Co1 x Midhipagal and MDU 1 x VK1 (Priya) exhibited significant negative specific combining ability (*sca*) effects (Gopalakrishnan, 1986). He also reported the predominance of specific combining ability (SCA) variance over general combining ability (GCA) variance. Kharitra *et al.* (1994) reported, ACC 32, ARU 41 and BG 14 as best general combiners, among the crosses Pusa Do Mausami x Priya was the best specific combiner. Rajeswari (1998) observed that Preethi as the best general combiner and most of crosses were registered negative *sca* effects.

Falslabad, URBT 78 found to be good combiners by Ram *et al.* (1999). They also reported negative general combining ability (*gca*) and *sca* effects. Prasad (2000) observed that MC 48 and MC 53 showed negative *gca* effects and MC 48 found to be the best general combiner. Hybrid MC 34 x MC 53 performed with highest negative *sca* effect.

2.4.2 Sex ratio

Arka Harit and Priya were found to be the best general combiners for sex ratio. The cross combination MDU 1 x Konkan Tara exhibited high specific combining ability in negative direction though their parents had high positive *gca* effect (Rajeswari, 1998).

2.4.3 Number of fruits per plant

Sirohi and Choudhury (1977) registered S-113 as good general combiner and Pusa Do Mausami x S 144 as good specific combiner and also the GCA variance was greater than SCA variance. Singh and Joshi (1980) observed BWL 1 as best general combiner and BWM 1 x BWL 1 and BWL 1 x BS 1 as good specific combinations. GCA variance reported as higher than the SCA variance. Gopalakrishnan (1986) found

that MDU 1 and Priya recorded positive *gca* effects. Similarly Midlipagal x MC 55 recorded significant positive *sca* effect. Lawande and Patil (1990) reported that Hisar selection and Green Long as the best general combiners and Muurad Local x MC 23 as the best specific combiner. Significant positive *gca* and *sca* effects were reported by Choudhury and Kale (1991a).

Devadas (1993) reported MC 13 and MC 41 x MC 78 as best general and specific combiners respectively. Kharitra *et al.* (1994) reported that ACC 32 and BG 14 x ACC 32 registered the highest *gca* and *sca* effects respectively. Mishra *et al.* (1994) noticed that parent Thulsi showed significant positive *gca* effect and Coimbatore Long x Gadabeta recorded significant positive *sca* effect. Significant positive *gca* and *sca* effects were obtained by Kennedy (1994) and Munshi and Sirohi (1994a). In study conducted by Rajeswari (1998) found that Preethi as the best combiner. Ram *et al.* (1999) reported that Narendra and VRBT 77 as good general combiners and many crosses also recorded desirable *sca* effects.

The parent ARU 41 found to be good general combiner by Khattra *et al.* (2000). The parents have showed both positive and negative *gca* effects, MC 21 noticed as good general combiner. The cross MC 17 x MC 48 recorded maximum *sca* effect (Prasad, 2000). Ranpise *et al.* (2001) reported Hisar Selection, HG 113, Kendeshi Mali and Coimbatore Long were the best combiners.

2.4.4 Fruit length

Sirohi and Choudhury (1977) and Singh and Joshi (1980) reported that SCA variances were greater than GCA variances. Gopalakrishnan (1986) found that MDU 1 exhibited high *gca* effect and MC 57 x MC 55 resulted in high positive *sca* effect. Vahab (1989) reported that Priya had high *gca* effect. Lawande and Patil (1990) noticed high positive *sca* effect in Hisar Selection x Konkan No.2. Devadas (1993) reported Co 1 as the best general combiner, Co 1 x Coimbatore Long Green and Co 1 x Arka Harit as good specific combinations. Kharitra *et al.* (1994) observed Pusa Do Mausami and Priya as the best general combiners and Pusa Do Mausami x Priya as the best specific combination.

Priya was found to be good general combiner. The cross combinations like Coimbatore Long x Gadabeta, Nakhama Local x Priya and Coimbatore Long x Thusi exhibited significant *sca* effects. In a study by Munshi and Sirohi (1994a), S 144 reported as best general combiner and BG-14 x Priya is the best specific combination. MDU 1 was the best general combiner as reported by Rajeswari (1998). Ram *et al.* (1999) recorded high *gca* for Narendra and VRBT 46. Prasad (2000) noticed that all seven parents expressed significant positive effects of *gca* and MC 48 found to be best general combiner. Hybrids MC 18 x MC 48, MC 17 x MC 34 and MC 21 x MC 53 recorded high positive *gca* effects.

2.4.5 Fruit girth

Sirohi and Choudhury (1977) reported that GCA variances were higher than SCA variances; *gca* and *sca* effects were significant. Similarly Gopalakrishnan (1986) reported high GCA variance than SCA variance. He also found that VK 1 Priya as the best combiner and among the crosses MDU 1 x MC 55 and Co 1 x Midhipagal as the best specific combinations. Devadas (1993) found that GCA variance was significant and SCA variance was non-significant. The parents, MDU 1, Arka Harit, MC 36 and White Long Coimbatore resulted in better general combiners. The crosses Pusa Do Mausami x White Long Coimbatore and MDU 1 x MC 78 had significant positive specific combining ability.

Kharitra *et al.* (1994) revealed that *gca* effects ranged from –0.14 to 0.1 and *sca* effects from –0.42 to 0.24. Munshi and Sirohi (1994a) recorded Kalyanpur Sona as the best general combiner and the Hybrid BG 14 x ARU 14 as the best specific combination as they showed the highest positive *gca* and *sca* effects respectively. Kennedy (1994) noticed Co 1, MC 84 and Udayamarthandam Local as the best general combiners and MC 47 x Arka Harit and MC 38 x MDU 1 as good specific combiners. Rajeswari (1998) found that Arka Harit, Preethi as the best combiners. Ram *et al.* (1999) stated that high x high and high x medium combiners produced good *sca* effects.

Prasad (2000) recorded MC 18, MC 48, MC 17 and MC 53 as good general combiners. The best specific combiners had at least one of the parents was good general

combiner *viz.*, MC 18 x MC 48 and MC 18 x MC 23. Ranpise *et al.* (2001) observed Hissar Selection, HG 113, Kandeshi Mali and Coimbatore Long as best combiners.

2.4.6 Fruit weight

Pusa Do Mausami, S 63 and S 144 and Pusa Do Mausami x S 144 recorded high *gca* and *sca* effects respectively (Sirohi and Choudhury, 1977). Pal *et al.* (1983) found that Monsoon Miracle as best general combiner with significant *gca* effect and Largest x Indian Prince showed highest positive significant effect. Gopalakrishnan (1986) recorded that Midhipagal and Midhipagal x MC 55 showed the highest positive *gca* and *sca* effects respectively. Lawande and Patil (1990) revealed that Green Long and Co 1 as the best general combiners. Choudhary and Kale (1991a) found that Coimbatore Long, Khandesh Mali and Hisar Selection as good general combiners. Devadas (1993) reported that MDU 1 with significant positive *gca* effect and the Pusa Do Mausami x VK 1 (Priya) with significant positive *sca* effect.

The *gca* effects ranged from –2.21 to 0.94 and *sca* effects from –13.59 to 8.63 (Kharitra *et al.*, 1994). The hybrids Nakhara Local x Tiansi, Tiansi x Gadabeta and Coimbatore Long x Gadabeta showed significant *sca* effects (Mishra *et al.*, 1994). Pusa Visesh showed highest *gca* effects and Pusa Visesh x Arka Harit recorded highest *sca* effects (Munshi and Sirohi, 1994a). Ottanchathram Local, MDU 1 as good general combiners with significant positive *gca* effects and MC 55 x VK 1 (Priya) and MC 38 x MC 18 as best specific combinations (Kennedy, 1994). Rajeswari (1998) reported that Preethi as good general combiner and Preethi x Co 1 cross with high *gca* parents resulted in high *sca*. In a study by Ram *et al.* (1999), Faislabad, MC 48, Arka Harit and VRBT 46 recorded highest *gca*. The crosses involving one of these as a parent found to have high *sca* effects. Khattra *et al.* (2000) reported ARU 41 which exhibited high *gca* effect. Prasad (2000) observed both positive and negative *gca* effects by parents and the best general combiner was MC 48. Among 11 positive significant hybrids MC 53 x MC 48 had high *sca* effect with both of the parents showed positive *gca* effect.

2.4.7 Fruit Yield per plant

The parent Pusa Do Mausami was the best general combiner and Pusa Do Mausami x S 144, Pusa Do Mausami x S 63 and Coimbatore Long x S 63 were good specific combinations based on high positive values of *gca* and *sca* respectively (Sirohi and Choudhury, 1977). Singh and Joshi (1980) found that BWL 1 and BWM 1 x BWL 1 were the best general combiner and specific combination respectively. They also noticed that GCA variance was higher than SCA variance.

The parents Priya, MC 84, MC 78 and MC 66 resulted high yield and high *gca* effects (Vahab, 1989). The significant positive *gca* and *sca* effects were obtained by Lawande and Patil (1990). The best combiner was Khanderh Mali with highest *gca* effect and the hybrids C 96 x Green Bittergourd, Washim Local x BG 112 and BG 114 x Coimbatore Long as good specific combinations (Choudhury and Kale, 1991a).

Devadas (1993) reported MDU 1 with high *gca* effect and Pusa Do Mausami x VK 1 (Priya) with high *sca*. The GCA to SCA variance was high. In a study by Kharitra *et al.* (1994), *gca* effects ranged from –0.16 to 3.85 and *sca* effects from –0.29 to 0.44 with Pusa Do Mausami and BG 14 x ACC 32 as the best general combiner and specific combination respectively. The Coimbatore Long as the best general combiner and Coimbatore Long x Gadabeta as best specific combination (Mishra *et al.*, 1994). The high SCA variance than GCA variance was observed for yield. The parents Pusa Visesh, Pusa Do Mausami and Kalyanpur Sona exhibited high *gca* and the hybrid Pusa Visesh x Arka Harit resulted in high *sca* effects (Munshi and Sirohi, 1994a).

The parents MC 84, Pusa Visesh and Coimbatore Long Green as the best general combiners and MC 40 x MC 18 and MC 55 x MDU 1 as good specific combiners (Kennedy, 1994). Preethi as best combiner for yield was reported by Rajeswari (1998). In a diallel analysis, BG 14 was observed to be the best general combiner and the crosses, Udaipur Local x BG 14 and NBPGR/TCR 727 x Jaunpuri Long showed the highest *sca* effects (Matoria and Khandelwal, 1999). Ram *et al.* (1999) noticed Narendra and VRBT 46 exhibited high *gca*. The crosses MC 63 x VRBT 77, IC 50516 x VRBT 77, Arka Harit x VRBT 78 and Narendra x VRBT 46 expressed

desirable *sca* effects. Most of the crosses were included in high x high and high x medium type of general combiner.

The parent ALU 41 exhibited high *gca* and BL 240-1 x Pusa Do Mausami showed high *sca* effects (Khattra *et al.*, 2000). The parent MC 48 found to be the best general combiner and the parents recorded both positive and negative *gca* effects. Nine hybrids were shown positive *sca* effects out of 21 hybrids, the highest *sca* effect was observed in MC 18 x MC 48, where both the parents expressed high *gca* effects (Prasad, 2000).

The parents Hissar Selection, HG 113, Kandesh Mali and Coimbatore Long were found to be the best combiners. The hybrids which gave best performance were involved one or both of the parental lines having highest general combining ability (Ranpise *et al.*, 2001).

2.5 Heterosis

2.5.1 Days to first female flowering

Negative heterobeltiosis (-16.7%) reported for this trait by Srivastava and Nath (1983). All three types of heterosis were in negative direction (Gopalakrishnan, 1986 and Vahab, 1989). The cross Pusa Do Mausami x Priya expressed –17.02 per cent heterosis over better parent (Khattra *et al.*, 1994). Celine and Sirohi (1996) reported heterobeltiosis ranging from –3.15 to 9.11 per cent with the lowest in Pusa Visesh x Arka Harit. Rajeswari (1998) noticed significant negative heterosis over better parent in the hybrids Co 1 x Arka Harit and Preethi x Co 1. Prasad (2000) recorded high heterobeltiosis in MC 17 x MC 34 and high standard heterosis in MC 18 x MC 48.

2.5.2 Sex ratio

The hybrid between Green Local x Bundelkhand Local resulted in –2.7 and –3.7 per cent relative heterosis and heterobeltiosis (Lal *et al.*, 1976). Similarly, negative relative heterosis and heterobeltiosis were observed by Rajeswari (1998).

2.5.3 Number of fruits per plant

Heterosis for fruits per plant was noticed by many workers (Pal and Singh, 1946; Aiyadurai, 1951; Srivastava, 1970; Lal *et al.*, 1976; Singh and Joshi, 1980 and Ranpise, 1985). Both positive and negative mid-parent heterosis and standard heterosis were recorded by Gopalakrishnan (1986). Positive heterobeltiosis were reported, ranging from 8.76 to 73.28 per cent and the highest value was expressed in C 96 x Green Bittergourd (Choudhury and Kale, 1991b).

Lawande *et al.* (1991) reported highest better parent heterosis of 93.33 per cent. Singh *et al.* (1992) revealed significant positive heterosis ranging from 22.32 to 64.47 per cent over better parent, with the highest manifestation in Pusa Do Mausami x Arka Harit. Devadas (1993) recorded both positive and negative estimates for all three types of heterosis. In a study by Munshi and Sirohi (1993) noticed 44.44 per cent heterobeltiosis in ARU 41 x S 144 and 35.02 per cent standard heterosis in Pusa Do Mausami x Priya. Khattra *et al.* (1994) reported 75.59 per cent heterobeltiosis in Pusa Do Mausami x Priya. Mishra *et al.* (1994) noticed high magnitude of heterobeltiosis (119.3%) in a hybrid Coimbatore Long x Gadabeta. Kennedy (1994) recorded 77.95 per cent heterobeltiosis in a cross between MC 38 x MDU 1.

Celine and Sirohi (1996) observed significant positive heterosis with the highest estimate of 44.85 per cent over better parent in a hybrid Pusa Visesh x S 144. Rajeswari (1998) noticed pronounced effect of relative heterosis and heterobeltiosis in a cross Preethi x MDU 1. Prasad (2000) found that the hybrid MC 48 x MC 53 showed significant high value than its mid-parent and better parent values though their parents have expressed negative *gca* effects and positive *sca* effect. The cross MC 21 x MC 34 performed with maximum standard heterosis.

2.5.4 Fruit length

Significant positive heterobeltiosis was reported by Srivastava (1970) and highest heterosis was observed in Green Local x White Local (38.8%) by Lal *et al.* (1976). Singh and Joshi (1980) observed 29.9 per cent heterobeltiosis. Gopalakrishnan (1986) recorded the hybrid MC 55 x Midhipagal as the best hybrid with 46.67 and

28.60 per cent relative heterosis and heterobeltiosis. Heterobeltiosis of 40.12 per cent recorded in BG 114 x BG 110 (Choudhury and Kale, 1991b) and 26 per cent in Green Long x MC 23 (Lawande *et al.*, 1991). Devadas (1993) noticed that only few hybrids recorded positive heterosis and many crosses expressed negative heterosis.

The heterobeltiosis of 24.04 per cent was recorded in Arka Harit x ARU 41 (Munshi and Sirohi, 1993) and 17.75 per cent in Pusa Do Mausami x Priya (Khattra *et al.*, 1994). The 35.2 per cent heterosis over better parent was noticed in Coimbatore Long x Gadabeta by Mishra *et al.*, 1994. The cross Peruvaramboor Local x Coimbatore Local registered 48.85 per cent relative heterosis (Kennedy, 1994). The better parent heterosis of 12.9 per cent in the hybrid Priya x S 144 (Celine and Sirohi, 1996). The hybrid MC 18 x MC 48 recorded high values of all three types of heterosis (Prasad, 2000).

2.5.5 Fruit girth

The cross NDBT 1 x ARU 41 expressed heterobeltiosis of 30.93 per cent and standard heterosis of 2.65 per cent in Pusa Visesh x Arka Harit (Munshi and Sirohi, 1993). All the three types of heterosis were found to be significant with maximum values in MC 18 x MC 48, where both parents are with high *gca* effects and the hybrid with *sca* effect (Prasad, 2000).

2.5.6 Fruit weight

The significant positive heterobeltiosis was reported by Srivastava (1970) and 155.4 per cent better parent heterosis in Green Local x White Local was observed by Lal *et al.* (1976). Gopalakrishnan (1986) observed both positive and negative heterosis with the highest estimate of 105.28 per cent over mid-parent and 82.33 per cent over better parent in MC 57 x Midhipagal. Choudhury and Kale (1991b) found 85.7 per cent of heterobeltiosis in BG 114 x Coimbatore Long. Lawande *et al.* (1991) revealed that the hybrids expressed both positive and negative heterosis with highest better parent heterosis of 68.43 per cent in Green Long x Konkan No.2. The hybrid Pusa Do Mausami x Priya expressed 36.24 per cent heterobeltiosis (Singh *et al.*, 1992). All these three types of heterosis were reported for this trait by Devadas (1993). Munshi

and Sirohi (1993) noticed the heterosis ranging from 2.5 to 48.35 per cent over better parent with the highest estimate in BG 14 x S 144 and 1.43 to 27.52 per cent better parent heterosis with the highest in Pusa Visesh x Arka Harit. The promising hybrid Makhna Local x Tiansi showed 124.4 per cent better parent heterosis (Mishra *et al.*, 1994). All three types of positive and negative heterosis were reported by Kennedy (1994). Celine and Sirohi (1996) recorded a range of 1.8 to 38.44 per cent heterobeltiosis with high estimate in Pusa Visesh x Arka Harit. Prasad (2000) noticed that MC 18 x MC 48 performed well with maximum heterotic effect with all three types of heterosis found to be significant.

2.5.7 Fruit yield per plant

Earlier reports of heterosis for yield were reported by Pal and Singh (1946), Aiyadurai (1951), Srivastava (1970) and Kolhe (1972). Lal *et al.* (1976) reported that hybrid Green Local x White Local expressed positive mid-parent heterosis of 192.4 per cent and heterobeltiosis of 139.1 per cent. Heterobeltiosis (16.8%) and standard heterosis (7.7%) were reported by Singh and Joshi (1980) and 64 per cent of heterobeltiosis by Srivastava and Nath (1983). All three types of positive and negative heterosis were noticed by Gopalakrishnan (1986). The hybrid Midhipagal x VK 1 (Priya) expressed 90.61 per cent heterobeltiosis and also significant positive mid-parent and better parent heterosis were reported by Vahab (1989). The hybrid C 96 x Green Bittergourd performed well with highest heterobeltiosis of 235.94 per cent (Choudhury and Kale, 1991b). An estimate of 100 per cent heterosis over better parent recorded in Delhi Local x Konkan No.2 (Lawande *et al.*, 1991).

The hybrid BG 14 x Pusa Visesh performed with 81.56 per cent heterobeltiosis (Singh *et al.*, 1992). Relative heterosis of 164.6 per cent and 104.36 per cent heterobeltiosis were observed by Devadas (1993). The highest heterobeltiosis of 98.82 per cent was observed in Priya x S 144 and 58.03 per cent standard heterosis in Pusa Visesh x Arka Harit (Munshi and Sirohi, 1993). Coimbatore Long x Gadabeta yielded with 139.9 per cent better parent heterosis (Mishra *et al.*, 1994). Significant positive heterosis over mid, better and best parents were recorded by Kennedy (1994).

The hybrid Pusa Visesh x Arka Harit exhibited 54 per cent heterobeltiosis (Celine and Sirohi, 1996). In a study by Rajeswari (1998), the highest heterosis was observed in Preethi x MDU 1 followed by Preethi x Arka Harit. Prasad (2000) recorded highest heterobeltiosis and standard heterosis in the cross MC 18 x MC 48. The parents of this hybrid had high *gca* effects and high *sca* effect for hybrid.

2.6 Gene action

The comprehensive literatures on gene action for various traits in bittergourd are presented below.

Characters/Gene action	References
Days to male flowering	
Additive x additive, additive x dominance, dominance x dominance	Tewari *et al.* (1998)
Non-additive	Prasad (2000)
Days to female flowering	
Additive	Pal *et al.* (1983)
Over dominance	Gopalakrishnan (1986)
Over dominance	Munshi and Sirohi (1994b)
Over dominance	Rajeswari (1998)
Non-additive	Prasad (2000)
Number of female flowers	
Additive and non additive	Prasad (2000)
Sex ratio	
Dominance	Rajeswari (1998)
Number of fruits	
Dominance, complementary epistasis	Sirohi and Choudhury (1979)
Additive	Singh and Joshi (1980)
Additive, non-additive	Gopalakrishnan (1986)
Additive, dominance	Lawande and Patil (1990)
Additive, dominance	Lawande and Patil (1991)
Additive, duplicate	Lawande *et al.* (1994)
Partial dominance, over dominance	Devadas (1993)
Over dominance	Munshi and Sirohi (1994b)
Non-additive	Kennedy (1994)
Dominance, dominance x dominance	Celine and Sirohi (1998)
Dominance	Rajeswari (1998)
Additive x additive, additive x dominance, dominance x dominance	Tewari *et al.* (1998)
Additive and non-additive	Prasad (2000)

Fruit length	
Complementary, duplicate epistasis, additive and dominance	Sirohi and Choudhury (1980)
Additive, partial dominance	Sirohi and Choudhury (1983)
Partial dominance	Gopalakrishnan (1986)
Additive, complementary epistasis	Lawande and Patil (1990)
Additive, dominance	Lawande and Patil (1991)
Additive, partial dominance	Devadas (1993)
Additive	Kennedy (1994)
Partial dominance	Munshi and Sirohi (1994b)
Additive, dominance	Ram *et al.* (1997)
Dominance, additive, dominance x dominance	Celine and Sirohi (1998)
Additive, dominance	Rajeswari (1998)
Additive x additive, additive x dominance, dominance x dominance	Tewari *et al.* (1998)
Additive	Prasad (2000)
Additive, dominance	Ram *et al.* (2000)
Fruit girth	
Complementary and duplicate epistasis, additive, dominance, additive x additive, additive x dominance, dominance x dominance	Sirohi and Choudhury (1980)
Additive with partial dominance	
Additive and non-additive	Sirohi and Choudhury (1983)
Over dominance	Gopalakrishnan (1986)
Additive, dominance	Lawande and Patil (1990)
Over dominance	Lawande and Patil (1991)
Non-additive	Devadas (1993)
Over dominance	Kennedy (1994)
Dominance x dominance, duplicate epistasis	Munshi and Sirohi (1994b)
Additive, dominance	Ram *et al.* (1997)
Additive x additive, additive x dominance, dominance x dominance	Rajeswari (1998)
Additive and non-additive	Tewari *et al.* (1998)
Additive, dominance	Prasad (2000)
	Ram *et al.* (2000)
Fruit weight	
Additive	Singh and Joshi (1980)
Additive, complementary epistasis, additive x additive, dominance x dominance	Sirohi and Choudhury (1980)
Non-additive	Pal *et al.* (1983)
Additive, non-additive, partial dominance	Gopalakrishnan (1986)
Additive, dominance, complementary epistasis	Lawande and Patil (1990)

Additive, dominance	Lawande and Patil (1991)
Partial dominance, over dominance	Devadas (1993)
Non-additive	Kennedy (1994)
Dominance, additive x additive, dominance x dominance	Lawande *et al.* (1994)
Over dominance	Munshi and Sirohi (1994b)
Duplicate and complementary epistasis, additive x dominance	Ram *et al.* (1997)
Additive, additive x additive	Celine and Sirohi (1998)
Additive, dominance	Rajeswari (1998)
Additive	Prasad (2000)
Additive, dominance	Ram *et al.* (2000)
Fruit yield per plant	
Additive, complementary epistasis	Sirohi and Choudhury (1979)
Non-additive, additive x additive, complementary epistasis	Pal *et al.* (1983)
Additive, non-additive	Gopalakrishnan (1986)
Additive, dominance	Lawande and Patil (1990)
Additive, dominance	Lawande and Patil (1991)
Additive, dominance, additive x additive, dominance x dominance	Lawande *et al.*, (1994)
Duplicate and complementary epistasis	Ram *et al.* 1997)
Over dominance	Rajeswari (1998)
Additive x additive, additive x dominance, dominance x dominance	Tewari *et al.* (1998)
Non additive	Prasad (2000)
Additive, dominance	Ram *et al.* (2000)

2.7 Character Association

2.7.1 Correlation

In an early study conducted by Srivastava and Srivastava (1976) using ten bittergourd lines found that days to first female flower had high negative correlation with number of fruits per plant and number of female flowers, whereas, positively correlated with fruit weight. Number of female flowers per plant was positively correlated with number of fruits per plant and yield per plant. Positive correlation was observed between number of fruits and yield per plant.

Singh *et al.* (1977) reported strong positive genetic correlation between number of fruits and yield; fruit length and days to female flower; number of fruits and fruit length; number of fruits and days to female flower and fruit length was positively correlated with days to female flowering.

Positive significant correlations were observed for yield with number of fruits, fruit weight, fruit length and fruit girth (Ramachandran and Gopalakrishnan, 1979). Mangal *et al.* (1981) reported positive correlation between yield and fruit weight and number of fruits. Similarly, fruit length had positive relationship with fruit weight. Indiresh (1982) noticed positive correlation of fruit weight, length of fruit and girth of fruit with yield. Choudhury *et al.* (1986) recorded positive relation of yield with number of fruits, fruit weight and fruit length. Similarly, Gopalakrishnan (1986) revealed positive relation of fruit weight, fruit length and fruit diameter with fruit yield.

High correlation of yield with fruit weight, length of fruit, fruit diameter and number of fruits were observed by Lawande and Patil (1989). Um and Kim (1990) found high positive correlation of fruit weight and fruit length on yield. Devadas (1993) recorded positive association of yield with number of fruits and fruit weight. Kennedy (1994) observed positive association of fruit weight, fruit length and number of fruits on yield.

Positive correlations were recorded for number of fruits and fruit weight with yield, fruit length with fruit weight. Fruit yield was negatively associated with days to first female flowering (Khattra *et al.*, 1994). Rajput *et al.* (1995) found that yield was positively correlated with number of fruits, fruit weight, fruit length and negatively associated with number of days to first harvest. Thakur *et al.* (1996b) revealed high positive relationship between fruit yield and number of fruits. Rajeswari (1998) reported high positive correlation of fruit weight and fruit girth with yield.

2.7.2 Direct and Indirect Effects

The limited information on direct and indirect effects on yield in bittergourd reviewed as below.

Ramachandran *et al.* (1979) revealed that fruit weight followed by number of fruits influenced positive direct effect on yield, the indirect effects through those traits also positive and high. The fruit length contributed negative and negligible direct

effect. Similarly the indirect effects of other component on yield through this trait were also negative.

Direct negative effects on yield were observed for days to first female flower appearance and days to first harvest (Rajput *et al.*, 1995). Fruit weight had maximum direct bearing on yield. However, number of fruits and fruit length indirectly contributed towards yield (Paranjape and Rajput, 1995).

Positive direct effects on yield were showed by days to first female flowering, sex ratio, fruit girth, fruit weight and number of fruits (Rajeswari, 1998). Puddan (2000) revealed that in segregating populations the traits fruit length, fruit girth and fruit weight had registered high direct effects on fruit yield per plant.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation entitled "Breeding for resistance to distortion mosaic virus in bittergourd (*Momordica charantia* L.) was carried out at the College of Horticulture, Kerala Agricultural University, Trichur from September 2000 to June 2002. The details of the experimental site, materials and methodologies are briefly presented hereunder.

3.1 Experimental Site

The field trials were conducted at the experimental plots of the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Trichur, Kerala. The site is located at 10°31' N latitude, 76°30' E longitude and at an altitude of 22.25 m above MSL. The area enjoys typical tropical humid climate. The mean annual rainfall was 3400 mm.

3.2 Experimental Materials

Eighty six bittergourd (*M. charantia*) germplasm collected from the Regional Station of the National Bureau of Plant Genetic Resources (NBPGR), Thrissur; Department of Olericulture, Kerala Agricultural University (KAU), Thrissur; Indian Institute of Horticultural Research (IIHR), Bangalore; Tamil Nadu Agricultural University (TNAU), Coimbatore and Farmers' field of Madurai and Kanyakumari districts of Tamil Nadu constituted the experimental materials. The details of germplasm are presented in Table 3.1.

3.3 Outline of the Experiment

The experiments were carried out in a phased manner. In the first phase all the collected 86 accessions were field screened for bittergourd distortion mosaic virus (BDMV) resistance, fruit yield and 47 genotypes were identified. In the second phase of the experiment, these 47 germplasm were further tested to confirm the resistance. These genotypes were also subjected to association and diversity analysis. From these studies eight high yielding disease resistance and susceptible genotypes were selected.

Table 3.1. Details of genotypes used in the study

Sl. No.	Genotypes	State/district	Source
		Kerala	
1	IC 85606	Ernakulam	NBPGR
2	IC 85608	Ernakulam	NBPGR
3	IC 85614	Ernakulam	NBPGR
4	IC 85616	Ernakulam	NBPGR
5	IC 85611	Ernakulam	NBPGR
6	IC 44411	Ernakulam	NBPGR
7	IC 85609	Ernakulam	NBPGR
8	IC 85610	Ernakulam	NBPGR
9	IC 44414	Idukki	NBPGR
10	IC 44436A	Idukki	NBPGR
11	IC 85618	Idukki	NBPGR
12	IC 85619A	Idukki	NBPGR
13	IC 85620	Idukki	NBPGR
14	IC 44438	Idukki	NBPGR
15	IC 85622	Idukki	NBPGR
16	IC 68250A	Kannur	NBPGR
17	IC 68251	Kannur	NBPGR
18	IC 68230	Kasargod	NBPGR
19	IC 68232	Kasargod	NBPGR
20	IC 44419	Kollam	NBPGR
21	IC 44426A	Kollam	NBPGR
22	IC 44418	Kollam	NBPGR
23	IC 85603	Kollam	NBPGR
24	IC 85623	Kottayam	NBPGR
25	IC 68286	Kozhikode	NBPGR
26	IC 68292	Malappuram	NBPGR
27	IC 68296	Malappuram	NBPGR
28	IC 68338	Malappuram	NBPGR
29	IC 68294	Malappuram	NBPGR
30	IC 68295	Malappuram	NBPGR
31	IC 68306	Palakkad	NBPGR
33	IC 68326	Palakkad	NBPGR
34	IC 68335	Palakkad	NBPGR
35	IC 68342 B	Palakkad	NBPGR
36	IC 68343	Palakkad	NBPGR
37	IC 68330	Palakkad	NBPGR
38	IC 68309	Palakkad	NBPGR
39	IC 43261	Palakkad	NBPGR
40	IC 68316	Palakkad	NBPGR
41	IC 68312	Palakkad	NBPGR
42	IC 68331	Palakkad	NBPGR
43	IC 68322	Palakkad	NBPGR
44	IC 44417	Pathanamthitta	NBPGR
45	IC 85624	Thrissur	NBPGR
46	IC 44410	Thrissur	NBPGR
47	IC 68345	Thrissur	NBPGR
48	IC 68263B	Wayanad	NBPGR
49	IC 68275	Wayanad	NBPGR
50	IC 68272	Wayanad	NBPGR
51	VKV 135	Thrissur	KAU
52	PBIG 2	Thrissur	KAU
53	V89/0-104	Thrissur	KAU
54	VKV 134	Thrissur	KAU
55	Priyanka	Thrissur	KAU
56	No16/oleri	Thrissur	KAU
57	Preethi	Thrissur	KAU
58	Priya	Thrissur	KAU
59	IC 68285	**	NBPGR
60	IC 68237	**	NBPGR
		Tamil Nadu	
61	KMK 1	Kannyakumari	Local collection
62	KMK 2	Kannyakumari	Local collection
63	MDU local	Madurai	Local collection
64	IC 85629	Coimbatore	NBPGR
65	IC 50516	Coimbatore	NBPGR
66	IC 45358	Dindugal	NBPGR
67	IC 50527	Kannyakumari	NBPGR
68	IC 45341	Madurai	NBPGR
69	IC 45351	Madurai	NBPGR
70	IC 85626	Thirunelveli	NBPGR
71	IC 85627A	Thirunelveli	NBPGR
72	IC 85633	Thirunelveli	NBPGR
73	IC 45339	Thirunelveli	NBPGR
74	IC 45338	Thirunelveli	NBPGR
75	IC 45346	Virudhunagar	NBPGR
76	Co 1	Coimbatore	TNAU
		Karnataka	
77	IIHR-89	Bangalore	IIHR
78	IIHR-92	Bangalore	IIHR
79	Arka Harit	Bangalore	IIHR
80	IC 50520A	Hassan	NBPGR
81	IC 50526	Mysore	NBPGR
		Maharashtra	
82	IC 85605	Poona	NBPGR
		Others	
83	IC 33227	**	NBPGR
84	IC 33275	**	NBPGR
85	IC 32817	**	NBPGR
86	IC 50523	**	NBPGR

In the next phase, these genotypes were inter-crossed *per se*. The resultant F_1 were evaluated for yield and yield attributes including disease resistance. The selected F_1 hybrids were then backcrossed to their parents to generate backcross (B_1 and B_2) progenies. These materials were evaluated to study the nature of gene action governing the resistance in bittergourd to distortion mosaic virus. The details of the individual experiment are detailed below.

3.3.1 Experiment I: Screening for BDMV and Fruit Yield

Indigenous but diverse 86 germplasm were planted in the pits of size 60 x 60 x 30 cm during September to December 2000. The spacing between the pits and row was 2 x 2 m. About four plants per genotype were maintained (Plate 1). Recommended package of practices as per KAU (KAU, 1996) were followed to establish good crop stand. No plant protection measures were adopted to ensure adequate vector population in the field. Further, the susceptible variety Priyanka was raised all around the field border as well as intermittently at a rate of one row per every five rows of test genotypes. Observation as detailed under 3.3.1.1 as well as symptomatology the disease were recorded. From this experiment 47 high yielding and BDMV resistant genotypes were selected for further testing.

3.3.1.1 Observations Recorded

The observations recorded on the flowering characters, yield and yield attributes and BDMV incidence are

i) Days to anthesis of male flower (AM)

The number of days was counted from the date of sowing to the date when the first male flower opened.

ii) Days to anthesis of female flower (AF)

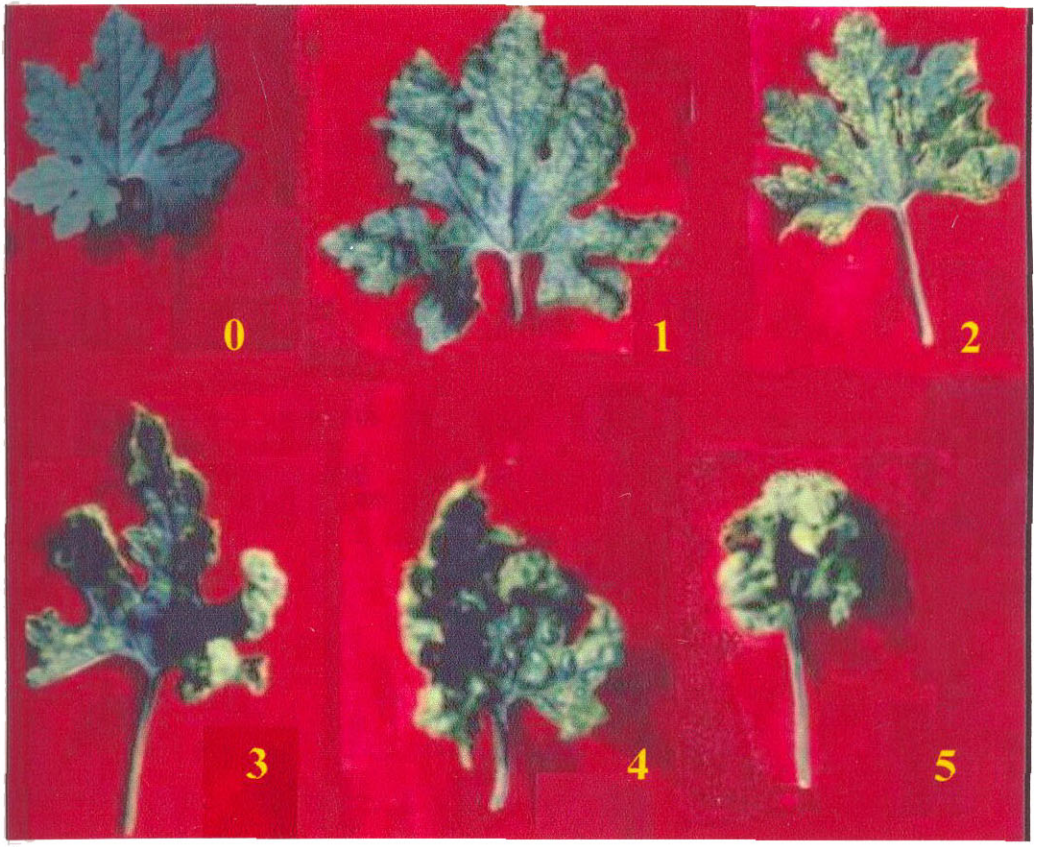
The number of days was counted from the date of sowing to the date of opening of the first female flower.

iii) Number of male flowers per plant (NM)

The number of male flowers was counted every day as and when they open, starting from the day of opening of first male flower.

PLATE 1. A VIEW OF EXPERIMENTAL FIELD

PLATE 2. DISEASE SCORE OF BDMV (0-5 SCALE)



iv) Number of female flowers per plant (NFF)

The number of female flowers was counted every day as and when they opened, starting from the day of opening of the first female flower.

v) Sex ratio (SR)

Sex ratio was calculated as a ratio of the number of female flowers to male flowers per plant.

vi) Fruit colour (FC)

Fruit colour of each genotype was recorded in the following classes *viz.*,

Fruit colour		Score
White (W)	-	1
Light green (LG)	-	2
Green (G)	-	3
Dark green (DG)	-	4

vii) Number of fruits per plant (NF)

The number of fruits in each plant was counted as and when the fruits were harvested and finally added together.

viii) Fruit length (FL)

During peak harvesting the maximum length of five fruits in each plant were measured in centimeter (cm) and the average was worked out.

ix) Fruit girth (FG)

During peak harvesting the maximum girth of five fruits in each plant were measured in centimeter (cm) and the average was worked out.

x) Fruit weight (FW)

Five fruits in each plant were weighed in gram (g) during peak harvesting and the average was worked out.

xi) Fruit yield per plant (FY)

The weight of all the harvested fruits from each plant were added up to get the total yield per plant and recorded in gram (g).

xii) Assessing BDMV incidence and its severity

The incidence of distortion mosaic and symptom development recorded at weekly intervals from the date of seedling emergence. Weekly weather data were collected from the Department of Agricultural Meteorology, College of Horticulture, Vellanikkara to know the favourable weather conditions for the development of distortion mosaic.

Five leaves were selected randomly from each plant and were tagged to observe the disease severity. The severity of the disease was assessed by adopting 0 to 5 score chart (Plate 2) as given below:

0: No symptom

1: Minute chlorotic specks/patches on leaf

2: Wide area of mosaic symptom on whole leaf without distortion

3: Distortion and reduction about 25 per cent of the normal leaf area

4: Distortion and reduction about 25 to 75 per cent of the normal leaf area

5: Distortion and reduction about more than 75 per cent of the normal leaf area

Based on the disease score, percent disease severity (PDS) was calculated using the formula

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

Percent disease incidence (PDI) was calculated using the formula

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

Based on PDS and PDI, the coefficient of infection (CI) was calculated according to Datar and Mayee (1981).

$$CI = \frac{PDS \times PDI}{100}$$

Based on the CI values, genotypes were grouped into six categories according to PDVR (1997) with slight modification.

Coefficient of infection (CI)	Category
0.0 to 5.0	Highly Resistant (HR)
5.1 to 10.0	Resistant (R)
10.1 to 20.0	Moderately Resistant (MR)
20.1 to 40.0	Moderately Susceptible (MS)
40.1 to 70.0	Susceptible (S)
70.1 to 100.0	Highly Susceptible (HS)

3.3.2 Experiment II: Confirmation Studies for BDMV

The experiment was taken from March to June 2001. The selfed seeds obtained from 47 selected genotypes were sown in randomised block design (RBD) with two replications. In each replication, three plants per genotype were maintained. All agronomic practices were similar to those of experiment I (3.3.1). Observations detailed under 3.3.1 were also recorded. The genotypes were selfed and sufficient seeds were obtained. The data generated herein was used for diversity analysis, correlation and path analysis.

3.3.3 Experiment III: Development of F_1 Hybrids

This experiment was conducted during July to August 2001. Hybridization was effected among the selected eight parents through "diallel mating design" without reciprocals and 28 F_1 hybrids were generated. The male and female flowers, which were expected to open in the next day morning, were covered with small brown paper cover in the previous day evening. In the next day morning 5.30 to 7.30 a.m., the male flowers from the desired parent were plucked and the pollen grains were dusted over the stigma of the desired female flowers. The pollinated female flowers were again covered with white butter paper cover, properly labelled and tagged. Simultaneously, the parents were selfed to maintain purity.

The eight genotypes selected from screening experiments and served as parents for this experiment are listed below:

Resistant genotypes		Susceptible genotypes	
Parent name	Name/identity	Parent name	Name/identity
P_1	IC 68335	P_5	Preethi
P_2	IC 68263 B	P_6	VKV 134
P_3	IC 68275	P_7	IC 45341
P_4	IC 68250 A	P_8	IC 68342 B

3.3.4 Experiment IV: Evaluation of Hybrids and Parents

The 28 F_1 hybrids were sown along with their parents and local checks. Priya and Priyanka, variety released from KAU and COBGOH 1(F_1 hybrid) was recently released from TNAU, Coimbatore. The crop was evaluated during October 2001 to January 2002 in RBD with two replications. In each parents, hybrids and checks five plants were raised per replication and observations were recorded on these plants. Cultivar Priyanka was raised at the rate of one row per five rows of test genotypes and also all around the field as infector plants. The Crop husbandry practices and observations were followed as in the Experiment I.

Simultaneously resistant F_1 hybrids were backcrossed to their parents to obtain B_1 and B_2 backcross progenies. The hybrids were selfed to produce F_2 seeds.

3.3.5 Experiment V: Evaluation of Different Generations

Two resistant *verses* susceptible crosses were selected from the above experiment, and their parents, populations from backcross and F_2 generation were used for this experiment. The details are given below.

Generations	Cross 1	Cross 2
Parent 1 (P_1)	IC 68335	IC 68250 A
Parent 2 (P_2)	Preethi	IC 68342 B
F_1 hybrids (F_1)	IC 68335 x Preethi	IC 68250 A x IC 68342 B
Backcross 1 (B_1)	F_1 x IC 68335	F_1 x IC 68250 A
Backcross 2 (B_2)	F_1 x Preethi	F_1 x IC 68342 B
F_2 generation (F_2)	Selfed F_1	Selfed F_1

The crop was grown during March to June 2002 in RBD with two replications. In each replication five plants of P_1, P_2, F_1, 15 plants of B_1 and B_2 and 30 plants of F_2 were maintained. The package of practices and the observations were recorded as in Experiment I.

3.4 Statistical Analysis

The data collected from the present study were analysed by using biometrical techniques. The analyses were carried out using SPAR1 software package.

3.4.1 Diversity Analysis

The data generated from the Experiment II involving 47 genotypes were utilised for genetic diversity and clustering analysis (Mahalanobis, 1928 and Rao, 1952).

3.4.2 Estimation of Genetic Parameters

The following genetic parameters were worked for the Experiments II and IV.

3.4.2.1 Phenotypic and genotypic coefficient of variation

The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were estimated by the formula suggested by Burton (1952). The PCV and GCV values were classified as suggested by Sivasubramanian and Menon (1973) that,

0 to 10 per cent	- Low
10 to 20 per cent	- Medium
20 per cent and above	- High

3.4.2.2 Heritability (Broad sense)

Heritability in broad sense was estimated using the formula of Hanson *et al.* (1956). The heritability was classified as suggested by Robinson *et al.* (1951).

0 to 30 per cent	- Low
30 to 60 per cent	- Moderate
60 per cent and above	- High

3.4.2.3 Genetic Advance

Genetic advance was worked out as per the formula suggested by Johnson *et al.* (1955) and genetic advance as percentage of mean was calculated as per the formula given below.

$$\text{Genetic advance as per cent of mean} = \frac{\text{Genetic advance}}{\text{Grand mean}} \times 100$$

The genetic advance as per cent of mean was categorized as below.

0 to 10 per cent	- Low
10 to 20 per cent	- Moderate
20 per cent and above	- High

3.4.3 Path Analysis

The characters that showed significant genotypic correlation with fruit yield per plant were subjected to path analysis as per Dewey and Lu (1959).

3.4.4 Combining Ability

The observations on combining ability of parents and hybrids of half diallel recorded from Experiment IV and analysed using the numerical approach of Griffing (1956) in Method 2 and Model 1.

3.4.5 Generation Mean Analysis

The data from different generations obtained from Experiment V were tested for the adequacy of additive-dominance model using A, B, C and D scaling test. When the above model fitted to data three parameters (m, d and h) were calculated. If three-parameter model failed to fit the data (presence of non-allelic interaction), six-parameter model incorporating m, d, h, i, j, l fitted to data using the method of Hayman (1958) and Mather and Jinks (1977).

Results

4. RESULTS

4.1 Experiment I

For effective plant breeding programme an assessment of variability of the selected characters is the prime requisite. The main object of the present investigation is the identification of genotypes for resistance to bittergourd distortion mosaic virus (BDMV). Eighty six bittergourd genotypes representing different ecogeographical situations of India were collected and raised in two seasons *viz.*, September to December, 2000 (Table 4.1) and March to June, 2001 under natural epiphytotic conditions for BDMV. The mean performances of these genotypes are presented in Table 4.2 with its mosaic reactions.

The genotypes expressed resistant to BDMV were resulted low to medium fruit yield per plant with few exceptions. Similarly, the high yielding genotypes exhibited moderate resistance or moderate susceptibility to BDMV (IC 68331, IC 32817, VKV 135, IC 85619A and IC 44414).

The mosaic reactor of the base population revealed that, nine genotypes responded with highly resistant, nine resistant, 16 moderately resistant, 26 moderately susceptible, 21 susceptible and five were highly susceptible (Table 4.3). All high yielding varieties released from Kerala Agricultural University *viz.*, Preethi, Priya and Priyanka were found to be susceptible.

The genotypes collected from northern (Wayanad and Kannur districts) and central parts (Malappuram, Palakkad and Idukki districts) of Kerala were recorded resistant to distortion mosaic virus, whereas genotypes from Southern Kerala and other states were found to be susceptible (Table 4.4).

The range, mean and coefficient of variation for all characters in 86 bittergourd genotypes are presented in Table 4.5. Early anthesis of male flower was noticed at 38 days after sowing (DAS) in the genotype IC 68250A and late anthesis in IC 68230 (53 days). Similarly, anthesis of female flower ranges from 40.5 (IC 50527) to 57.0 (VKV 134). Number of male flowers ranged from 3.6 (IC 33275) to 271.5

Table 4.1. BDMV reaction of 86 genotypes during September to December 2000

Sl. No.	Genotypes	BDMV reaction
1	IC 33227	R
2	IC 44414	HR
3	IC 44417	HR
4	IC 44419	R
5	IC 44426A	HR
6	IC 44436A	R
7	IC 45341	R
8	IC 45351	R
9	IC 45358	R
10	IC 50526	HR
11	IC 68230	R
12	IC 68232	HR
13	IC 68285	HR
14	IC 68263B	HR
15	IC 68275	HR
16	IC 68292	HR
17	IC 68296	HR
18	IC 68306	R
19	IC 68310	R
20	IC 68326	HR
21	IC 68335	HR
22	IC 68338	HR
23	IC 68342 B	R
24	IC 68343	R
25	IC 85606	R
26	IC 85608	HR
27	IC 85614	R
28	IC 85616	R
29	IC 85618	R
30	IC 85619A	HR
31	IC 85620	HR
32	IC 85623	HR
33	IC 85624	R
34	IC 85626	HR
35	IC 85627A	R
36	IC 85629	R
37	KMK 1	R
38	KMK 2	HR
39	VKV 135	HR
40	IC 68330	R
41	IC 33275	HR
42	IC 68309	R
43	IC 68237	HR
44	IC 68272	HR
45	IC 44438	R
46	IC 85622	R
47	IC 85611	R
48	PBIG 2	S
49	IC 43261	MS
50	IC 32817	MR
51	IC 85633	R
52	IC 68294	MS
53	IC 44418	MS
54	IC 44411	MS
55	IC 50523	R
56	IC 50520A	MR
57	IC 50516	S
58	IC 85605	MS
59	IC 85603	MR
60	IC 50527	S
61	IC 45339	R
62	IC 45338	HS
63	IC 68316	MS
64	IIHR-89	MR
65	IC 68250A	HR
66	IC 68251	S
67	IC 68295	MR
68	IC 68286	R
69	IIHR-92	S
70	IC 68312	HR
71	IC 44410	MR
72	IC 45346	MS
73	IC 68331	MS
74	IC 68345	MR
75	IC 68322	MS
76	MDU local	MR
77	V89/0-104	S
78	VKV 134	S
79	IC 85609	MS
80	IC 85610	MS
81	Priyanka	S
82	No16/oleri	S
83	Co 1	MS
84	Preethi	S
85	Priya	S
86	Arka Harit	HS

Table 4.2. Mean performance of 86 genotypes for twelve characters screened under natural epiphytotic conditions

Sl. No.	Genotypes	FC	AM	AF	NM	NFF	SR	NF	FL	FG	FW	FY	C
1	IC 33227	LG	42.0	50.5	73.5	27.0	0.3673	26.0	10.6	4.5	64.1	800.0	HS
2	IC 44414	W	45.5	46.0	144.0	41.0	0.2847	39.5	12.4	3.7	47.6	1565.0	MS
3	IC 44417	G	47.5	49.5	67.5	21.0	0.3111	21.0	18.3	3.6	59.4	1025.0	S
4	IC 44419	W	51.0	50.0	133.5	29.5	0.2210	25.5	20.9	3.9	67.3	852.5	HS
5	IC 44426A	G	50.0	42.5	16.5	8.0	0.4848	0.0	0.0	0.0	0.0	0.0	S
6	IC 44436A	G	47.5	47.0	65.5	17.5	0.2672	16.0	16.3	3.6	62.4	632.5	MR
7	IC 45341	W	46.0	47.5	105.0	12.5	0.1190	11.5	12.1	3.6	38.8	397.5	S
8	IC 45351	G	46.5	49.5	40.5	5.0	0.1235	5.0	9.1	4.3	33.5	167.5	MR
9	IC 45358	G	41.0	47.5	86.0	21.0	0.2442	21.0	9.4	3.9	36.2	440.0	S
10	IC 50526	W	44.0	48.0	133.5	24.0	0.1798	24.0	16.7	3.9	75.0	1095.0	S
11	IC 68230	DG	53.0	48.0	51.0	19.0	0.3725	18.5	13.5	4.1	45.5	580.0	MR
12	IC 68232	W	49.0	46.0	135.0	39.0	0.2889	37.0	16.9	3.5	117.3	1555.0	R
13	IC 68285	DG	48.5	46.5	85.0	24.5	0.2882	17.0	20.5	4.0	55.8	740.0	HR
14	IC 68263B	G	41.5	46.0	72.0	30.0	0.4167	28.5	12.6	4.1	53.7	1317.5	HR
15	IC 68275	DG	45.0	46.5	80.0	25.0	0.3125	21.5	14.0	4.3	46.7	817.5	HR
16	IC 68292	W	44.0	44.0	153.0	34.5	0.2255	33.5	12.2	4.2	44.3	1200.0	S
17	IC 68296	LG	44.0	43.0	172.0	27.5	0.1599	25.5	15.1	4.5	65.0	1040.0	HR
18	IC 68306	DG	45.5	44.5	100.5	21.0	0.2090	19.5	15.4	4.1	51.7	680.0	MR
19	IC 68310	LG	42.0	45.5	108.5	34.0	0.3134	29.0	15.8	4.0	58.3	1222.5	R
20	IC 68326	G	41.0	42.5	87.0	35.0	0.4023	34.0	16.6	3.6	76.3	1597.5	MR
21	IC 68335	LG	46.0	45.5	69.0	31.5	0.4565	28.5	11.3	4.5	61.9	1115.0	HR
22	IC 68338	W	44.0	45.0	75.0	20.0	0.2667	20.0	15.3	3.7	46.9	715.0	R
23	IC 68342 B	DG	41.0	42.5	41.0	18.0	0.4390	17.0	12.7	3.8	24.4	487.5	S
24	IC 68343	DG	40.5	50.0	81.0	9.5	0.1173	8.0	9.9	2.7	38.5	237.5	MS
25	IC 85606	G	41.5	45.5	97.5	43.0	0.4410	38.0	16.7	4.1	99.7	1407.5	MR
26	IC 85608	LG	49.0	50.5	138.0	32.5	0.2355	31.0	14.9	4.2	43.5	1085.0	MR
27	IC 85614	G	46.0	43.0	106.0	34.0	0.3208	34.0	13.2	4.2	39.2	845.0	MS
28	IC 85616	G	49.5	55.5	74.0	29.5	0.3986	28.0	11.7	3.6	83.1	757.5	MS
29	IC 85618	G	44.0	47.0	120.5	35.5	0.2946	34.5	15.4	4.5	58.3	1422.5	R

Continued

Table 4.2 Continued

Sl. No.	Genotypes	FC	AM	AF	NM	NFF	SR	NF	FL	FG	FW	FY	C
30	IC 85619A	W	46.0	43.5	137.0	52.0	0.3796	50.5	12.1	4.4	32.1	1465.0	MR
31	IC 85620	DG	43.5	44.5	92.0	25.5	0.2772	24.0	14.8	5.3	29.2	842.5	HR
32	IC 85623	G	42.5	41.5	96.5	26.0	0.2694	21.5	10.4	3.7	36.5	632.5	HS
33	IC 85624	G	44.5	44.0	168.5	27.0	0.1602	26.5	10.0	3.9	40.2	592.5	MS
34	IC 85626	LG	44.5	46.0	271.5	31.5	0.1160	29.5	16.6	4.8	64.0	1170.0	S
35	IC 85627A	DG	52.5	54.5	96.0	14.5	0.1510	12.5	8.9	3.8	34.1	385.0	S
36	IC 85629	DG	44.5	47.5	117.0	18.5	0.1581	18.0	13.6	4.0	57.1	642.5	MS
37	KMK 1	LG	48.0	49.0	114.0	37.5	0.3289	33.5	15.1	3.9	99.3	1417.5	S
38	KMK 2	DG	48.5	49.5	129.0	24.5	0.1899	22.0	13.0	4.0	46.9	995.0	MS
39	VKV 135	LG	48.0	49.0	117.5	24.0	0.2043	21.0	18.3	5.5	130.0	1545.0	MS
40	IC 68330	LG	51.5	43.0	90.0	17.5	0.1944	16.5	13.2	3.3	34.8	512.5	R
41	IC 33275	G	45.5	46.0	3.6	2.0	0.5634	1.1	3.1	1.6	6.3	8.2	HS
42	IC 68309	G	47.5	48.0	47.0	20.0	0.4255	18.0	11.4	3.1	38.8	605.0	MS
43	IC 68237	DG	46.0	49.0	82.5	24.0	0.2909	22.0	15.7	3.5	85.7	1020.0	MS
44	IC 68272	DG	46.5	48.0	75.0	36.5	0.4867	34.0	14.1	4.4	54.2	1065.0	HR
45	IC 44438	G	45.5	45.5	90.0	33.5	0.3722	31.5	14.8	4.5	73.1	1135.0	MS
46	IC 85622	DG	43.0	45.5	97.5	38.5	0.3949	38.0	14.4	4.3	40.6	1465.0	MS
47	IC 85611	G	47.5	43.5	84.5	10.0	0.1183	10.0	14.4	3.9	122.9	705.5	MS
48	PBIG 2	DG	42.0	47.5	60.0	6.0	0.1000	6.0	9.9	4.9	65.0	390.0	S
49	IC 43261	W	42.0	43.5	31.5	14.5	0.4603	14.0	21.4	6.1	94.3	640.0	MS
50	IC 32817	G	44.5	38.0	117.0	36.0	0.3077	34.5	13.0	5.2	78.8	1715.5	MR
51	IC 85633	W	46.5	55.0	150.0	23.0	0.1533	23.0	11.0	3.9	28.3	985.0	R
52	IC 68294	LG	46.5	47.5	81.0	27.0	0.3333	27.5	17.1	3.9	50.0	900.0	MS
53	IC 44418	G	49.0	47.0	156.5	26.5	0.1693	24.5	9.9	3.3	27.5	640.5	MS
54	IC 44411	W	40.0	50.5	137.0	38.5	0.2810	36.5	12.3	3.4	43.8	990.5	MS
55	IC 50523	DG	47.0	42.5	136.0	17.0	0.1250	15.0	17.5	2.9	28.0	335.0	R
56	IC 50520A	DG	39.0	42.5	90.5	43.0	0.4751	40.0	13.3	3.5	43.7	1040.0	MR
57	IC 50516	DG	50.5	51.5	138.5	33.5	0.2419	21.0	12.1	3.3	34.2	1180.5	S
58	IC 85605	DG	42.5	44.5	93.0	29.5	0.3172	26.5	16.9	4.3	35.0	1350.5	MS

Continued

Table 4.2. Continued

Sl. No.	Genotypes	FC	AM	AF	NM	NFF	SR	NF	FL	FG	FW	FY	C
59	IC 85603	W	48.0	43.0	156.0	41.5	0.2660	30.5	19.2	3.8	52.5	1200.0	MR
60	IC 50527	DG	45.0	40.5	75.5	41.0	0.5430	38.5	14.7	3.3	53.5	1300.0	S
61	IC 45339	G	43.5	47.0	148.5	29.0	0.1953	27.0	21.2	4.3	47.5	750.0	R
62	IC 45338	LG	47.5	44.5	58.5	19.0	0.3248	15.5	14.7	3.2	86.6	670.5	HS
63	IC 68316	G	39.0	46.5	75.0	24.0	0.3200	18.5	16.7	3.8	91.6	1240.5	MS
64	IIHR-89	G	47.0	46.0	60.0	21.5	0.3583	17.0	15.7	3.8	51.8	710.5	MR
65	IC 68250A	G	38.0	42.5	45.0	17.0	0.3778	15.0	6.6	3.3	68.7	745.5	HR
66	IC 68251	G	39.0	44.0	60.5	31.5	0.5207	27.0	14.7	2.2	55.0	990.0	S
67	IC 68295	LG	43.0	47.0	138.5	23.0	0.1661	21.0	16.7	3.4	28.1	660.0	MR
68	IC 68286	G	41.0	44.5	142.0	47.0	0.3310	37.5	13.2	3.6	17.5	290.0	R
69	IIHR-92	G	43.0	47.0	87.0	35.0	0.4023	32.5	15.2	4.8	39.3	1090.5	S
70	IC 68312	LG	40.0	40.5	105.5	25.5	0.2417	23.5	13.2	3.3	36.0	595.0	HR
71	IC 44410	W	43.5	48.5	144.5	33.0	0.2284	31.5	21.7	4.2	105.0	910.5	MR
72	IC 45346	LG	43.5	47.0	144.0	53.5	0.3715	49.0	13.9	3.8	37.5	1625.5	MS
73	IC 68331	G	40.5	47.5	162.0	48.5	0.2994	41.5	20.3	4.1	36.7	1860.0	MS
74	IC 68345	G	42.5	47.5	150.0	37.0	0.2467	33.5	21.9	3.6	54.0	1075.0	MR
75	IC 68322	DG	46.0	50.0	147.5	17.5	0.1186	16.0	12.7	4.3	45.0	615.0	MS
76	MDU local	DG	49.0	50.0	140.0	8.0	0.0571	5.0	11.8	3.2	14.0	95.5	MR
77	V89/0-104	LG	50.5	54.0	234.5	37.0	0.1578	34.0	11.9	3.8	21.4	745.0	S
78	VKV 134	LG	50.5	57.0	93.0	18.5	0.1989	16.5	15.1	4.8	45.0	705.0	S
79	IC 85609	G	40.5	40.5	141.5	33.5	0.2367	29.5	15.2	3.2	18.0	565.5	MS
80	IC 85610	G	47.0	54.5	147.0	37.5	0.2551	32.5	15.6	4.3	45.0	915.0	MS
81	Priyanka	W	48.5	46.5	135.0	17.0	0.1259	14.0	15.1	5.0	120.0	835.5	S
82	No16/oleri	G	48.0	48.0	150.0	12.0	0.0800	10.5	15.3	4.3	50.0	380.0	S
83	Co 1	W	48.5	44.0	60.0	19.5	0.3250	16.0	17.0	5.5	60.8	915.0	MS
84	Preethi	LG	45.5	43.5	159.0	24.0	0.1509	21.5	12.0	3.8	59.0	855.0	S
85	Priya	G	40.0	41.5	24.0	6.4	0.2702	2.6	14.4	3.3	30.8	617.5	S
86	Arka Harit	G	43.0	45.0	6.0	34.3	0.1827	3.3	13.6	4.0	36.2	118.5	HS
	Mean		**45.1**	**46.5**	**104.5**	**26.7**	**0.3575**	**23.9**	**14.1**	**3.8**	**52.9**	**874.8**	
	Variance		**11.9**	**13.0**	**2147.3**	**121.7**	**0.0136**	**114.8**	**13.5**	**0.6**	**672.2**	**168065.3**	

Note: FC- fruit colour, AM- Anthesis of male flower, AF- Anthesis of female flower, NM- Number of male flower, NFF- Number of female flower, SR- Sex ratio, NF- Number of fruits per plant, FL- Fruit length, FG- Fruit girth, FW- Fruit weight, FY- Fruit yield per plant, C- Category.

Table 4.3. BDMV reaction of 86 bittergourd genotypes

Genotypes	PDS	PDI	C.I.	Reaction
IC 68296	0	0	0.0	HR
IC 68335	0	0	0.0	HR
IC 68263B	4	20	0.8	HR
IC 68275	4	20	0.8	HR
IC 68250A	4	20	0.8	HR
IC 85620	6	30	1.8	HR
IC 68285	12	30	3.6	HR
IC 68312	8	40	3.2	HR
IC 68272	12	40	4.8	HR
IC 68330	14	40	5.6	R
IC 68338	16	40	6.4	R
IC 45339	16	40	6.4	R
IC 68232	20	50	10.0	R
IC 68310	12	60	7.2	R
IC 85618	12	60	7.2	R
IC 85633	12	60	7.2	R
IC 50523	12	60	7.2	R
IC 68286	12	60	7.2	R
IC 44436A	28	50	14.0	MR
IC 85608	28	50	14.0	MR
IC 68326	36	50	18.0	MR
IC 45351	36	50	18.0	MR
IC 68230	38	50	19.0	MR
IC 68306	20	60	12.0	MR
IC 85603	20	60	12.0	MR
IC 44410	20	60	12.0	MR
IIHR-89	24	60	14.4	MR
MDU local	24	60	14.4	MR
IC 85619A	28	60	16.8	MR
IC 32817	22	70	15.4	MR
IC 85606	24	70	16.8	MR
IC 68295	24	80	19.2	MR
IC 50520A	20	100	20.0	MR
IC 68345	20	100	20.0	MR
IC 44438	46	50	23.0	MS
IC 85614	47	50	23.5	MS
IC 68343	48	50	24.0	MS
IC 45346	36	60	21.6	MS
IC 85611	28	80	22.4	MS
IC 43261	28	80	22.4	MS
IC 68294	28	80	22.4	MS
IC 44411	28	80	22.4	MS
Co 1	28	80	22.4	MS
IC 85610	32	80	25.6	MS
VKV 135	36	80	28.8	MS
IC 85605	36	80	28.8	MS
IC 85616	40	80	32.0	MS
IC 44418	40	80	32.0	MS
IC 68331	40	80	32.0	MS
IC 68309	50	80	40.0	MS
IC 44414	50	80	40.0	MS
IC 68322	28	100	28.0	MS
IC 85624	32	100	32.0	MS
KMK 2	32	100	32.0	MS
IC 85629	36	100	36.0	MS
IC 68237	36	100	36.0	MS
IC 85622	36	100	36.0	MS
IC 85609	36	100	36.0	MS
IC 44419	40	100	40.0	MS
IC 68316	40	100	40.0	MS
Priya	70	80	56.0	S
IC 44426A	74	80	59.2	S
Priyanka	48	90	43.2	S
IC 45341	46	100	46.0	S
Preethi	50	100	50.0	S
KMK 1	52	100	52.0	S
PBIG 2	52	100	52.0	S
IC 85627A	54	100	54.0	S
IC 50516	56	100	56.0	S
IC 50527	56	100	56.0	S
IC 68251	56	100	56.0	S
IIHR-92	56	100	56.0	S
V89/0-104	56	100	56.0	S
No16/oleri	56	100	56.0	S
IC 44417	60	100	60.0	S
IC 50526	60	100	60.0	S
IC 68292	60	100	60.0	S
IC 68342 B	60	100	60.0	S
VKV 134	60	100	60.0	S
IC 85626	62	100	62.0	S
IC 45358	70	100	70.0	S
Arka Harit	82	95	77.9	HS
IC 33227	72	100	72.0	HS
IC 45338	74	100	74.0	HS
IC 33275	88	100	88.0	HS
IC 85623	100	100	100.0	HS

Note: PDS - Percent disease severity, PDI - Percent disease incidence,
CI - Coefficient of infection

Table 4.4. BDMV reactions of 86 genotypes and its source of collection

Source	BDMV Reaction						Total no. of genotypes
	HR	R	MR	MS	S	HS	
Kerala							
Kannur	1				1		2
Kozhikode		1					1
Kasargod		1	1				2
Wayanad	3						3
Malappuram	1	1	1	1	1		5
Palakkad	2	2	1	7	1		13
Thrissur			2	3	6		11
Ernakulam			2	6			8
Idukki	1	1	2	1	2		7
Kottayam						1	1
Pathanamthitta					1		1
Kollam			1	2	1		4
Tamil Nadu							
Kannyakumari				1	2		3
Coimbatore				2	1		3
Dindugal					1		1
Virudhunagar				1			1
Thirunelvelli		2			2	1	5
Madurai			3				3
Karnataka							
Hassan			1				1
Bangalore			1		1	1	3
Mysore					1		1
Maharastra							
Poona				1			1
Others	1	1	1	1		2	6
Total no. of genotypes	9	9	16	26	21	5	86

Table 4.5. Range, mean, coefficient of variation in 86 bittergourd genotypes

Characters	Range *				Mean	CV (%)
	Low	Genotype	High	Genotype		
Anthesis of male flower	38.0	IC 68250 A	53.0	IC 68230	45.1	7.6
Anthesis of female flower	40.5	IC 50527	57.0	VKV 134	46.5	7.5
Number of female flowers	5.0	IC 45.351	53.5	IC 45346	26.7	4.3
Number of male flowers	3.6	IC 33275	271.5	IC 85626	104.5	4.4
Sex ratio	0.057	MDU Local	0.563	IC 33275	0.357	32.6
Number of fruits per plant	1.1	IC 33275	50.5	IC 85619 A	23.9	44.8
Fruit length (cm)	3.1	IC 33275	21.9	IC 68345	14.1	26.0
Fruit girth (cm)	1.6	IC 33275	6.1	IC 43261	3.8	20.3
Fruit weight (g)	6.3	IC 33275	130.0	VKV 135	52.9	49.0
Fruit yield per plant (g)	8.2	IC 33275	1860.0	IC 68331	874.8	46.8

* Excluding genotype having 100 per cent yield loss

(IC 85626). Minimum number of female flower was noticed in IC 45351 (5.0) and maximum (53.5) in IC 45346. Low sex ratio recorded in MDU Local (0.057) and high in IC 33275 (0.563). Though IC 33275 produced high sex ratio it recorded lower values for number of fruits per plant (1.10), fruit length (3.1), fruit girth (1.6), fruit weight (6.3) and fruit yield per plant (8.2) due to high susceptibility to BDMV. None of genotypes recorded maximum value for more than one character. Similarly genotypes which recorded maximum value for each character did not confer resistance to BDMV. High fruit yield per plant was recorded in IC 68331 (1860 g). Low coefficient of variation was observed for flowering traits *viz.*, anthesis of male flower (7.6), anthesis of female flower (7.7), number of female flowers (4.1) and number of male flowers (4.4). High variation was recorded in fruit weight (49.0) followed by fruit yield per plant (46.8) and number of fruits per plant (44.8).

4.1.1 Symptomatology of BDMV

The disease appeared at all stages of crop growth irrespective of season. Symptom first appeared in the newly formed leaves and later rapidly spreads to other leaves of the same vine. The infected leaves showed chlorotic spots then coalesce to form large chlorotic patches and afterwards developed into typical mosaic pattern. In another case, leaves exhibited typical mosaic symptoms of light green and dark green patches. At this stage, the leaf margin starts to curl upward, leaf size gets reduced due to severe puckering, crinkling and the leaves are distorted (Plate 3). As the disease progressed, shortening of internodes resulted in clustering appearance with distorted leaves. Long tendrils, unusual thickening of the tip of the vines with numerous hairs were also noticed (Plate 4). Reduction in flowering due to infection was noticed and the flowers on infected vines failed to open. Severely infected plants failed to produce any flowers (Plate 5).

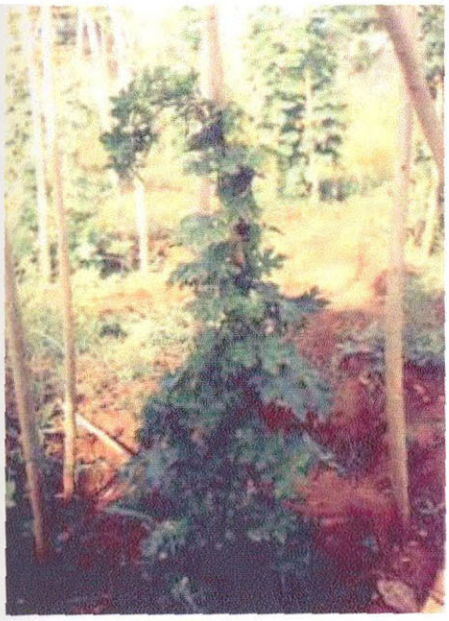
4.2 Experiment II

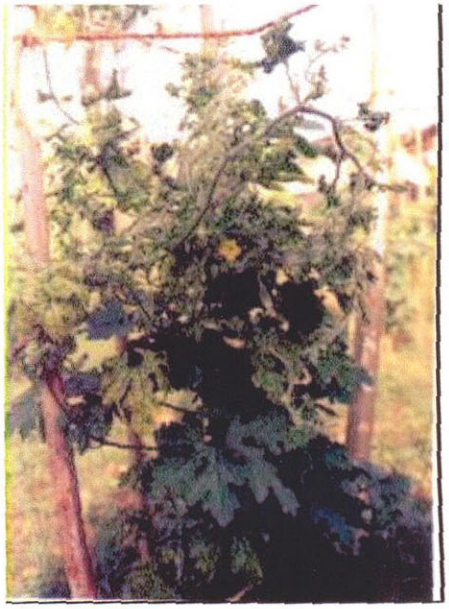
Forty seven genotypes were selected from initial screening experiment based on resistant to BDMV. This experiment was aimed to assess variability, genetic diversity, and association of characters and confirmation of mosaic reaction.

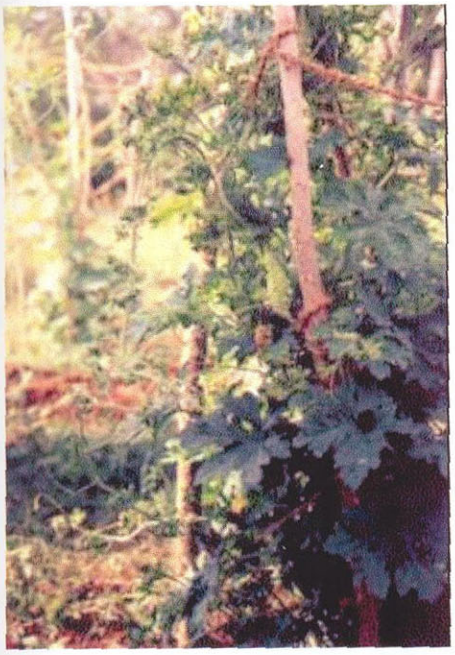
PLATE 3 . VARIOUS STAGES OF SYMPTOMATOLOGY OF BDMV IN LEAVES

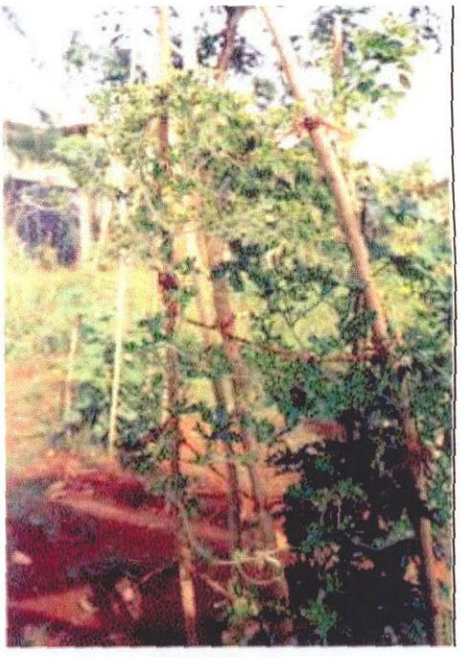
PLATE 4 . SYMPTOMATOLOGY OF BDMV IN VINES

PLATE 5. FIELD VIEW OF BDMV INFECTED PLANTS









4.2.1 Variability

Phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and expected genetic advance as per cent of mean are presented in Table 4.6.

High PCV values were recorded for all the traits except for anthesis of male (8.1) and female (9.1) flowers. Maximum PCV was recorded in fruit weight (63.86). Similarly low GCV values were registered in anthesis of male (4.17) and female (3.41) flowers. Moderate GCV recorded for fruit length (14.75) and fruit girth (15.83). All other traits showed high GCV values, the highest value recorded in resistant to BDMV (46.62) and fruit yield per plant (37.81).

Lower heritability estimates were observed in fruit weight (13.7), anthesis of female flower (14.0), fruit length (16.2) and number of male flower (18.0). Moderate heritability was noticed for number of female flower (43.4), sex ratio (44.2), number of fruits per plant (48.4) and fruit yield per plant (46.7). Anthesis of female flower recorded low genetic gain (2.62) followed by anthesis of male flower (4.44). High genetic gain recorded resistance to BDMV (88.94) and fruit yield per plant (53.24).

4.2.2 Association of Characters

4.2.2.1 Correlation

The phenotypic and genotypic correlations for twelve characters in 47 genotypes are presented in Table 4.7.

Phenotypic correlation values indicated that anthesis of male flower positively correlated with anthesis of female flower (0.367) only. Number of female flowers was positively correlated with number of male flowers (0.478), number of fruits per plant (0.981), fruit length (0.383), fruit girth (0.338) and fruit yield per plant (0.791). All the traits recorded positive association with fruit yield per plant except anthesis of male flower, anthesis of female flower and fruit colour.

Table 4.6. Phenotypic and genotypic coefficients of variation, heritability and genetic gain for twelve characters in 47 bittergourd genotypes

Characters	Range*	Mean	PCV (%)	GCV (%)	$h^2_{(bs)}$ (%)	Genetic gain (%)
Anthesis of male flower	40.5–53.00	45.74	8.10	4.17	26.50	4.44
Anthesis of female flower	41.5–55.50	46.64	9.10	3.41	14.00	2.62
Number of female flowers	20.0–52.00	25.79	47.70	31.41	43.40	42.60
Number of male flowers	3.60–27.10	97.99	59.59	25.26	18.00	22.05
Sex ratio	0.10–0.51	0.29	44.72	22.00	44.20	23.97
Number of fruits per plant	1.10–50.50	23.88	50.32	34.99	48.40	50.11
Fruit length (cm)	3.10–20.90	13.47	36.64	14.75	16.20	12.25
Fruit girth (cm)	1.60-5.50	3.88	25.79	15.83	37.70	20.09
Fruit weight (g)	6.30-130.0	55.73	63.86	23.60	13.70	17.96
Fruit yield per plant (g)	8.20-1597.5	893.46	55.30	37.81	46.70	53.24
Resistance to BDMV (%)	0-100	74.92	50.35	46.62	85.80	88.94
Fruit colour score	1-4	2.73	30.84	30.35	71.70	53.11

* Excluding genotype having 100 per cent yield loss

Table 4.7 . Phenotypic and genotypic correlations for twelve characters in 47 genotypes

Traits	Anthesis of male flower	Anthesis of female flower	No. of female flower	No. of male flower	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Resistance score	Fruit colour score
Anthesis of male flower	**1.000**	0.367*	-0.122	0.062	-0.195	-0.118	-0.046	0.022	-0.006	-0.113	0.138	-0.049
Anth. of female flower	0.464*	**1.000**	-0.192	0.084	-0.356	-0.213	-0.124	-0.131	-0.128	-0.258	-0.024	-0.027
No. of female flower	-0.184	-0.200	**1.000**	0.478*	0.507	0.981**	0.383*	0.338*	0.151	0.791*	0.305	-0.200
No. of male flower	-0.579**	-1.150**	0.700**	**1.000**	-0.306	0.500**	0.292*	0.301	0.040	0.413*	0.326	-0.260
Sex ratio	0.302*	0.347*	0.730**	0.079	**1.000**	0.484**	0.242	0.183	0.156	0.412*	0.072	0.073
No. of fruits/ plant	-0.142	-0.278	0.995**	0.711*	0.761*	**1.000**	0.372*	0.378*	0.145	0.796*	0.324*	-0.221
Fruit length	0.588*	0.993**	0.744**	0.359*	0.081	0.781**	**1.000**	0.539*	0.482*	0.545*	0.424*	-0.122
Fruit girth	0.303	-0.340*	0.847**	0.324*	0.570*	0.894**	1.002*	**1.000**	0.312*	0.445*	0.439*	-0.161
Fruit weight	1.206*	1.012**	1.087**	0.642*	-0.267	1.061**	1.003*	0.855*	**1.000**	0.496*	0.371*	-0.168
Fruit yield/ plant	-0.017	0.038	-0.986**	0.911**	0.522**	1.017**	0.438**	0.777**	1.039**	**1.000**	0.431*	-0.253
Resistance score	0.343*	-0.076	0.442**	0.849*	0.017	0.463**	0.901*	0.658*	1.074*	0.675**	**1.000**	-0.215
Fruit colour score	-0.005	-0.191	-0.399**	-0.774**	0.178	-0.417**	-0.435**	-0.203	-0.578**	-0.431**	-0.260	**1.000**

Note : Upper diagonal in phenotypic correlation values, lower diagonal in genotypic correlation values
*, ** : Significant at 5%, 1% respectively

Genotypic correlations among the yield attributing traits were found to be positive and significant, with few exceptions of significant negative and non-significant associations. Fruit yield showed high positive genotypic correlation (1.039) with fruit weight per plant followed by number of fruits per plant (1.017), number of male flowers (0.911), fruit girth (0.777), resistance to BDMV (0.675), sex ratio (0.522) and fruit length (0.438). BDMV resistance was positively associated with yield attributing traits *viz*., number of fruits per plant (0.463), fruit length (0.901), fruit girth (0.658) and fruit weight (1.074).

4.2.2.2 Direct and Indirect Effects

Positive direct effect on fruit yield per plant (Table 4.8) was recorded through number of fruits per plant (7.074), fruit colour (0.509), resistance to BDMV (0.32), fruit length (0.307) and fruit weight (0.25). High indirect effects were noticed in fruit weight (7.504), number of female flower (7.038), fruit girth (6.325), fruit length (5.525) and sex ratio (5.385) *viz*., number of fruits per plant. High negative direct effect was noticed through number of female flowers (-1.046) followed by fruit girth (-0.755), sex ratio (-0.67), number of male flowers (-0.47) and anthesis of male flower (-0.396).

4.2.3 Genetic Diversity

The analysis of variance indicated significant differences among 47 genotypes for most of the traits except anthesis of male flower, number of male flowers and fruit length (Table 4.9).

Forty seven genotypes were grouped into six clusters, but they did not cluster based on its geographical origin (Table 4.10). The cluster VI was having maximum genotypes of 13 followed by cluster II (12), cluster IV (10), cluster I (6), cluster V (4), cluster III (2) and no solitary cluster was found. Entries in cluster VI were having high yielding genotypes with mosaic resistance. Clusters I, III, IV and V are having the genotypes susceptible to BDMV with few exceptions. High cluster mean for fruit yield per plant was recorded in cluster VI (1365.4 g) followed by clusters IV (935.8 g), II (836.3 g), I (610 g), V (296.9 g) and III (4.12 g).

Table 4.8. Direct and indirect effects of yield attributes on fruit yield in 47 genotypes

Traits	Anthesis of male flower	Anth. of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit lengh	Fruit girth	Fruit weight	Resistance to BDMV	Fruit colour
Anthesis of male flower	**-0.396**	-0.184	0.073	0.229	-0.120	0.056	-0.233	-0.120	-0.478	-0.136	0.002
Anthesis of female flower	0.027	**0.056**	-0.012	-0.071	0.021	-0.016	0.059	-0.020	0.083	-0.004	-0.011
Number of female flowers	0.930	1.007	**-1.046**	-3.534	-3.681	-5.02	-3.754	-4.276	-5.482	-2.232	2.014
Numbr of male flowers	0.272	0.562	-0.350	**-0.470**	-0.037	-0.334	-0.639	-0.623	-0.914	-0.400	0.364
Sex ratio	-0.202	-0.233	-0.489	-0.053	**-0.670**	-0.510	-0.540	-0.382	0.179	-0.012	-0.119
Number of Fruits per plant	-1.008	-1.965	7.038	5.028	5.385	**7.074**	5.525	6.325	7.504	3.273	-2.950
Fruit lengh	0.180	0.305	0.228	0.417	0.025	0.240	**0.307**	0.307	0.492	0.276	-0.133
Fruit girth	-0.229	0.257	-6.639	-0.999	-0.430	-0.675	-0.756	**-0.755**	-0.645	-0.496	0.153
Fruit weight	0.302	0.354	0.272	0.486	-0.067	0.266	0.402	0.214	**0.250**	0.269	-0.145
Resistance to BDMV	0.110	-0.024	0.142	0.272	0.006	0.148	0.288	0.210	0.344	**0.320**	-0.115
Fruit colour	-0.003	-0.097	-0.203	-0.394	0.090	-0.212	-0.221	-0.103	-0.294	-0.183	**0.509**
Genetic Correlation	-0.017	0.038	-0.986	0.911	0.522	1.017	0.438	0.777	1.039	0.675	-0.431

Residual effect: 0.1521

Table 4.9. Analysis of variance for twelve characters in forty seven bittergoud genotypes

Source of variation	df	Mean sum of squares											
		Anthesis of male flower	Anthesis of female flower	No. of female flower	No. of male flower	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Resistant score	Fruit colour score
Treat ments	46	19.75	18.06*	217.10**	4021.86	0.0242*	214.31**	28.30	13.81**	1439.96**	358223.77**	2643.3**	6.07*
Error	6	14.89	10.48	85.74	2796.72	0.0129	74.58	20.41	6.25	109.39	130043.33	202.58	1.00

*, ** : Significant at 5%, 1% respectively

Table 4.10. Cluster wise mean and variance for twelve characters in 47 genotypes

Clusters	Genotypes	Anthesis of male flower	Anthesis of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Fruit colour score	BDMV reaction
Cluster I	IC 68230	53.0	48.0	19.0	51.0	0.380	18.5	13.5	4.1	4 5.5	580.0	2	MR
	IC 68342 B	41.0	42.5	18.0	41.0	0.400	17.0	12.7	3.8	24.4	487.5	1.50	S
	IC 85614	46.0	43.0	34.0	106.0	0.310	34.0	13.2	4.2	39.2	845.0	3.00	S
	IC 85623	42.5	41.5	26.0	96.5	0.320	21.5	10.4	3.7	36.5	632.5	1.00	HS
	IC 68330	51.5	43.0	17.5	90.0	0.210	16.5	13.2	3.3	34.8	512.5	4.00	R
	IC 68309	47.5	48.0	20.0	47.0	0.430	18.0	11.4	3.1	38.8	605.0	3.50	S
	Mean	**46.9**	**44.3**	**22.4**	**71.9**	**0.342**	**20.9**	**12.4**	**3.7**	**34.7**	**610.4**	**2.5**	
	Variance	**22.7**	**8.4**	**41.6**	**821.4**	**0.006**	**44.1**	**1.5**	**0.2**	**36.4**	**16233.5**	**1.4**	
Cluster II	IC 33227	42.0	50.5	27.0	73.5	0.370	26.0	10.6	4.5	64.1	800.0	1.00	HS
	IC 45358	41.0	47.5	21.0	86.0	0.310	21.0	9.4	3.9	36.2	440.0	3.00	HS
	IC 50526	44.0	48.0	24.0	133.5	0.310	24.0	16.7	3.9	75.0	1095.0	3.00	S
	IC 68275	45.0	46.5	25.0	80.0	0.340	21.5	14.0	4.3	46.7	817.5	1.00	HR
	IC 68292	44.0	44.0	34.5	153.0	0.220	33.5	12.2	4.2	44.3	1200.0	4.00	S
	IC 68296	44.0	43.0	27.5	172.0	0.320	25.5	15.1	4.5	65.0	1040.0	1.50	HR
	IC 68306	45.5	44.5	21.0	100.5	0.240	19.5	15.4	4.1	51.7	680.0	3.50	MR
	IC 68338	44.0	45.0	20.0	75.0	0.270	20.0	15.3	3.7	46.9	715.0	3.00	R
	IC 85620	43.5	44.5	25.5	92.0	0.330	24.0	14.8	5.3	29.2	842.5	3.00	HR
	IC 85624	44.5	44.0	27.0	168.5	0.170	26.5	10.0	3.9	40.2	592.5	1.50	MS
	IC 85626	44.5	46.0	31.5	271.5	0.110	29.5	16.6	4.8	64.0	1170.0	2.00	S
	IC 85629	44.5	47.5	18.5	117.0	0.200	18.0	13.6	4.0	57.1	642.5	4.00	MS
	Mean	**43.9**	**45.9**	**25.2**	**126.9**	**0.266**	**24.1**	**13.6**	**4.3**	**51.7**	**836.3**	**2.5**	
	Variance	**1.6**	**4.7**	**22.4**	**3348.1**	**0.006**	**20.0**	**6.3**	**0.2**	**185.5**	**58814.2**	**1.2**	
Cluster III	IC 44426A	50.0	42.5	5.5	14.5	0.370	0.0	0.0	0.0	0.0	0.0	2.50	S
	IC 33275	45.5	46.0	2.0	6.5	0.300	1.1	3.1	1.6	6.3	8.2	2.00	HS
	Mean	**47.8**	**44.3**	**3.8**	**10.5**	**0.344**	**0.5**	**1.5**	**0.8**	**3.2**	**4.12**	**2.3**	
	Variance	**10.1**	**6.1**	**6.1**	**32.0**	**0.003**	**0.6**	**4.8**	**1.3**	**19.8**	**0.0**	**0.1**	

Continued

Table 4.10. Continued

Clusters	Genotypes	Anthesis of male flower	Anth. of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Fruit colour Score	BDMV reaction
Cluster IV	IC 44417	47.5	49.5	21.0	67.5	0.310	21.0	18.3	3.6	59.4	1025.0	2.50	S
	IC 44419	51.0	50.0	29.5	133.5	0.230	25.5	20.9	3.9	67.3	852.5	1.50	S
	IC 44436A	47.5	47.0	17.5	65.5	0.270	16.0	16.3	3.6	62.4	632.5	4.00	MR
	IC 68285	48.5	46.5	24.5	85.0	0.340	17.0	20.5	4.0	55.8	740.0	4.00	HR
	IC 85608	49.0	50.5	32.5	138.0	0.250	31.0	14.9	4.2	43.5	1085.0	3.00	MR
	IC 85616	49.5	55.5	29.5	74.0	0.380	28.0	11.7	3.6	83.1	757.5	2.50	MS
	KMK 2	48.5	49.5	24.5	129.0	0.190	22.0	13.0	4.0	46.9	995.0	3.50	MS
	VKV 135	48.0	49.0	24.0	117.5	0.210	21.0	18.3	5.5	130.0	1545.0	3.00	MS
	IC 68237	46.0	49.0	24.0	82.5	0.300	22.0	15.7	3.5	85.7	1020.0	3.00	MS
	IC 85611	47.0	43.5	10.0	84.5	0.100	10.0	14.4	3.9	122.9	705.0	1.50	MS
	Mean	**48.3**	**49.0**	**23.7**	**97.7**	**0.258**	**21.4**	**16.4**	**4.0**	**75.7**	**935.8**	**2.8**	
	Variance	**2.0**	**9.6**	**42.2**	**817.2**	**0.007**	**36.9**	**9.4**	**0.4**	**901.0**	**70473.7**	**0.8**	
Cluster V	IC 45341	46.0	47.5	12.5	105.0	0.120	11.5	12.1	3.6	38.8	397.5	3.00	S
	IC 45351	46.5	49.5	5.0	40.5	0.150	5.0	9.1	4.3	33.5	167.5	3.00	MR
	IC 68343	40.5	50.0	9.5	81.0	0.110	8.0	9.9	2.7	38.5	237.5	2.00	MS
	IC 85627A	52.5	54.5	14.5	96.0	0.130	12.5	8.9	3.8	34.1	385.0	3.50	S
	Mean	**46.4**	**50.4**	**10.4**	**80.6**	**0.128**	**9.3**	**10.0**	**3.6**	**36.2**	**296.9**	**2.8**	
	Variance	**24.1**	**8.7**	**17.1**	**813.6**	**0.000**	**11.8**	**2.2**	**0.5**	**7.8**	**12718.2**	**0.4**	
Cluster VI	IC 44414	45.5	46.0	41.0	144.0	0.310	39.5	12.4	3.7	47.6	1565.0	2.00	S
	IC 68232	49.0	46.0	39.0	135.0	0.290	37.0	16.9	3.5	117.3	1555.0	3.50	MR
	IC 68563B	41.5	46.0	30.0	72.0	0.420	28.5	12.6	4.1	53.7	1317.5	2.00	HR
	IC 68310	42.0	45.5	34.0	108.5	0.340	29.0	15.8	4.0	58.3	1222.5	3.50	R
	IC 68326	41.0	42.5	35.0	87.0	0.380	34.0	16.6	3.6	76.3	1597.5	2.00	S
	IC 68335	46.0	45.5	31.5	69.0	0.460	28.5	11.3	4.5	61.9	1115.0	2.00	HR
	IC 85606	41.5	45.5	43.0	97.5	0.440	38.0	16.7	4.1	99.7	1407.5	3.00	MR
	IC 85618	44.0	47.0	35.5	120.5	0.300	34.5	15.4	4.5	58.3	1422.5	3.50	R
	IC 85619A	46.0	43.5	52.0	137.0	0.410	50.5	12.1	4.4	32.1	1465.0	3.50	MR
	KMK 1	48.0	49.0	37.5	114.0	0.340	33.5	15.1	3.9	99.3	1417.5	4.00	S
	IC 68272	46.5	48.0	36.5	75.0	0.510	34.0	14.1	4.4	54.2	1065.0	2.50	HR
	IC 44438	45.5	45.5	33.5	90.0	0.400	31.5	14.8	4.5	73.1	1135.0	4.00	S
	IC 85622	43.0	45.5	38.5	97.5	0.390	38.0	14.4	4.3	40.6	1465.0	3.00	MS
	Mean	**44.6**	**45.8**	**37.5**	**103.6**	**0.384**	**35.1**	**14.5**	**4.1**	**67.1**	**1365.4**	**2.9**	
	Variance	**6.8**	**2.8**	**32.3**	**641.7**	**0.004**	**35.0**	**3.5**	**0.1**	**630.7**	**32165.5**	**0.6**	
Overall Mean		46.3	46.6	20.5	81.9	0.287	18.6	11.4	3.4	44.8	674.8	2.73	
CV (%)		8.43	6.94	35.89	53.96	38.93	36.15	33.53	20.36	59.34	40.36	19.05	

The maximum inter-cluster distance of 79.156 was recorded between clusters III and VI (Table 4.11). Generally all the clusters were distantly related from cluster III. Cluster II and IV were very closely related with low inter-cluster distance of 4.955. High intra cluster distance was observed in cluster I (4.923) followed by cluster IV (4.524) and cluster V (4.405). Low intra cluster distance was noticed in cluster III (2.637).

4.3 Experiment III

Eight parents were selected from above screening experiments (Table 4.12). Parents were chosen based on distortion mosaic reaction and diverse nature. Eight parents (four resistant and four susceptible) were raised and crossed in half diallel fashion (8x8) which resulted in 28 hybrids.

4.4 Experiment IV

Twenty eight hybrids were evaluated along with eight parents. The analysis of variance indicated significant difference among genotypes for all the characters (Table 4.13). Lack of significant variability was registered for anthesis of male flower, number of male flowers, fruit girth and fruit weight in parents. Similarly variability was found to be insignificant for anthesis of male flower and fruit weight in crosses.

4.4.1 Variability

Phenotypic coefficient of variation (PCV) was low for anthesis of male (8.77) and female (10.18) flowers. Medium PCV values were recorded in fruit girth (14.55) and fruit weight (17.50). High PCV was recorded in fruit yield per plant (36.01) followed by number of fruits (32.88), number of male flowers (30.18), sex ratio (30.15), number of female flowers (29.32) and fruit length (21.72). Similar trend was noticed for genotypic coefficient of variation (GCV) with an exception of fruit girth and fruit weight (Table 4.14).

Low heritability values were recorded for fruit weight (25.5), anthesis of male flower (26.6) and fruit girth (28.3). Sex ratio (44.8) and anthesis of female flower

Table 4.11. Average intra and inter cluster D^2 (upper) and D (lower) values of 47 genotypes in bittergourd

Clusters	I	II	III	IV	V	VI
I	4.923 2.219					
II	8.427 2.903	3.932 1.983				
III	35.106 5.925	60.031 7.748	2.637 1.624			
IV	10.536 3.246	4.955 2.226	62.331 7.895	4.524 2.127		
V	11.783 3.433	15.681 3.96	27.499 5.244	14.853 3.854	4.405 2.099	
VI	13.198 3.633	6.101 2.47	79.156 8.897	8.851 2.975	33.223 5.764	3.655 1.912

Table 4.12. Characteristics of parents selected for half diallel analysis

Parents	Genotypes	Fruit colour	Anth. of male flower	Anth. of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Cluster
1	IC 68335	Light green	46.0	45.5	69.0	31.5	0.4565	28.5	11.3	4.5	61.9	1115.0	VI
2	IC 68263B	Green	41.5	46.0	72.0	30.0	0.4167	28.5	12.6	4.1	53.7	1317.5	VI
3	IC 68275	Dark green	45.0	46.5	80.0	25.0	0.3125	21.5	14.0	4.3	46.7	817.5	II
4	IC 68250A	Green	38.0	42.5	45.0	17.0	0.3778	15.0	6.6	3.3	68.7	745.5	*
5	Preethi	Light green	45.5	43.5	159.0	24.0	0.1509	21.5	12.0	3.8	59.0	855.0	**
6	VKV 134	Light green	50.5	57.0	93.0	18.5	0.1989	16.5	15.1	4.8	45.0	705.0	*
7	IC 45341	Green	46.0	47.5	105.0	12.5	0.1190	11.5	12.1	3.6	38.8	397.5	V
8	IC 68342 B	Dark green	41.0	42.5	41.0	18.0	0.4390	17.0	12.7	3.8	24.4	487.5	I

Note: Parents 1 to 4 – Resistant parents
Parents 5 to 8 – Susceptible parents
* Selected from unreplicated screening experiment
** Variety

Table 4.13. Analysis of variance for eleven characters in parents and hybrids

Source of variation	df	Mean sum of squares										
		Anthesis of male flower	Anthesis of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Coefficient of infection
Genotypes	35	15.65*	32.97*	51.74**	1483.91**	0.0071**	51.95**	12.95**	0.2820**	53.67*	83309.26**	870.64**
Parents	7	15.89	22.83*	61.10**	738.22	0.0111**	57.07**	22.27**	0.3070	33.30	91303.57**	2223.88**
Parents vs crosses	1	1.35	35.62	177.50**	875.65	0.0074	131.44**	1.43**	0.4446	309.38**	286200.62**	1218.99**
Crosses	27	16.12	35.31**	44.66**	1699.75**	0.0060*	47.68**	10.96**	0.3411*	49.48	73722.17**	506.90**
Error	35	9.06	10.62	6.55	36.14	0.0027	4.54	1.99	0.1571	31.82	4214.25	74.48

*, ** : Significant at 5%, 1% respectively

Table 4.14. Phenotypic and genotypic coefficients of variation, heritability and genetic gain parents and hybrids

Characters	Range	Mean	PCV (%)	GCV (%)	$h^2_{(bs)}$ (%)	Genetic gain (%)
Anthesis of male flower	36.7-48.7	40.13	8.77	4.53	26.60	4.82
Anthesis of female flower	39.5-45.0	45.72	10.18	7.23	51.20	10.61
Number of female flowers	8.7-33.2	19.44	29.32	25.84	77.40	47.75
Number of male flowers	47.0-144.5	93.40	30.18	29.44	84.10	52.30
Sex ratio	0.09-0.48	0.25	30.15	20.25	44.80	27.84
Number of fruits per plant	7.7-30.5	16.78	32.88	30.67	83.30	56.47
Fruit length (cm)	7.1-17.7	12.50	21.72	18.58	73.30	32.72
Fruit girth (cm)	2.4-4.1	3.26	14.55	7.88	28.30	8.45
Fruit weight (g)	29.5-54.4	38.69	17.50	8.17	25.50	9.20
Fruit yield per plant (g)	255.0-1120.0	617.38	36.01	34.90	90.10	66.83

172000

(51.2) registered medium heritability. Heritability estimates were high for fruit yield per plant (90.1), number of male flower (84.1), number of fruits (83.3), number of female flowers (77.4) and fruit length (73.3). All the traits exhibited high genetic gain except anthesis of male and female flowers, fruit girth and fruit weight. High genetic gain was recorded in fruit yield per plant (66.83) followed by number of fruits per plant (56.47).

4.4.2 Association of Characters

4.4.2.1 Correlation

Phenotypic correlation in parents and hybrids population revealed that, anthesis of male and female flowers had no relationship with yield and yield attributing traits (Table 4.15). High positive correlation was observed between number of female flowers and number of fruits (0.9684). Fruit yield per plant was positively associated with number of female flowers (0.8725), number of male flowers (0.3523), sex ratio (0.3868) and number of fruits per plant (0.9024).

High genetic correlation was recorded between number of female flowers and number of fruits (1.003). Sex ratio negatively associated with anthesis of male flower (-0.5751), anthesis of female flower (-0.5424) and number of male flowers (-0.411). However sex ratio was positively associated with number of female flowers (0.3906), number of fruits per plant (0.4118), fruit weight (0.6250) and fruit yield per plant (0.6206). Number of female flowers (0.9658), number of male flowers (0.4076), sex ratio (0.6206), number of fruits per plant (0.9525) and fruit weight (0.5237) were showing positive influence with fruit yield per plant. But anthesis of female flower registered negative correlation (-0.3596) with fruit yield per plant.

4.4.2.2 Direct and Indirect Effects

In parents and hybrids population, the high direct effect on fruit yield per plant was contributed by number of fruits per plant (5.071). Fruit weight (0.196), number of male flower (0.194) and sex ratio (0.152) also contributed small quantum of direct effect (Table 4.16). High indirect effects observed in number of female flowers

Table 4.15. Phenotypic and genotypic correlations for ten character in parents and hybrids

Traits	Anthesis of male flower	Anthesis of female flower	No. of female flower	No. of male flower	Sex ratio	No. of fruits per plant	Fruit length	Fruit girth	Fruit weight	Fruit yield per plant
Anthesis of male flower	**1.0000**	0.0572	-0.0515	-0.0752	0.0171	-0.0699	0.0220	-0.1305	-0.1618	-0.0207
Anth. of female fower	0.5695*	**1.0000**	-0.2693	0.0148	-0.3232	0.2613	0.1513	0.0358	-0.1067	-0.2185
No. of female flower	-0.3147	-0.4559**	**1.0000**	0.4578**	0.3967*	0.9684**	-0.1308	-0.0408	0.0347	0.8725**
No. of male flower	0.2460	-0.0702	0.6415*	**1.0000**	-0.5797**	0.4303**	0.0877	-0.1212	-0.0472	0.3523*
Sex ratio	-0.5751**	-0.5424**	0.3906*	-0.4110*	**1.0000**	0.3995*	-0.2309	-0.0101	0.0872	0.3868*
No. of fruits per plant	-0.3300*	-0.4306**	1.0003*	-0.6217**	0.4118**	**1.0000**	-0.1480	-0.0219	0.0637	0.9024**
Fruit length	0.4036*	0.3991*	-0.1336	-0.0319	-0.1943	-0.1620	**1.0000**	-0.0661	0.1539	0.0535
Fruit girth	-0.4081*	0.6247**	0.0864	-0.1564	-0.0059	-0.0582	-0.3262	**1.0000**	0.1129	-0.6857
Fruit weight	-0.1751	-0.2524	0.5294*	-0.1454	0.6250**	-0.5223**	0.1083	0.4411*	**1.0000**	-0.2489
Fruit yield per plant	-0.0902	-0.3596*	0.9658*	0.4076**	0.6206**	0.9525**	0.0557	0.0195	0.5237**	**1.0000**

Note : Upper diagonal in phenotypic correlation values, lower diagonal in genotypic correlation values
*, ** : Significant at 5%, 1% respectively

Table 4.16. Direct and indirect effects of yield attributes on fruit yield per plant in parents and hybrids population

Traits	Anthesis of female flower	No. of female flower	No. of male flower	Sex ratio	No. of fruits/ plant	Fruit weight
Anthesis of female flower	**-0.061**	0.028	0.004	0.034	0.026	0.016
No. of female flower	2.036	**-4.425**	-2.784	-1.795	-4.427	-2.338
No. of male flower	-0.014	0.122	**0.194**	-0.078	0.118	-0.031
Sex ratio	-0.084	0.062	-0.061	**0.152**	0.065	0.107
No. of fruits/ plant	-2.184	5.074	3.085	2.169	**5.071**	2.573
Fruit weight	-0.053	0.104	-0.031	0.138	0.100	**0.196**
Genetic correlation	-0.360	0.965	0.407	0.620	0.953	0.523

Residual = 0.1367

(5.074), number of male flowers (3.085), fruit weight (2.573) and sex ratio (2.169) *viz.*, number of fruits per plant.

4.4.3 Combining Ability

Analysis of variance for combining ability indicated that variance due to general combining ability (GCA) was significant for all traits. But specific combining ability (SCA) is significant for only seven characters (Table 4.17).

General combining ability effects for eleven characters are presented in Table 4.18. For early flowering the parent P_6 was found to be best general combiner for anthesis of male flower (-1.69) and anthesis of female flower (-1.54). The parent P_4 was the best general combiner for number of male flower (22.35) and number of female flowers (2.26). The best combiners for sex ratio are P_3 (0.03), P_6 (0.03) and P_8 (0.02).

The parents P_3, P_4 and P_6 were recorded as best general combiners for number of fruits and fruit yield per plant. Parents P_2 (1.61), P_4 (0.69), P_5 (0.7) and P_8 (1.99) recorded positive *gca* effects for fruit length. Only one parent exhibited positive significant *gca* effect for fruit girth (P_1 = 0.29) and fruit weight (P_8 = 3.68). For coefficient of infection, the parents P_1 (-6.53), P_2 (-8.82) and P_3 (-11.62) were recorded as best general combiners in terms of negative *gca* effect.

The specific combing ability effects (Table 4.19) indicated that, three crosses recorded as best combiners for anthesis of female flower with its *sca* effects *viz.*, P_2 x P_6 (-6.5), P_7 x P_8 (-5.43) and P_1 x P_8 (-4.48). The best combination of hybrids with significant *sca* effects for number of female flowers was observed in P_6 x P_8 (11.55), P_4 x P_5 (10.32) and P_2 x P_3 (6.30). Similarly, for number of male flowers P_4 x P_7 (66.47), P_5 x P_6 (36.04) and P_1 x P_4 (31.94) and for sex ratio P_3 x P_4 (0.16) and P_2 x P_6 (0.07) were found to be best combinations. The hybrids P_6 x P_8, P_4 x P_5 and P_2 x P_3 were noticed as best combinations for number of fruits and fruit yield per plant. Highest negative *sca* effects were recorded in P_4 x P_8 (-34.75), P_3 x P_8 (-22.01) and P_2 x P_7 (-21.39) for coefficient of infection.

Table 4.17. Analysis of variance for combining ability, GCA and SCA variances for eleven characters

Source of variation	df	Mean sum of squares										
		Anthesis of male flower	Anthesis of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Coefficient of infection
GCA	7	11.51*	16.07*	32.94**	1084.57**	0.0042*	40.82**	22.85**	0.2004*	42.72*	50669.81*	660.09**
SCA	28	6.90	16.59**	24.10**	656.29**	0.0030**	22.26**	2.38	0.1261	22.86	39400.83**	379.13**
Error(σ_e^2)	35	4.53	5.31	3.27	180.70	0.0013	2.27	0.99	0.0785	15.91	2107.12	37.24
σ_g^2		0.46	0.05	0.88	42.82	0.0001	1.85	2.04	0.0074	1.98	1126.89	28.09
σ_s^2		2.37	11.28	20.83	475.59	0.0017	19.99	1.39	0.0476	6.95	37293.71	341.89
SE (GCA)		0.60	0.91	1.76	56.99	0.0022	2.12	1.14	0.0110	2.22	803.13	34.52
SE (SCA)		2.13	4.61	6.48	180.64	0.0008	5.97	0.67	0.0380	7.19	755.54	101.71
Pr		0.28	0.01	0.08	0.15	0.12	0.16	0.75	0.24	0.36	0.06	0.14

Note: *, **: Significant at 5%, 1% respectively

SE (GCA) and SE (SCA) were calculated as per Comstock and Moll, 1963 (Dabholkar, 1999)

Predictability ratio (Pr): $2\sigma_g^2/(2\sigma_g^2 + \sigma_s^2)$- Baker (1978)

Table 4.18. General combining ability effects for eleven characters in eight parents

Parents	Anthesis of male flower	Antheis of female flower	No. of female flowers	No. of male flowers	Sex ratio	No. of fruits/ plant	Fruit length	Fruit girth	Fruit weight	Fruit yield/ plant	Coefficient of infection
Parent 1	-0.02	1.33	-1.54**	-4.60	-0.01	-1.67**	-2.05**	0.29**	-1.00	-95.81**	-6.53**
Parent 2	1.86**	2.08**	-1.42	-8.25*	0.01	-1.80**	1.61**	-0.17*	-2.03	-20.01	-8.82**
Parent 3	0.98	-0.42	0.43	-10.05*	0.03**	0.95*	-0.05	-0.01	0.06	80.32**	-11.62**
Parent 4	-0.42	-1.29	2.26**	22.35**	-0.01	2.53**	0.69*	-0.14	-0.53	80.27**	4.57*
Parent 5	-0.04	0.63	-0.27	5.60	-0.02*	-0.08	0.70*	0.08	2.30	0.44	-1.72
Parent 6	-1.69*	-1.54*	3.11**	0.55	0.03**	3.17**	-1.72**	0.01	-0.09	64.59**	5.47**
Parent 7	0.11	-0.72	-1.72**	-6.12	0.00	-1.98**	-1.17**	-0.01	-2.38	-92.28**	8.51**
Parent 8	-0.77	-0.07	-0.84	0.52	0.02*	-1.12*	1.99**	-0.03	3.68*	-17.53	9.53**
SEgi	**0.62**	**0.68**	**0.53**	**3.97**	**0.01**	**0.44**	**0.27**	**0.08**	**1.17**	**13.58**	**1.80**
SE(gi-gj)	**0.95**	**1.03**	**0.81**	**6.01**	**0.02**	**0.67**	**0.44**	**0.12**	**1.78**	**20.52**	**2.72**
CD 5%(gi)	**1.27**	**1.38**	**1.42**	**8.07**	**0.02**	**0.90**	**0.59**	**0.16**	**2.39**	**27.56**	**3.66**
CD 1%(gi)	**1.70**	**1.86**	**1.45**	**10.88**	**0.03**	**1.21**	**0.74**	**0.21**	**3.21**	**37.23**	**4.93**

*, ** : Significant at 5% and 1% respectively

Table 4.19. Specific combining ability effects for significant seven characters in bittergourd

Hybrids	Anthesis of female flower	Number of female flowers	Number of male flowers	Sex ratio	Number of fruits per plant	Fruit yield per plant	Coefficient of infection
$P_1 \times P_2$	9.37**	-2.22	-9.71	-0.01	-2.30	-103.39*	6.64
$P_1 \times P_3$	0.62	1.67	5.09	0.00	2.45	86.29*	17.99**
$P_1 \times P_4$	-1.00	0.60	31.94*	-0.05	0.62	110.09*	3.51
$P_1 \times P_5$	0.07	-2.88	-24.56	0.02	-1.78	-45.34	-7.85
$P_1 \times P_6$	3.25	-0.75	27.99*	-0.07*	0.78	-59.24	-0.07
$P_1 \times P_7$	-1.08	1.58	5.17	0.00	0.62	36.39	13.82*
$P_1 \times P_8$	-4.48*	3.70*	-6.73	0.06	3.02*	157.89**	-20.44**
$P_2 \times P_3$	0.87	6.30*	31.74*	0.00	5.82**	290.24**	0.23
$P_2 \times P_4$	-3.25	-0.03	0.09	-0.01	-0.75	-21.46	28.35*
$P_2 \times P_5$	1.57	4.00*	5.84	0.03	3.60*	170.36**	-3.16
$P_2 \times P_6$	-6.50**	-0.62	-24.11	0.07*	0.35	1.21	-12.35*
$P_2 \times P_7$	-2.58	3.95*	-5.68	0.06	5.25**	281.84**	-21.39**
$P_2 \times P_8$	-2.73	-1.17	25.42	-0.06	-2.60	-132.91**	12.21*
$P_3 \times P_4$	-3.28	-3.12	-57.86**	0.16**	-2.75	-54.79	18.25**
$P_3 \times P_5$	-0.93	-2.85	6.14	-0.04	-2.90*	-221.21**	-5.44
$P_3 \times P_6$	-2.75	-1.23	8.69	-0.04	-1.90	-189.11**	12.70*
$P_3 \times P_7$	7.42**	-5.40**	-11.13	-0.05	-4.25**	-147.24**	-20.99**
$P_3 \times P_8$	3.77	3.72*	7.22	0.02	3.40*	195.51**	-22.01**
$P_4 \times P_5$	-0.80	10.32**	13.49	0.06	11.27**	420.09**	10.35
$P_4 \times P_6$	0.62	-6.05**	-23.96	-0.04	-4.73**	-175.31**	23.86*
$P_4 \times P_7$	-0.70	4.78**	66.47**	-0.07*	4.42**	69.06	1.92
$P_4 \times P_8$	1.15	1.40	-5.18	0.01	0.57	31.81	-34.75**
$P_5 \times P_6$	0.95	2.72	36.04**	-0.04	1.87	22.01	15.89**
$P_5 \times P_7$	4.12	1.05	-0.53	0.01	-0.48	-8.61	-6.94
$P_5 \times P_8$	-2.53	-2.58	-21.43	0.02	-2.83*	-44.61	-7.76
$P_6 \times P_7$	-3.70	-6.32**	-26.23*	-0.02	-6.98**	-176.51**	-17.43**
$P_6 \times P_8$	-2.60	11.55**	25.87	0.04	11.42**	446.24**	-12.00*
$P_7 \times P_8$	-5.43*	1.38	-27.96*	0.10	0.57	9.36	-2.14
SE sij	**2.08**	**1.64**	**12.18**	**0.03**	1.36	**41.62**	**5.53**
SE (sij-ik)	**3.09**	**2.42**	**18.03**	**0.05**	**2.02**	**61.58**	**8.18**
SE (sij-skl)	**2.91**	**2.28**	**17.00**	**0.04**	**1.91**	**58.06**	**7.71**
CD 5% (sij)	**4.22**	**3.32**	**26.14**	**0.07**	**2.77**	**84.49**	**11.22**
CD 1% (sij)	**5.70**	**4.49**	**33.39**	**0.08**	**3.72**	**114.12**	**15.16**

*, ** : Significant at 5% and 1% respectively

The gene action based on variance (Table 4.17) indicated that, additive gene action was significant for fruit yield per plant (σ^2_g = 1126.89 ± 803.13) and fruit length (σ^2_g = 2.04 ± 1.14). The predominance of non-additive gene action in all the traits was evident from the significant SCA variance. None of the character approach to unity for predictability ratio (Pr), which revealed the less predictability of hybrid performance/combinations, based on general combining ability alone.

4.4.4 Heterosis

The mean performance of parents, hybrids and checks are presented in Table 4.20. The result indicated significance of mean performance of parents and hybrids for all the traits, except for anthesis of male and female flowers. Hybrid P_4 x P_5 recorded 31.75 female flower per plant, 30.50 fruits per plant and 1120.0 g of fruit yield per plant. Cross combination P_6 x P_8 yielded 30.25 fruits per plant and 1112.5 g of fruit yield per plant. Only one hybrid (P_5 x P_8) was recorded significantly high fruit weight (55.4 g). The cross combination *viz.*, P_4 x P_8, P_3 x P_8 and P_2 x P_5 were long fruited types with fruit length of 17.76, 17.45 and 16.55 cm respectively. Among hybrids fruit yield varied from 400.0 to 1120.0 g per plant with an average of 619.2 g per plant. The yield potential of highly resistant hybrids are 460.0 g (P_3 x P_7), 478.5 g (P_1 x P_5), 478.75 g (P_3 x P_5), 658.75 g (P_1 x P_8), 788.75 g (P_2 x P_7), 877.5 g (P_3 x P_8) and 969.75 g (P_2 x P_3). The mid-parent and better parent heterosis indicated that, both positive and negative heterosis were recorded for all the traits (Table 4.21). Standard heterosis in desirable direction was noticed in all the traits except for anthesis of male flower.

The range of standard/useful heterosis over the local check varieties (Priya and Priyanka) and a recently released hybrid from TNAU (COBGOH-1) for all the characters were concisely presented in Table 4.22. Among promising hybrids, the combinations *viz.*, P_4 x P_5, P_6 x P_8, P_2 x P_3 and P_3 x P_8 recorded high heterosis for fruit yield per plant. The hybrid (P_3 x P_8) expressed high heterosis for sex ratio and fruit length along with resistance to mosaic. In overall performance the hybrid P_4 x P_5 performed well for number of male and female flowers, number of fruits per plant, fruit girth and fruit yield per plant.

Table 4.20. Mean performance of parents and hybrids under natural epiphytotic conditions

Parents	AM	AF	NFF	NM	SR	NF	FL	FG	FW	FY	C	FC
P_1	45.00	45.00	15.50	71.00	0.2198	12.50	7.05	3.35	31.40	338.75	HR	G
P_2	41.75	51.50	11.50	61.50	0.2209	8.50	15.55*	3.16	30.85	336.25	HR	G
P_3	41.75	42.00	20.75	79.75	0.2692	18.75	11.48	3.21	39.00	800.00*	HR	G
P_4	38.75	46.75	20.00	127.00	0.1597	17.50	16.36*	3.08	35.15	590.00	HR	LG
P_5	37.50	45.75	14.00	98.50	0.1427	12.25	15.54*	3.04	36.38	473.75	MS	W
P_6	36.75	48.00	26.00*	83.75	0.3375*	23.50*	10.43	3.15	34.90	776.25*	S	G
P_7	37.50	45.25	15.50	82.50	0.1943	13.25	10.57	3.03	29.55	402.50	S	G
P_8	40.00	52.00	8.75	97.25	0.0918	7.75	15.00	2.95	41.25	255.00	HS	G
Hybrids												
$P_1 \times P_2$	38.25	58.50	14.25	72.25	0.2007	11.00	11.96	3.85	38.58	400.00	MS	G
$P_1 \times P_3$	38.50	47.25	20.00	85.25	0.2362	18.50	11.04	3.67	36.40	690.00	MS	G
$P_1 \times P_4$	39.00	44.75	20.75	144.50*	0.1458	18.25	10.51	3.11	42.80	713.75	MR	G
$P_1 \times P_5$	38.50	47.75	14.75	71.25	0.2070	13.25	10.79	3.46	43.95	478.50	HR	LG
$P_1 \times P_6$	38.00	48.75	20.25	118.75	0.1705	17.50	9.16	3.54	39.00	528.75	MR	G
$P_1 \times P_7$	39.00	45.25	17.75	89.25	0.1999	13.75	11.19	3.90	34.98	467.50	MS	G
$P_1 \times P_8$	39.75	42.50	20.75	84.00	0.2502	17.00	13.13	4.05*	39.70	658.75	HR	G
$P_2 \times P_3$	44.25	48.25	24.75*	108.25	0.2451	21.75*	14.33	3.14	37.95	969.75*	HR	G
$P_2 \times P_4$	40.50	43.25	20.25	109.00	0.2022	16.75	15.23	2.60	34.25	655.00	MS	G
$P_2 \times P_5$	48.75	50.00	21.75	98.00	0.2242	18.50	16.55*	2.91	41.85	770.00*	R	G
$P_2 \times P_6$	39.00	39.75	20.50	63.00	0.3273*	18.50	12.15	3.48	37.13	665.00	MR	G
$P_2 \times P_7$	43.00	44.50	20.25	74.75	0.2798	18.25	11.91	2.86	38.88	788.75*	HR	G
$P_2 \times P_8$	42.50	45.00	16.00	112.50	0.1503	11.25	15.19	2.44	37.53	408.75	MS	G

Cont...

Table 4.20. Continued

Hybrids	AM	AF	NFF	NM	SR	NF	FL	FG	FW	FY	C	FC
P_3 x P_4	40.50	40.75	19.00	49.25	0.3865*	17.50	10.26	2.62	45.10	740.00	MS	G
P_3 x P_5	43.00	45.00	16.75	96.50	0.1743	14.75	12.39	3.24	35.05	478.75	HR	G
P_3 x P_6	38.50	41.00	21.75	94.00	0.2350	19.00	10.52	3.27	35.60	575.00	MS	G
P_3 x P_7	46.00	52.00	12.75	67.50	0.1900	11.50	12.90	3.75	41.25	460.00	HR	G
P_3 x P_8	36.75	49.00	22.75	47.00	0.4840*	20.00	17.45*	3.20	39.40	877.50*	HR	G
P_4 x P_5	38.25	44.25	31.75*	136.25*	0.2407	30.50*	12.06	3.79	44.23	1120.00*	MS	LG
P_4 x P_6	37.25	43.50	18.75	93.75	0.2033	17.75	11.42	3.17	38.35	588.75	S	G
P_4 x P_7	42.50	43.00	24.75*	177.50	0.1392	21.75*	9.86	2.97	30.65	676.25	MS	G
P_4 x P_8	41.50	45.50	22.25	112.50	0.1973	18.75	17.76*	3.65	37.25	713.75	R	G
P_5 x P_6	40.25	45.75	25.00	137.00*	0.1831	21.75*	10.68	3.13	44.03	706.25	MR	G
P_5 x P_7	39.50	49.75	18.50	93.75	0.2018	14.25	10.48	3.26	34.90	518.75	MS	G
P_5 x P_8	37.50	43.75	15.75	79.50	0.1979	12.75	15.28	3.80	54.40*	557.50	MS	G
P_6 x P_7	39.75	39.75	14.50	63.00	0.2318	11.00	9.80	3.30	36.90	415.00	MS	G
P_6 x P_8	38.00	41.50	33.25*	121.75	0.2730	30.25*	10.60	2.95	46.50	1112.50*	MS	G
P_7 x P_8	37.50	39.50	18.25	61.25	0.2975	14.25	13.41	3.18	47.70	518.75	MS	G
Mean	**40.13**	**45.71**	**19.43**	**94.81**	**0.2172**	**16.77**	**12.48**	**3.26**	**38.68**	**619.20**		
SE	3.01	3.25	2.56	19.01	0.0530	2.13	1.41	0.40	5.64	64.91		
CD(5%)	6.11	6.59	5.19	38.59	0.1075	4.32	2.86	0.80	11.44	131.76		
Check												
Priya	40.00	41.50	24.00	88.25	0.2702	21.25	14.40	2.60	30.80	617.50	S	LG
Priyanka	45.75	52.00	17.00	113.00	0.1526	14.00	15.65	5.95	41.25	565.00	S	W
CoBGoH 1	39.75	39.50	27.75	98.50	0.2969	22.25	13.98	3.70	47.65	857.50	MR	LG
Mean	**41.83**	**44.33**	**22.92**	**99.92**	**0.2399**	**19.17**	**14.68**	**4.08**	**39.90**	**680.00**		

Note: AM- Anthesis of male flower, AF- Anthesis of female flower, NM- Number of male flower, NFF- Number of female flower, SR- Sex ratio, NF- Number of fruits per plant, FL- Fruit length, FG- Fruit girth, FW- Fruit weight, FY- Fruit yield per plant, C- Category, FC- fruit colour.

Table 4.21. Percentage of mid-parent, better parent, standard heterosis for 28 hybrids in bittergourd

Sl. No.	Hybrids	Anthesis of male flower					Anthesis of female flower				
		MPH	BPH	SH (1)	SH (2)	SH (3)	MPH	BPH	SH (1)	SH (2)	SH (3)
1	$P_1 \times P_2$	-11.82	-15.00	31.9	27.5	23.39	21.24	13.59	40.96	12.50	48.10
2	$P_1 \times P_3$	-11.24	-14.44	32.76	28.33	24.19	8.62	5.00	13.86	-9.135	19.62
3	$P_1 \times P_4$	-6.87	-13.33	34.48	30	25.81	-2.45	-4.28	7.831	-13.94	13.29
4	$P_1 \times P_5$	-6.67	-14.44	32.76	28.33	24.19	5.23	4.37	15.06	-8.173	20.89
5	$P_1 \times P_6$	-7.03	-15.56	31.03	26.67	22.58	4.84	1.56	17.47	-6.25	23.42
6	$P_1 \times P_7$	-5.45	-13.33	34.48	30	25.81	0.28	0.00	9.036	-12.98	14.56
7	$P_1 \times P_8$	-6.47	-11.67	37.07	32.5	28.23	-12.37	18.27	2.41	-18.27	7.595
8	$P_2 \times P_3$	5.99	5.99	52.59	47.5	42.74	3.21	-6.31	16.27	-7.212	22.15
9	$P_2 \times P_4$	0.62	-2.99	39.66	35	30.65	-11.96	16.02	4.217	-16.83	9.494
10	$P_2 \times P_5$	23.03	16.77	68.1	62.5	57.26	2.83	-2.91	20.48	-3.846	26.58
11	$P_2 \times P_6$	-0.64	-6.59	34.48	30	25.81	-20.10	-22.82	-4.217	-23.56	0.633
12	$P_2 \times P_7$	8.52	2.99	48.28	43.33	38.71	-8.01	-13.59	7.229	-14.42	12.66
13	$P_2 \times P_8$	3.98	1.80	46.55	41.67	37.1	-13.04	-13.46	8.434	-13.46	13.92
14	$P_3 \times P_4$	0.62	-2.99	39.66	35	30.65	-8.17	-12.83	-1.807	-21.63	3.165
15	$P_3 \times P_5$	8.52	2.99	48.28	43.33	38.71	2.56	-1.64	8.434	-13.46	13.92
16	$P_3 \times P_6$	-1.91	-7.78	32.76	28.33	24.19	-8.89	-14.58	-1.205	-21.15	3.797
17	$P_3 \times P_7$	16.09	10.18	58.62	53.33	48.39	19.20	14.92	25.3	0	31.65
18	$P_3 \times P_8$	-10.09	-11.98	26.72	22.5	18.55	4.26	-5.77	18.07	-5.769	24.05
19	$P_4 \times P_5$	0.33	-1.29	31.9	27.5	23.39	-4.32	-5.35	6.627	-14.9	12.03
20	$P_4 \times P_6$	-1.32	-3.87	28.45	24.17	20.16	-8.18	-9.38	4.819	-16.35	10.13
21	$P_4 \times P_7$	11.48	9.68	46.55	41.67	37.1	-6.52	-8.02	3.614	-17.31	8.861
22	$P_4 \times P_8$	5.40	3.75	43.1	38.33	33.87	-7.85	-12.50	9.639	-12.5	15.19
23	$P_5 \times P_6$	8.42	7.33	38.79	34.17	29.84	-2.40	-4.69	10.24	-12.02	15.82
24	$P_5 \times P_7$	5.33	5.33	36.21	31.67	27.42	9.34	8.74	19.88	-4.327	25.95
25	$P_5 \times P_8$	-3.23	-6.25	29.31	25	20.97	-10.49	15.87	5.422	-15.87	10.76
26	$P_6 \times P_7$	7.07	6.00	37.07	32.5	28.23	-14.75	-17.19	-4.217	-23.56	0.633
27	$P_6 \times P_8$	-0.98	-5.00	31.03	26.67	22.58	-17.00	-20.19	0	-20.19	5.063
28	$P_7 \times P_8$	-3.23	-6.25	29.31	25	20.97	18.77	-24.04	-4.819	-24.04	0

Note: MPH- Mid-parent heterosis, BPH- Better parent heterosis
SH (1)- Standard heterosis over Priya
SH (2)- Standard heterosis over Priyanka
SH (3)- Standard heterosis over COBGOH 1

Cont.....

Table 4.21 Contomued

Sl. No.	Hybrids	Number of female flowers					Number of male flowers				
		MPH	BPH	SH (1)	SH (2)	SH (3)	MPH	BPH	SH (1)	SH (2)	SH (3)
1	$P_1 \times P_2$	5.56	-8.06	-40.63	-16.18	-48.65	5.09	1.76	-18.13	-36.06	-26.65
2	$P_1 \times P_3$	10.34	-3.61	-16.67	17.65	-27.93	13.10	6.90	-3.399	-24.56	-13.45
3	$P_1 \times P_4$	16.90	3.75	-13.54	22.06	-25.23	45.96	13.78	63.739	27.88	46.7
4	$P_1 \times P_5$	0.00	-4.84	-38.54	-13.24	-46.85	-15.96	-27.66	-19.26	-36.95	-27.66
5	$P_1 \times P_6$	-2.41	-22.12	-15.63	19.12	-27.03	53.47	41.79	34.561	5.088	20.56
6	$P_1 \times P_7$	14.51	14.52	-26.04	4.412	-36.04	16.29	8.18	1.1331	-21.02	-9.391
7	$P_1 \times P_8$	71.13	33.87	-13.54	22.06	-25.23	-0.15	-13.62	-4.816	-25.66	-14.72
8	$P_2 \times P_3$	53.49	19.28	3.125	45.59	-10.81	48.03	35.74	22.663	-4.204	9.898
9	$P_2 \times P_4$	28.57	1.25	-15.63	19.12	-27.03	12.66	-14.17	23.513	-3.54	10.66
10	$P_2 \times P_5$	70.59	55.36	-9.375	27.94	-21.62	18.79	-0.51	11.048	-13.27	-0.508
11	$P_2 \times P_6$	9.33	-21.15	-14.58	20.59	-26.13	-16.14	-24.78	-28.61	-44.25	-36.04
12	$P_2 \times P_7$	50.00	30.65	-15.63	19.12	-27.03	0.34	-9.39	-15.3	-33.85	-24.11
13	$P_2 \times P_8$	58.02	39.13	-33.33	-5.882	-42.34	37.40	15.68	27.479	-0.442	14.21
14	$P_3 \times P_4$	-6.75	-8.43	-20.83	11.76	-31.53	-52.36	-61.22	-44.19	-56.42	-50
15	$P_3 \times P_5$	-3.60	-19.28	-30.21	-1.471	-39.64	8.27	-2.03	9.3484	-14.6	-2.03
16	$P_3 \times P_6$	-6.95	-16.35	-9.375	27.94	-21.62	14.98	-2.03	6.5156	-16.81	-4.569
17	$P_3 \times P_7$	-29.66	-38.55	-46.88	-25	-54.05	-16.80	-18.18	-23.51	-40.27	-31.47
18	$P_3 \times P_8$	54.24	9.64	-5.208	33.82	-18.02	4.52	-4.88	-46.74	-58.41	-52.28
19	$P_4 \times P_5$	86.76	58.75	32.29	86.76	14.41	20.84	7.28	54.391	20.58	38.32
20	$P_4 \times P_6$	-18.48	-27.88	-21.88	10.29	-32.43	-11.03	-26.18	6.2323	-17.04	-4.822
21	$P_4 \times P_7$	39.44	23.75	3.125	45.59	-10.81	69.45	39.76	101.13	57.08	80.2
22	$P_4 \times P_8$	54.78	11.25	-7.292	30.88	-19.82	0.33	-11.42	27.479	-0.442	14.21
23	$P_5 \times P_6$	25.00	-3.85	4.167	47.06	-9.91	50.34	39.09	55.241	21.24	39.09
24	$P_5 \times P_7$	25.42	19.35	-22.92	8.824	-33.33	3.59	-4.82	6.2323	-17.04	-4.822
25	$P_5 \times P_8$	38.46	12.50	-34.38	-7.353	-43.24	-18.77	-19.29	-9.915	-29.65	-19.29
26	$P_6 \times P_7$	-30.12	-44.23	-39.58	-14.71	-47.75	-24.21	-24.78	-28.61	-44.25	-36.04
27	$P_6 \times P_8$	91.37	27.88	38.54	95.59	19.82	34.53	25.19	37.96	7.743	23.6
28	$P_7 \times P_8$	50.52	17.74	-23.96	7.353	-34.23	-31.85	-37.02	-30.59	-45.8	-37.82

Note: MPH- Mid-parent heterosis, BPH- Better parent heterosis
SH (1)- Standard heterosis over Priya
SH (2)- Standard heterosis over Priyanka
SH (3)- Standard heterosis over COBGOH 1

Cont.....

Table 4.21 Continued

Sl. No.	Hybrids	Sex ratio					Number of fruits per plant				
		MPH	BPH	SH (1)	SH (2)	SH (3)	MPH	BPH	SH (1)	SH (2)	SH (3)
1	P_1 x P_2	-1.92	-8.71	-25.68	33.769	-33.12	4.76	-12.00	-48.24	-21.43	-50.56
2	P_1 x P_3	1.21	-4.59	-12.51	57.482	-21.26	18.46	-1.33	-12.94	32.143	-16.85
3	P_1 x P_4	-23.18	-33.67	-46.01	-2.809	-51.4	21.67	4.29	-14.12	30.357	-17.98
4	P_1 x P_5	14.23	-5.82	-23.33	38.013	-30.99	7.07	6.00	-37.65	-5.357	-40.45
5	P_1 x P_6	-39.03	-49.77	-36.86	13.644	-43.18	-2.78	-25.53	-17.65	25	-21.35
6	P_1 x P_7	-3.55	-9.06	-25.97	33.26	-33.37	6.80	3.77	-35.29	-1.786	-38.2
7	P_1 x P_8	60.61	13.83	-7.328	66.809	-16.6	67.90	36.00	-20	21.429	-23.6
8	P_2 x P_3	12.05	-1.25	-9.204	63.433	-18.28	59.63	16.00	2.353	55.357	-2.247
9	P_2 x P_4	15.85	6.79	-25.11	34.806	-32.6	28.85	-4.29	-21.18	19.643	-24.72
10	P_2 x P_5	35.10	18.44	-16.95	49.493	-25.25	78.31	51.02	-12.94	32.143	-16.85
11	P_2 x P_6	23.79	-3.58	21.212	118.18	9.0909	15.62	-21.28	-12.94	32.143	-16.85
12	P_2 x P_7	45.70	43.69	3.6125	86.502	-6.749	67.82	37.74	-14.12	30.357	-17.98
13	P_2 x P_8	6.96	20.60	-44.33	0.2129	-49.89	38.46	32.35	-47.06	-19.64	-49.44
14	P_3 x P_4	89.48	55.70	43.146	157.66	28.832	-3.45	-6.67	-17.65	25	-21.35
15	P_3 x P_5	-10.77	29.75	-35.43	16.232	-41.88	-4.84	-21.33	-30.59	5.3571	-33.71
16	P_3 x P_6	-20.01	-30.75	-12.95	56.682	-21.66	-10.06	-19.15	-10.59	35.714	-14.61
17	P_3 x P_7	-14.19	-23.45	-29.63	26.667	-36.67	-28.12	-38.67	-45.88	-17.86	-48.31
18	P_3 x P_8	45.76	-0.18	77.77	220.00	60.00	50.94	6.67	-5.882	42.857	-10.11
19	P_4 x P_5	59.25	50.72	-10.84	60.487	-19.76	105.04	74.29	43.53	117.86	37.08
20	P_4 x P_6	-18.53	-40.09	-24.7	35.537	-32.23	-13.41	-24.47	-16.47	26.786	-20.22
21	P_4 x P_7	-24.28	-31.08	-48.46	-7.227	-53.61	41.46	24.29	2.353	55.357	-2.247
22	P_4 x P_8	56.93	23.54	-26.92	31.544	-34.23	48.51	7.14	-11.76	33.929	-15.73
23	P_5 x P_6	-24.04	-46.06	-32.18	22.084	-38.96	21.68	-7.45	2.353	55.357	-2.247
24	P_5 x P_7	19.64	3.65	-25.26	34.53	-32.74	11.76	7.55	-32.94	1.7857	-35.96
25	P_5 x P_8	68.89	38.78	-26.69	31.962	-34.02	27.50	4.08	-40	-8.929	-42.7
26	P_6 x P_7	-13.20	-31.71	-14.15	54.538	-22.73	-40.14	-53.19	-48.24	-21.43	-50.56
27	P_6 x P_8	26.58	-19.60	1.1068	81.992	-9.004	93.60	28.72	42.35	116.07	35.96
28	P_7 x P_8	107.72	52.81	10.194	98.35	-0.825	35.71	7.55	-32.94	1.7857	-35.96

Note: MPH- Mid-parent heterosis, BPH- Better parent heterosis
SH (1)- Standard heterosis over Priya
SH (2)- Standard heterosis over Priyanka
SH (3)- Standard heterosis over COBGOH 1

Cont.....

Table 4.21 Continued

Sl. No.	Hybrids	Fruit length					Fruit girth				
		MPH	BPH	SH (1)	SH (2)	SH (3)	MPH	BPH	SH (1)	SH (2)	SH (3)
1	$P_1 \times P_2$	5.84	-23.09	-16.94	-23.58	-14.45	18.28	14.93	48.08	-35.29	4.054
2	$P_1 \times P_3$	19.16	-3.83	-23.33	-29.46	-21.03	11.98	9.55	41.15	-38.32	-0.811
3	$P_1 \times P_4$	-10.21	-35.76	-27.01	-32.84	-24.82	-3.27	-7.16	19.62	-47.73	-15.95
4	$P_1 \times P_5$	-4.47	-30.57	-25.07	-31.05	-22.82	8.29	3.28	33.08	-41.85	-6.486
5	$P_1 \times P_6$	4.81	12.18	-36.39	-41.47	-34.48	8.92	5.67	36.15	-40.5	-4.324
6	$P_1 \times P_7$	27.01	5.87	-22.29	-28.5	-19.96	22.26	16.42	50	-34.45	5.405
7	$P_1 \times P_8$	19.09	-12.47	-8.819	-16.1	-6.08	28.57	20.90	55.77	-31.93	9.459
8	$P_2 \times P_3$	6.03	-7.85	-0.486	-8.435	2.504	-1.34	-2.03	20.77	-47.23	-15.14
9	$P_2 \times P_4$	-4.54	-6.91	5.764	-2.684	8.941	-16.67	-17.72	0	-56.3	-29.73
10	$P_2 \times P_5$	6.47	6.43	14.93	5.751	18.38	-3.23	-5.06	11.92	-51.09	-21.35
11	$P_2 \times P_6$	-6.47	-21.86	-15.63	-22.36	-13.09	10.14	9.97	33.65	-41.6	-6.081
12	$P_2 \times P_7$	-8.81	-23.41	-17.29	-23.9	-14.81	-7.59	-9.49	10	-51.93	-22.7
13	$P_2 \times P_8$	-0.56	-2.32	5.486	-2.939	8.655	-20.29	-22.94	-6.346	-59.08	-34.19
14	$P_3 \times P_4$	-26.29	-37.29	-28.75	-34.44	-26.61	-16.63	-18.25	0.769	-55.97	-29.19
15	$P_3 \times P_5$	-8.29	-20.27	-13.96	-20.83	-11.37	3.76	1.09	24.62	-45.55	-12.43
16	$P_3 \times P_6$	-3.97	-8.36	-26.94	-32.78	-24.75	2.91	2.03	25.77	-45.04	-11.62
17	$P_3 \times P_7$	17.01	12.37	-10.42	-17.57	-7.725	20.29	17.00	44.23	-36.97	1.351
18	$P_3 \times P_8$	31.80	16.33	21.18	11.5	24.82	3.98	-0.16	23.08	-46.22	-13.51
19	$P_4 \times P_5$	-24.39	-26.28	-16.25	-22.94	-13.73	23.86	23.05	45.77	-36.3	2.432
20	$P_4 \times P_6$	-14.74	-30.20	-20.69	-27.03	-18.31	1.77	0.63	21.92	-46.72	-14.32
21	$P_4 \times P_7$	-26.77	-39.73	-31.53	-37	-29.47	-2.78	-3.57	14.23	-50.08	-19.73
22	$P_4 \times P_8$	9.60	5.04	23.33	13.48	27.04	17.74	15.26	40.38	-38.66	-1.351
23	$P_5 \times P_6$	-17.75	-31.27	-25.83	-31.76	-23.61	14.05	12.06	20.38	-47.39	-15.41
24	$P_5 \times P_7$	-19.72	-32.56	-27.22	-33.04	-25.04	7.41	7.24	25.38	-45.21	-11.89
25	$P_5 \times P_8$	0.07	-1.67	6.111	-2.364	9.299	26.88	25.00	46.15	-36.13	2.703
26	$P_6 \times P_7$	-6.67	-7.28	-31.94	-37.38	-29.9	6.80	4.76	26.92	-44.54	-10.81
27	$P_6 \times P_8$	-16.63	-29.33	-26.39	-32.27	-24.18	-3.28	-6.35	13.46	-50.42	-20.27
28	$P_7 \times P_8$	4.89	-10.60	-6.875	-14.31	-4.077	6.35	4.95	22.31	-46.55	-14.05

Note: MPH- Mid-parent heterosis, BPH- Better parent heterosis
SH (1)- Standard heterosis over Priya
SH (2)- Standard heterosis over Priyanka
SH (3)- Standard heterosis over COBGOH 1

Cont.....

Table 4.21 Continued

Sl. No.	Hybrids	Fruit weight					Fruit yield per plant				
		MPH	BPH	SH (1)	SH (2)	SH (3)	MPH	BPH	SH (1)	SH (2)	SH (3)
1	$P_1 \times P_2$	23.94	22.85	25.24	-6.485	-19.05	18.52	18.08	-35.22	-29.2	-0.53
2	$P_1 \times P_3$	3.41	-6.67	18.18	-11.76	-23.61	21.19	-13.75	11.74	22.12	-0.20
3	$P_1 \times P_4$	28.63	21.76	38.96	3.758	-10.18	53.70	20.97	15.59	26.33	-0.17
4	$P_1 \times P_5$	29.69	20.82	42.69	6.545	-7.765	17.78	1.00	-22.51	-15.31	-0.44
5	$P_1 \times P_6$	17.65	11.75	26.62	-5.455	-18.15	-8.24	-35.07	-14.37	-6.416	-0.38
6	$P_1 \times P_7$	14.77	11.39	13.56	-15.21	-26.6	26.14	16.15	-24.29	-17.26	-0.45
7	$P_1 \times P_8$	9.29	-3.76	28.9	-3.758	-16.68	121.89	94.46	6.68	16.59	-0.23
8	$P_2 \times P_3$	8.66	-2.69	23.21	-8	-20.36	70.69	21.22	57.04	71.64	0.13
9	$P_2 \times P_4$	3.79	-2.56	11.2	-16.97	-28.12	42.08	11.53	6.073	15.93	-0.24
10	$P_2 \times P_5$	24.51	15.05	35.88	1.455	-12.17	90.12	62.53	24.7	36.28	-0.10
11	$P_2 \times P_6$	12.93	6.38	20.54	-10	-22.09	15.65	-18.28	7.692	17.7	-0.22
12	$P_2 \times P_7$	28.73	26.01	26.22	-5.758	-18.42	113.54	95.96	27.73	39.6	-0.08
13	$P_2 \times P_8$	4.09	-9.03	21.83	-9.03	-21.25	51.80	33.46	-33.81	-27.65	-0.52
14	$P_3 \times P_4$	21.65	15.64	46.43	9.333	-5.352	4.32	-9.38	19.84	30.97	-0.14
15	$P_3 \times P_5$	-7.00	-10.13	13.8	-15.03	-26.44	-24.83	-40.16	-22.47	-15.27	-0.44
16	$P_3 \times P_6$	-3.65	-8.72	15.58	-13.7	-25.29	-28.74	-29.34	-6.883	1.77	-0.33
17	$P_3 \times P_7$	20.35	5.77	33.93	0	-13.43	-23.49	-42.50	-25.51	-18.58	-0.46
18	$P_3 \times P_8$	-1.84	-4.48	27.92	-4.485	-17.31	66.35	9.69	42.11	55.31	0.02
19	$P_4 \times P_5$	23.66	21.58	43.59	7.212	-7.188	110.53	89.83	81.38	98.23	0.31
20	$P_4 \times P_6$	9.49	9.10	24.51	-7.03	-19.52	-16.12	-27.65	-4.656	4.204	-0.31
21	$P_4 \times P_7$	-5.26	-12.80	-0.487	-25.7	-35.68	36.27	14.62	9.514	19.69	-0.21
22	$P_4 \times P_8$	-2.49	-9.70	20.94	-9.697	-21.83	68.93	20.97	15.59	26.33	-0.17
23	$P_5 \times P_6$	23.54	21.03	42.94	6.727	-7.608	9.71	-13.21	14.37	25	-0.18
24	$P_5 \times P_7$	5.88	-4.05	13.31	-15.39	-26.76	18.40	9.50	-15.99	-8.186	-0.40
25	$P_5 \times P_8$	40.16	31.88	76.62	31.88	14.17	53.00	17.68	-9.717	-1.327	-0.35
26	$P_6 \times P_7$	14.51	5.23	19.81	-10.55	-22.56	-31.76	-49.00	-32.79	-26.55	-0.52
27	$P_6 \times P_8$	22.13	12.73	50.97	12.73	-2.413	108.19	36.71	80.16	96.9	0.30
28	$P_7 \times P_8$	34.75	15.64	54.87	15.64	0.105	57.79	28.88	-15.99	-8.186	-0.40

Note: MPH- Mid-parent heterosis, BPH- Better parent heterosis
SH (1)- Standard heterosis over Priya
SH (2)- Standard heterosis over Priyanka
SH (3)- Standard heterosis over COBGOH 1

Table 4.22. Range of standard heterosis and promising hybrids in bittergourd

Characters	Range of standard heterosis over checks (%)			Promising hybrids over check(s)
	Priya	Priyanka	COBGOH 1	
Anthesis of male flower	26.72 (P_3xP_8) to 68.10 (P_2xP_5)	22.50 (P_3xP_8) to 62.50 (P_2xP_5)	20.16 (P_4xP_6) to 57.26 (P_2xP_5)	Nil
Anthesis of female flower	-4.82(P_7xP_8) to 40.96 (P_1xP_2)	-24.04 (P_7xP_8) to 12.50 (P_1xP_2)	0.00 (P_7xP_8) to 48.10(P_1xP_2)	P_7xP_8, P_2xP_6, P_6xP_7, P_6xP_8
Number of female flowers	-46.88 (P_3xP_7) to 38.54 (P_6xP_8)	-25.00 (P_3xP_7) to 95.59 (P_6xP_8)	-54.05 (P_3xP_7) to 19.82 (P_6xP_8)	P_6xP_8, P_4xP_5, P_5xP_6, **P_2xP_3**
Number of male flowers	-46.74 (P_3xP_8) to 101.13 (P_4xP_7)	-58.41 (P_3xP_8) to 57.08 (P_4xP_7)	-52.28 (P_3xP_8) to 80.20 (P_4xP_7)	P_4xP_7, P_1xP_4, P_5xP_6, P_4xP_5
Sex ratio	-46.01 (P_1xP_4) to 375.53 (P_3xP_8)	-7.23 (P_4xP_7) to 755.95 (P_3xP_8)	-53.61 (P_4xP_7) to 327.98 (P_3xP_8)	**P_3xP_8**, P_3xP_4, P_2xP_6, P_7xP_8
Number of fruits per plant	-48.24 (P_6xP_7/ P_1xP_2) to 43.53 (P_4xP_5)	-21.43 (P_6xP_7/ P_1xP_2) to 117.86 (P_4xP_5)	-50.50 (P_6xP_7/ P_1xP_2) to 37.08 (P_4xP_5)	P_4xP_5, P_6xP_8, P_5xP_6, P_4xP_7
Fruit length	-36.39 (P_1xP_6) to 23.33 (P_4xP_8)	-37.38 (P_6xP_7) to 13.48 (P_4xP_8)	-34.48 (P_1xP_6) to 18.38 (P_2xP_5)	**P_4xP_8, P_3xP_8, P_2xP_5**
Fruit girth	-6.35 (P_2xP_8) to 55.77 (P_1xP_8)	-59.08 (P_2xP_8) to 31.93 (P_1xP_8)	-34.19 (P_2xP_8) to 9.46 (P_1xP_8)	P_1xP_8, P_1xP_7, P_5xP_8, P_4xP_5
Fruit weight	-0.49 (P_4xP_7) to 76.62 (P_5xP_8)	-25.70 (P_4xP_7) to 31.88 (P_5xP_8)	-35.68 (P_4xP_7) to 14.17 (P_5xP_8)	P_5xP_8, P_7xP_8, P_6xP_8, **P_3xP_4**
Fruit yield per plant	-35.22 (P_1xP_2) to 81.38 (P_4xP_5)	-29.20 (P_1xP_2) to 98.23 (P_4xP_5)	0.53 (P_1xP_2) to 0.31 (P_4xP_5)	P_4xP_5, P_6xP_8, **P_2xP_3**, **P_3xP_8**

Note: Hybrids in bold are resistant to BDMV

4.5 Experiment V

4.5.1 Gene Action

To study the gene action of BDMV resistance, it is essential to have cross between resistant *versus* susceptible cross and their segregating generations. So, the two crosses namely cross 1 (P_1 x P_5) and cross 2 (P_4 x P_8) were selected and used for this study. Gene action of different traits obtained through six parameter model is presented in Table 4.23a and b. The result indicated adequacy of three parameters (m, d, h) model for all the traits, except number of fruits per plant, fruit yield per plant and coefficient of infection.

Additive and dominance effects for anthesis of male flowers were found to be negative in both the crosses. High dominance effect was noticed for anthesis of female flower (14.85) in cross 1. The dominance effect for number of female flower was found to be negative (-22.71) in cross 2. Positive dominance gene action (18.42) was registered for fruit weight in cross 1.

Number of fruits per plant in high dominance (-22.78) and dominance x dominance interaction (36.43) were recorded in cross 2. Both additive (112.40) and dominance (316.61) effects were found to be important for fruit yield per plant in cross 1. But these effects were negative in cross 2 and dominance x dominance interaction was high (794.80). Negative additive (-10.31) and positive dominance effects (10.34) were recorded for coefficient of infection in cross 1. The interaction effects for this trait were found to be significant in both the crosses. High negative dominance x dominance interaction was noticed in cross 1 (-138.13) and cross 2 (-76.06).

The BDMV reactions of segregating generation indicated that, the gene action of resistance does not fit with perfect digenic interactions (Table 4.24). The segregating generations from two crosses revealed the possibility of getting high yielding types with resistance to distortion mosaic from resistant x susceptible crosses.

Table 4.23a. Gene action for eight characters in two crosses

Characters	Cross	(m) Mean	(d) Additive	(h) Dominance	Scaling test
Anthesis of male flower	Cross 1	39.31	-0.09	-8.31	NS
	Cross 2	36.66	-0.46	-7.25	NS
Anthesis of female flower	Cross 1	43.56	0.23	14.85	NS
	Cross 2	43.50	2.08	-3.53	NS
Number of female flowers	Cross 1	16.21	2.66	7.73	NS
	Cross 2	20.96	-4.36	-22.71	NS
Number of male flowers	Cross 1	119.53	18.56	43.03	NS
	Cross 2	114.76	-26.66	-62.91	NS
Sex ratio	Cross 1	0.12	0.009	0.10	NS
	Cross 2	0.19	-0.004	-0.17	NS
Fruit length	Cross 1	8.01	-0.65	-0.33	NS
	Cross 2	9.32	0.75	5.94	NS
Fruit girth	Cross 1	3.59	0.10	0.81	NS
	Cross 2	3.86	0.02	-1.22	NS
Fruit weight	Cross 1	28.24	3.15	18.42	NS
	Cross 2	34.58	2.18	-7.12	NS

Table 4.23b. Gene action for interacting characters in two crosses

Traits	Cross	(m)	(d)	(h)	(i)	(j)	(l)	Epistasis
No. of fruits per plant	Cross 1	12.90	3.13	3.46	-	-	-	-
	Cross 2	18.18	-4.00	-22.78	-25.13	-7.75	36.43	D
Fruit yield per plant	Cross 1	384.80	112.40	316.61	-	-	-	-
	Cross 2	579.83	-118.50	-582.06	-627.66	-287.40	794.80	D
Coefficient of infection	Cross 1	41.52	-10.31	10.34	36.18	25.01	-138.13	D
	Cross 2	30.71	-5.70	-3.95	32.16	37.26	-76.06	C

Note: m – mean, (d)- additive, (h)- dominance, (i)- additive x additive
(j)- additive x dominance, (l)- dominance x dominance
D- Duplicate, C- complimentary
Cross 1- IC 68335 x Preethi (P_1 x P_5)
Cross 2- IC 68250 A x IC 68342 B (P_4 x P_8)

Table 4.24. BDMV reactions in different generations of two crosses and the best segregants

Cross/ goveration	BDMV reaction						Best segerants*
	HR	R	MR	MS	S	HS	
Cross 1							
P1	10	-	-	-	-	-	
P2	-	-	-	-	3	7	
F1	2	2	5	1	-	-	
F2	8	2	6	14	18	12	1185 (MR), 1135 (MS)
BC1	3	2	2	8	7	8	1580 (HR), 1430 (R)
BC2	1	1	7	1	6	14	1448 (MR), 1310 (MR)
Cross 2							
P1	6	4	-	-	-	-	
P2	-	-	-	-	-	10	
F1	4	2	3	1	-	-	
F2	22	4	6	7	11	10	1255 (HR), 1235 (HR), 1205 (R), 1145 (HR)
BC1	9	1	3	7	4	6	995 (MS), 980 (MS)
BC2	6	3	3	4	7	7	2060 (R), 1750 (MR)

Note: * based on fruit yield per plant(g)
Entries in parenthesis indicate reaction to BDMV
Cross 1- IC 68335 x Preethi (P_1 x P_5)
Cross 2- IC 68250 A x IC 68342 B (P_4 x P_8)

4.5.2 Epidemiology of BDMV

Seasonal influence of various genotypes to BDMV incidence was also studied to have a preliminary idea about the influence of different weather parameters like maximum and minimum temperature, rainfall and relative humidity. Weekly observations of three seasons (2000 to 2002) were recorded (Figs. 4.1, 4.2 and 4.3). The observations revealed that maximum number of genotypes expressed mosaic symptoms, when maximum temperature was 31 to 35°C, minimum temperature of 23 to 25°C with a mean temperature of 27 to 29°C. Relative humidity of 70 to 85 per cent and very low rainfall highly favoured for disease development. It is also noted that high rainfall is not favouring for the mosaic development. High incidence of this disease was observed during April and May months.

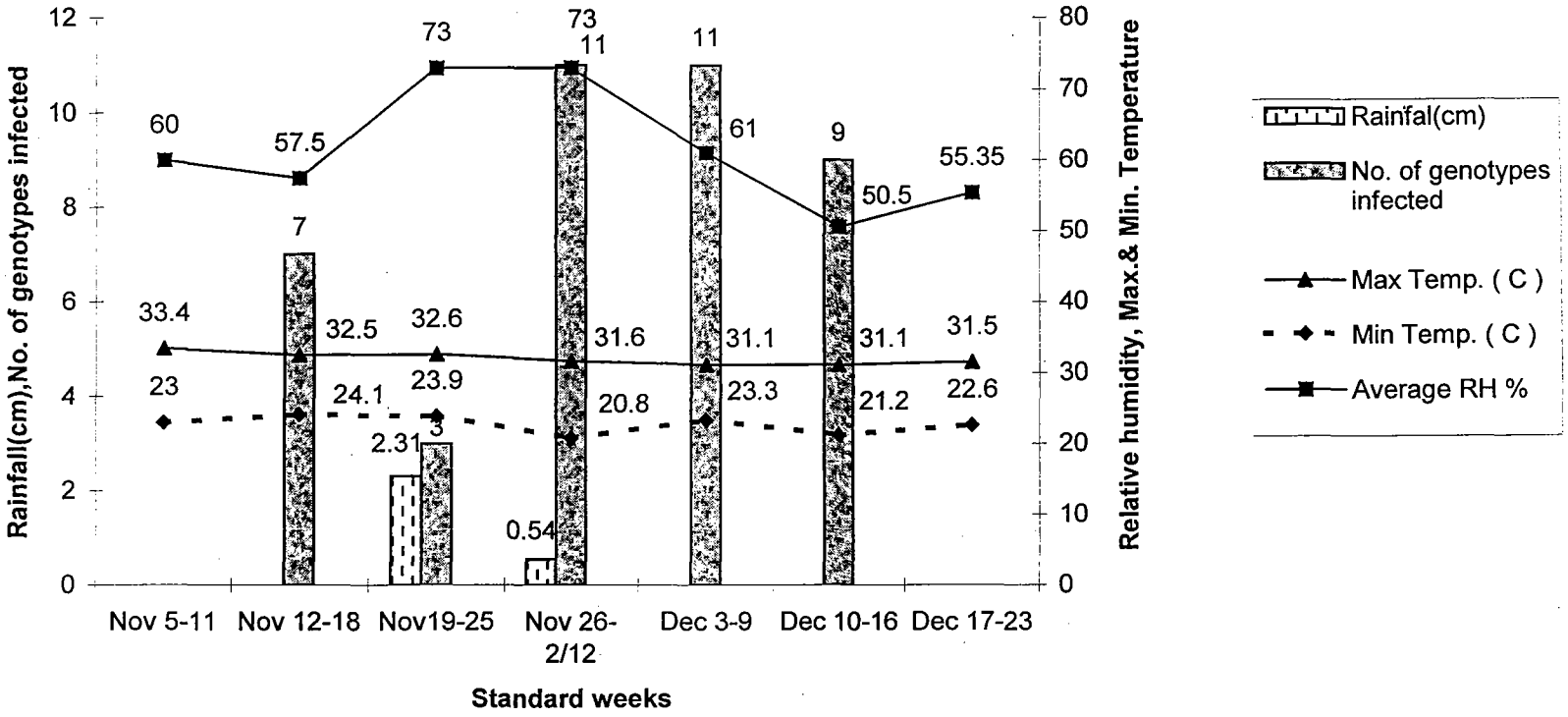


Fig. 4.1 Weather parameters and BDMV incidence during October to December 2000

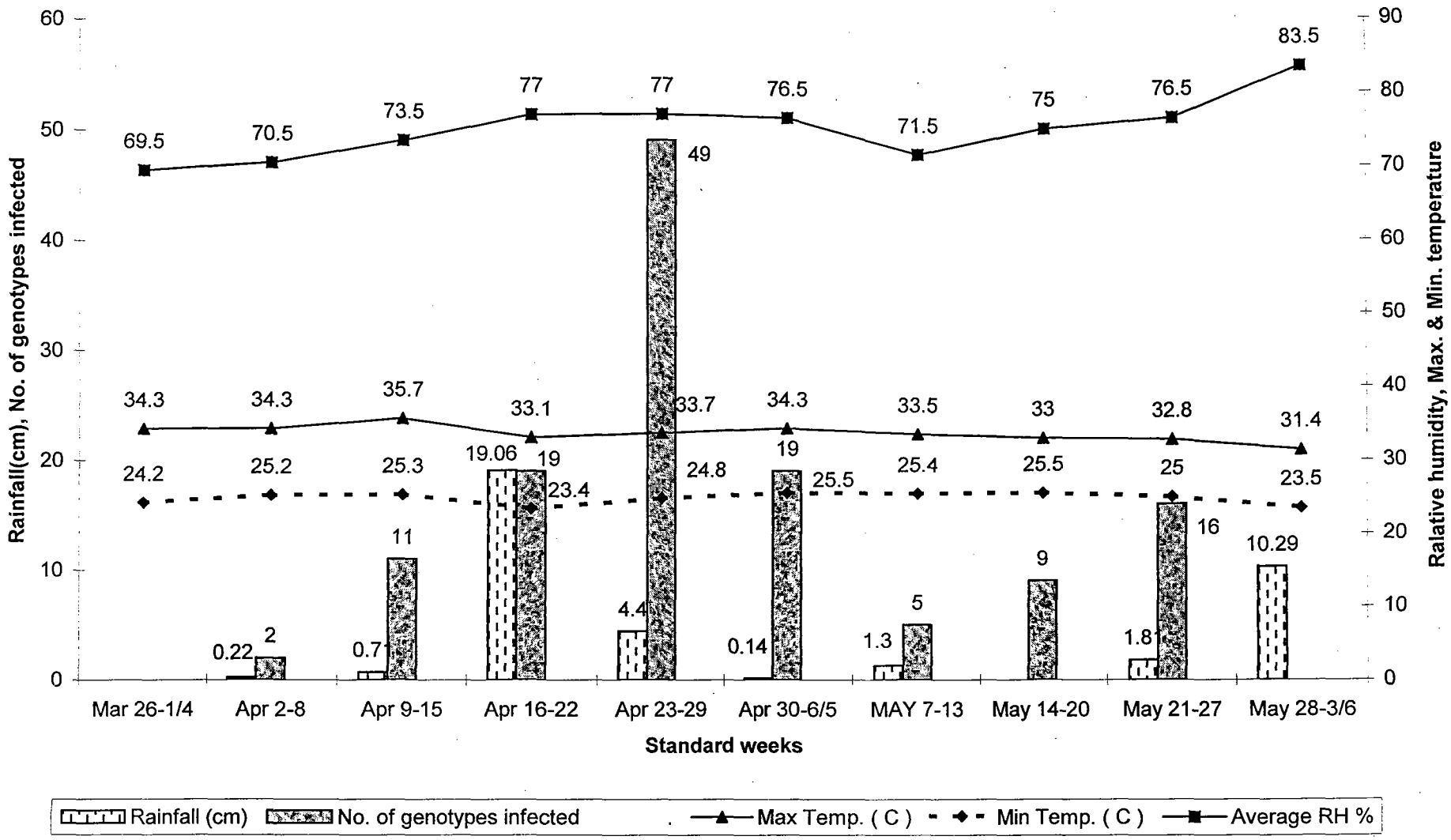


Fig. 4.2. Weather parameters and BDMV incidence during March to June 2001

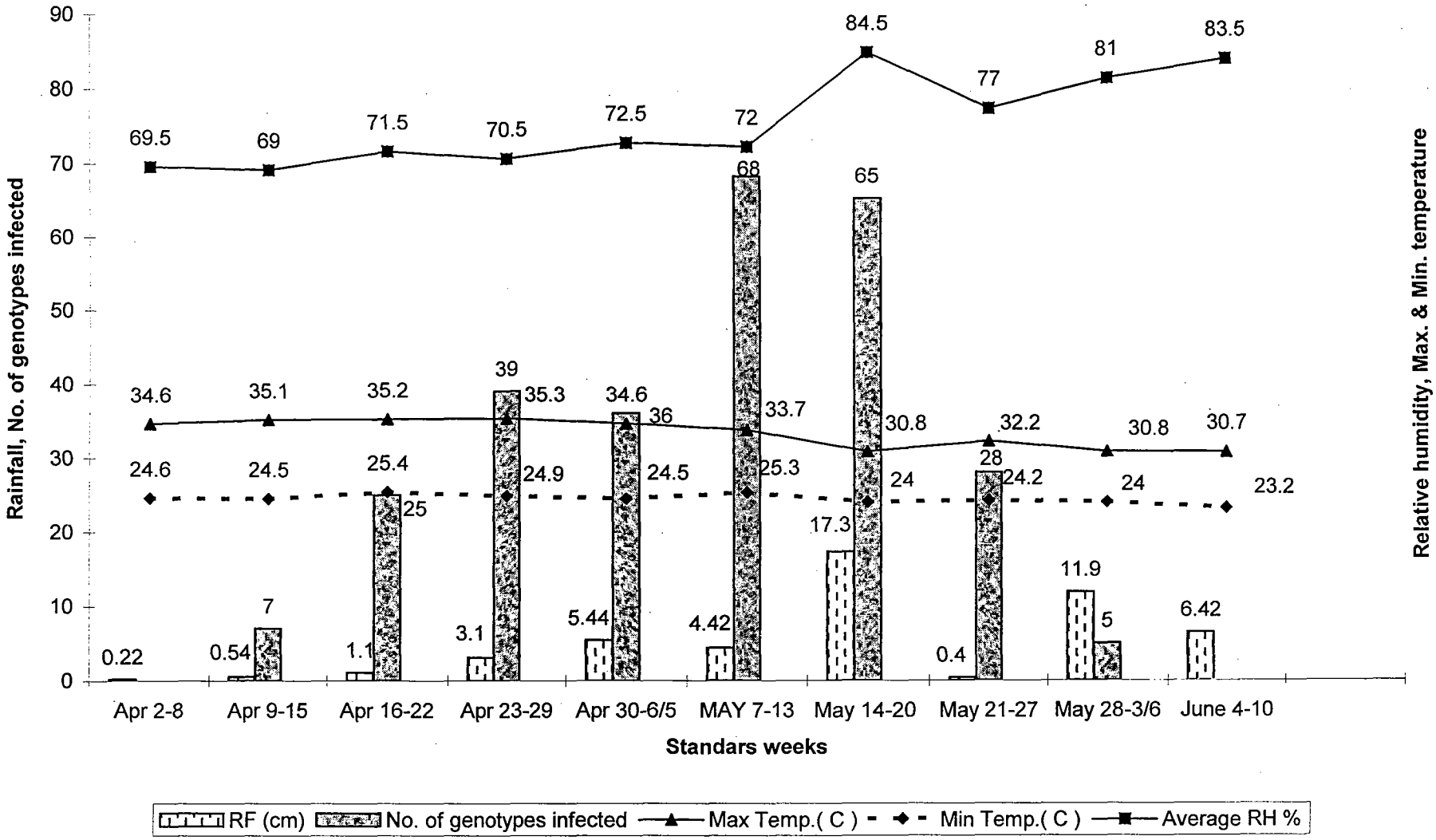


Fig. 4.3. Weather parameters and BDMV incidence during April to June

Discussion

5. DISCUSSION

5.1 Survey and Collection of Bittergourd Germplasm

In any breeding programme, it is essential to have basic information regarding the quantum and nature of variability present in the available germplasm. The variability once assessed is to be partitioned into heritable and non-heritable components with the help of parameters like phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance. Informations on the above parameters are of vital importance to the breeders in deciding the appropriate methods of breeding. Since variability is the outcome of divergence in a population, it is always better to study the variability along with the genetic diversity. Many workers have emphasized the importance of genetic diversity of parents in hybridization programme.

Correlation studies reveal association between yield and yield contributing traits. Knowledge on the degree of association among the traits would help the breeders to pin point the character(s) for an efficient plant selection. However, this will not give a true picture of the relative merits or demerits of each of the component to final yield, which is a complex character. Hence, an assessment of the merit of each character by examining the direct and indirect effects of the same towards final yield will be of immense value for final selection. Path coefficient analysis, which permits partition of the correlation coefficient into components of direct and indirect effects, is an efficient tool for this purpose.

Bittergourd is one of the most important cucurbitaceous vegetable crops in Kerala both in production and net value. But very often when the farmers are raising this crop during summer season they have to face various diseases affecting the crop, among which bittergourd distortion mosaic virus (BDMV) is known to cause serious damage and some times leads to total devastation (Mathew *et al.*, 1991). No successful attempt was made to screen the resistant source and transfer this trait into cultivated high yielding varieties. A search for source of resistance would be rewarding from the region where the crop exhibit maximum diversity. With these objectives an extensive

survey and collection of bittergourd (*Momordica charantia* L.) germplasm was carried out covering Kerala, Tamil Nadu and Karnataka through research stations and institutions like NBPGR, Trichur; KAU, Trichur; IIHR, Bangalore; TNAU, Coimbatore and 86 diverse germplasm (Plate 6, 7 and 8) were assembled and subjected for the present study.

5.2 Screening for BDMV and Fruit Yield

Since it is a preliminary study, the only option is to screen resistant or tolerant genotypes against BDMV under natural epiphytotic conditions. The screening was done for two seasons (September to December 2000 and March to June 2001) for getting confirmative results.

Among 86 bittergourd accessions screened, nine genotypes were highly resistant during both seasons *viz.*, IC 68296, IC 68335, IC 68263B, IC 68275, IC 68250A, IC 85620, IC 68285, IC 68312 and IC 68272. The above stable resistant genotypes could be used as donors for incorporating BDMV resistance. However, they were poor yielders indicating negative relationship between BDMV resistance and yield contributing genes. The varieties like Preethi, Priya, Priyanka, Co 1 and Arka Harit were found to be susceptible to BDMV. Purushothaman (1994) and Rekha (1999) were also reported similar findings. But ARBTH 1 and Pusa Do Mausami reported to be resistant to this disease (Pandey *et al.*, 1998).

It is observed that the accessions collected from Northern and Central parts of Kerala were found to be resistant (Fig.5.1), while genotypes from Southern Kerala, Tamil Nadu, Karnataka and Maharashtra were susceptible. In order to diversify the resistant source against this disease, an intensive collection especially from Wayanad, Kannur, Malappuram, Palakkad and Idukki districts of Kerala is suggested as a future line of work.

People of Northern Kerala mostly prefer green fruited bittergourd whereas, this trend was just opposite in southern Kerala. No significant association was observed between fruit colour and BDMV resistance. But there was positive

PLATE 6. VARIABILITY IN WHITE FRUITED BITTERGOURD

PLATE 7. VARIABILITY IN GREEN FRUITED BITTERGOURD

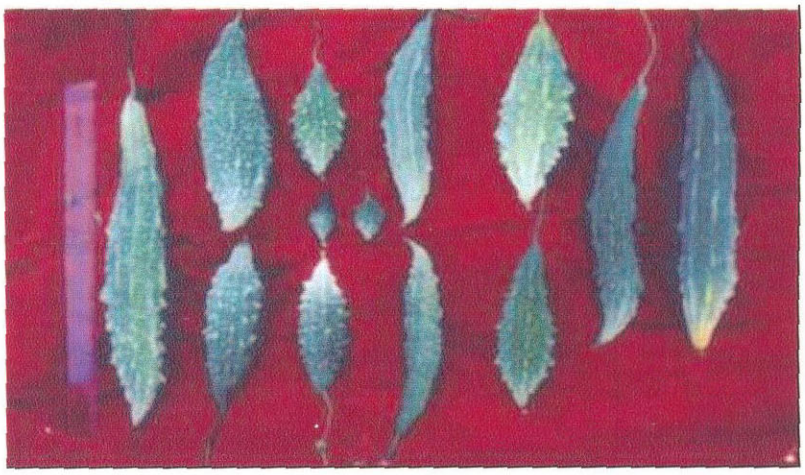
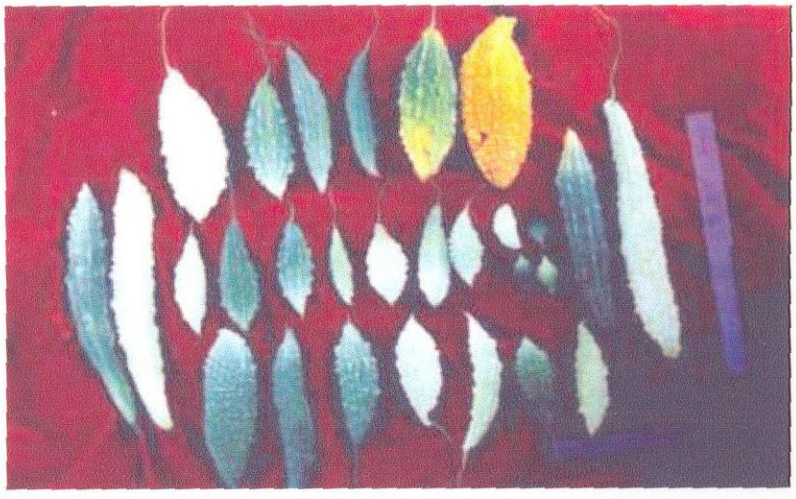


PLATE 8. FRUIT COLOUR AND SIZE VARIATION IN BITTERGOURD



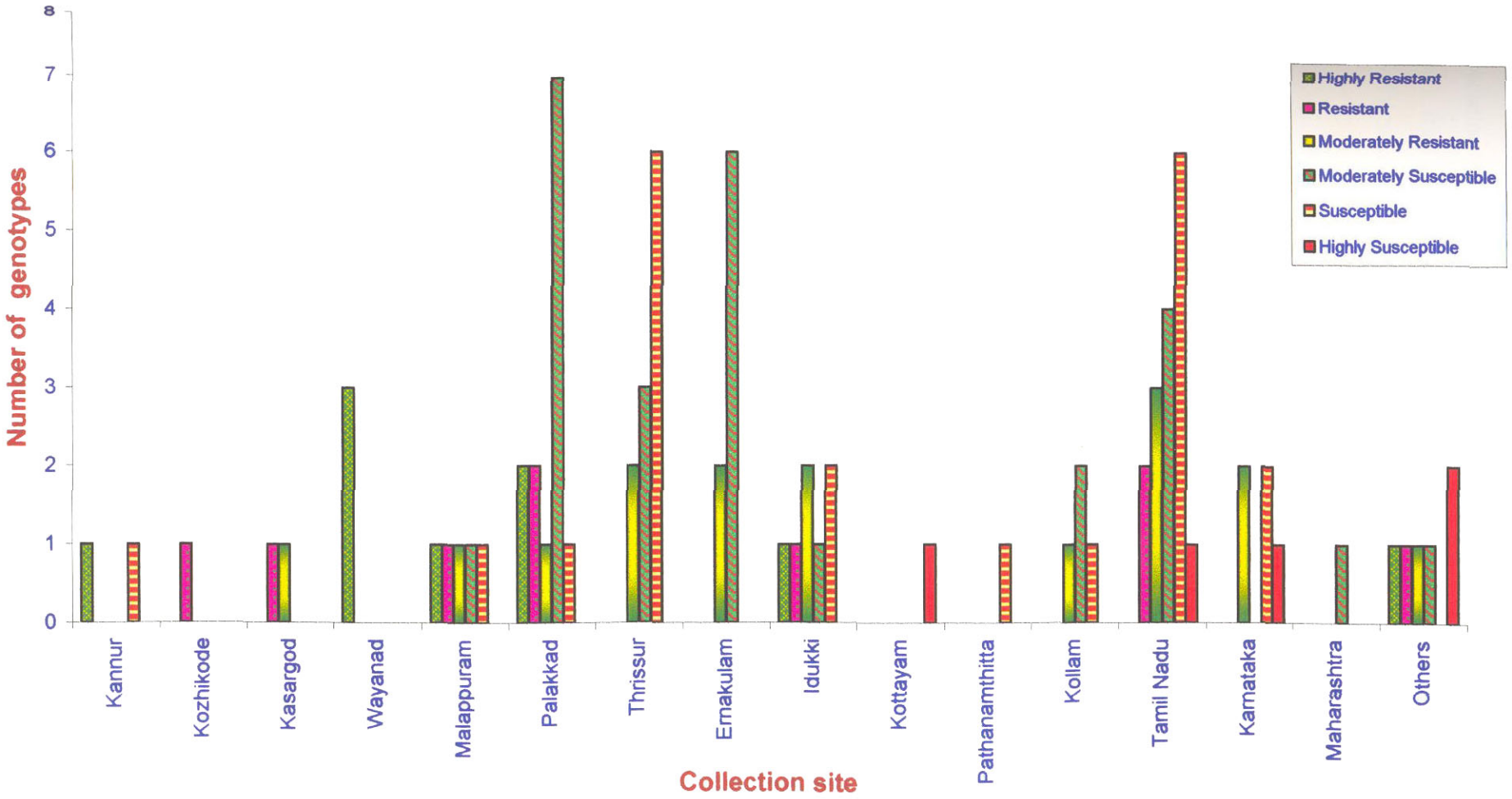


Fig.5.1 BDMV reactions versus collection site of genotypes

association between BDMV resistance and yield attributes like number of fruits, fruit length, fruit girth and fruit weight. This trend indicated the possibility of incorporating BDMV resistance genes to high yielding genotypes irrespective of its fruit colour.

5.3 Symptomatology of BDMV

Symptoms observed were mostly similar to those described by Giri and Mishra (1986) and Pandey *et al.* (1998). In addition to these, distorted leaves with clustered appearance of vines, long tendrils, unusual thickening of the tip of the vines with numerous hairs were also noticed.

5.4 Genetic Diversity

When large germplasm collections are available to the breeder, in the bit to generate genotypes possessing desirable attributes (in the present study resistance to BDMV and high yield), the breeder would like to choose genetically distant parents for hybridization. Mahalanobis D^2 statistic is a powerful tool in the hands of plant breeders to assess the degree of dissimilarity among the genotypes and to group them based on their phenotypic expressions.

Forty-seven selected bittergourd genotypes were grouped into six clusters. The cluster VI had maximum number of genotypes (13) followed by cluster II (12) and cluster IV (10). Cluster III recorded minimum number of two genotypes and there was no solitary cluster. Clustering pattern did not follow the geographical origin of the genotypes. This result is in conformity with Vahab and Gopalakrishnan (1993). But the genotypes were organized in relation with mosaic reaction. Twenty-five germplasm collected from Kerala were grouped into 10 clusters (Ramachandran *et al.*, 1981). Thirteen varieties from different states formed six clusters (Parhi *et al.*, 1993).

The cluster III was distantly related from all other clusters (Fig.5.2). This was mainly due to the fact that genotypes in this cluster are prone to infection at an early stage leading to heavy yield loss. Genotypes in clusters IV and V showed moderate susceptibility. The genotypes belonging to cluster VI and II were moderately high yielding (IC 68563B, IC 68335, IC 68272 and IC 68296) with resistance to

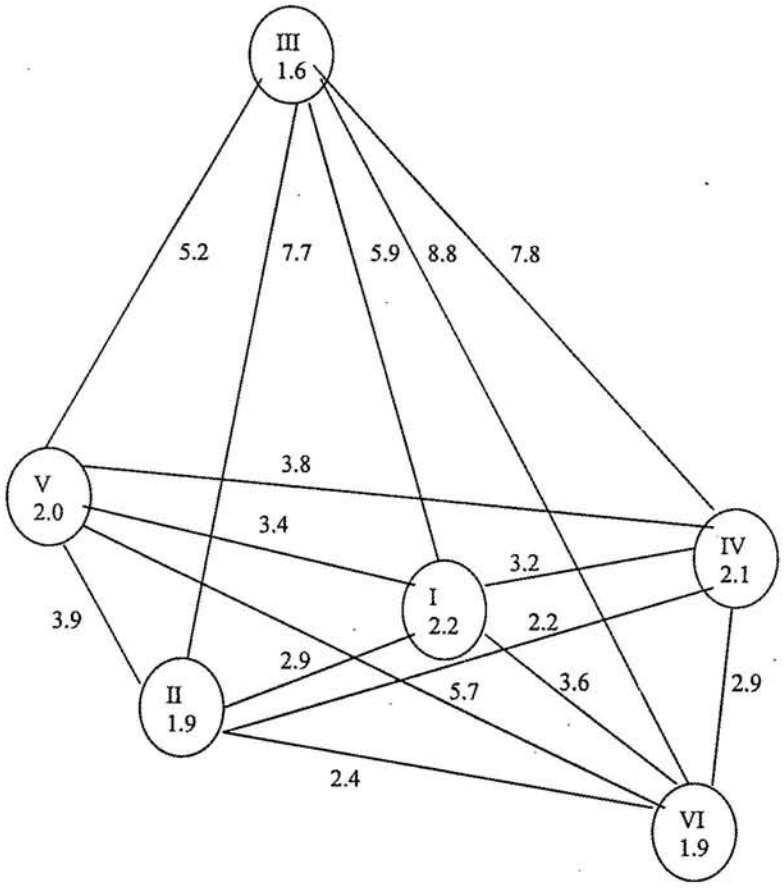


Fig. 5.2. Cluster diagram for 47 genotypes in bittergourd

BDMV, which can be used as parents in heterosis breeding. The characters such as fruit weight, number of fruits and fruit yield have contributed maximum to diversity. Ramachandran *et al.* (1981) and Parhi *et al.* (1993) also reported the contribution of number of fruits and fruit yield per plant towards divergence.

5.5 Variability

The variability expressed in a population can be studied by means of measures of dispersion. Apparent variability may be due to genetic and/or environmental factors besides their interaction effects. The influence of genetic and environmental factors on expressed variability can be studied by determining the magnitude of phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and expected genetic gain. The trends of above parameters are presented in Figs. 5.3 and 5.4. The 47 bittergourd genotypes used for present investigation after initial screening against BDMV showed significant differences for nine out of 12 characters studied, indicating sufficient variability in the experimental materials for these traits. Similarly, significant differences were noticed among parents and hybrids for all the traits.

Low PCV and GCV were observed for anthesis of male and female flowers in 47 selected genotypes, indicating inherently limited variability among the genotypes for these traits. Similar trend was also reported by Mangal *et al.* (1981) and Prasad (2000). High PCV and GCV recorded for number of male and female flowers, sex ratio, number of fruits and fruit yield in both population, was suggestive for greater magnitude of variability on these traits. The reports of Srivastava and Srivastava (1976), Singh *et al.* (1977), Mangal *et al.* (1981), Choudhury (1987) and Vahab (1989) were in support of the above findings.

High PCV and medium GCV for fruit length and fruit girth indicated the influence of environment on the character expression. Fruit weight registered high PCV and GCV in 47 genotypes, but they turned out to be low in parents and hybrids. This has happened due to selection of parents mainly for resistance to BDMV and further hybridization among parents, which narrow down the range of expression for this trait.

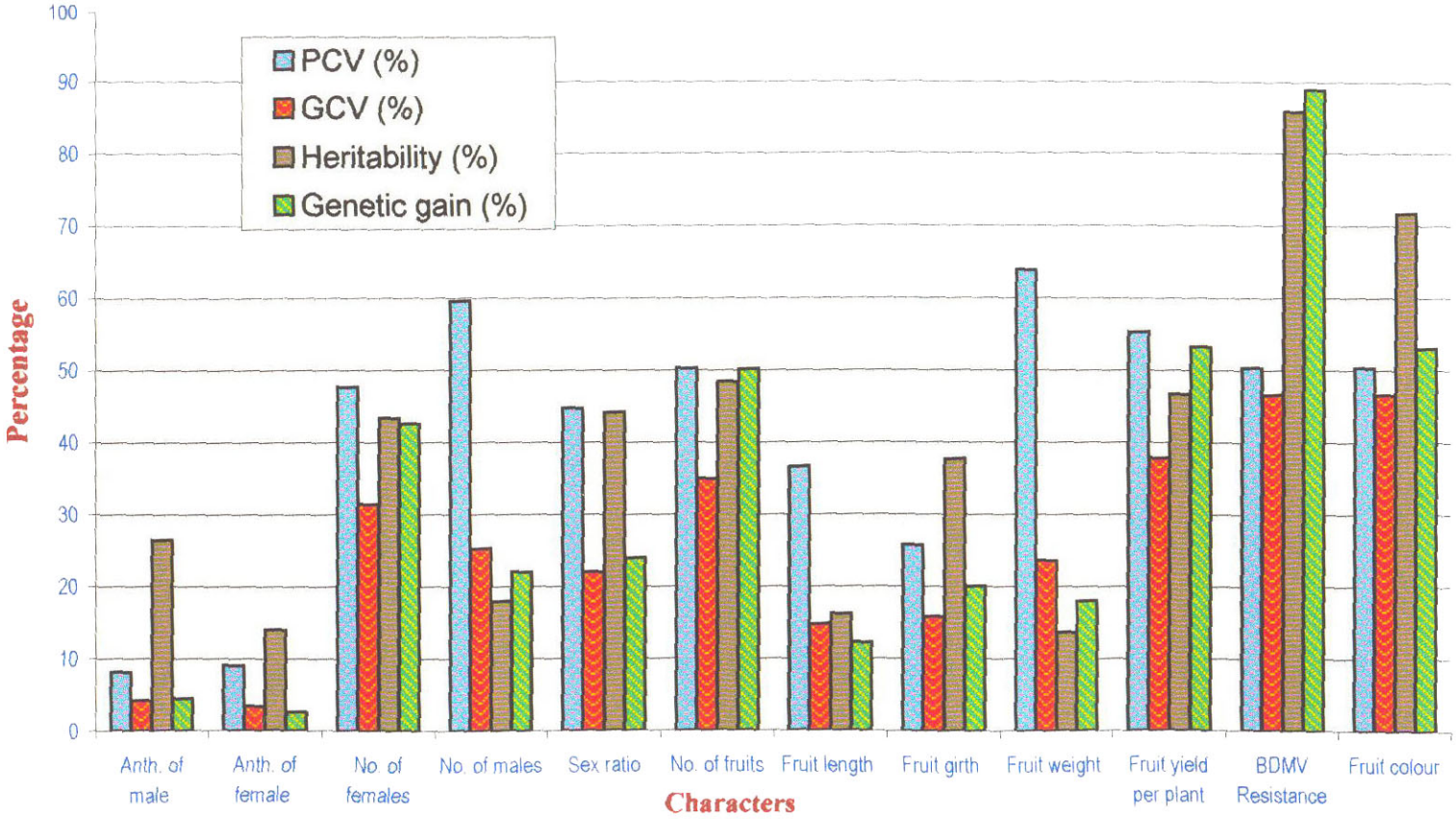


Fig. 5.3 . PCV, GCV, heritability and genetic gain in 47 genotypes

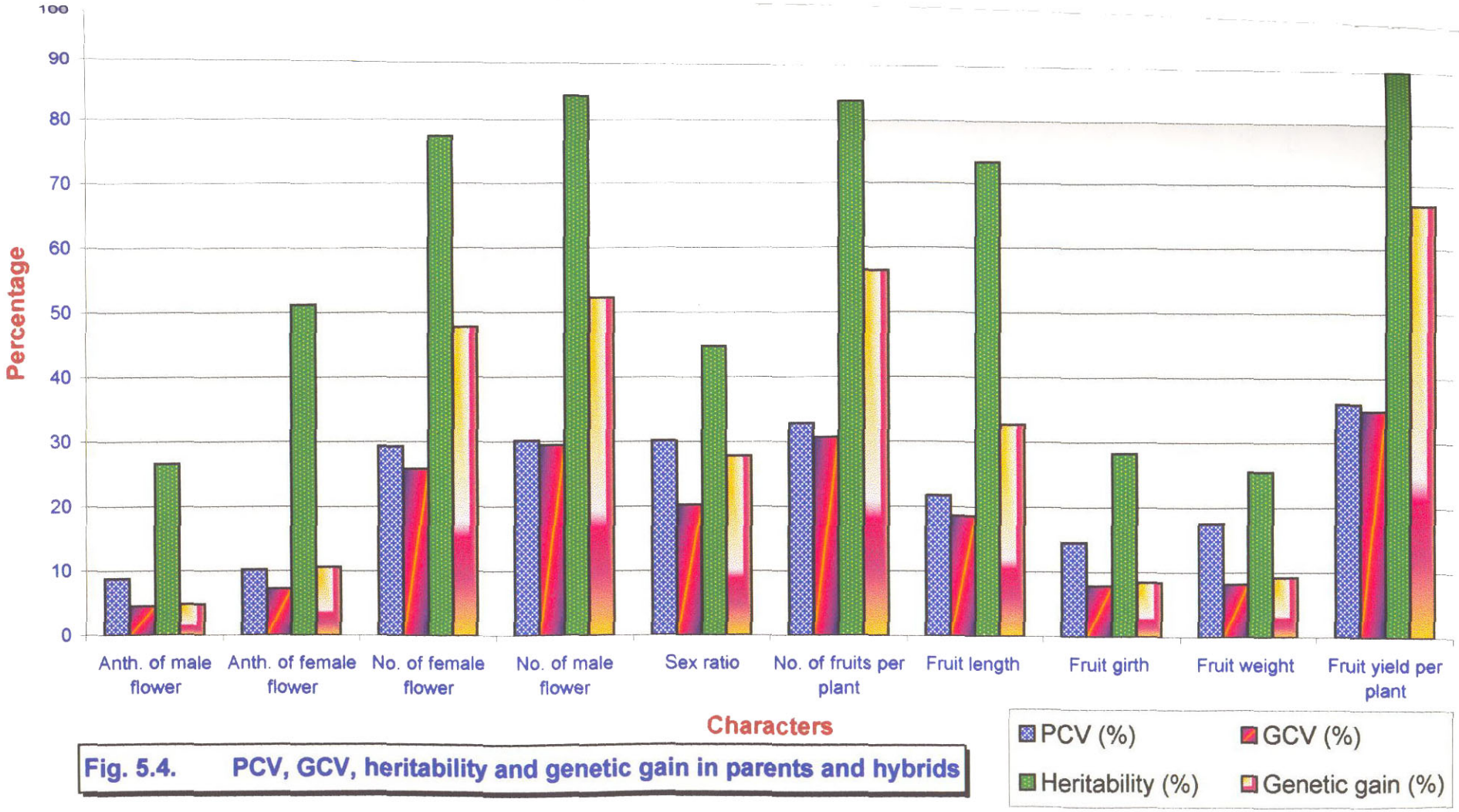


Fig. 5.4. PCV, GCV, heritability and genetic gain in parents and hybrids

Lack of high broad sense heritability for all the traits were noticed in 47 genotypes. The heritability was medium for number of female flowers, sex ratio, number of fruits, fruit girth and fruit yield. Whereas, the following traits *viz*., number of male and female flowers, number of fruits, fruit length and fruit yield recorded high heritability in parents and hybrids. These results were in conformity with the reports of Mangal *et al.* (1981), Vahab (1989) and Prasad (2000).

Genetic advance as percentage of mean (GA) were high for number of male and female flowers, sex ratio, number of fruits and fruit yield in both selected and hybrid population. High genetic advance had been reported for number of male flowers (Srivastava and Srivastava, 1976), number of fruits and fruit yield (Mangal *et al.*, 1981 and Vahab, 1989).

Low values of GA, PCV, GCV and heritability were noted for anthesis of male and female flowers, fruit girth and fruit weight in both the populations. Simple selection for traits may not be rewarding. The PCV, GCV, heritability and genetic gain were quite encouraging for number of female flowers, number of fruits and fruit yield for favour of genetic improvement through selection. The influence of additive gene action is expected for these traits.

5.6 Association of Characters

Association among yield and yield attributes gives the idea about the kind of relationship among characters, which plays major role in selection. The low heritable characters effectively improved by indirect selection (correlated response), if the trait chosen for indirect selection had high heritability and high genetic correlation with the trait to be improved.

5.6.1 Correlation

Linearity of phenotypic and genotypic correlation was observed for most of the traits except for relationship with flowering traits like anthesis of male and female flowers and sex ratio (Table 4.7). This suggests that the expression of flowering traits was highly modified by environmental influence. Number of female flowers registered

high phenotypic correlation with number of fruits, which in turn contributed to high fruit yield per plant. Srivastava and Srivastava (1976), Choudhury *et al.* (1986) and Thakur *et al.* (1996b) also reported similar relationships. All the traits exhibited positive significant genotypic correlation with fruit yield except anthesis of male and female flowers.

The character association in parents and hybrids population also indicated high positive phenotypic correlation among number of female flowers, number of fruits and fruit yield (Fig. 5.5). Early anthesis of female flower increases the number of female flowers, sex ratio, number of fruit and fruit yield, which was evident from the significant negative genetic correlation of these traits with anthesis of female flower. Srivastava and Srivastava (1976) also reported negative correlation between anthesis of female flower and fruit yield.

Negative genotypic correlation between number of fruits and fruit weight revealed that, simultaneous improvement of both these traits is difficult. Srivastava and Srivastava (1976) and Kennedy (1994) have also reported similar relationships for these traits. But both the traits exhibited positive correlation with fruit yield. These results are in conformity with the findings of Ramachandran and Gopalakrishnan (1979), Mangal *et al.* (1981), Devadas (1993), Khattra *et al.* (1994) and Rajput *et al.* (1995). This finding indicates that for increasing fruit yield there should be optimum number of fruit along with high fruit weight.

5.6.2 Direct and Indirect Effects

Path coefficient analysis is helpful in partitioning total correlation into direct and indirect effects, so that direct influences of component traits are unconfounded by other traits and their effects can be clearly understood.

The characters such as number of female flowers, fruit girth, sex ratio and number of male flowers exerted moderate to high negative direct effect on yield, although they exhibited positive and significant correlation with fruit yield (Table 4.8). So, consideration of mere interrelationship between the traits for selection will not

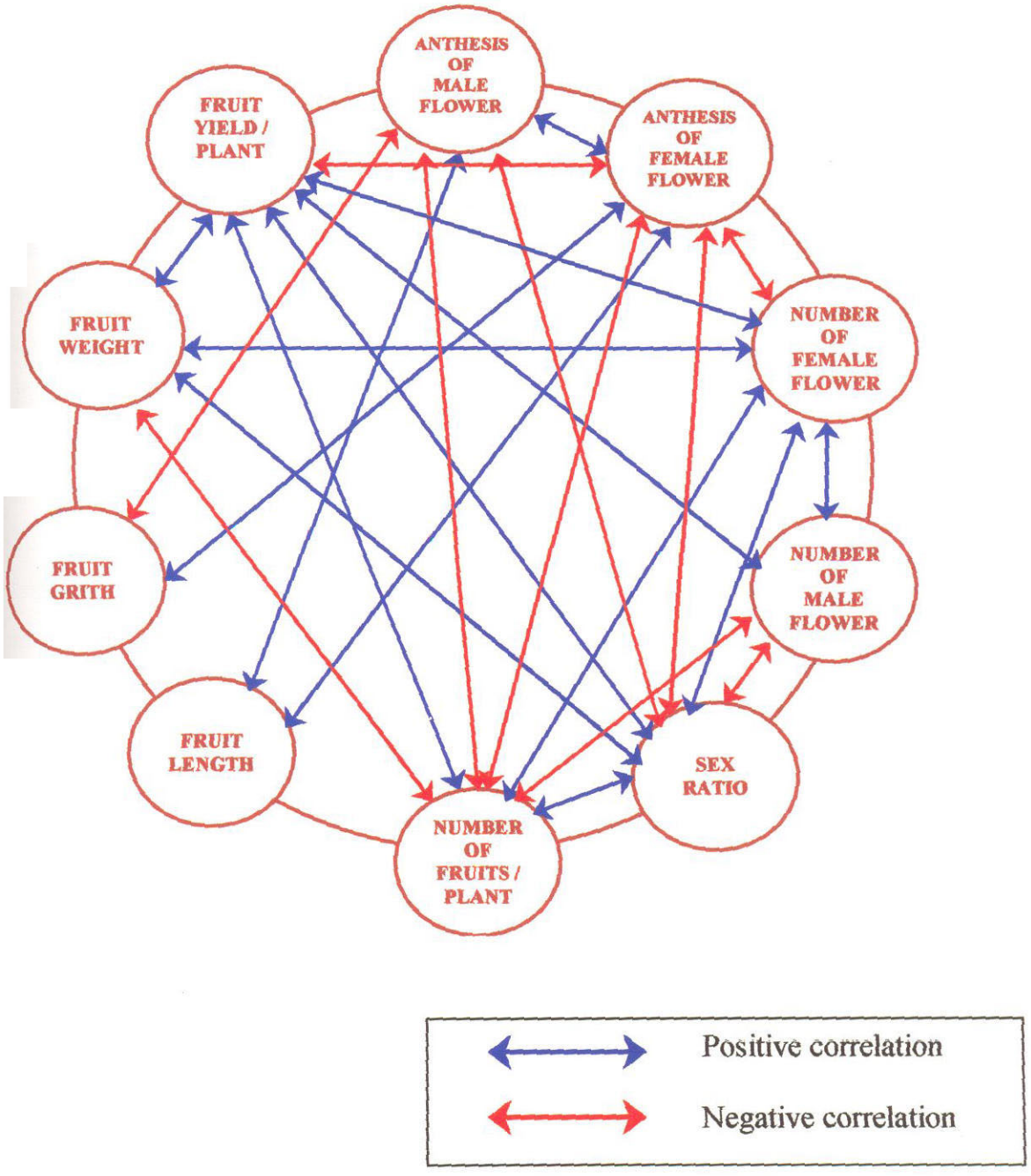


Fig. 5.5. Genotypic correlations in parents and hybrids population

yield fruitful results. Number of fruits per plant exerted maximum direct effect on yield. Further number of female and male flowers, sex ratio, fruit length, fruit girth and fruit weight contributed indirectly on yield *via* number of fruits. Therefore, selection for number of fruits per plant will bring about simultaneous improvement of correlated traits. The traits like fruit weight, fruit length and mosaic resistance also contributed positive direct effect on yield.

High positive direct effect on yield in parents and hybrids was observed through number of fruits and some extent fruit weight, number of male flowers and sex ratio in parents and hybrids population (Table 4.16). Earlier studies also supported the positive direct effect on yield *via* fruit weight (Paranjape and Rajput, 1995; Puddan, 2000), number of fruits and sex ratio (Rajeswari, 1998). Number of female flowers exerted negative direct effect on yield, though its genetic correlation was high and positive. But this trait indirectly contributed through number of fruits per plant. This revealed that the heterotic vigour in hybrid population increases the number of female flowers, but they failed to convert it into productive fruits. All the traits except anthesis of female flowers indirectly contributed through number of fruits to increase fruit yield. Direct negative effect of days to first female flower was reported by Rajput *et al.* (1995).

The path coefficient analysis of various yield attributing traits in both selected genotypes and parent and hybrid population suggested that selection based on number of fruits, fruit weight, fruit length and BDMV resistance will give good response for improving fruit yield in bittergourd.

5.7 Combining Ability Analysis

The combining ability analysis provides an understanding of the genetic architecture of the traits, which would be useful to identify parents for heterosis breeding and handling segregating materials. The ability of a parent to combine well with other parents is depends on various complex gene interactions, which cannot be realised from phenotypic values. Diallel analysis is an efficient tool for the plant breeders to estimate the genetic components of variation and combining ability of the

selected lines in a series of crosses. Since quantitative traits are not influenced much in the reciprocal crosses, half diallel technique was followed for estimating general combining ability (GCA), specific combining ability (SCA) variances and its effects. GCA variance is due to additive gene action, which is equal to twice GCA variance. However, if epistasis is present GCA variance will include additive x additive component also. SCA variance that deals with non-additivity of genes is mainly attributable to dominance variance. However, it may also include all the three types of epistatic interactions *viz.*, additive x additive, additive x dominance and dominance x dominance if epistasis is present.

5.7.1 Combining Ability Variance

Analysis of variance for combining ability showed significance of mean squares due to GCA effects for all the characters and SCA effects for seven characters, there by indicating the importance of both additive and non-additive gene actions.

The greater magnitude of SCA variance over GCA variance for all the traits except fruit length indicated preponderance of non-additive gene action for these traits. Similar observations for different traits were also made by Kennedy (1994) and Prasad (2000). Both additive and non-additive gene actions were found to be important for fruit length and fruit yield. This is in conformity with the findings of Gopalakrishnan (1986).

The general combining ability (*gca*) effects revealed that, the parent P_6 for early flowering and P_4 for number of male and female flowers were the best combiners (Table 5.1). To improve sex ratio the parents having high *gca* effects *viz.*, P_3, P_6 and P_8 can be utilized in hybridisation programme. Improvement of number of fruits and fruit yield per plant can be achieved by using P_6, P_4 and P_3 as parents in heterosis breeding. The parent P_1 and P_8 are the best combiners for fruit girth and fruit weight respectively. Since plants exhibiting low coefficient of infection (CI) are grouped under resistant category, a low CI and negative *gca* effects are desirable. Accordingly, the parents P_1, P_2 and P_3 were found to be best general combiners for BDMV resistant.

Table 5.1. Promising parents and hybrids identified based on combining ability and heterosis

Characters	Combining ability		Heterosis	
	gca effect	*sca* effect	Promising hybrids	*gca* status of parents
Anthesis of male flower*	P_6	-	-	-
Anthesis of female flower*	P_6	P_2xP_6 P_7xP_8 **P_1xP_8**	-	-
Number of female flowers	P_6,**P_4**	P_6xP_8 P_4xP_5 **P_2xP_3**	P_6xP_8 P_4xP_5 P_5xP_6 **P_2xP_3**	HxL HxL LxH LxL
Number of male flowers	**P_4**	P_4xP_7 P_1xP_4 P_5xP_6	P_4xP_7 P_1xP_4 P_5xP_6 P_4xP_5	HxL LxH LxL LxL
Sex ratio	**P_3**, P_6, P_8	P_3xP_4 P_2xP_6	**P_3xP_8** P_3xP_4 P_2xP_6 P_7xP_8	HxH HxL LxH LxH
Number of fruits per plant	P_6, **P_4**, **P_3**	P_4xP_5 P_6xP_8 **P_2xP_3** **P_2xP_7**	P_4xP_5 P_6xP_8 P_5xP_6 P_4xP_7	HxL HxL LxH HxL
Fruit length	P_8, **P_2**, P_5, **P_4**	-	**P_4xP_8** **P_3xP_8** **P_2xP_5**	HxH LxH LxH
Fruit girth	**P_1**	-	P_1xP_8 P_1xP_7 P_5xP_8 P_4xP_5	HxL HxL LxL LxL
Fruit weight	P_8	-	P_5xP_8 P_7xP_8 P_6xP_8 P_3xP_4	LxL LxL HxL LxL
Fruit yield per plant	**P_3**, **P_4**, P_6	P_4xP_5 P_6xP_8 **P_2xP_3** **P_2xP_7**	P_4xP_5 P_6xP_8 **P_2xP_3** **P_3xP_8**	HxL HxL LxL HxL
Coefficient of infection*	**P_3**, **P_2**, **P_1**	**P_3xP_8** **P_3xP_7** **P_2xP_7** **P_4xP_8**	**P_3xP_8** **P_3xP_7** **P_2xP_7** **P_4xP_8**	LxH LxH LxH HxH

Note: Resistant parents and hybrids are represented in bold.

* Negative values were considered, H – High, L - Low

The overall performance of parents for different traits revealed that, the improvement of flowering traits could be achieved using P_6 as parent. The parent P_3 serves as best combiner for improving sex ratio, number of fruits and fruit yield per plant coupled with resistance to BDMV. The parent P_4 has high *gca* effects for flowering, yield and yield attributing traits.

The cross combinations having significant specific combining ability (*sca*) effects indicated that, no hybrid combinations resulted in consistent performance for flowering traits. The best combiners for number of fruits and fruit yield per plant are P_6 x P_8, P_4 x P_5, P_2 x P_3 and P_2 x P_7. The latter two combinations also showed resistance to BDMV. The variety Preethi (P_5) was reported as best combiner for number of fruits and fruit yield per plant (Rajeswari, 1998). These results indicated that number of fruits per plant had direct relationship with fruit yield per plant.

5.8 Heterosis

Cross combinations such as P_6 x P_8, P_4 x P_5 and P_4 x P_7 recorded significantly high *per se* performance for number of female flowers. Hybrids P_4 x P_5 and P_6 x P_8 for number of fruits, P_4 x P_8 and P_3 x P_8 for fruit length and P_5 x P_8 for fruit weight were the best combinations with high *per se*. For fruit yield per plant hybrid P_4 x P_5 followed by P_6 x P_8 are the best hybrids, these two crosses also performed well for other yield contributing traits. The *per se* performance of parents and hybrids registered direct relationship with *gca* and *sca* effects respectively for most of the traits. Ram *et al.* (1999) reported that the performance of parents bears direct relation with *gca* effects for fruit yield per plant.

Positive and negative mid-parent and better parent heterosis was recorded for all the traits. Similar observations were made by Munshi and Sirohi (1993), Celine and Sirohi (1996), Rajeswari (1998) and Prasad (2000). However, the usefulness of hybrids for commercial utility can be assessed by standard heterosis. Many hybrids were out performed over checks (Priya, Priyanka and COBGOH 1) for different traits. But lack of negative standard heterosis over all three checks was observed for anthesis

of male flower. Similarly, no positive heterosis was noticed for anthesis of female flower over COBGOH 1 and fruit girth over Priyanka (Fig. 5.6).

Among superior performing hybrids, the combination P_4 x P_5 performed better for number of male and female flowers, number of fruits and fruit yield per plant (Table 5.1). The hybrids P_2 x P_3 and P_3 x P_8 showed resistance to BDMV with moderately high fruit yield indicating that these can be used directly as commercial hybrids. The crosses *viz.*, P_6 x P_8 and P_4 x P_5 inspite of their high yield potential (Plate 9) expressed moderate susceptibility to BDMV. Hence, the standard heterosis of these hybrids can be exploited for its commercial worthiness with adequate plant protection measures.

The overall performance of hybrids revealed that the hybrids, which exhibited high heterosis for yield and yield attributes were invariably susceptible to BDMV and *vice versa*.

The hybrids which registered high heterotic vigour were also having high *sca* effects for the characters *viz.*, number of male and female flowers, sex ratio, number of fruits per plant, fruit yield per plant and coefficient of infection (Table 5.1). This indicates the importance of dominant gene action for hybrid vigour. Prasad (2000) also noticed similar results for fruit yield per plant. Reddy and Arunachalam (1981) stated that most of the heterotic crosses expressed on the strength of high specific combining ability only.

The hybrid combinations *viz.*, P_2 x P_3, P_4 x P_5 and P_6 x P_8 were found to be the best combiners in terms of high *sca* effects and *per se* performance for fruit yield per plant. The above cross combinations indicated that, cross between the best (P_3, P_4 and P_6) and poor (P_2, P_5 and P_8) general combiners resulted heterotic hybrids. Similarly, high heterotic nature of crosses for different traits was mostly resulted from high x low (or) low x high parental combinations. This is due to the fact that high x low crosses were ensured genetic divergence between parents, which produced more

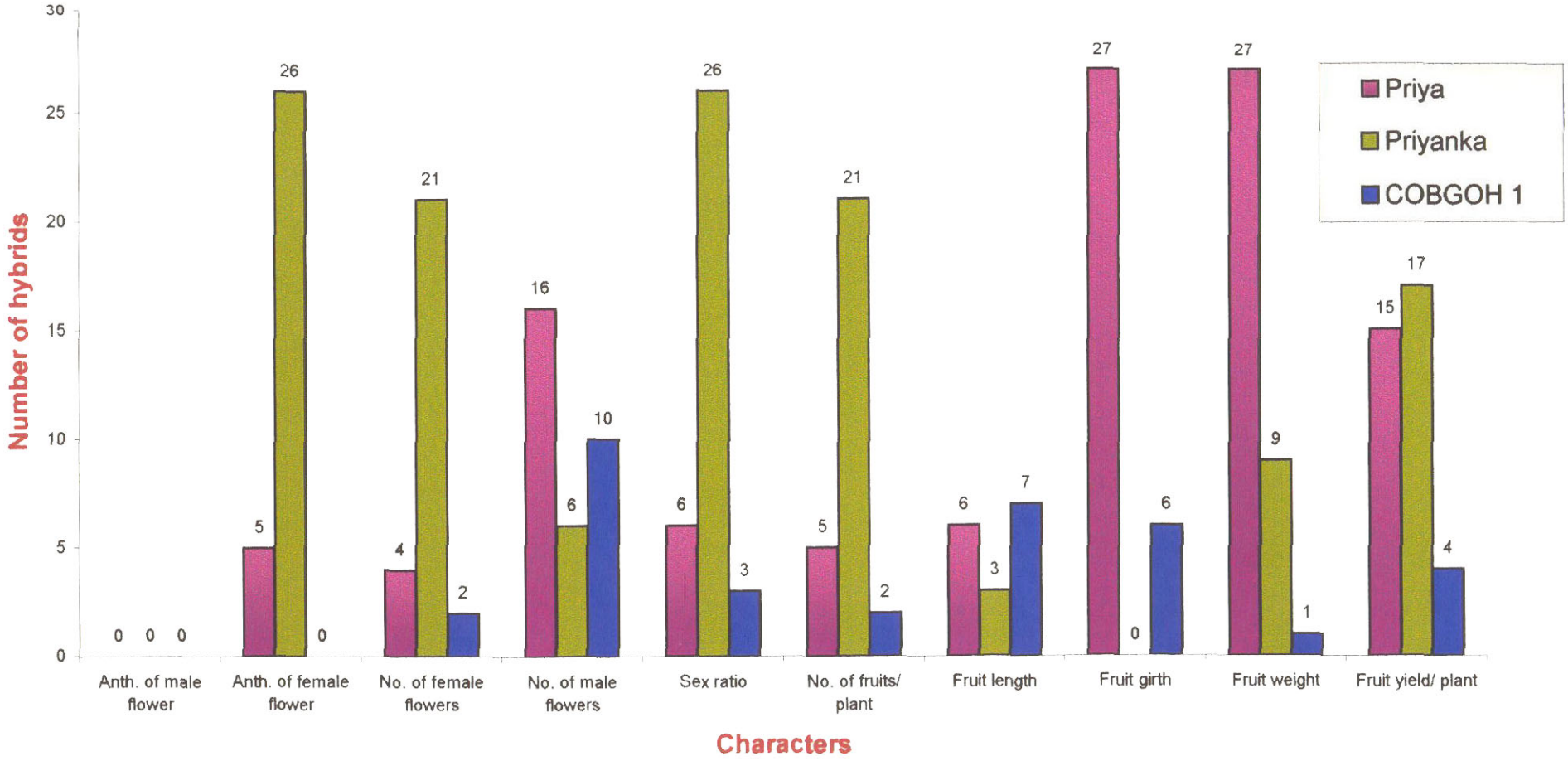
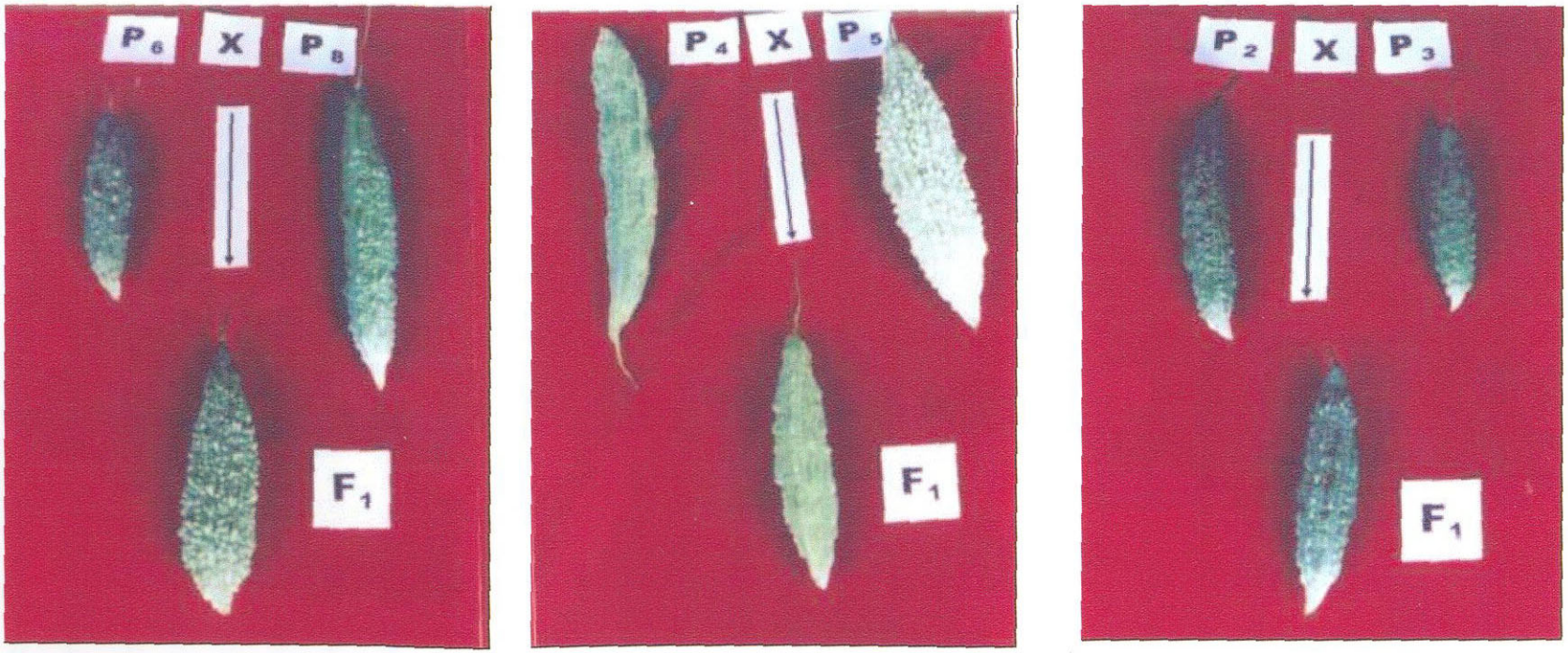


Fig.5.6. Number of hybrids showing desirable standard heterosis

PLATE 9. PROMISING HYBRIDS AND THEIR PARENTS



number of heterotic crosses followed by low x low and high x high combinations (Reddy and Arunachalam, 1981). Further heterotic crosses resulted from high x low combiners are having more potential to yield transgressive segregants (Arunachalam and Reddy, 1981). So, the cross combination P_3 x P_8 which exhibited moderately high yield, resistance to BDMV and having the status of high x low combination can be advanced to further generation to isolate transgressive segregants for both the traits.

The low x low cross combinations were resulted in heterotic vigour for number of female flowers (P_2 x P_3), number of male flowers (P_5 x P_6 and P_4 x P_5), fruit girth (P_5 x P_8 and P_4 x P_5), fruit weight (P_5 x P_8, P_7 x P_8 and P_3 x P_4) and fruit yield per plant (P_2 x P_3). The hybrid vigour in these crosses might have resulted from complementary gene effects (Ram *et al.*, 1999).

5.9 Genetic Architecture

Since the quantitative traits are governed by polygenes, the phenotypic manifestation of genes at a locus may be influenced by genes located at other loci. So the information of gene action and its epistatic effects of quantitative characters will guide to adopt appropriate breeding strategy in bringing about desirable changes. Adequacy of three-parameter model was observed for all the traits, except for number of fruits per plant, fruit yield per plant and coefficient of infection (Tables 4.23a and b).

The negative dominance gene effect and non-significance of its interaction effects indicated that, dominance gene action favours for early anthesis of male flowers. High magnitude of dominance gene action was found to be important for flowering traits like number of male and female flowers and sex ratio in cross 1. These results were in conformity with Rajeswari (1998) and Prasad (2000). Similarly, magnitude of dominance was high for fruit length (cross 2), fruit girth and fruit weight (cross 1). The importance of dominance gene action was stressed in earlier reports for fruit length (Celine and Sirohi, 1998), fruit girth (Lawande and Patil, 1990; Devadas, 1993; Munshi and Sirohi, 1994b) and fruit weight (Munshi and Sirohi, 1994b). The insignificance of genic interaction and preponderance of dominance gene action for

number of male and female flowers, sex ratio, fruit length, fruit girth and fruit weight revealed that, these traits can be well exploited through heterosis breeding.

Additive and dominance gene actions were found to be significant for number of fruits and fruit yield per plant in cross 1, but their interaction effects found to be insignificant. Similar nature of gene action was observed by Lawande and Patil (1990 and 1991). In cross 2, only dominance x dominance interaction resulted in positive direction with duplicate epistatic effect. Lawande *et al.* (1994) reported similar digenic interaction effects for fruits per plant. These findings revealed that additive, dominance and dominance x dominance gene actions were important for number of fruits and fruit yield per plant. To improve these traits recurrent selection will be the best option.

In terms of coefficient of infection negative gene action is preferable for BDMV resistance. Additive gene action and dominance x dominance type of inter allelic interaction were found to be important for resistance. To exploit above conditions, intermating of genotypes having desirable traits and then accumulation of favourable genes by simple selection is proposed. These will help to isolate genotypes having resistant to BDMV with elite genetic background for high yielding attributes.

5.10 Gene Action for Resistance to BDMV

The diallel analysis indicates that gene action of BDMV resistance follows a complicated pattern. Whenever a susceptible *versus* susceptible cross (Preethi x VKV 134) was made, it resulted in moderately resistant hybrid. Likewise highly resistant *versus* highly resistant (IC 68250A x IC 68275) cross produced moderately susceptible hybrid. Further cross between resistant *versus* susceptible parents does not give neither all the F_1 hybrids with resistant nor susceptible. But they showed low coefficient of infection as seen in $P_2 \times P_7$, $P_3 \times P_7$, $P_3 \times P_8$, $P_3 \times P_5$, $P_1 \times P_8$, $P_4 \times P_8$ and $P_2 \times P_5$. All these observations indicate that BDMV resistance was not conditioned by monogenic inheritance. However digenic or polygenic control is presumed (Table 5.2).

Table 5.2. Reaction of parents and hybrids against BDMV

Sl. No.	Parents	IC 68335	IC 68263B	IC 68275	IC 68250A	Preethi	VKV 134	IC 45341	IC 68342 B
1	IC 68335	HR (4.4)	MS (24.0)	MS (24.8)	MR (18.2)	HR (4.0)	MR (17.5)	MS (30.1)	HR (3.2)
2	IC 68263B		HR (2.3)	HR (2.3)	MS (28.0)	R (8.8)	MR (12.6)	HR (2.0)	MS (25.2)
3	IC 68275			HR (0.3)	MS (35.0)	HR (2.7)	MS (26.0)	HR (0.0)	HR (0.0)
4	IC 68250A				HR (0.0)	MS (30.3)	S (52.2)	MS (32.6)	R (7.2)
5	Preethi					MS (34.0)	MR (12.0)	MS (20.1)	MS (23.8)
6	VKV 134						S (53.8)	MS (30.3)	MS (34.4)
7	IC 45341							S (43.9)	MS (40.0)
8	IC 68342 B								HS (77.0)

Note : Parental reaction represented in diagonally
Values in parentheses indicate coefficient of infection
HR : Highly resistant
R : Resistant
MR : Moderately resistant
MS : Moderately susceptible
S : Susceptible
HS : Highly susceptible

The segregation patterns in the generation mean analysis also reflect the same trend of gene action. The two crosses of resistant *versus* susceptible combinations showing complex segregating pattern in F_1 and F_2 and its respective backcrosses, which cannot be fited into any mendalian digenic interactions (Table 4.24). This reveals the polygenic nature of inheritance for BDMV resistance. The quantitative nature of inheritance for cucumber mosaic virus resistance was noticed by Pink and Walkey (1985) in pumpkin and Mayer *et al.* (1987) in cucumber. The cucumber green mottle mosaic virus in muskmelon was governed by polygenes with recessive nature (Rajamony *et al.* 1990).

Since polygenic traits are highly influenced by weather parameters, whenever the maximum temperature increased from 31 to 35°C, with its corresponding minimum temperature of 23 to 25°C and a mean temperature of 27 to 29°C there were higher incidence of BDMV (Fig. 4.1, 4.2 and 4.3). Incidence of this disease was also influenced by relative humidity and rainfall. Relative humidity with a range of 70 to 85 per cent and very low rainfall favours the high incidence of disease. The intensity of mosaic and crop loss was maximum during summer months (April and May). Mathew *et al.*, (1991) and Rekha (1999) were also observed high incidence of bittergourd distortion mosaic during summer. Latha (1992) observed maximum whitefly population during April and May. As the whitefly is considered as vector of BDMV, which may also one of the reasons for high incidence of BDMV during summer season.

Summary

6. SUMMARY

The salient features of present investigation are presented below.

- Among 86 genotypes screened against bittergourd distortion mosaic virus (BDMV) for two seasons, nine genotypes were found to be highly resistant and another nine genotypes were resistant.
- Accessions collected from Northern and Central parts of Kerala were found to be resistant, whereas, genotypes from Southern Kerala and other states were recorded susceptible reaction.
- Clustering pattern of genotypes did not follow geographical origin, but they were grouped based on BDMV reaction.
- The characters number of male and female flowers, number of fruits, fruit yield per plant and resistance to BDMV which recorded high PCV, GCV, heritability and genetic advance can be improved through direct selection.
- Path coefficient analysis indicated that selection based on number of fruits, fruit length, fruit weight and resistance to BDMV will reward high fruit yield per plant.
- All the traits exhibited significant positive correlation with fruit yield except anthesis of male and female flowers. But number of fruits is negatively associated with fruit weight.
- No linkage relationship between resistance and fruit colour was observed in this study. The resistance to BDMV also recorded positive association with yield attributing traits. This indicates that the incorporation of resistance source to high yielding genetic background irrespective of fruit colour is possible.
- Parent P_6 (VKV 134) for flowering traits and P_3 (IC 68275) for sex ratio, number of fruits and fruit yield were found to be the best combiners.
- Hybrids VKV 134 x IC 68342B, IC 68250A x Preethi, IC 68263B x IC 68275 and IC 68263B x IC 45341 are good specific combiners for number of fruits and fruit yield per plant. The latter two crosses expressed resistance to distortion mosaic.
- The hybrids IC 68250A x Preethi and VKV 134 x IC 68342B were found to have high standard heterosis, but they showed moderate susceptibility to BDMV.

Hence, these hybrids can be utilized for commercial purpose, where BDMV incidence is low or cultivating in seasons other than summer.

- The resistant hybrids *viz.*, IC 68263B x IC 68275 and IC 68275 x IC 68343B can be directly exploited as commercial hybrids, where high incidence of BDMV is noticed.
- Highly heterotic crosses were resulted from high x low or low x high cross combinations.
- Dominance gene action was found to be important for number of male and female flowers, sex ratio, fruit length, fruit girth and fruit weight.
- Additive, dominance, dominance x dominance and duplicate epistatic gene effects were observed for number of fruits and fruit yield per plant.
- Present investigation indicates the polygenic inheritance of BDMV resistance and they are highly influenced by weather parameters.

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* Original not seen

BREEDING FOR RESISTANCE TO DISTORTION MOSAIC VIRUS IN BITTERGOURD

(Momordica charantia **L.***)*

By

P. ARUNACHALAM

ABSTRACT OF THE THESIS

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COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680656

KERALA, INDIA

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ABSTRACT

The investigation on "Breeding for resistance to distortion mosaic virus in bittergourd (*Momordica charantia* L.)" was conducted at Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Trichur, during 2000 to 2002. This study aims to identify the source(s) of resistance against bittergourd distortion mosaic virus (BDMV) and scope of incorporating these genes to high yielding varieties. This project also envisages the extent of genetic diversity, character association, combining ability, heterosis and gene action of quantitative traits in bittergourd.

Out of 86 genotypes screened against BDMV, nine genotypes from Northern and Central parts of Kerala were identified as resistant *viz.*, IC 68296, IC 68335, IC 68263B, IC 68275, IC 68250A, IC 85620, IC 68285, IC 68312 and IC 68272. Clustering pattern of genotypes did not follow geographical origin, but they were grouped based on BDMV reaction. The parent IC 68275 was identified as the best general combiner for BDMV resistance and fruit yield per plant. The other resistant parents *viz.*, IC 68335 and IC 68263B were resulted in low fruit yield per plant can be used to diversify the source of resistance in hybridisation programme. Hybrids IC 68250A x Preethi and VKV 134 x IC 68342B can be exploited commercially for high fruit yield in seasons of less incidence of distortion mosaic. The resistant hybrids IC 68263B x IC 68275 and IC 68275 x IC 68342B having moderately high yield can be utilized commercially during seasons or areas of high incidence of distortion mosaic. The resistant genes for this disease are freely transferable to high yielding varieties. Selection based on number of fruits, fruit weight and resistance to BDMV can be used for improving fruit yield. BDMV resistance is controlled by polygenes and their expressions are highly influenced by environment. The higher incidence of distortion mosaic was noticed during summer. Scope of exploitation of heterosis with resistance to distortion mosaic is suggested for further studies for confirmation and utilization.