GENETIC ANALYSIS OF F_2 AND F_3 GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO DISTORTION MOSAIC VIRUS DISEASE IN BITTER GOURD (*Momordica charantia* L.)

By
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THESIS

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DECLARATION

I hereby declare that this thesis entitled **"Genetic analysis of F_2 and F_3 generations for yield attributes and resistance to distortion mosaic virus disease in bitter gourd (*Momordica charantia* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled **"Genetic analysis of F_2 and F_3 generations for yield attributes and resistance to distortion mosaic virus disease in bitter gourd (*Momordica charantia* L.)"** is a record of work done independently by **Ms.Sumarani, P.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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SUMA RANI, P.

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Affectionately
Dedicated to beloved
Achan, Amma &
loving Husband

Introduction

INTRODUCTION

Bitter gourd (*Momordica charantia* L.) is a nutritive and commercially important vegetable grown through out the country. It is one of the most important vegetable crop of Kerala. It is rich in vitamin C (88 mg per kg). The fruit is also good source of iron (1.8 mg per 100 g) with low sugar content and is considered to have prominent role in the diabetic patients.

Incidence of pest and disease is the most important production constraint of bitter gourd cultivation (Jayapalan and Sushama, 2001). Among the diseases, bitter gourd distortion mosaic is the serious problem affecting the bitter gourd cultivation in the state. Bitter gourd distortion mosaic has caused a drastic reduction in the yield especially during the summer season (Mathew *et al.*, 1991). This dismal scenario calls for an peremptory strategy for controlling the mosaic virus.

Kerala Agricultural University has so far released three bitter gourd varieties namely Priya, Priyanka and Preethi. Unfortunately all the released varieties are susceptible to bitter gourd distortion mosaic virus. The conventional plant protection measures for the control of vectors are inefficient and undesirable from the point of view of environmental pollution. The only way out is the development of resistant varieties (Horwath, 1984).

Genetic improvement in bitter gourd, especially with focus on mosaic resistance has been conducted only to a very limited scale in India. It is in this context that the present research programme on "Genetic analysis of F_2 and F_3 generations for yield attributes and resistance to distortion mosaic virus disease in bitter gourd (*Momordica charantia* L.)" becomes relevant. The present study was undertaken with the following objectives.

i) To understand the genetics of yield attributes and resistance to mosaic virus.

ii) To identify resistant genotype with desirable yield attributes.

Review of Literature

2. REVIEW OF LITERATURE

The success of a breeding programme depends on the knowledge of estimates of genetic parameters, association of characters and their effect on yield. The present study was under taken to elicit the information on the genetics of yield and component characters along with resistance to distortion mosaic virus in bitter gourd. A review of literature pertaining to the study is attempted in this chapter.

2.1 COMPONENTS OF VARIANCE

Variability studies were made in ten lines of bitter gourd by Srivastava and Srivastava (1976). They reported high genotypic coefficient of variation for number of fruits per plant followed by fruit yield and fruit weight and lowest for number of male flowers per plant and days taken for anthesis of first female flower.

Singh *et al.* (1977) analysed the data from twenty bitter gourd varieties indicating maximum phenotypic coefficient of variation and genotypic coefficient of variation for number of fruits per plant followed by fruit yield per plant.

The highest phenotypic coefficient of variation (39.88%) and genotypic coefficient of variation (37.82%) was recorded for fruit yield per plant in twenty five varieties of bitter gourd by Ramachandran (1978).

Mangal *et al.* (1981) conducted an experiment with twenty one varieties of bitter gourd and reported high estimates of genotypic coefficient of variation for fruit yield, number of fruits and fruit weight and lowest for days to first female flower.

Prasad and Singh (1989) noticed high phenotypic coefficient of variation and genotypic coefficient of variation for yield and number of fruits in ridge gourd.

Maximum phenotypic coefficient of variation and genotypic coefficient of variation were observed for fruit weight (48.77%) followed by yield per plant (31.82%) while both coefficients were moderate for fruit length (29.56%) and female flowers per plant (27.37%) in bitter gourd (Vahab, 1989).

Genetic variability and heritability studies were carried out by Thakur *et al.* (1994) in bitter gourd. They recorded high genotypic coefficient of variation and phenotypic coefficient of variation for total yield (56.41).

Varalakshmi *et al.* (1995) reported high phenotypic coefficient of variation and genotypic coefficient of variation for fruit yield per plant, number of fruits per plant and node of first female flower appearance in ridge gourd.

In bitter gourd maximum value of phenotypic coefficient of variation and genotypic coefficient of variation was observed for fruit yield per plant followed by fruit weight (Katiyar *et al.*, 1996).

Study conducted by Rajput *et al.* (1996) in bitter gourd revealed that maximum variation was observed for yield per vine and fruits per vine both at genotypic and phenotypic level. Ram *et al.* (1997) recorded significant genetic variability for days to anthesis of 50 per cent male and female flowers, fruit length and fruit diameter in bitter gourd.

Genotypic coefficient of variation was high for mean fruit weight, number of fruits per plant, number of seeds per fruit and yield per plant in pumpkin (Kumaran *et al.*, 1997). Genetic parameters were studied in eight diverse inbred lines of pumpkin by Mohanty *et al.* (1999). The result revealed that both phenotypic coefficient of variation and genotypic coefficient of variation were high for yield per plant (49.33% and 34.22% respectively) and number of fruits per plant (42.15% and 20.80% respectively).

Sarkar *et al.* (1999) reported high genotypic variance for fruit volume and fruit weight with high percentage of heritability in pointed gourd. In a study conducted by Pariari *et al.* (2000) with twenty one widely divergent germplasm of pointed gourd, the highest phenotypic variance was observed for fruit volume followed by fruit weight, number of seeds per fruit and number of fruits per plant.

Studies were made on seven parents and twenty one bitter gourd hybrids by Prasad (2000). He noticed maximum phenotypic coefficient of variation for fruit yield per plant (28.83%) followed by fruit weight (26.82%) and fruit length (25.05%) and lowest for days to male flower opening (12.3%) and days to female flower opening (13.18%). Fruit yield recorded a high genotypic coefficient of variation of 29.18 per cent followed by fruit weight (26.74%).

Mohanty (2000) studied the extent of variability for important economic traits in pumpkin and observed high phenotypic coefficient of variation for yield (43.48%) followed by number of fruits per plant (33.34%), average fruit weight (30.04%), vine length (24.64%) and number of female flowers (22.65%). Similarly the magnitude of genotypic coefficient of variation was high for yield (40.07%), number of fruits per plant (30.28%) and average fruit weight (29.15%).

Arunachalam (2002) recorded maximum phenotypic coefficient of variation for fruit weight (63.86) and genotypic coefficient of variation for resistance to bitter gourd distortion mosaic virus (46.62) and fruit yield per plant (37.81).

In ridge gourd Rao *et al.* (2002) reported high phenotypic coefficient of variation for yield per vine (39.17%), fruits per branch (35.50%) and node of first male flower (36.41%).

2.2 CORRELATION AND PATH ANALYSIS

Yield is an expression of complexity and depends on a number of component characters. Hence knowledge of association between yield and its contributing traits are of great value. Correlation analysis helps in the evaluation of relationship existing between yield and its components along with the inter relationship among the yield components. But it does not give the exact position of the relative importance of direct and indirect effects of the various yield attributes. Path analysis facilitates the partitioning of correlation coefficients into direct and indirect effects of various characters on yield or any other attribute.

Study conducted by Srivastava and Srivastava (1976) in bitter gourd revealed that number of fruits and female flowers per plant was positively correlated with yield per plant both at phenotypic and genotypic level. They also noticed positive inter correlation between days to first female flower opening and fruit weight.

In bitter gourd, yield was positively correlated with number of fruits and fruit length. Strong positive genetic correlation was observed for days to anthesis of female flower with fruit length and number of fruits (Singh *et al.*, 1977).

Ramachandran and Gopalakrishnan (1979) reported high positive genotypic and phenotypic correlation of length of main vine with yield per plant. This was closely followed by weight of fruit, length of fruit, number of fruits per plant and number of female flowers per plant. Fruit weight was positively correlated with fruit girth and 100 seed weight. The number of female flowers per plant showed a positive association with the number of fruits per plant.

Path coefficient analysis in bitter gourd by Ramachandran *et al.* (1979) revealed that fruit weight exerted maximum positive effect on yield followed by number of fruits. Contribution of fruit length to yield was negative.

Positive correlation of yield with fruit weight, number of fruits, length of fruits and fruit diameter was observed in bitter gourd by Mangal *et al.* (1981).

Indiresh (1982) noticed positive and significant correlation of yield with fruit weight, fruit length, diameter and vine length in bitter gourd. Similar trends were observed in other cucurbitaceous vegetables also. Kondalraj *et al.* (1984) reported strong association of yield per plant with number of fruits and fruit weight in snake gourd. Singh *et al.* (1984) recorded positive effect of fruit number and fruit weight on yield in bottle gourd. They also observed significant positive correlation of days to first female flower opening with marketable maturity.

Positive effect on yield was showed by number of fruits per vine, average individual fruit weight, per cent fruit set, vine length, number of nodes on main axis. Number of primary branches per vine and average fruit weight exerted negative effect on yield. With regard to sex ratio (male: female), its correlation with fruit set and number of fruits per vine is negative and significant in bottle gourd (Murali *et al.*, 1986).

Choudhury *et al.* (1986), Gopalakrishnan (1986) and Lawande and Patil (1989) reported positive correlation of yield with fruit weight, fruit length, fruit girth and number of fruits per plant in bitter gourd.

Investigation carried out by Nagaprasuna and Rao (1989) in cucumber revealed that node at which first female flower appeared, number of days to first female flower appearance, number of female flowers per vine and average fruit weight recorded positive association with yield per vine at phenotypic and genotypic levels. Based on path coefficient analysis number of fruits per vine and average fruit weight were found to be most important variables.

Number of fruits had a highly significant and positive correlation with yield. Significant positive correlation between fruit diameter and fruit length was also noticed by Prasad and Singh (1989).

Path coefficient analysis in watermelon has indicated that the average fruit weight exerted a strong positive direct effect on fruit yield (Rajendran and Thamburaj, 1989).

In cucumber, fruit yield per plant had significant positive genotypic and phenotypic correlation with number of female flowers per plant, fruit weight and number of fruits per plant. Number of female flowers had significant positive correlation with number of fruits per plant (Rastogi and Deep, 1990).

Um and Kim (1990) observed high positive correlation of fruit weight and fruit length on yield in bitter gourd. Devadas, (1993) and Kennedy, (1994) found that number of fruits, fruit weight and fruit length have positive association with yield.

Negative association of fruit yield with days to first female flowering was observed in bitter gourd by Khattra *et al.* (1994). Number of fruits and fruit length had contributed indirectly towards yield (Paranjape and Rajput, 1995)

Rajput *et al.* (1995) studied correlation and path analysis in bitter gourd for fruit yield. They reported positive correlation of yield with number of fruits, fruit weight, fruit length and negative association with number of days to first harvest. The fruit weight exerted maximum positive direct effect on yield.

Studies on correlation and path analysis carried out in eight genotypes of cucumber showed that yield per plant had strong positive association with fruiting per cent, number of fruits per plant, fruit weight and fruit length both at genotypic and phenotypic level. Path coefficient analysis revealed that number of fruits per plant had maximum direct genotypic effect on yield followed by fruit weight (Saikia *et al.*, 1995).

High positive relationship between fruit yield and number of fruits in bitter gourd was recorded by Thakur *et al.* (1996). Rajeswari (1998) reported positive correlation of yield with fruit weight and fruit girth in bitter gourd. She also reported positive direct effects of days to first female flowering, sex ratio, fruit diameter, fruit weight and number of fruits on yield.

Correlation and path coefficient studies in pointed gourd by Sarkar *et al.* (1999) indicated that fruit weight and fruit girth were positively and significantly correlated with yield per plant at genotypic and phenotypic level. Path analysis revealed that fruit weight and fruit girth had maximum positive direct effect on yield. Pariari *et al.* (2000) reported high correlation of fruit volume and fruit weight with yield in pointed gourd.

In segregating population of bitter gourd, the traits viz., length, fruit girth and fruit weight had exerted maximum direct effect on fruit yield per plant (Puddan, 2000). Arunachalam (2002) noticed high positive genotypic correlation of fruit yield with fruit weight followed by number of fruits per plant, number of male flowers per plant, resistance to BDMV, fruit length and fruit weight.

Lakshmi *et al.* (2002) revealed that yield per vine in pumpkin was significantly and positively associated with number of fruits per vine and fruit weight.

2.3 HERITABILITY AND GENETIC ADVANCE

Heritability is the proportion of the total variation caused by the genotype and aims at the partitioning of the estimated variance in to its genetic and environment component.

Srivastava and Srivastava (1976) reported high heritability for number of fruits per plant and lowest for number of male flowers per plant in bitter gourd.

Singh *et al.* (1977) realized that in bitter gourd yield, number of fruits per plant and fruit length exhibited high heritability and high genetic advance, while days to 50 per cent flowering had low heritability and very low genetic advance.

High estimates of heritability for number of fruits per plant followed by yield per plant and days to female flower opening in bitter gourd was recorded by Ramachandran and Gopalakrishnan (1979).

High estimates of heritability along with genetic advance for yield, number of fruits and fruit weight and lower estimates for number of days to first female flower anthesis have been noticed in bitter gourd (Mangal *et al.*, 1981). According to Indiresh (1982) characters, viz., fruit weight, fruit length and fruit girth showed high heritability estimates.

Days to first female flower appearance, percentage fruit set, yield per plant and number of fruits registered high heritability estimates and low genetic gain in bitter gourd (Suribabu *et al.*, 1986). Similar results were observed by Choudhury (1987) in bitter gourd. High heritability along with high genetic gain was noticed for fruit yield per plant, fruit weight and number of fruits in bitter gourd by Vahab (1989).

In ridge gourd, high heritability and high genetic advance for yield and number of fruits was revealed by Prasad and Singh (1989).

Fruit length and fruit diameter in cucumber showed high genetic advance as percent of mean (Muthulakshmi and Pappiah, 1995). Rajput *et al.* (1996) reported high heritability for fruit yield and number of fruits per vine. High heritability coupled with high genetic advance was observed for yield per plant, fruit weight and number of fruits per plant in pumpkin (Kumaran *et al.*, 1997). Pariari *et al.* (2000) recorded high heritability for fruit length, fruit diameter and number of fruits per plant in pointed gourd.

Analysis of genetic parameters in bitter gourd by Prasad (2000) revealed high heritability for fruit yield and fruit girth. Genetic advance was high in fruit yield (58.73%) followed by fruit weight (54.93%).

Analysis of F_2 and F_3 generations of bitter gourd showed that first female flower appearance, fruit length, fruit girth and fruit weight showed high heritability with high genetic advance (Puddan, 2000). Higher estimates of genetic advance as per cent of mean were observed for yield per vine, fruits per vine and fruits per branch in ridge gourd. (Rao *et al.*, 2002)

Arunachalam (2002) recorded high heritability with high genetic gain for resistance to BDMV followed by fruit colour score.

2.4 GENE ACTION

Knowledge of the gene actions underlying the inheritance of quantitative characters associated with yield is indispensable in the construction of plant breeding strategies. The comprehensive literatures on gene action for various traits in cucurbitaceous crops are presented below.

2.4.1 Days to male flowering

Crop	**Gene action**	**Reference**
Bottle gourd	Additive	Sharma *et al.* (1983)
Bottle gourd	Additive	Sirohi *et al.* (1986)
Pumpkin	Additive	Sirohi (1994)
Bitter gourd	Over dominance	Munshi and Sirohi (1994)
Pumpkin	Non additive	Mohanty (1999)
Pumpkin	Non additive	Mohanty and Mishra (1999)
Bitter gourd	Non additive	Prasad (2000)

2.4.2 Number of male flowers

Pumpkin	Over dominance	Mohanty (1999)
Pumpkin	Non additive	Mohanty and Mishra (1999)

2.4.3 Number of female flowers

Pumpkin	Non additive	Mohanty (1999)
Pumpkin	Epistasis	Mohanty *et al.* (1999)
Bitter gourd	Additive and non additive	Prasad (2000)

2.4.4 Days to female flowering

Summer squash	Partial dominance	Gill *et al.* (1971)
Bitter gourd	Partial dominance	Srivastava and Nath (1976)
Water melon	Partial dominance	Sachan and Nath (1977)
Pumpkin	Additive, dominance and epistasis	Doijode and Sulladmath (1981)
Bitter gourd	Additive	Pal *et al.* (1983)
Bitter gourd	Over dominance	Gopalakrishnan (1986)
Bottle gourd	Duplicate epistasis	Sirohi and Ghorui (1993)
Bitter gourd	Over dominance	Munshi and Sirohi (1994a)
Pumpkin	Additive	Sirohi (1994)
Pumpkin	Partial dominance	Mohanty (1999)
Pumpkin	Non additive	Mohanty and Mishra (1999)
Bitter gourd	Non additive	Prasad (2000)
Bottle gourd	Dominance	Singh *et al.* (2000)
Bitter gourd	Dominance	Rajeswari and Natarajan (2002)
Bitter gourd	Dominance	Arunachalam (2002)

2.4.5 Sex ratio

Bitter gourd	Dominance	Rajeswari (1998)

2.4.6 Number of fruits

Summer squash	Non additive	Gill *et al.* (1971)
Bitter gourd	Dominance	Srivastava and Nath(1976)
Water melon	Partial dominance	Sachan and Nath (1977)
Bitter gourd	Dominance, complementary epitasis	Sirohi and Choudhury (1979)
Summer squash	Additive and non additive	Bachandani *et al.* (1980)
Bitter gourd	Additive	Singh and Joshi (1980)
Bitter gourd	Additive	Pal *et al.* (1983)
Bottle gourd	Over dominance	Sharma *et al.* (1983)
Bitter gourd	Additive	Sirohi and Choudhury (1983)
Bitter gourd	Additive, non additive	Goapalakrishnan (1986)
Bitter gourd	Additive, dominance	Lawande and Patil (1990)
Bitter gourd	Additive, dominance	Lawande and Patil (1991)
Bitter gourd	Partial dominance, overdominance	Devadas (1993)
Bitter gourd	Non additive	Kennedy (1994)
Bitter gourd	Additive, duplicate	Lawande *et al.* (1994)
Bitter gourd	Over dominance	Munshi and Sirohi (1994)
Pumpkin	Over dominance	Sirohi (1994)
Bitter gourd	Dominance	Rajeswari (1998)
Pumpkin	Epistasis	Mohanty *et al.* (1999)
Bitter gourd	Additive and non additive	Prasad (2000)
Bottle gourd	Dominance	Singh *et al.* (2000)
Bitter gourd	Dominance	Rajeswari and Natarajan (2002)
Bitter gourd	Dominance	Arunachalam (2002)

2.4.7 Fruit length

Summer squash	Non additive	Gill *et al.* (1971)
Bitter gourd	Additive	Singh and Joshi (1980)
Bitter gourd	Complementary, duplicate epistasis, additive, dominance	Sirohi and Choudhury (1980)
Bitter gourd	Partial dominance	Gopalakrishnan (1986)
Ridge gourd	Non additive	Prasad and Singh (1989)
Bitter gourd	Additive, complementary epistasis	Lawande and Patil (1990)
Bitter gourd	Additive, dominance	Lawande and Patil (1991)
Bitter gourd	Additive, partial dominance	Devadas (1993)
Bitter gourd	Additive	Kennedy (1994)
Bitter gourd	Additive, dominance	Mishra *et al.* (1994)
Bitter gourd	Partial dominance	Munshi and Sirohi (1994)
Bottle gourd	Additive	Kushwaha and Ram (1996)
Bitter gourd	Additive, dominance	Ram *et al.* (1997)
Bitter gourd	Dominance, additive	Celine and Sirohi (1998)
Bitter gourd	Additive, dominance	Rajeswari (1998)
Bitter gourd	Additive	Prasad (2000)
Bitter gourd	Additive, dominance	Ram *et al.* (2000)
Bottle gourd	Additive, dominance, non additive	Singh *et al.* (2000)
Bitter gourd	Additive, dominance	Rajeswari and Natarajan (2002)

2.4.8 Fruit girth

Bitter gourd	Complementary, duplicate epistasis, additive, dominance	Sirohi and Choudhury (1980)
Bitter gourd	Additive with partial dominance	Sirohi and Choudhury (1983)
Bottle gourd	Over dominance	Sharma *et al.* (1983)
Bitter gourd	Over dominance	Gopalakrishnan (1986)
Bottle gourd	Over dominance	Sirohi *et al.* (1988)
Ridge gourd	Non additive	Prasad and Singh (1989)
Bitter gourd	Additive, dominance	Lawande and Patil (1990)
Bitter gourd	Over dominance	Lawande and Patil (1991)
Bitter gourd	Non additive	Devadas (1993)
Bitter gourd	Over dominance	Kennedy (1994)
Bitter gourd	Additive, Non additive	Mishra *et al.* (1994)
Bitter gourd	Duplicate epistasis	Munshi and Sirohi (1994)
Bottle gourd	Additive	Kushwaha and Ram (1996)
Bitter gourd	Additive, dominance	Ram *et al.* (1997)
Bitter gourd	Additive and non additive	Prasad (2000)
Bitter gourd	Additive, dominance	Ram *et al.* (2000)
Bottle gourd	Dominance	Singh *et al* (2000)
Bitter gourd	Additive and dominance	Rajeswari and Natarajan (2002)
Bitter gourd	Non additive	Arunachalam (2002)

2.4.9 Fruit weight

Bitter gourd	Partial dominance	Srivastava and Nath (1976)
Water melon	Partial dominance	Sachan and Nath (1977)
Bitter gourd	Additive	Singh and Joshi (1980)
Bitter gourd	Additive, complementary epistasis,	Sirohi and Choudhury (1980)
Bitter gourd	Non additive	Pal *et al.* (1983)
Bottle gourd	Over dominance	Sharma *et al.* (1983)
Bitter gourd	Additive	Siriohi and Choudhury (1983)
Bitter gourd	Additive, non additive, partial dominance	Gopalakrishnan (1986)
Bitter gourd	Additive, dominance, complementary epistasis	Lawande and Patil (1990)
Bitter gourd	Additive, dominance	Lawande and Patil (1991)
Bitter gourd	Partial dominance, over dominance	Devadas (1993)
Bitter gourd	Non additive	Kennedy (1994)
Bitter gourd	Dominance,	Lawande *et al.* (1994)
Bitter gourd	Additive, non additive	Mishra *et al.* (1994)
Bitter gourd	Over dominance	Munshi and Sirohi (1994)
Pumpkin	Over dominance	Sirohi (1994)
Bitter gourd	Duplicate, complemantary epistasis	Ram *et al.* (1997)
Bitter gourd	Additive	Celine and Sirohi (1998)
Bitter gourd	Additive, dominance	Rajeswari (1998)
Pumpkin	Epistasis	Mohanty *et al.* (1999)
Bitter gourd	Additive, dominance	Ram *et al.* (2000)
Bitter gourd	Additive,	Prasad (2000)
Bitter gourd	Additive, dominance	Rajeswari and Natarajan (2002)
Bitter gourd	Dominance	Arunachalam (2002)

2.4.10 Fruit yield per plant

Summer squash	Non additive	Gill *et al.* (1971)
Bitter gourd	Dominance	Srivastava and Nath (1976)
Water melon	Partial dominance	Sachan and Nath (1977)
Bitter gourd	Additive, complementary epistasis	Sirohi and Choudhury (1979)
Summer squash	Non additive	Bachandani *et al.* (1980)
Bitter gourd	Additive	Singh and Joshi (1980)
Bitter gourd	Non additive, complementary epistasis	Pal *et al.* (1983)
Bitter gourd	Over dominance	Sharma *et al.* (1983)
Bitter gourd	Epistasis	Sirohi and Choudhury (1983)
Bitter gourd	Additive, non additive	Gopalakrishnan (1986)
Bitter gourd	Additive, dominance	Lawande and Patil (1990)
Bitter gourd	Additive, dominance	Lawande and Patil (1991)
Bottle gourd	Dominance	Sirohi and Ghorui (1993)
Bitter gourd	Additive, dominance	Lawande *et al.* (1994)
Bitter gourd	Additive, non additive	Mishra *et al.* (1994)
Bitter gourd	Over dominance	Munshi and Sirohi (1994)
Pumpkin	Dominance	Sirohi (1994)
Bitter gourd	Duplicate and complementary epistasis	Ram *et al.* (1997)
Bitter gourd	Over dominance	Rajeswari (1998)
Pumpkin	Epistasis	Mohanty *et al.* (1999)
Pumpkin	Additive	Mohanty and Mishra (1999)
Bitter gourd	Non additive	Prasad (2000)
Bitter gourd	Additive, dominance	Ram *et al.* (2000)
Bitter gourd	Additive, non additive	Tewari *et al.* (2001)
Bitter gourd	Dominance	Rajeswari and Natarajan (2002)

2.5 MOSAIC DISEASE OF BITTER GOURD

Mosaic disease of bittergourd so far considered as minor disease has gained importance in many parts of Kerala in the recent part. The occurrence of bittergourd mosaic virus (BMV) in India was first reported by Uppal (1993).

Nagarajan and Ramakrishnan (1971) found that bitter gourd mosaic virus are transmitted to healthy bitter gourd plants by aphids viz. *Aphis gossypii, Aphis malvae, Aphis nerii, Myzus persicae* and *Brevicoryne brassicae.*

Bitter gourd distortion mosaic virus (BDMV) was characterized by typical mosaic leaf curling, crinkling and severe stunting and reduced flower bud production. The fruits were deformed, rough and corky in texture (Giri and Mishra, 1986). Bitter gourd plants with mosaic symptoms were reported from different parts of the country (Singh, 1987).

Bitter gourd distortion mosaic virus (BDMV) was first reported in Kerala by Mathew *et al.* (1991). Occurrence of severe mosaic disease characterized by typical leaf curling, crinkling, mottling and severe stunting was observed in bittergourd in Kerala. They also mentioned that yield loss in early infected crop was almost 100 per cent and whitefly (*Bemesia tabaci* Genn.) could be the vector of the disease. The virus could be transmitted to cucumber (*Cucumis sativus* L.) but not to snakegourd (*Trichosanthes anguina* L.) and pumpkin (*Cucurbita moschata*) on artifical inoculation.

Purushothaman (1994) mentioned that varieties such as Priya, Co1 and Arka Harit were susceptible to bittergourd mosaic virus. Varietal evaluation of 30 germplasm lines in bittergourd revealed that BG 14-4, BL 240, BG 14, HK 12 and Palwal Set 1 were free from yellow mosaic virus caused by Zucchini yellow mosaic poty virus (Thakur *et al.*, 1996).

Doraisamy *et al.* (1998) recorded that the indigenous germplasm accession IC 68324 was least susceptible to bitter gourd mosaic virus. Varietal reaction of bitter gourd to bitter gourd mosaic virus showed that the variety Priya was highly susceptible with 90 per cent infection and other accessions like 61 white medium, 87 green long, 177 green medium, IC 68324 and IC 4358 were least susceptible with 40 per cent infection (Lakshman *et al.*, 1998).

Pandey *et al.* (1998) observed the presence of twinned germinate virus particles, measuring 19 x 30 nm, in infected leaf tip preparation. They tested the varietal response of 15 bitter gourd varieties to bitter gourd distortion mosaic virus and found that only two varieties viz., ARBTH 1 and Pusa Do Mausami were found to be resistant. They further reported that the virus could be transmitted by sap, seed and through grafting.

Serological properties of the bitter gourd mosaic virus indicate that bitter gourd mosaic virus disease found in Kerala may be caused by *Cucumis* virus I (Purushothaman *et al.*, 1998b). Purushothaman *et al.* (1998a) mentioned that bitter gourd mosaic virus could be transmitted through graft inoculation and not transmissible through seeds. The yield loss in variety Preethi due to BDMV was 100 per cent (Rekha, 1999).

Arunachalam *et al.* (2002) screened 86 genotypes against bitter gourd distortion mosaic virus (BDMV). He reported that only nine genotypes were found to be highly resistant (IC 68296, IC 68335, IC 68263 B, IC 68275, IC 68250 A, IC 68312, IC 68285 and IC 68272) and high yielding varieties such as Priya, Priyanka and Preethi released by Kerala Agricultural University were found to be susceptible.

Materials and Methods

3. MATERIALS AND METHODS

The present study entitled "Genetic analysis of F_2 and F_3 generations for yield attributes and resistance to distortion mosaic virus disease in bitter gourd (*Momordica charantia* L.)" was carried out in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agriculture University. Field trials were laid out at the experimental plots of the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agriculture University. The area is located at latitude of 10^0.31' N, longitude of 76^0 30'E and at an elevation of 22.2 m above MSL. The whole investigation was grouped into two experiments.

3.1 EXPERIMENT NO. 1

3.1.1 Experimental Materials

Eighty-six accessions of bitter gourd (*Momordica charantia* L.) were field screened for bitter gourd distortion mosaic virus (BDMV) resistance and fruit yield and 47 genotypes were identified. These 47 genotypes were further tested to confirm the resistance. From screening studies eight high yielding disease resistant and susceptible genotypes were selected and these genotypes were inter crossed per se (Arunachalam, 2002). The resultant F_1 was evaluated for yield and yield attributes including disease resistance. Seeds from F_1 plants of three crosses and their parents selected from the screening experiments formed the materials for the study. Selected crosses and their parents are given in Table 1.

3.1.2 Out line of the Experiment

3.1.2.1 Raising F_2 generation of selected crosses and their parents

Selfed seeds of the selected crosses and their parents were sown on September 2002 (Plate 1). The spacing between the pits and rows was 2 x 2 m. The experiment was laid out in Randomised Block Design with three replications for each of the 10 treatments. All cultural operations were carried out as per the Package of Practices Recommendations of KAU, 2002. No plant protection measures were adopted to ensure adequate vector population.

Table 1.Parents and crosses of bitter gourd selected for experiment No. I and II

Resistant genotypes		Susceptible genotypes		Crosses
Parent name	Name/Identity	Parent name	Name/Identity	
P_1	IC 68335	P5	Preethi	P1 x P5 (IC68335 x Preethi)
P2	IC 68263 B	P6	VKB 134	P2 x P5 (IC68263B x Preethi)
P3	IC 68275	P8	IC 68342 B	P4 x P8 (IC68250 x IC68342B)
P4	IC 68250			

PLATE: 1 FIELD VIEW OF EXPERIMENT NO: 1

PLATE: 2 FIELD VIEW OF EXPERIMENT NO: 2

For selfing, female flowers were covered with butter paper on the day just before anthesis. Next day morning, pollen from the male flower of the same plant is dusted over the stigma of the female flower and butter paper cover was replaced to ensure self-pollination.

3.2 EXPERIMENT NO 2

3.2.1 Experimental Materials

The selfed seeds of selected crosses in F_2 generation and their parents were used for raising F_3 generation.

3.2.2 Out line of the Experiment

3.2.2.1 Raising F_3 generation of selected crosses and parents

Selfed seeds of selected crosses and their parents were sown on April 2003 (Plate 2). The spacing between the pit was 2x2m. Experiment was laid out in Randomised Block Design with three replication for each of the 10 treatments. All cultural operations were carried out as per the Package of Practices Recommendations of KAU, 2002. No plant protection measures were adopted to ensure adequate vector population. Selfing procedure was same as in first experiment.

3.3 OBSERVATIONS RECORDED

The observations on flowering characters, yield and yield attributes and BDMV incidence were recorded for experiment 1 and experiment 2. Observations taken include:

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 when the first female flower opened.

iii) Number of male flowers per plant (NMF)

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

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) 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.

vi) Sex ratio (SR)

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

vii) Fruit weight (FW)

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

viii) Fruit girth (FG)

Maximum girth of five fruits in each plant was measured in centimeter (cm) during peak harvesting period and the average was worked out.

ix) Fruit length (FL)

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

x) Fruit yield per plant (FY)

The total weight of harvested fruits from each plant were recorded in gram (g)

xi) Assessment of BDMV incidence and its severity

Five leaves were selected randomly from each plant and were tagged to observe the disease severity. The disease severity is shown in Plates 3 & 4. It was assessed by adopting 0 to 5. Score chart as given bellow:

0 : No Symptom

1 : Minute chlorotic specks/patches on leaf.

2 : Wide area of mosaic symptom on whole leaf with out distortion

3 : Distortion and reduction about 25 percent 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, per cent disease severity (PDS) was calculated using the formula

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

Percent disease Incidence (PDI) was calculated using the formula

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

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

$$\text{CI} = \frac{\text{PDS x PDI}}{100}$$

PLATE: 3 SYMPTOMATOLOGY OF BDMV-DISTORTED PLANTS

PLATE: 4 SYMPTOMATOLOGY OF BDMV -DISTORTED BRANCH

PLATE: 5 SYMPTOMATOLOGY OF BDMV-DISTORTED GRADES OF LEAVES

Based on the CI Values, genotypes were grouped in to 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)

xii) Fruit colour

Fruit colour (Plate 7) of each genotype was recorded in the following class viz.,

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

3.4 STATISTICAL ANALYSIS

The data collected were analysed using biometrical techniques.

3.4.1 Phenotypic and genotypic coefficient of variation

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

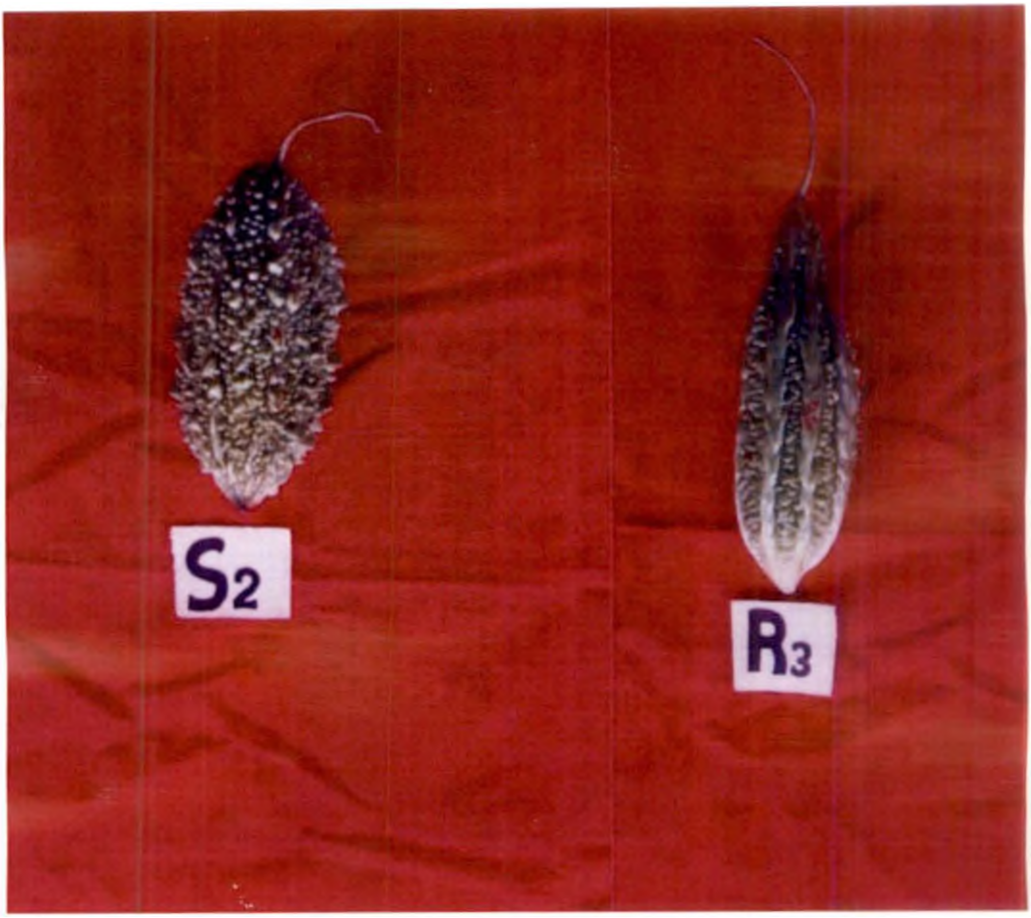


PLATE: 6 FRUIT OF SUSCEPTABLE AND RESISTANT PARENTS

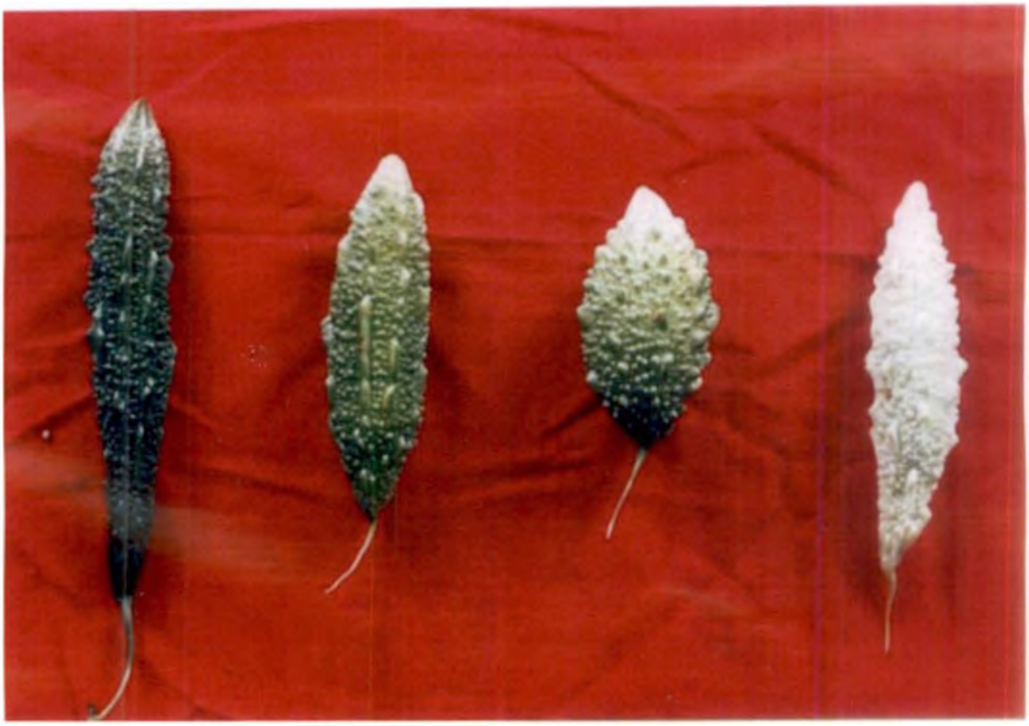


PLATE: 7 DIFFERENT TYPES OF FRUITS OF BITTER GOUARD

0 to 10 per cent - Low

10 to 20 per cent - Medium

20 per cent and above - High

$$PCV = \frac{\sqrt{Vp}}{\bar{X}} \times 100$$

Vp = Phenotypic variance

$\bar{X}$ = mean of the character under study

$$GCV = \frac{\sqrt{Vg}}{\bar{X}} \times 100$$

Vg = genotypic variance

$\bar{X}$ = mean of the character under study

3.4.2 Phenotypic and genotypic correlation

The phenotypic and genotypic correlation between yield and various yield attributes and among themselves were estimated (Johnson *et al.* 1955)

Phenotypic correlation coefficient between two Characters 1 and 2

$$(rp12) = \frac{COVp12}{(Vp1 . Vp2)^{1/2}}$$

COVp12 = Phenotypic covariance between characters 1 and 2

Vp 1 = phenotypic variance of characters 1

Vp 2 = phenotypic variance of character 2

Genotypic correlation coefficient between two character 1 and 2

$$(rg12) = \frac{COVg12}{(Vg1 . Vg2)^{1/2}}$$

COVg12 = genotypic covariance between character 1 and 2

Vg 1 = genotypic variance of character 1

Vg 2 = genotypic variance of character 2

3.4.3 Genetic advance

Genetic advance was estimated as per formula suggested by Johnson *et al*. (1955).

$$\text{Genetic advance} = \frac{Vg}{\sqrt{Vp}} \times K$$

K = Selection differential at 5 % (2.06)

Vg = genotypic variance

Vp = phenotypic variance

3.4.4 Genetic gain

Expected genetic gain under selection was calculated by formula suggested by Johnson *et al*. (1955)

$$\text{Genetic gain} = \frac{\text{Genetic advance}}{\text{Grand mean}} \times 100$$

The genetic advance as per cent of mean was categorized as:

0 to 10 per cent - Low

10 to 20 per cent - Moderate

20 per cent and above - High

3.4.5 Path analysis

To study the cause and effect relationship of yield and its attributes, direct and indirect effects were analysed using path coefficient analysis as suggested by Wright (1923).

3.4.6 Heritability (Broad sense)

Heritability, in broad sense, was worked out as per the formula suggested by Hanson *et al.* (1956). The heritability was categorized 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

$H^2 = (Vg / Vp) \times 100$

Vg = genotypic variance

Vp = phenotypic variance

Results

4. RESULTS

4.1 EXPERIMENT NO.1 - F_2

The main objective of the present investigation is the identification of genotypes resistant to bitter gourd distortion mosaic virus (BDMV) coupled with high yield. The selfed seeds of three selected crosses along with their parents were raised in experiment-1 and the genetic variability for the important economic traits were assessed. The extent of genetic variability with respect to twelve characters in ten genotypes was estimated. The mean performance of crosses and the parents are presented in the Table 4.1. The abstract of analysis of variance for these characters are given in Table 4.2. The data on range, and estimates of genetic parameters for these yield related characters are represented in Table 4.3.

4.1.1 Genetic variability

The analyses of variance for yield and associated characters in F_2 progenies of three resistant vs susceptible crosses and parents revealed that all the twelve characters differ significantly among the genotypes.

There was a large range of variation for all the twelve characters among the crosses and its parents (Table 4.3). The anthesis of male flower varied from 52 days (VKB 134) to 34 days (IC 68250) whereas anthesis of female flower varied from 60 days in VKB 134 to 40 days in genotypes IC 68250 and IC 68342 B. Their averages were 43.07 and 47.19 respectively. With regard to number of male and female flowers produced per plant, the range of variation was from 169 (Preethi) to 41 (IC 68342 B) and 35 (IC 68335) to 121 (IC 68263 B) respectively and average being 80.73 and 19.25. Low sex ratio was recorded in Preethi (0.116) and high in IC 68335 (0.479) with an average of 0.264. The range of variation for number of fruits per plant was 31 (IC 68335) to 9 (VKB 134) with average being 16.64. Maximum fruit length was noticed in IC 68335 x Preethi (15.55 cm) and minimum in IC 68335 (4.5 cm). Fruit characters, viz., fruit girth and fruit weight varied from 10.2 cm (IC 68335 x Preethi) to 3.95 cm (IC 6834213) and 144.60 g (IC 68335 x Preethi) to 30.5 g (IC 68335)

Table 4.1. Mean performance of F_2 progenies of three selected crosses (resistant vs susceptible) and parents under natural epiphytotic condition

Sl. No.	Genotype	Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield/ plant	Coefficient of infection	Fruit colour
1	$P_4 \times P_8$	41.80	47.97	102.27	19.17	0.18	17.13	11.17	7.07	97.75	1562.19	7.37	3.50
2	$P_1 \times P_5$	37.07	46.73	73.73	16.23	0.24	14.97	15.19	9.45	140.24	1882.33	5.83	2.67
3	$P_2 \times P_5$	48.33	51.20	90.67	18.50	0.20	16.20	14.44	8.60	131.70	1809.17	6.83	2.30
4	P_5	44.13	46.67	160.27	22.53	0.14	19.10	12.08	8.44	86.20	1370.48	48.63	3.83
5	P_6	49.17	56.73	85.10	16.23	0.19	13.23	7.14	7.70	45.97	703.21	30.53	1.47
6	P_8	41.10	41.57	43.17	18.17	0.42	15.33	8.22	4.50	61.23	724.72	75.80	2.47
7	P_1	45.57	47.90	66.90	31.37	0.48	28.33	4.91	8.22	33.15	648.35	5.10	2.40
8	P_2	41.10	45.00	64.90	13.23	0.20	11.00	6.07	5.06	55.37	590.50	21.07	2.43
9	P_3	43.43	45.43	69.00	21.07	0.28	16.90	6.83	5.22	59.07	841.61	6.70	2.17
10	P_4	39.04	42.70	51.33	16.03	0.30	14.20	10.41	5.37	70.26	708.93	8.60	2.83
	Mean	43.07	47.19	80.73	19.25	0.246	16.64	9.65	6.96	78.094	1084.15	21.64	2.61

Table 4.2. Analysis of variance for yield and associated character in F2 progenies of resistant vs susceptible crosses and parents

Source of variation	Degree of freedom	Mean sum of squares											
		Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield/ plant	Coefficient of infection	Fruit colour
Replication	2	1.262	0.301	0.031	0.730	0.00005	0.0518	0.0516	0.0275	2.930	614.00	2.158	0.0063
Treatment	9	44.694**	56.14**	3270.44**	75.80**	0.0369**	65.71**	37.99**	9.49**	3820.93**	793596.7**	1693.67**	1.35**
Error	18	0.1935	0.6437	0.3643	0.3689	0.000087	0.2466	0.0744	0.0340	0.7220	983.19	1.59990	0.0186

* Significance at 5%
**Significance at 1%

respectively and their averages were 6.93 cm and 78.094 g respectively. Highest fruit yield was observed in the cross IC 68335 x Preethi (1886 g) and lowest in IC 68263 B (56.50). In the case of coefficient of infection, lowest (4.8) was recorded for the resistant parent IC 68335 and the highest (77.9) for the susceptible parent IC 68342 B. The average coefficient of infection was 21.33. The three crosses namely IC 68335 x Preethi, IC 68263 B x Preethi and IC 68250 x IC 68342 B also recorded comparitively lower coefficient of infection for bitter gourd distortion mosaic virus.

4.1.2 Coefficient of variation

The phenotypic and genotypic coefficient of variation of twelve characters were estimated and presented in Table 4.3.

The coefficient of variation both at phenotypic and genotypic level showed low to high for all the characters studied. Anthesis of male flower (9.00, 8.94) and anthesis of female flower (9.27, 9.11) recorded lowest PCV and GCV whereas rest of the characters exhibited high magnitude of coefficient of variation at both levels. The maximum magnitude of coefficient of variation was indicated by coefficient of infection (109.87, 109.71) followed by yield (47.50, 47.41), fruit weight (45.71, 45.69) and sex ratio (42.14, 42.0).

4.1.3 Heritability and Genetic gain

The broad sense heritability values ranged from 96.0 to 99.9 per cent. Maximum heritability was observed for the character fruit weight (99.9) and lowest for fruit colour (96.0). All the characters showed high broad sense heritability.

The genetic advance expressed as percentage over mean (genetic gain) ranged from 18.29 (anthesis of male flower) to 225.67 (coefficient of infection). The characters, viz., number of female flowers (53.24), number of male flowers (88.42), sex ratio (87.22), number of fruits per plant (57.51), fruit length (75.6), fruit girth (52.28), fruit weight (94.11), fruit yield (97.08) and fruit colour (51.41) recorded more than 50 per cent genetic gain whereas anthesis of male and female flowers (18.29, 18.46) showed less than 20 per cent genetic gain.

Table 4.3. Range and estimates of genetic parameters for yield and associated characters in F_2 progenies of resistant vs susceptible crosses and parents

Sl. No.	Characters	Range	GCV (%)	PCV (%)	Heritability Broadsense (%)	Genetic advance	Genetic gain (%)
1	Anthesis of male flower	52 (P_6) to 34 (P_4)	8.94	9.00	98.70	7.88	18.290
2	Anthesis of female flowers	60 (P_6) to 40 (P_4)	9.11	9.27	96.60	8.71	18.457
3	Number of male flowers	169 (P_5) to 41(P_8)	40.89	40.90	99.00	68.00	88.423
4	Number of female flowers	35 (P_6) to 12 (P_2)	26.04	26.23	98.60	10.25	53.238
5	Sex ratio	0.479 (P_1) to 0.116 (P_5)	42.00	42.14	99.30	0.23	87.220
6	No. of fruits per plant	31 (P_1) to 9 (P_6)	28.07	28.23	98.90	9.57	57.512
7	Fruit length	15.55 (P_1xP_5) to 4.5 (P_1)	36.85	36.96	99.40	7.30	75.600
8	Fruit girth	10.2 (P_1xP_5) to 3.95 (P_8)	25.50	25.64	98.90	3.64	52.278
9	Fruit weight	144.60 (P_1xP_5) to 30.5 (P_1)	45.69	45.71	99.90	73.49	94.105
10	Fruit yield per plant	1886 (P_1xP_5) to 565.50 (P_2)	47.41	47.50	99.60	1056.89	97.076
11	Coefficient of infection	4.8 (P_1) to 77.9(P_8)	109.71	109.87	99.70	48.85	225.67
12	Fruit colour	1.5 (P_6) to 3.8 (P_5)	25.52	26.05	96.00	1.34	51.41

4.1.4 Association of characters

4.1.4.1 Correlation

The genotypic and phenotypic correlation coefficients between yield and eleven different yield component characters and among themselves are presented in the Table 4.4.

Phenotypic and genotypic correlation among the yield attributing traits were found to be positive and significant with few exceptions of significant negative associations with sex ratio (-0.488, -0.492) and coefficient of infection (-0.266, -0.267). Positive correlations were shown by the characters fruit weight (0.948, 0.950), fruit length (0.910, 0.913), fruit girth (0.684, 0.690), number of male flowers (0.485, 0.486) and days to opening of first female flower (0.198, 0.203) with yield per plant.

The inter correlation among the yield component characters indicted different magnitude both at phenotypic and genotypic level and in different direction. Fruit weight exerted significant positive association with fruit length (0.959, 0.961) and fruit girth (0.535, 0.538). It also showed positive correlation with number of male flowers (0.292, 0.293) while sex ratio (-0.469, -0.470), number of female flowers (-0.311, -0.313); number of fruits (-0.231, -0.233) and anthesis of male flower (-0.256, -0.253) showed negative correlation. Fruit girth is positively correlated to almost all characters except sex ratio (-0.284, -0.288). Sex ratio (-0.483, -0.487), number of fruits per plant (-0.216, -0.218), number of female flowers (-0.288, -0.292) and days to anthesis of male flower (-0.231, -0.233) showed negative relation with fruit length. Flowering attributes, viz., anthesis of female flower (0.756, 0.772) and number of male flowers (0.346, 0.351) exhibited positive relationship with days to opening of first female flower.

4.1.4.2 Direct and indirect effects

Among the twelve yield attributes studied eight characters exhibited significant effect on yield. The estimates of direct and indirect effects of these characters on yield are presented in Table 4.5. It was observed that maximum positive

Table 4.4. Genotypic and phenotypic correlation for twelve characters in F_2 progenies of resistant vs susceptible crosses and parents

Characters	Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield/ plant	Coefficient of infection	Fruit colour
Anthesis of male flowers	1.000	0.772**	0.317**	0.329**	-0.128	0.257**	-0.233*	0.279**	-0.253*	-0.089	0.023	-0.419**
Anthesis of female flowers	0.756**	1.000	0.351**	0.036	-0.419**	0.023	0.050	0.594**	0.052	0.203*	-0.242*	-0.438**
Number of male flowers	0.316**	0.346**	1.000	0.202*	-0.664**	0.176	0.388**	0.558**	0.293**	0.486**	0.086	0.596**
Number of female flowers	0.325**	0.034	0.201*	1.000	0.534**	0.992**	-0.292**	0.314**	-0.313**	-0.088	-0.111	0.155
Sex ratio	-0.131	-0.413**	-0.661**	0.526**	1.000	0.548**	-0.487**	-0.288**	-0.470**	-0.492**	0.120	-0.266**
Number of fruits	0.256**	0.022	0.175	0.978**	0.545**	1.000	-0.216*	0.381**	-0.233*	-0.019	-0.171	0.195
Fruit length	-0.231*	0.045	0.387**	-0.288**	-0.483**	-0.210*	1.000	0.555**	0.961**	0.913**	-0.134	0.437**
Fruit girth	0.273**	0.584**	0.554**	0.313**	-0.284**	0.376**	0.553**	1.000	0.538**	0.690**	-0.329**	0.147
Fruit weight	-0.250**	0.051	0.292**	-0.311**	-0.469**	-0.231*	0.959**	0.535**	1.000	0.950**	-0.248*	0.345**
Fruit yield	-0.087	0.198*	0.485**	-0.090	-0.488**	-0.018	0.910**	0.684**	0.948**	1.000	-0.267**	0.418**
Coefficient of infection	0.022	-0.239*	0.085	-0.109	0.118	-0.170	-0.133	-0.328**	-0.248*	-0.266**	1.000	0.094
Fruit colour	-0.416**	-0.426**	0.583**	0.147	-0.256**	0.190	0.423**	0.136	0.336**	0.409**	0.092	1.000

Upper diagonal represent genotypic correlation
Lower diagonal represent phenotypic correlation

*Significance at 5%
**Significance at 1%

Table 4.5. Direct and indirect effect of yield components on yield in F_2 progenies of resistant vs susceptible crosses and parents

Characters	Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Coefficient of infection	Fruit colour	Genotypic correlation with yield
Anthesis of male flowers	**-0.374**	0.505	0.061	0.071	0.003	0.079	0.051	-0.134	-0.351	0.003	-0.003	0.089
Anthesis of female flowers	-0.289	**0.655**	0.068	0.008	0.011	0.007	-0.011	-0.285	0.073	-0.029	-0.004	0.203
Number of male flowers	-0.119	0.230	**0.194**	0.044	0.018	0.054	-0.086	-0.268	0.405	0.010	0.005	0.486
Number of female flowers	-0.123	0.024	0.039	**0.217**	-0.014	0.303	0.064	-0.151	-0.435	-0.013	0.001	-0.088
Sex ratio	0.048	-0.274	-0.128	0.116	**-0.026**	0.167	0.107	0.138	-0.652	0.014	-0.002	-0.492
Number of fruits	-0.096	0.015	0.034	0.215	-0.014	**0.306**	+0.048	-0.183	-0.324	-0.020	0.002	-0.019
Fruit length	0.087	0.033	0.075	-0.063	0.013	-0.066	**-0.220**	-0.267	1.333	-0.016	0.004	0.913
Fruit girth	-0.104	0.389	0.108	0.068	0.008	0.116	-0.122	**-0.480**	0.746	-0.039	0.001	0.690
Fruit weight	0.095	0.034	0.056	-0.068	0.012	-0.071	-0.212	-0.258	**1.388**	-0.030	0.003	0.950
Coefficient of infection	-0.008	-0.158	0.017	-0.024	-0.003	-0.052	0.030	0.158	-0.345	**0.120**	0.001	-0.267
Fruit colour	0.157	-0.286	0.115	0.034	0.007	0.060	-0.096	-0.071	0.479	0.011	**0.008**	0.418

R = 0.0062

The diagonal values indicates direct effect direct effect was exerted by fruit weight (1.388) followed by anthesis of female flower (0.655), number of fruits (0.306) and number of female flowers (0.216). Highest negative direct effect was noticed for the character fruit girth (-0.480) followed by anthesis of male flower (-0.374).

The highest positive indirect effect was recorded for fruit weight through fruit length (1.33) and fruit girth (0.746). Maximum negative indirect effect on yield was exerted by fruit weight through sex ratio (-0.652) followed by number of female flowers (-0.435).

4.2 EXPERIMENT NO.2 - F_3

Main objective of the second experiment was to elicit information on the resistance of three selected crosses (resistant vs. susceptible) and parents to bittergourd distortion mosaic virus (BDMV) along with desirable traits. The selfed seeds of F_2 generation of three selected crosses and their parents were raised in this experiment.

4.2.1. Genetic variability

Extent of genetic variability in yield and related attributes in F_3 population of three selected crosses and seven parents were studied and the mean performance of these ten different genotypes for twelve characters are presented in Table 4.6. Analysis of variance for yield and associated characters in F_3 progenies and their parents are given in Table 4.7. The data on range, phenotypic and genotypic coefficient of variation, heritability, genetic advance and genetic gain are presented in Table 4.8.

Analysis of variance for all the twelve characters in F_3 progenies of three selected crosses and their parents recorded significant difference. The range of variation for all the twelve characters studied was also large.

Early anthesis of male flower was noticed for IC 68275 and IC 68250 (34.6 days) from the date of sowing and anthesis was comparatively late in the cross IC 68263B x Preethi (47.3 days). The number of days for first female flower to open

Table 4.6. Mean performance of F_3 progenies of three selected crosses (resistant vs susceptible) and parents under natural epiphytotic condition

Sl. No.	Genotype	Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield/ plant	Coefficient of infection	Fruit colour
1	P_4 x P_8	40.68	45.42	106.43	20.02	0.19	17.72	16.13	11.63	118.18	1884.88	7.20	3.37
2	P_1 x P_5	39.27	43.80	73.10	17.03	0.23	15.87	19.93	12.96	177.76	2801.37	6.40	3.20
3	P_2 x P_5	46.20	48.23	93.60	20.18	0.22	17.27	14.33	11.91	150.10	2570.87	7.20	3.03
4	P_5	39.48	45.80	104.18	14.84	0.14	12.16	21.47	11.20	74.37	870.42	70.00	3.63
5	P_6	37.25	41.67	75.55	25.76	0.34	22.82	12.05	13.29	88.79	2056.89	32.00	2.40
6	P_8	38.72	47.87	92.63	8.99	0.10	7.55	19.11	11.26	81.93	622.20	88.00	2.30
7	P_1	41.57	43.50	70.20	15.30	0.22	12.91	8.76	13.18	57.47	741.10	7.20	1.40
7	P_2	40.00	45.42	62.27	12.84	0.21	10.05	14.81	11.46	70.21	700.37	16.80	2.73
8	P_3	38.80	43.63	69.17	20.46	0.30	17.15	12.26	11.62	118.34	1921.38	14.40	1.33
9	P_4	37.62	45.60	128.03	20.09	0.16	15.73	19.12	11.21	78.14	964.32	18.00	1.27

Table 4.7. Analysis of variance for yield and associated character in F3 progenies of resistant vs susceptible crosses and parents

Source of variation	Degree of freedom	Mean sum of squares											
		Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield/ plant	Coefficient of infection	Fruit colour
Replication	2	1.13	10.65	15.83	0.68	0.000163	0.75	0.36	0.37	75.81	7316.0	52.08	0.363
Treatment	9	35.12**	47.42**	1179.29**	62.49**	0.02**	54.91**	32.57**	5.93**	4651.49**	1874968**	2512.83**	2.33**
Error	18	4.60	3.42	28.96	0.50	0.0000818	0.25	0.85	0.48	57.65	4255.67	25.21	0.493

*Significance at5%
**significance at 1%

varied from 40.4 days (VKB 134) to 49.6 days (IC 68342B). Maximum number of male flowers was noticed in IC 68250 (131.09) and the minimum number was in IC 68263 B (61.2), the average being 87.51. Maximum number of female flowers produced per plant and highest sex ratio was noticed for VKB 134 (26.08 and 0.345) whereas the minimum values for both the characters were noticed in IC 68342 B. The averages recorded for these two characters were 17.55 and 0.209 respectively. The average for number of fruits harvested per plant was 14.92 with highest number of fruits per plant for VKB 134 (23.17) and lowest for IC 68342 (7.48). In the case of fruit length, variability ranged from 21.8 cm (IC 68335 x Preethi) to 8.31 cm (IC 68 335) and the average value was 15.80 cm. With regard to fruit girth, maximum diameter was recorded for IC 68335 (13.66 cm) and the minimum for IC 68250 (10.44 cm), the average being 11.97 cm. The range of variability for fruit weight was from 179.25 g in the cross IC 68335 x Preethi to 55.78 g in the resistant parent IC 68335 with average being 101.53 g. Fruit yield per plant showed an average value of 1513.38 g and variability ranging between 598.8 and 2836.1 g (IC 68342B and IC 68335 x Preethi respectively). In the case of coefficient of infection lowest value (6.4) was recorded for the cross IC 68335 x Preethi, which gave highest fruit yield per plant whereas the susceptible parent IC 68342B showed highest coefficient of infection (88.0).

4.2.2 Coefficient of variation

The phenotypic and genotypic coefficient of variation of yield and eleven yield related attributes are presented in Table.4.8. All the twelve characters under study showed either low or high magnitude of GCV and PCV. Coefficient of infection recorded maximum PCV (109.4) and GCV (107.77) and minimum for anthesis of female flower (5.64 and 3.76 respectively).

4.2.3 Heritability and Genetic gain

Heritability estimates varied from medium to high value with minimum of 44.5 per cent for anthesis of female flower and maximum of 99.3 per cent for fruit

Table 4.8. Range and estimates of genetic parameters for yield and associated characters in F_3 progenies of resistant vs susceptible and its parents

Sl. No.	Characters	Range	GCV (%)	PCV (%)	Heritability Broadsense (%)	Genetic advance	Genetic gain (%)
1	Anthesis of male flower	43 (P_2xP_5) to 34.6 (P_3, P_4)	5.63	7.66	54.0	3.41	8.53
2	Anthesis of female flowers	49.6 (P_8) to 40.4 (P_6)	3.76	5.64	44.5	2.33	5.17
3	Number of male flowers	131.09 (P_4) to 61.2 (P_2)	23.81	24.33	95.8	42.10	48.00
4	Number of female flowers	26.08 (P_6) to 8.75 (P_8)	27.03	27.22	98.6	9.70	55.27
5	Sex ratio	0.345 (P_6) to 0.089 (P_8)	34.19	34.59	97.7	0.15	71.77
6	No. of fruits per plant	23.17 (P_6) to 7.48 (P_8)	29.21	29.49	98.1	8.89	59.58
7	Fruit length	21.8 (P_1xP_5) to 8.31 (P_1)	25.74	26.21	96.4	8.23	52.93
8	Fruit girth	13.66 (P_1) to 10.435 (P_4)	6.29	8.31	57.3	1.17	9.77
9	Fruit weight	179.25 (P_1xP_5) to 55.78 (P_1)	38.02	38.34	98.3	78.83	78.29
10	Fruit yield per plant	2836.1 (P_1xP_5) to 598.8 (P_8)	54.53	54.72	99.3	1694.24	11.95
11	Coefficient of infection	6.4 (P_1xP_5) to 88 (P_8)	107.7	109.4	97.0	58.44	218.7
12	Fruit colour	1.5 (P_6) to 3.8 (P_5)	35.36	36.49	93.9	1.74	70.53

yield per plant. Moderate heritability was shown by characters, viz., days to anthesis of female flower (44.5) anthesis of male flower (54.0) and fruit girth (57.3) respectively.

Estimates of genetic advance, expressed as percentage of mean (genetic gain) was lowest (5.17) for days to anthesis of female flower followed by days to anthesis of male flower (8.53) and fruit girth (9.774) and maximum for coefficient of infection (218.7). All the characters under study showed low and high genetic gain, none of the character expressed moderate value.

4.2.4 Association of characters

4.2.4.1 Correlation

The phenotypic and genotypic correlation for twelve characters in ten genotypes are represented in Table.4.9.

Yield had strong positive relation with almost all characters except anthesis of female flower (-0.176, -0.215) and coefficient of infection (-0.513, -0.515). Fruit weight exerted maximum (0.913, 0.914) positive association with yield followed by number of fruits (0.712, 0.722), number of female flowers (0.627, 0.630), sex ratio (0.570, 0.571), fruit girth (0.38, 0.468), anthesis of male flower (0.232, 0.331) and fruit colour (0.301, 0.317).

The inter correlation among different yield attributes elicit different direction and magnitude at phenotypic and genotypic level. The correlation values indicates that anthesis of male flower had positive significant correlation with anthesis of female flower (0.393, 0.657), fruit weight (0.269, 0.386), fruit yield per plant (0.232, 0.331) and fruit colour (0.269, 0.315) while it exhibited negative relationship with fruit length (-0.231, -0.268) and coefficient of infection (-0.255, -0.415). Days to opening of first female flower were positively and significantly related to almost all characters with few exceptions viz., number of female flowers (-0.434, -0.605) and fruit girth (-0.494, -0.895).

Table 4.9. Genotypic and phenotypic correlations of twelve characters in F_3 progenies of resistant vs susceptible and their parents

Characters	Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Fruit yield/ plant	Coefficient of infection	Fruit colour
Anthesis of male flowers	1.000	0.657**	-0.081	-0.050	-0.079	-0.041	-0.268**	0.051	0.386**	0.331**	-0.415**	0.315**
Anthesis of female flowers	0.393**	1.000	0.553**	-0.605**	-0.895**	-0.654**	0.576**	-0.895**	0.111	-0.215*	0.382**	0.296**
Number of male flowers	0.001	0.372**	1.000	0.101	-0.584**	0.028	0.585**	-0.589**	-0.077	-0.144	0.227**	0.079
Number of female flowers	-0.039	-0.434**	0.100	1.000	0.744**	0.991**	-0.353**	0.438**	0.304**	0.630**	-0.533**	-0.107
Sex ratio	-0.091	-0.633**	-0.584**	0.741**	1.000	0.779**	-0.661**	0.734**	0.259**	0.571**	-0.539**	-0.195**
Number of fruits	-0.012	-0.437**	0.036	0.969**	0.750**	1.000	-0.341**	0.555**	0.404**	0.72**	-0.527	-0.024
Fruit length	-0.231*	-0.321**	0.541**	-0.341**	-0.624**	-0.333	1.000	-0.629**	0.195*	-0.062	0.506**	0.505**
Fruit girth	-0.006	-0.494**	-0.475**	0.342**	0.571**	0.410**	-0.435**	1.000	0.209*	0.468**	-0.446	-0.080
Fruit weight	0.269**	0.032	-0.088	0.303**	0.264**	0.397**	0.203*	0.195*	1.000	0.914**	-0.406**	0.394**
Fruit yield	0.232*	-0.176	-0.148	0.627**	0.570**	0.712**	-0.052	0.380**	0.913**	1.000	-0.515**	0.317**
Coefficient of infection	-0.255**	0.317**	0.275**	-0.521**	-0.530**	-0.515**	0.476**	-0.366**	-0.407**	-0.513**	1.000	0.166
Fruit colour	0.269**	0.280*	0.079	-0.115	-0.201*	-0.007	0.477**	-0.109	0.371**	0.301**	0.176	1.000

Upper diagonal represent genotypic correlation
Lower diagonal represent phenotypic correlation

*Significance at 5%
**Significance at 1%

Significant positive correlation both at phenotypic and genotypic level, with fruit weight was showed by number of female flowers (0.303, 0.304), sex ratio (0.264, 0.259), number of fruits per plant (0.397, 0.404), fruit length (0.203, 0.195), fruit girth (0.195, 0.209) and fruit colour (0.371, 0.394). Coefficient of infection was negatively associated with all the characters except number of male flowers (0.225, 0.227) and fruit length (0.476, 0.506). The genotypic correlation was higher than phenotypic correlation for all the characters studied except for fruit weight and sex ratio (0.264, 0.259).

4.2.4.2 Direct and indirect effects

For estimating direct and indirect effect of the constituent characters on yield, the genotypic correlation of all the characters under study were included. The estimates of direct and indirect effect of these characters on yield are presented in Table.4.10 In parents and hybrid population, the high positive direct effect on fruit yield per plant was contributed by sex ratio (1.001) followed by fruit weight (0.524), fruit length (0.420) number of male flowers (0.391) and anthesis of male flower (0.325). The number of female flowers showed a negative direct effect (-0.212) on yield.

The maximum positive indirect effect was noticed in sex ratio through number of fruits per plant (0.780), number of female flowers (0.745) and fruit girth (0.735). High negative indirect effect was noticed in sex ratio through anthesis of female flower (-0.896) followed by fruit length (-0.662), number of male flowers (-0.585) and coefficient of infection (-0.540).

Table 4.10. Direct and indirect effect of yield components on yield in F_3 progenies of resistant vs susceptible crosses and parents

Characters	Anthesis of male flower	Anthesis of female flower	Number of male flowers	Number of female flowers	Sex ratio	Number of fruits	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Coefficient of infection	Fruit colour	Genotypic correlation with yield
Anthesis of male flowers	**0.325**	0.060	-0.032	0.011	-0.079	-0.001	-0.112	0.015	0.202	-0.033	-0.025	0.331
Anthesis of female flowers	0.214	**0.092**	0.216	0.128	-0.896	-0.016	0.242	-0.260	0.058	0.030	-0.023	-0.215
Number of male flowers	-0.026	0.051	**0.391**	-0.021	-0.585	0.001	0.245	-0.171	-0.041	0.018	-0.006	-0.144
Number of female flowers	-0.016	-0.055	0.039	**-0.212**	0.745	0.024	-0.148	0.127	0.159	-0.042	0.008	0.630
Sex ratio	-0.026	-0.082	-0.228	-0.158	**1.001**	0.019	-0.278	0.213	0.136	-0.043	0.015	0.571
Number of fruits	-0.013	-0.060	0.011	-0.210	0.780	**0.025**	-0.143	0.162	0.212	-0.042	0.002	0.720
Fruit length	-0.087	0.053	0.229	0.075	-0.662	-0.008	**0.420**	-0.183	0.102	0.040	-0.040	-0.062
Fruit girth	0.016	-0.082	-0.231	-0.093	0.735	0.014	-0.264	**0.291**	0.110	-0.035	0.006	0.468
Fruit weight	0.126	0.010	-0.030	-0.064	0.259	0.010	0.082	0.061	**0.524**	-0.032	-0.031	0.914
Coefficient of infection	-0.135	0.035	0.089	0.113	-0.540	-0.013	0.213	-0.130	-0.213	**0.079**	-0.013	-0.515
Fruit colour	0.102	0.027	0.031	0.023	-0.195	-0.001	0.212	-0.023	0.206	0.013	**-0.079**	0.317

R = 0.01

The diagonal values indicates direct effect

Discussion

5. DISCUSSION

5.1 EXPERIMENT NO.1 - F_2

5.1.1 Genetic variability in F_2

In any plant breeding programme, the extent of genetic variability present in the population will regulate the efficiency of selection. An insight to the magnitude of variability present in the population is of utmost importance for selecting required genotypes. The importance of genetic variability for disease resistance and wider adaptability is also well known.

Genetic variability in F_2 population of the present study was high enough among the genotypes for the improvement of characters through selection. The magnitude of range of variation for all the characters studied was also high. The variability of different characters were previously observed by workers like Srivastava and Srivastava (1976) and Singh *et al.* (1977) in bittergourd and Kumaran *et al.* (1997) in pumpkin for number of fruits per plant and fruit yield per plant by Singh *et al.* (1977), Ramachandran (1978), Mangal *et al.* (1981), Thakur *et al.* (1994), Katiyar *et al.* (1996), Prasad (2000) and Arunachalam (2002). Variability in fruit weight and fruit length was reported by Mangal *et al.* (1981), Vahab (1989), Ram *et al.* (1997) and Prasad (2000).

5.1.2 Genotypic and phenotypic coefficient of variation, heritability and Genetic gain

All the twelve characters under study indicated low to high coefficient of variation. Nature of coefficient of variation both at phenotypic and genotypic level is diagramaticaly presented in Fig.5.1. All the quantitative characters studied showed high broad sense heritability. The genetic advance expressed as percentage over mean (genetic gain) revealed that all the characters except anthesis of male and female flowers showed more than 50 per cent genetic gain. High heritability accompanied with high genetic gain indicated the scope of selection for improving the economic traits. It also showed the presence of segregation population in the required magnitude for the above characters in F_2 populations. High GCV, followed by high heritability was reported by many workers in bitter gourd and other cucurbitaceous crops.

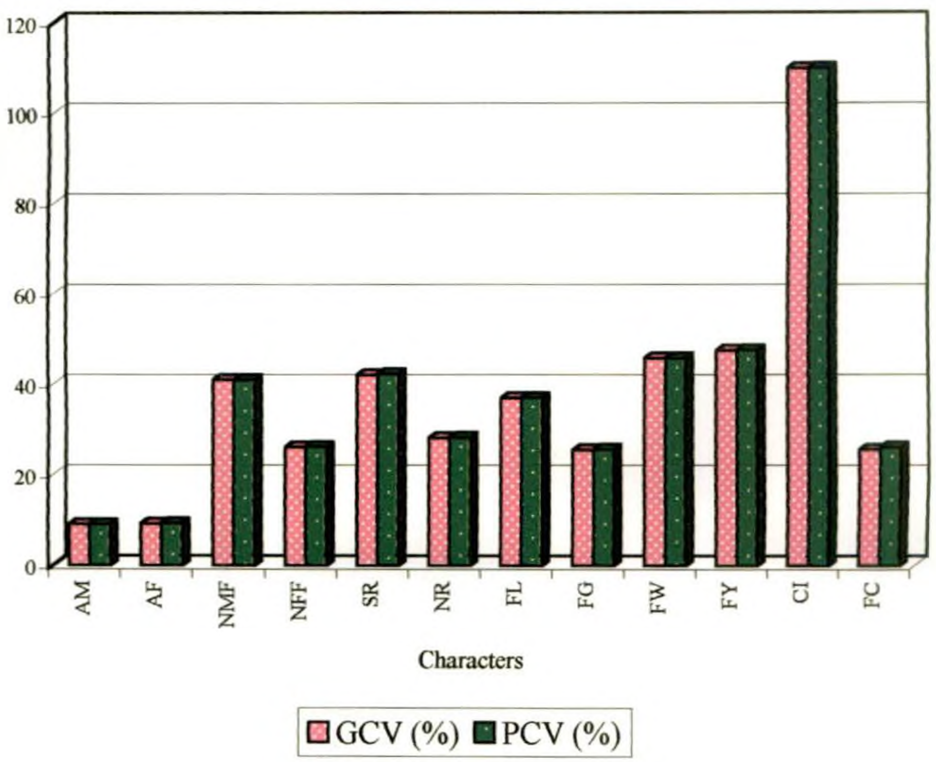


Fig. 5.1. Genotypic and phenotypic variation of twelve characters in F_2 generation

AM - Anthesis of male flower

AF - Anthesis of female flowers

NMF - Number of male flowers

NFF - Number of female flowers

SR - Sex ratio

NR - No. of fruits $plant^{-1}$

FL - Fruit length

FG - Fruit girth

FW - Fruit weight

FY - Fruit yield $plant^{-1}$

CI - Coefficient of infection

FC - Fruit colour

High PCV, GCV, heritability and genetic gain recorded for fruit yield per plant, fruit weight, sex ratio, number of male flowers and fruit length was suggestive for greater magnitude of variability on these traits. The trends of above genetic parameters, viz., heritability and genetic gain are presented in Fig.5.2. The reports of Srivastava and Srivastava (1976), Singh *et al.* (1977), Vahab (1989), Prasad (2000) and Arunachalam (2002) in bittergourd and Kumaran *et al.* (1997) and Mohanty (2000) in pumpkin were in support of these findings. Low GCV, PCV and genetic gain were observed for anthesis of male and female flowers in ten genotypes, indicating inherently limited variability among the genotypes. Similar results were also reported by Mangal *et al.* (1981) Prasad (2000) and Arunachalam (2002). The high estimates of GCV, PCV, broad sense heritability and genetic gain were observed for coefficient of infection to BDMV and fruit colour. Same trend was noticed by Arunachalam *et al.* (2002).

Simple selection for the two traits, viz., anthesis of male and female flowers showing low values of genetic gain, PCV and GCV may not be rewarding. The high PCV, GCV, heritability and genetic gain were quite encouraging for the other ten characters in F_2 for favour of genetic improvement through direct selection. The influence of additive gene action is expected for these traits. Similar nature of gene action was observed by Singh and Joshi (1980), Pal *et al.* (1983) and Sirohi and Choudhury (1983) for number of fruits per plant, Singh and Joshi (1980), Kennedy (1994) and Prasad (2000) for fruit length, Kushwaha and Ram (1996) for fruit girth in bottlegourd, Singh and Joshi (1980), Sirohi and Choudhury (1983), Celine and Sirohi (1998) and Prasad (2000) for fruit weight, Singh and Joshi (1980) in bittergourd and Mohanty and Mishra (1999) in pumpkin for fruit yield per plant.

5.1.3 Association of characters

5.1.3.1 Correlation

The study of association of characters is necessary to understand the genetics of the crop. Correlation study helps the plant breeder to assess the mutual relationship between various plant characters and determines the component

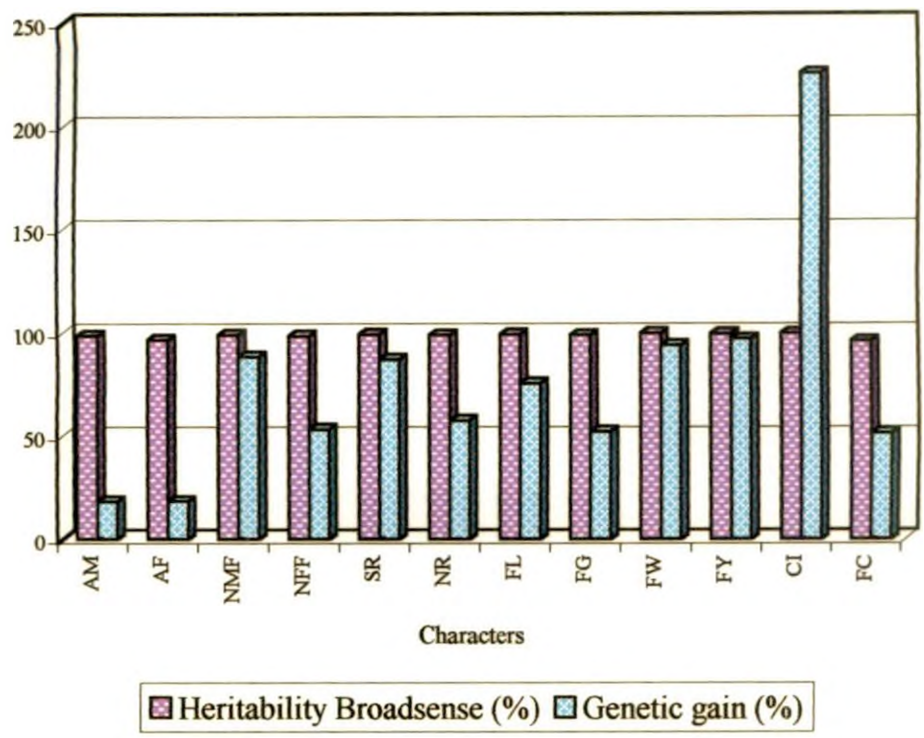


Fig. 5.2. Heritability and Genetic gain of twelve characters in F_2 generation

AM - Anthesis of male flower
AF - Anthesis of female flowers
NMF - Number of male flowers
NFF - Number of female flowers
SR - Sex ratio
NR - No. of fruits plant^{-1}
FL - Fruit length
FG - Fruit girth
FW - Fruit weight
FY - Fruit yield plant^{-1}
CI - Coefficient of infection
FC - Fruit colour

characters on which selection can be based for genetic improvement of the crop. It also give an idea of the complexity of the character and dependability of the component trait for the improvement of yield. In the present investigation correlation between fruit yield per plant and eleven yield components are studied. (Fig 5.3)

Among the phenotypic correlation of eleven characters with fruit yield, fruit weight, followed by fruit length, fruit girth, number of male flower and anthesis of female flower indicated high positive association towards yield, whereas sex ratio is the only character which showed a significant negative trend in association with yield.Choudhury *et al.* (1986), Gopalakrishnan (1986) and Lawande and Patil (1989), Rajeswari (1998) and Puddan (2000) also reported significant positive correlation of yield with fruit girth along with other fruit characters. At genotypic level similar trends, both, in magnitude and direction was shown by above characters with yield. The above results were in agreement with reports of Singh *et al.* (1977) for fruit length, Ramachandran and Gopalakrishnan (1979), Mangal *et al.* (1981), Indiresh (1982), Um and Kim (1990), Rajput *et al.* (1995), Puddan (2000) for fruit length and weight in bittergourd.

The intercorrelation among the yield component characters are dealt in detail below. Positive and significant association of fruit weight was observed with different fruit attributes, viz., fruit length and girth and number of male flowers, whereas negative association was observed with sex ratio, number of female flowers, number of fruits and anthesis of male flowers. Similar findings were reported by Ramachandran and Gopalakrishnan (1979).Intercorrelation of fruit girth is positively significant to almost all characters except sex ratio. Mangal *et al.* (1981), Indiresh (1982) and Khattra *et al.* (1994) also mentioned about positive intercorrelation of fruit girth and fruit length which was in consistence with above findings.

Positive inter correlations were observed among number of female flowers, sex ratio and number of fruits. Arunachalam (2002) also mentioned about similar relationships. Negative genotypic correlation between number of fruits and fruit weight revealed that simultaneous improvement of both these traits is difficult.

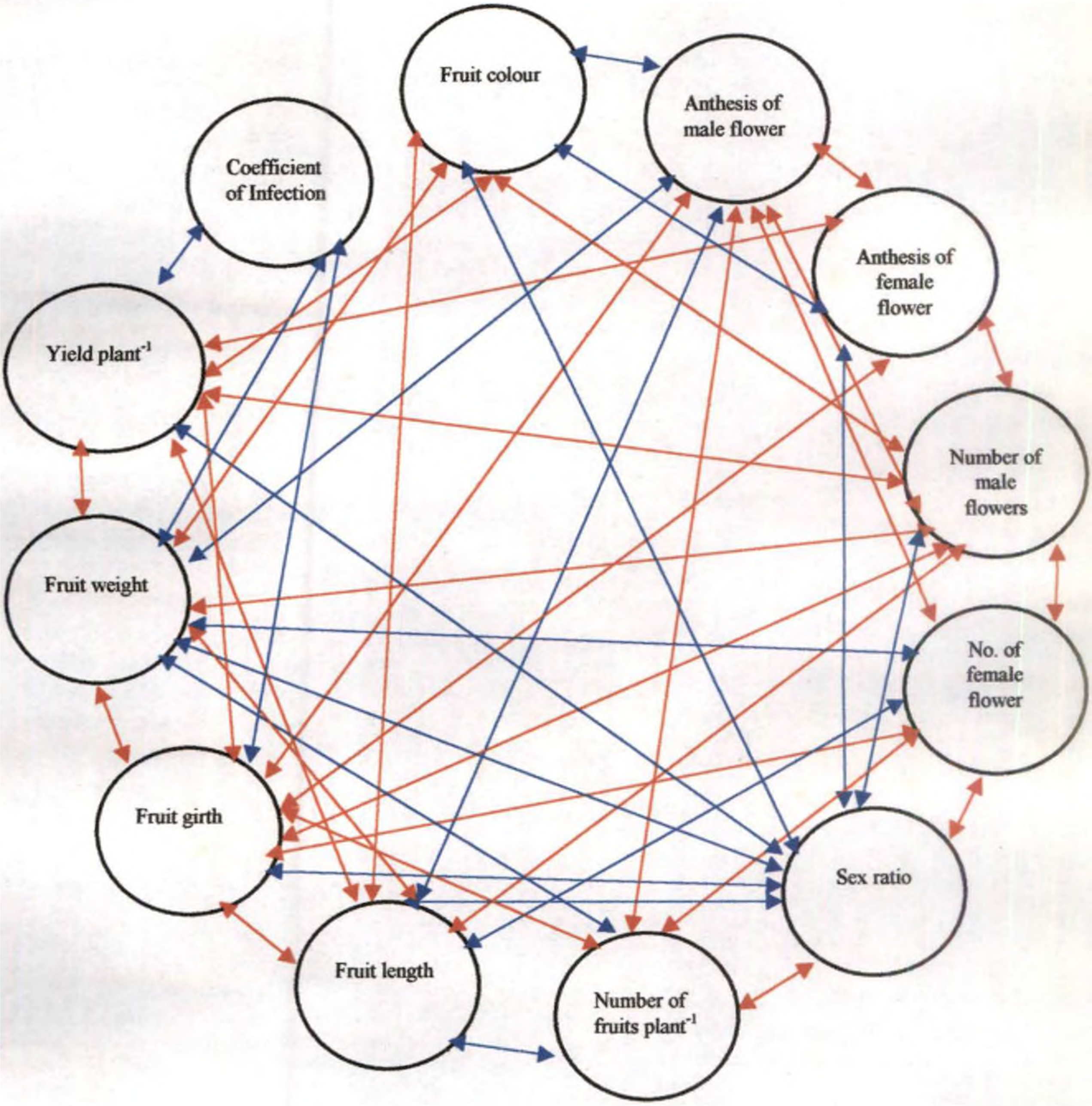


Fig. 5.3. Genotypic correlation among different characters in F_2 generation

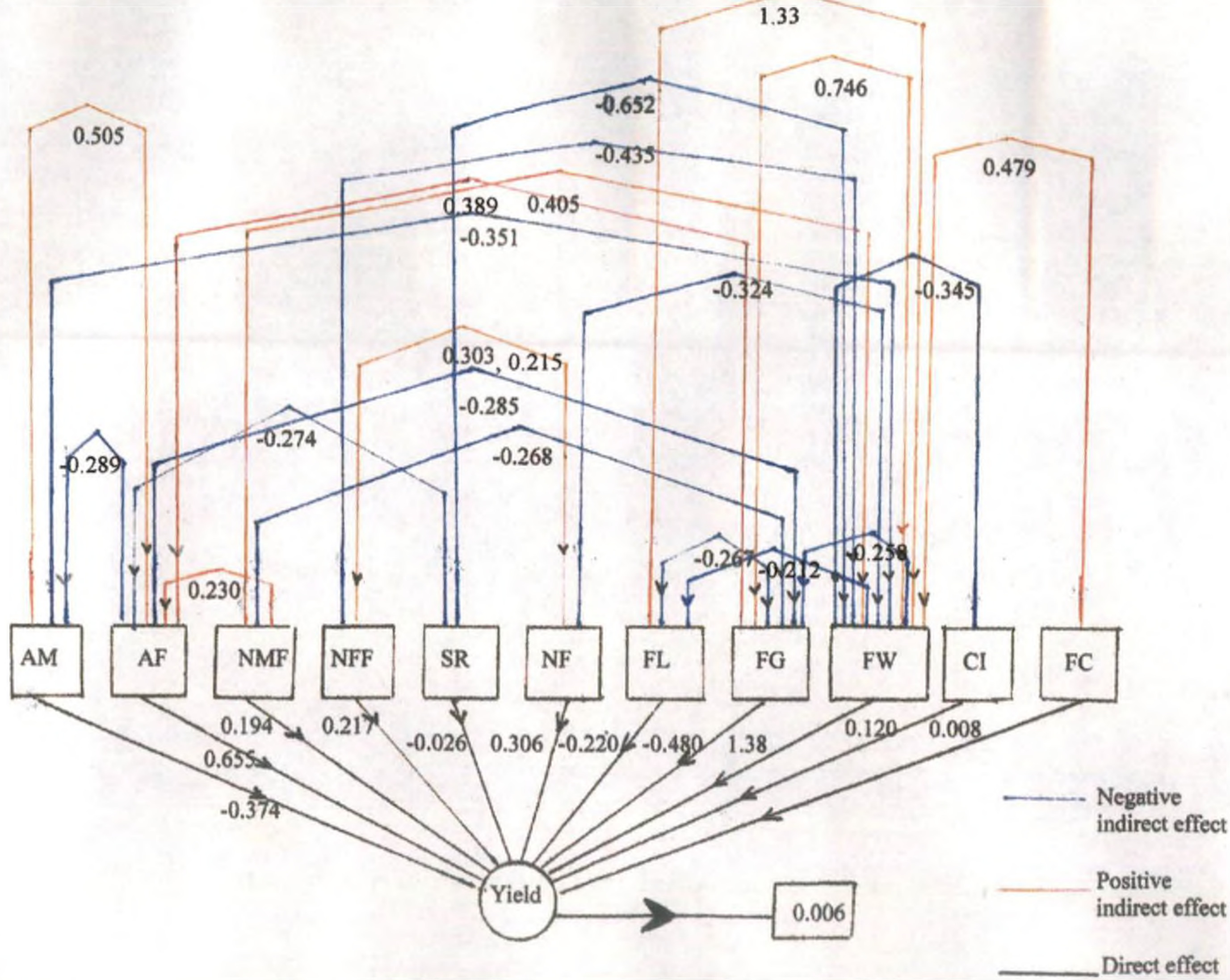
Significant positive correlation
Significant negative correlation

Srivastava and Srivastava (1976), Kennedy (1994) and Arunachalam (2002) have also reported similar relationships for these traits. An increase in resistance to BDMV will have corresponding improvement in fruit attributes viz., fruit girth, fruit weight and fruit yield per plant. Reports of Giri and Mishra (1986) and Arunachalam (2002) confirm the above findings.

In general, present study about the association of characters with fruit yield and among themselves indicated that a strong association existed between fruit yield with fruit weight, fruit length, fruit girth and number of male flowers. An increase in the magnitude of these characters will have corresponding improvement in fruit yield. The sex ratio and coefficient of infection showed a negative trend towards fruit yield. An increase in number of female flowers will reduce the fruit size, which further indicated optimum size for fruits. Negative association of coefficient of infection of BDMV to yield and other contributing characters indicates that susceptibility towards BDMV affecting the fruit yield. Lower incidence of this disease coupled with other yield contributing traits contributes towards the improvement of fruit yield.

5.1.3.2 Direct and indirect effects

Path analysis elicit information on the direct and indirect relations for association between yield and various yield components. The character which exhibited a direct relation with yield can be selected for improving the yield. Indirect effect of the characters through another trait necessitate the breeder to select for the attribute through which the indirect effect is exerted (Singh and Choudhury, 1985). Path analysis has been extensively used in different crops for indirect selection for yield. Indirect selection of character with high heritability and correlation with yield will result in greater yield response. All the eleven characters have been used for estimating the direct and indirect effects of the constituent traits on yield. The direct and indirect effects of yield contributing traits on yield is diagramatically represented in Fig.5.4 In a breeding programme it is very difficult to have complete knowledge of all component traits of yield. The residual effect permits precise explanation about the pattern of interaction of other possible components of yield. In this study, residual



AM - Anthesis of male flower
AF - Anthesis of female flowers
NMF - Number of male flowers
NFF - Number of female flowers
SR - Sex ratio
NR - No. of fruits plant^{-1}
FL - Fruit length
FG - Fruit girth
FW - Fruit weight
CI - Coefficient of infection
FC - Fruit colour

Fig. 5.4. Path diagram indicating the direct and indirect effects of component characters on yield in F_2 generation

effect is estimated as 0.01 which indicated that other possible components of yield are rather very low.

Maximum direct effect toward fruit yield per plant was shown by fruit weight with corresponding high genotypic correlation. This indicate a true relationship between yield and fruit weight. Hence direct selection for fruit weight will improve fruit yield per plant. This was in agreement with reports of Ramachandran *et al.* (1979), Devadas (1993), Kennedy (1994), Paranjape and Rajput (1995), Rajaput *et al.* (1995) and Puddan (2000). Other traits which exerted direct effect on yield include number of fruits, number of female flowers and anthesis of female flower. Earlier studies also supported the positive direct effect of yield *via* number of fruits (Ramachandran *et al.*, 1979; Devadas, 1993; Kennedy, 1994; Paranjape and Rajput, 1995; Rajeswari, 1998).Though the direct effect of fruit length on yield was negative, the correlation coefficient was found to be positive due to positive indirect effect through fruit weight.

The path analysis of various yield attributing traits for F_2 progenies of selected crosses and parents suggested that selection of fruit weight, number of fruits per plant, anthesis of female flower and number of female flower will give good response for improving fruit yield in bittergourd.

5.2 EXPERIMENT NO.2 - F_3

5.2.1 Genetic variability in F_3

The success of a breeding programme depends on the extent of genetic variability in the population. This is prerequisite for effective selection process. Variability may be due to genetic or environmental factors besides their interaction effect.

In the present study, significant differences among the F_3 progenies of three selected crosses and parents were noticed. The range of variation for almost all traits except anthesis of male and female flowers studied was high. Existence of variability for different traits in bittergourd and other gourds was reported by earlier workers viz. Srivastava and Srivastava (1976), Singh *et al.* (1977), Mangal *et al.* (1981), Vahab (1989), Katiyar *et al.* (1996) and Prasad (2000) for fruit yield and fruit weight, Mangal *et al.* (1981) and Arunachalam (2002) Prasad and Singh (1989) and Varalakshmi *et al.* (1995) in ridge gourd, Pariari *et al.* (2000) in pointed gourd for number of fruits, Singh *et al.* (1977), Mangal *et al.* (1981), Choudhury (1987), Vahab (1989) and Arunachalam (2002) for sex ratio and number of male and female flowers and Arunachalam (2002) for disease incidence in bitter gourd. All the characters listed above show maximum variability.

5.2.2 Genotypic and phenotypic coefficient of variation, heritability and Genetic gain

High GCV and PCV was observed for yield and yield related attributes except for anthesis of male and female flower and fruit girth (Fig 5.5)

Highest GCV and PCV values were recorded for resistance to BDMV and fruit yield per plant. Reports of Arunachalam (2002) was in consistence with above results. Similarly low GCV, PCV, genetic gain and heritability values were registered in anthesis of male and female flowers and fruit girth. Simple selection for these traits may not be rewarding. These results are in agreement with that of Srivastava and Srivastava (1976), Mangal *et al.* (1981) for anthesis of first female flower. Records of Prasad (2000) and Arunachalam (2002) was in accordance with the findings of present study.High values of GCV and PCV for a trait suggest very high variability and scope for selection.

Genetic advance as percentage of mean (GA) were high for character, viz., resistance to BDMV, fruit yield per plant, fruit weight, sex ratio, fruit colour, number of fruits per plant, number of female and male flowers and fruit length. . The trends of genetic parameters are presented in Fig.5.6.The reports of Srivastava and Srivastava (1976) for number of fruits per plant, Singh *et al.* (1977) for yield, fruit length and number of fruits per plant, Ramachandran and Gopalakrishnan (1979), Suribabu *et al.* (1985) and Vahab (1989) for yield and number of fruits per plant, Mangal *et al.* (1981) for yield, number of fruits, and fruit weight, Indiresh (1982) for fruit weight and fruit

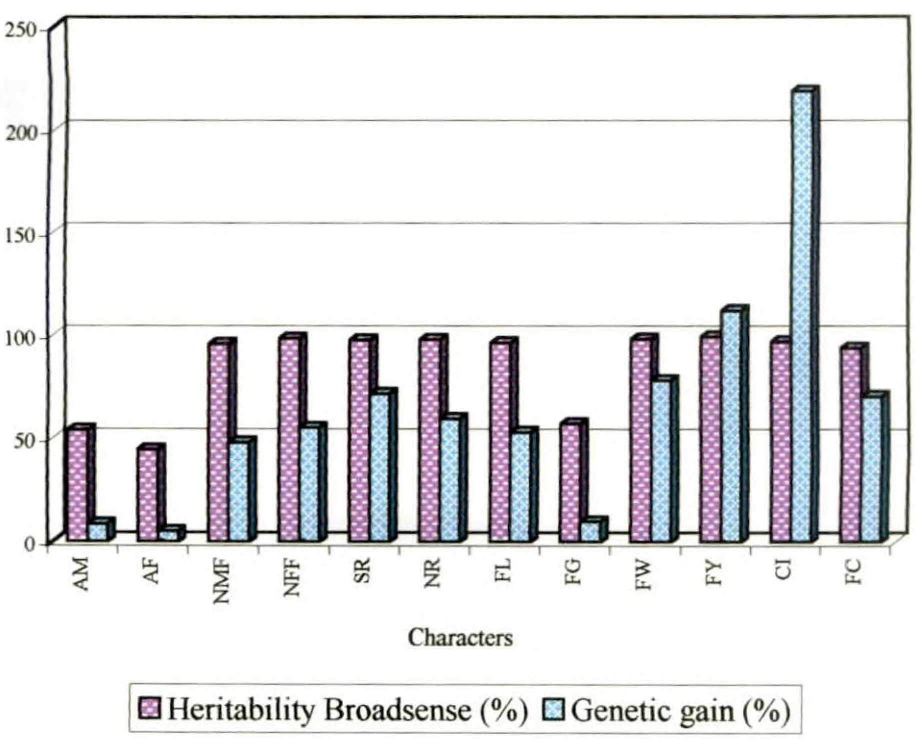


Fig. 5.6. Heritability and Genetic gain of twelve characters in F_3 generation

AM - Anthesis of male flower
AF - Anthesis of female flowers
NMF - Number of male flowers
NFF - Number of female flowers
SR - Sex ratio
NR - No. of fruits plant^{-1}
FL - Fruit length
FG - Fruit girth
FW - Fruit weight
FY - Fruit yield plant^{-1}
CI - Coefficient of infection
FC - Fruit colour

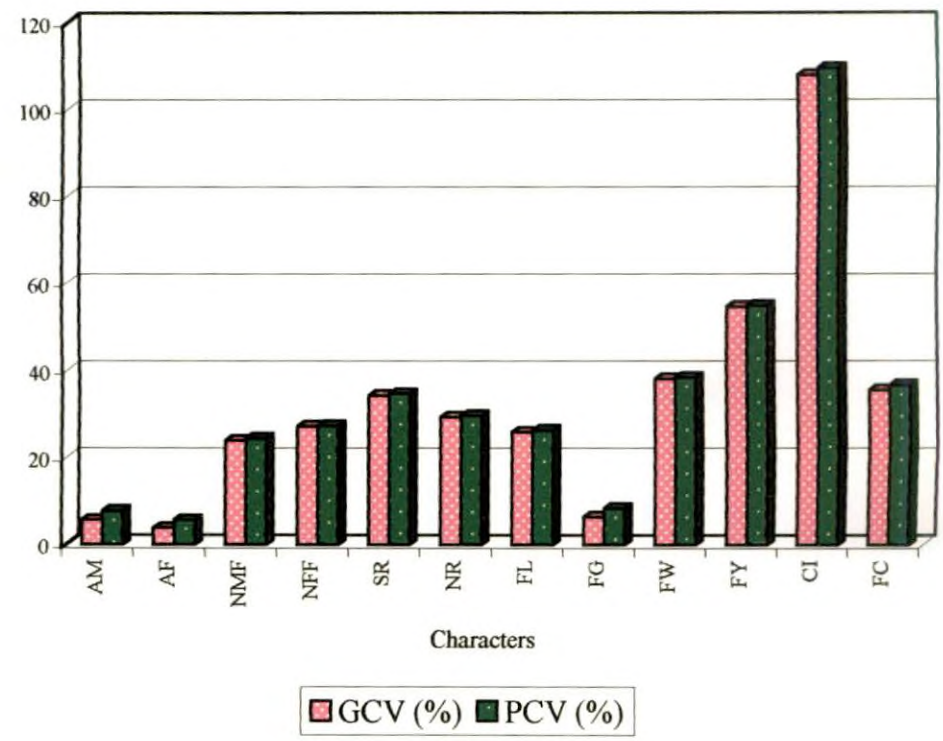


Fig. 5.5. Genotypic and phenotypic variation of twelve characters in F_3 generation

AM - Anthesis of male flower
AF - Anthesis of female flowers
NMF - Number of male flowers
NFF - Number of female flowers
SR - Sex ratio
NR - No. of fruits plant^{-1}
FL - Fruit length
FG - Fruit girth
FW - Fruit weight
FY - Fruit yield plant^{-1}
CI - Coefficient of infection
FC - Fruit colour

length were in support of above findings. High genetic advance had been reported for number of male and female flowers (Srivastava and Srivastava, 1976). Low values of genetic gain, PCV and GCV and heritability were noticed for anthesis of male and female flowers and fruit girth. These results were in confirmity with Singh *et al.* (1977), Mangal *et al.* (1981) and Arunachalam (2002).

Traits with high genetic gain and heritability recorded additive gene action whereas non additive action noticed in characters with low genetic gain. Similar nature of gene action, was noticed for days to first male flower opening by Munshi and Sirohi (1994) and Prasad (2000) in bittergourd, Mohanty (1999) and Mohanty and Mishra (1999) in pumpkin, for days to anthesis of female flower by Gopalakrishnan (1986), Munshi and Sirohi (1994), Prasad (2000), Arunachalam (2002) and Rajeswari and Natarajan (2002), number of female flowers (Prasad, 2000), number of fruits (Singh and Joshi, 1980; Pal *et al.*, 1983; Lawande *et al.*, 1994; Prasad, 2000), fruit length (Singh and Joshi, 1980; Kennedy, 1994; Prasad, 2000; Rajeswari and Natarajan, 2002), fruit girth (Gopalakrishnan, 1986; Devadas, 1993; Kennedy, 1994; Arunachalam, 2002), fruit weight (Singh and Joshi, 1980; Sirohi and Choudhury, 1983; Celine and Sirohi, 1998; Prasad, 2000) and for fruit yield per plant by (Singh and Joshi(1980), Mishra *et al.* (1994) Tewari *et al.* (2001) and Arunachalam (2002).

5.2.3 Association of characters

5.2.3.1 Correlation

In the present investigation, correlation between yield and eleven yield components in the F_3 progenies of crosses (resistant vs susceptible) and parents were evaluated and results are discussed (Fig 5.7)

Yield was found to be significantly and positively correlated with number of fruits, number of female flowers, fruit weight, fruit girth, sex ratio and fruit colour (Fig.5). Correlation between yield and number of fruits per plant in bittergourd was noted by Srivastava and Srivastava (1976), Singh *et al.* (1977), Choudhury *et al.* (1986), Gopalakrishnan (1986), Lawande and Patil (1989), Devdas (1993), Kennedy

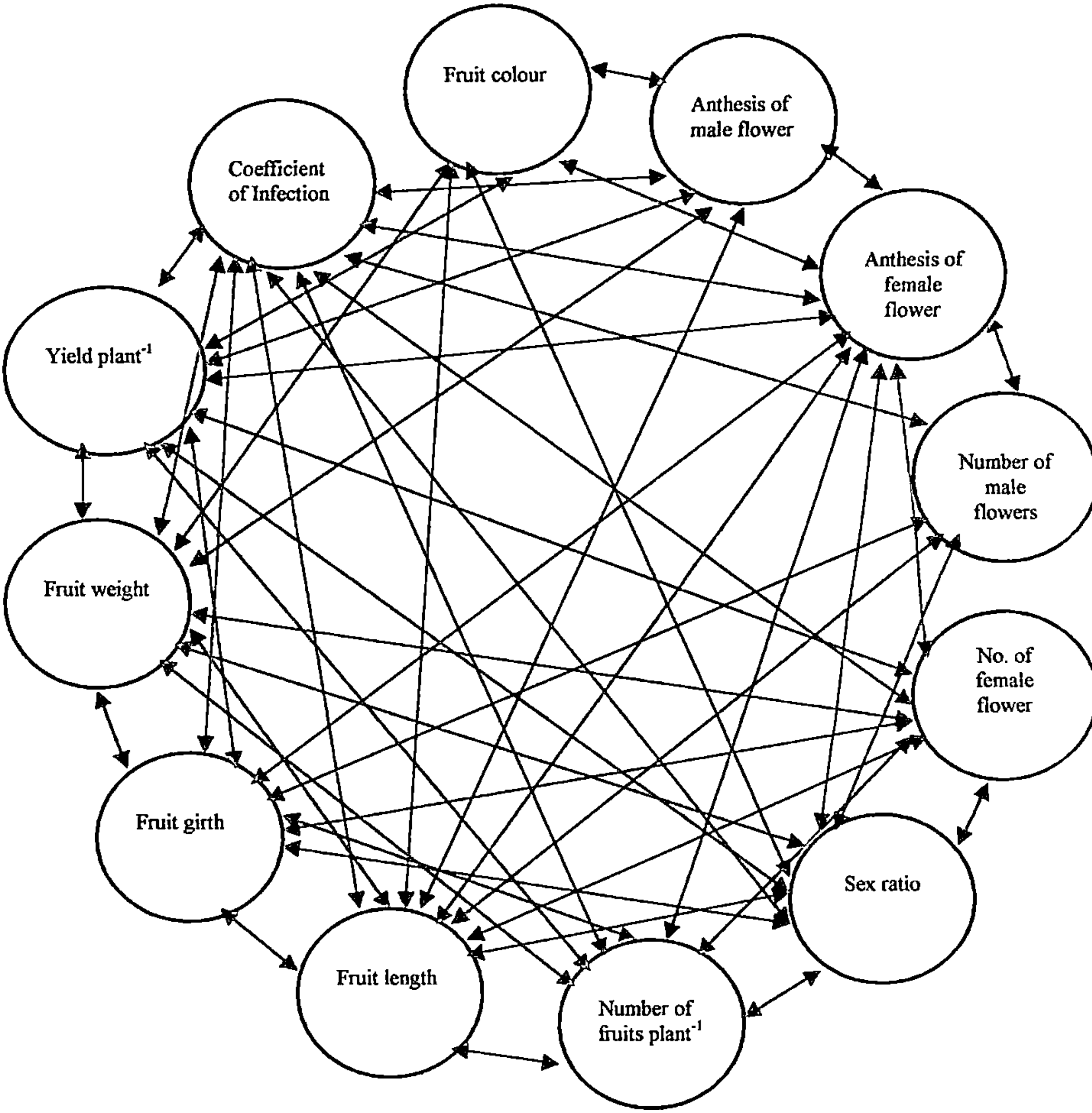


Fig. 5.7. Genotypic correlation among different characters in F_3 generation

Significant positive correlation
Significant negative correlation

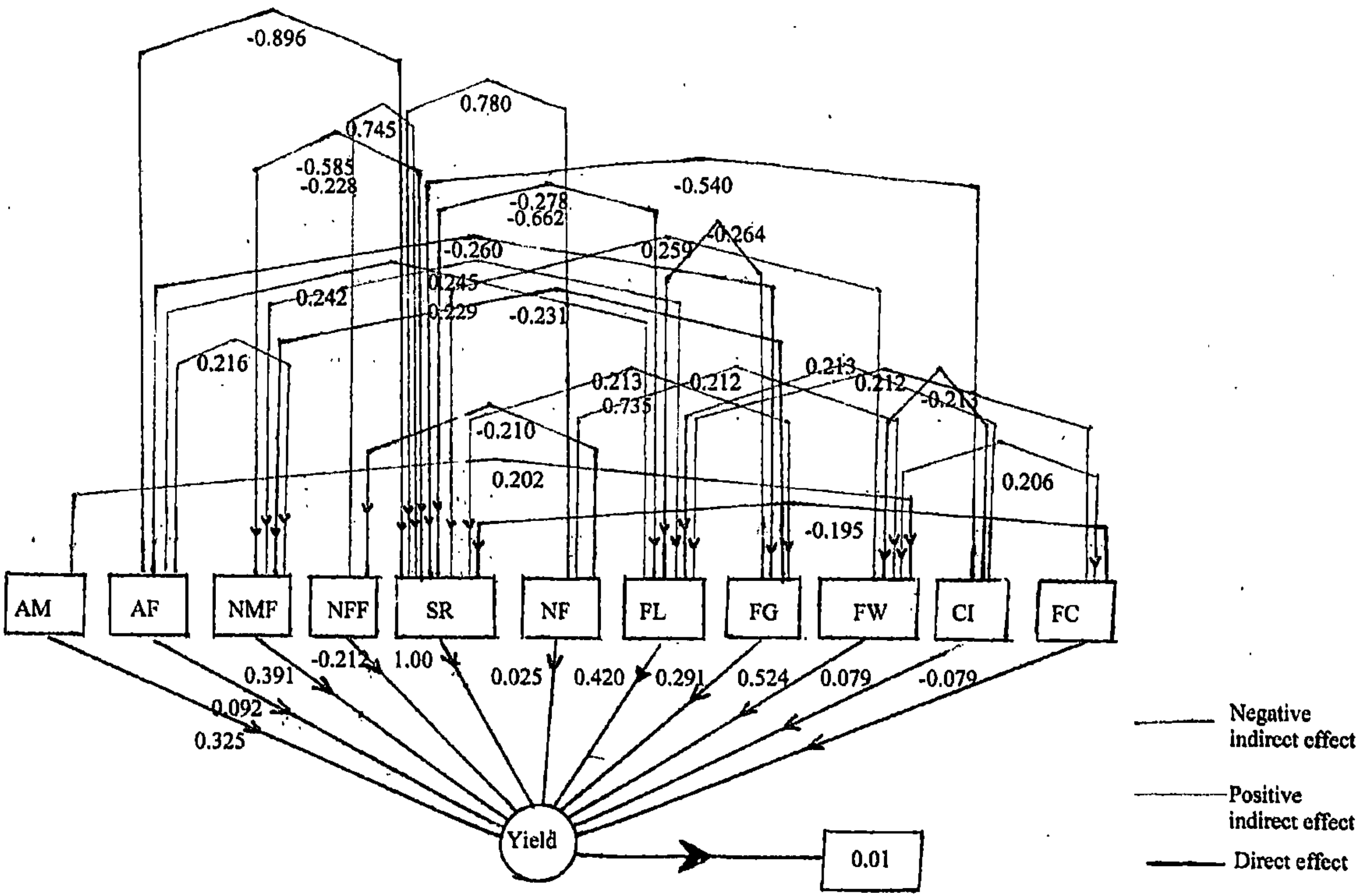
(1994) and Arunachalam (2002), fruit weight and fruit girth by Ramachandran and Gopalakrishnan (1979), Mangal *et al.* (1981), Prasad and Singh (1989), Puddan (2000) and Arunachalam (2002) and sex ratio by Arunachalam (2002). The negative correlation of fruit length with yield was supported by results of Paranjape and Rajput (1995). Anthesis of female flower and resistance to BDMV incidence exhibited negative relationship with yield (Arunachalam, 2002).

Inter correlation among yield components are dealt in detail below. Number of female flowers registered high correlation with number of fruits, which in turn contributed to high fruit yield per plant. Srivastava and Srivastava (1976), Choudhury *et al.* (1986), Thakur *et al.* (1996) and Arunachalam (2002) also reported similar relationships. Sex ratio and number of female flowers had positive relation with fruit weight. These findings indicate that simultaneous improvement of both these characters can be done. Fruit weight exerted strong association with sex ratio, number of fruits, fruit length and fruit girth. Positive correlation of sex ratio and number of female flower per plant was reported by Arunachalam (2002).

5.2.3.2 Direct and indirect effects

In the present investigation on F_3 population a path coefficient analysis was performed to depict the cause and effect relationship of yield with eleven yield components. The direct and indirect effects are discussed below. (Fig.5.8)

As in F_2 generation the F_3 population also indicted similar direct and indirect effect of constituent characters towards yield. Maximum positive direct effect was shown by sex ratio followed by fruit weight with corresponding positive genotypic correlation with yield. This indicated true relationship between yield and these two characters. Similar findings were reported by Rajput *et al.* (1995), Rajeswari (1998) and Puddan (2000). An increase in number of female flowers has simultaneous improvement in fruit yield. Similar relationship was also indicated by anthesis of male flower and fruit girth. The results of Rajeswari (1998), Puddan (2000) in bittergourd and Sarkar *et al.* (1999) in pumpkin were in support to these findings. In contrast to F_2



AM - Anthesis of male flower
AF - Anthesis of female flowers
NMF - Number of male flowers
NFF - Number of female flowers
SR - Sex ratio
NR - No. of fruits plant^{-1}
FL - Fruit length
FG - Fruit girth
FW - Fruit weight
CI - Coefficient of infection
FC - Fruit colour

Fig. 5.8. Path diagram indicating the direct and indirect effects of component characters on yield in F_3 generation

generation, the tendency of relationship with constituent characters towards yield were slightly different and this may be due to higher segregation in F_3 generation.

Number of female flowers indicated negative indirect effect with a positive genotypic association with yield. This shows that an optimum number of female flowers can be considered for the improvement of fruit yield per plant. Direct negative effect of number of female flowers on yield was reported by Arunachalam (2002).

Residual effect of 0.01 revealed that about 99 per cent of effects are contributed by the different traits and remaining due to unknown factors.

The result of present investigation revealed that most of the yield contributing characters such as fruit weight, number of fruits, sex ratio, number of female flowers, and fruit colour had high heritability and genetic gain indicating additive gene action. For the improvement of fruit yield in bitter gourd genotypes due weightage have to be given for an optimum number of flowers, a higher sex ratio, higherfruit weight, low incidence of BDMV, long fruits and early anthesis of female flowers. The results of study also revealed that two crosses, viz., IC 68335 x Preethi and IC 68263 B x Preethi (Plate 8 & 9) gave consistently high yield for two generation coupled with low coefficient infection to bittergourd distortion mosaic virus (BDMV) and had widely acceptable fruit colour (Plate 10). Hence, as a future line of work, screening of these two crosses as multilines may lead to the development of elite genotypes with resistance to BDMV.

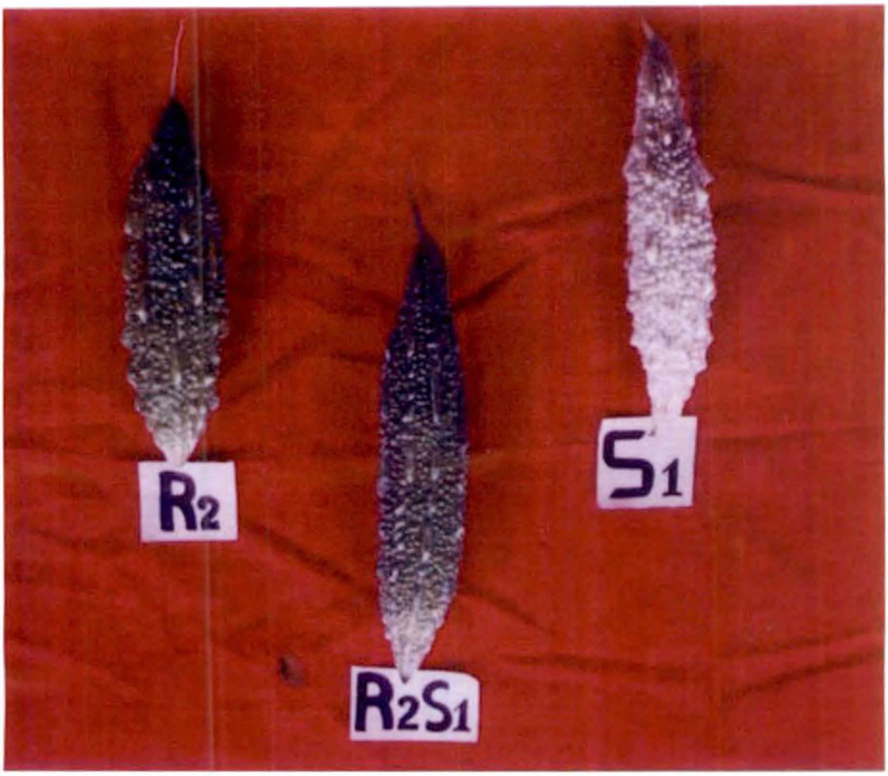


PLATE: 8 RESISTANT VS SUSCEPTABLE PARENT AND CROSS

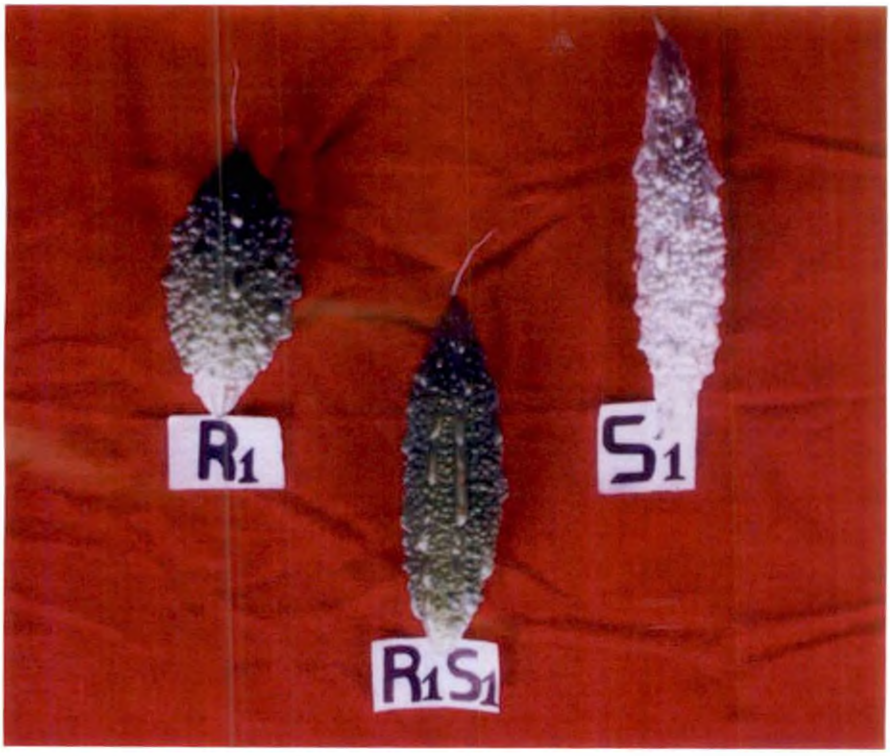


PLATE: 9 RESISTANT VS SUSCEPTABLE PARENT AND CROSS

PLATE: 10 BDMV RESISTANT HIGH YIELDING GENOTYPE OF BITTER GOURD

Summary

6. SUMMARY

The present investigation of "Genetic analysis of F_2 and F_3 generations for yield attributes and resistance to distortion mosaic virus disease in bittergourd (*Momordica charantia* L.) was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara during 2001-2003.

The study was envisaged with a view to understand the genetics of distortion mosaic virus disease along with high yield and yield contributing characters. The ultimate objective was to identify best genotype among the selected three crosses having economic characters such as high fruit yield, widely accepted fruit colour and resistance to the dreaded disease.

The experimental material consisted of selfed seeds from three selected F_1 crosses, which were previously evaluated at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara. The crosses included IC 68335 x Preethi, IC 68263 B x Preethi and IC 68250 x IC 68342 B. The parents of these crosses were of diverse origin. Selfed seeds of crosses and parents were raised in plots laid out in RBD with three replication. Evaluation of F_2 and F_3 generations were done during September 2002 to June, 2003 and observations of twelve characters including coefficient of infection and fruit colour were taken.

The salient features of the investigation are presented below:

- Improvement through direct selection can be done for most of the yield attributing traits, in both F_2 and F_3 generations as evidenced by their high genetic variability and large range of variation.
- Generally the PCV and GCV for all the characters studied in both generations were almost same indicating low environmental effect in the expression of characters.
- Broad sense heritability were higher in F_2 and F_3 for all the characters studied.

- The characters except anthesis of male and female flower exhibited more than 50 per cent genetic gain accompanied with high heritability and controlled mainly by additive genes render scope for direct selection in fruit yield.
- Number of days for anthesis of male and female flowers is comparatively influenced by non additive components.
- Fruit yield in bittergourd is positively associated with fruit length, fruit girth, number of male flowers and anthesis of female flowers, whereas sex ratio is negatively associated with fruit yield in the F_2 population.
- In F_3 population fruit girth, fruit weight, number of fruits per plant, sex ratio, number of female flowers, anthesis of male flowers and fruit colour is positively associated with fruit yield whereas coefficient of BDMV infection and anthesis of female flower showed a negative association with yield.
- In F_2 population, maximum positive direct effect on fruit yield per plant was exhibited by fruit weight followed by anthesis of female flowers.
- In F_3 population, sex ratio followed by fruit weight exhibited maximum positive direct affect on fruit yield per plant.
- Sex ratio, number of female flowers per plant, days to anthesis of male flowers, fruit girth and fruit weight indicated a true relationship with fruit yield.
- For increasing fruit yield per plant, there should be lower incidence of bittergourd distortion mosaic virus disease along with an optimum number of female flowers, synchronized anthesis of male and female flowers and bigger sized heavy light green fruits.
- The segregating population derived from the crosses IC 68335 x Preethi and IC 68263 B x Preethi are suggested to be the best genotypes based on the results from the present study.
- As a future line of study, individual plants from these crosses may be screened to develop an outstanding variety resistant to BDMV coupled with high yield.

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GENETIC ANALYSIS OF F_2 AND F_3 GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO DISTORTION MOSAIC VIRUS DISEASE IN BITTER GOURD
(*Momordica charantia* L.)

By
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ABSTRACT OF THE THESIS

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ABSTRACT

The research project "Genetic analysis of F_2 and F_3 generations for yield attributes and resistance to distortion mosaic virus disease in bittergourd (*Momordica charantia* L.)" was carried out in Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during the period 2002-2003. The major objectives of the study were to understand the genetics of yield attributes and resistance to bittergourd distortion mosaic virus (BDMV) and to identify resistant genotype with desirable yield traits. The whole investigation was grouped into two experiments in Randomised Block Design with three replication.

The F_2 and F_3 generation of three selected crosses and parents were evaluated for yield attributes and resistance to BDMV. Significant variation was noticed for almost all characters except anthesis of male and female flowers. Highest phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were observed for BDMV followed by fruit yield and fruit weight in both generations. High heritability coupled with high genetic gain was noted for fruit weight, fruit yield and coefficient of infection. These characters are controlled mainly by additive genes which rendered scope for direct selection.

High yield was achieved by higher sex ratio, higher fruit weight, long fruit, optimum number of female flowers and low incidence of BDMV. Based on the results from populations derived from the crosses IC68335 x Preethi and IC 68263B x Preethi as the best genotypes with high yield and resistance to bitter gourd distortion mosaic virus (BDMV) consecutively in both generations.