GENETIC VARIABILITY STUDIES FOR YIELD AND FRUIT FLY RESISTANCE IN BITTER GOURD (*Momordica charantia* L)

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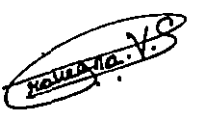
DECLARATION

I, hereby declare that this thesis entitled **"Genetic variability studies for yield and fruit fly resistance 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, associateship, fellowship or other similar title of any other University or Society.



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(2008 – 11 - 111)

CERTIFICATE

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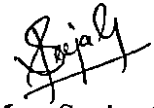

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DEDICATED
TO MY
BELOVED FAMILY
AND
TEACHERS

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"By the grace of God I am what I am"

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INTRODUCTION

1. INTRODUCTION

Bitter gourd (*Momordica charantia* L.) belongs to the family Cucurbitaceae is one of the most important vegetable crops cultivated throughout India, particularly in Kerala and it is native to the Old World Tropics. In India it is cultivated in an area of 30,000 ha with a total production of 3.5 lakh tonnes (IIVR, 2005). Uttar Pradesh, Orissa, Maharashtra, Andhra Pradesh, Tamil Nadu and Kerala are the leading States in production. In Kerala total cropped area is about 2,129 ha (FIB, 2008).

Bitter gourd is a rich source of minerals and vitamins. The unripe fruits are rich in minerals like calcium, phosphorus, iron and vitamins like vitamin A and vitamin C. Moreover the roots, vines, leaves, flowers and seeds of bitter gourd are used in traditional medicine for various ailments. It is well known for its unique anti-diabetic and anti-oxidant properties. Hence it is widely accepted as a neutraceutical. Considering the nutritive value, medicinal properties, domestic and export market potential cultivation of this crop is a promising one to the farmers. However, its large scale cultivation is hampered mainly due to the lack of superior varieties and incidence of pests and diseases.

Of the various pests, melon fruit fly (*Bactrocera cucurbitae* Coquillett) is a destructive pest causing direct yield loss in bitter gourd and the percentage of damage varied from 15 - 100%. It is one of the most preferred hosts of fruit fly. Eventhough various chemical control measures have been adopted, it is not advisable to rely on insecticides alone for controlling this pest. Development of host plant resistance through different breeding approaches is the best option in integrated pest management programme because it does not cause any adverse effects to the environment and also economic to the farmers.

Before launching a crop improvement programme, a breeder should bear in mind that enhanced production and development of resistance are the two major targets to achieve the goal. Therefore genetic information pertaining to the extent of genetic variability for desirable traits along with the presence of pests and diseases resistance in the available germplasm is a prerequisite for developing elite varieties for commercial cultivation in a particular crop species. Presence of large variability ensures better chances to produce superior variety with desirable qualities. Meanwhile variability parameters like coefficients of variation, heritability, predicted genetic advance and magnitude of divergence besides degree of association between various characters and direct effects of yield contributing characters on total fruit yield and resistance to fruit fly are of paramount factors in formulating an appropriate breeding strategy aimed at exploiting inherent variability of the original population. This crop has not been fully exploited by the plant breeders in view of developing high yielding and fruit fly resistant varieties. Hence its cultivation became non-profitable to the farmers. Therefore attention in its genetic improvement attained prime importance.

Characterization of the available genotypes and identification of the traits which are associated with fruit fly resistance are essential to chalk out successful breeding programme. In this backdrop the present investigation was envisaged in bitter gourd with the following objectives.

1. To estimate genetic variability for different yield attributes and resistance to the fruit fly.

2. To identify high yielding genotypes tolerant to fruit fly.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Information on important biometrical techniques such as simple measures of variability, components of variability, association analysis, D^2 statistics and discriminant function analysis are essential for the systematic assessment of variability existing in the natural population, selection of elite genotypes and to chalk out an efficient breeding programme for the genetic improvement of yield and its contributing traits in relation to fruit fly resistance in bitter gourd. A review of literature on these aspects is presented below.

2.1. Variability

2.1.1. Biometric characters

Significant variability between genotypes is the most important factor needed for the selection of superior genotypes from a population (Allard, 1960)

In bitter gourd significant variability was reported by Choudhary and Sirohi (1972) in various cultivars for yield, fruit size, shape and colour; Srivastava and Srivastava (1976) for number of fruits per plant, fruit length, girth, weight and yield per plant; Sirohi and Choudhury (1977) for fruit length, diameter, weight, flesh thickness, fruits per plant and total yield per plant; Mangal et al. (1983) in twenty one genotypes for average length of fruit, periphery of fruit, weight of fruit, number of fruits per plant and yield per plant; Suri et al. (1986) in six genotypes for yield per plant, weight and colour of fruit; Lawande and Patil (1989) for yield per plant, average fruit weight, number of fruits per vine, fruit diameter, fruit length, days to first female flower opening and fruit colour; Jaiswal et al.(1990) in seven cultivars for yield, fruit colour, length, diameter and weight; Lawande and Patil (1991) in

eleven purelines for fruit weight, length, diameter , fruit number and yield per vine; Parhi et al. (1993) in 13 genotypes for number of fruits, days to first male flower opening, days to first harvest, yield per plant, fruit weight, length and breadth; Lingaiah et al. (1993) for number and yield of fruits; Thakur et al. (1994) for all the characters studied; Thakur and Khattra (1996) for days to first harvest, fruits per plant, fruit weight, fruit length, fruit fly infestation and marketable yield; Celine and Sirohi (1996) for fruit length, weight, fruits per plant and yield; Ram et al. (1996) in 18 accessions for days to first male flower, days to first female flower, number of fruits per plant, fruit weight, fruit length and fruit breadth; Ram et al. (1997) in inheritance studies for fruit length, diameter, weight, number of fruits per plant and yield per plant; Kutty and Dharmatti (2004) for days to opening of first female flower, days to first harvest, fruit length, fruit weight, number of fruits per plant and total yield per plant; Sangeetakutty and Dharmatti (2005) in 40 genotypes for days to first female flower opening, days to first harvest, fruit length, number of fruits per plant, total yield per plant, fruit weight and fruit fly infestation; Ram et al. (2006) in 26 diverse genotypes for days to first male flower anthesis, days to first female flower anthesis, number of fruits per plant, fruit length, fruit diameter, average fruit weight and yield per plant and Murlee et al. (2008) in 28 genotypes for days to first appearance of female and male flower, length of fruit, width of fruit, weight per fruit, number of fruits per vine and per plot, yield per plant, per plot and per ha.

2.1.2. Biochemical characters

Ramachandran and Gopalakrishnan (1980) studied total soluble solids and crude protein content in 25 diverse types of Momordica and reported wide range of significant variation among them.

Aswathi and Jaiswal (1986) reported 1.05 to 2.08 per cent reducing and 1.86 to 3.01 per cent total sugar in nine varieties of bitter gourd.

Dubey and Gaur (1990) reported highly significant difference for total soluble solids, reducing sugars, non reducing sugars and protein content with the difference in strains and periods of development of fruits. Total soluble solids ranged from 6.02 to 6.38 per cent. Moreover total soluble solids increased significantly with the advancement of age of fruits and maximum at fourth stage (22 days after fruit setting).

Jaiswal et al. (1990) reported a range of 88.5 to 90.4 per cent moisture content, 1.18 to 2.32 per cent protein content and 6.9 to 8.55 per cent carbohydrate in seven cultivars of bitter gourd.

Kale et al. (1991) reported considerable variation in protein, carbohydrate and sugars in freshly harvested fruits of six improved varieties in bitter gourd.

Xiang et al. (2000) observed a range of 11.4 – 20.9 $g.kg^{-1}$ crude protein content in thirteen bitter gourd varieties.

Kore et al. (2003) reported that of the ten varieties evaluated, MC-84 and Preethi had highest total soluble solids content (3.30 and 3.10 Brix). They also reported highest moisture content (95.17%) in Hirkani cultivar and highest fruit protein content (1.6%) in Preethi. But none of the genotypes exhibited significant difference for carbohydrate content.

2.1.3. Incidence of fruit fly

Bactrocera cucurbitae Coq., commonly known as fruit fly or melon fruit fly, is highly polyphagous and its preferred hosts are bitter gourd, musk melon,

snap melon and snake gourd (Srivastava and Bhutani, 1998). It is known to be found at certain heights in a canopy of host gourds when these are grown on a pandal (Jiji et al., 2005; Sisodiya et al., 2005). The fruit fly causes more than 50% yield loss in bitter gourd (Narayan and Batra, 1960; Gupta and Verma, 1978; Rabindranath and Pillai, 1986).

Sixty six accessions of bitter gourd were screened for fruit fly resistance by Padmanabhan (1989) and classified them into highly susceptible, moderately susceptible and moderately resistant types. Bitter gourd varieties 'Green Rough', 'Green Smooth', 'White Rough' and 'White Smooth' showed resistance to fruit fly. Peter (1998) reported that more prickly variety 'Phule BG 4' was comparatively resistant to fruit fly. Kalyanpur Baramasi was also found tolerant to fruit fly (Rai et al., 2005). Satpathy et al. (2005) reported that level of infestation varied between 21 and 29% and it did not significantly differ. Preethi was reported to be less susceptible to fruit fly attack (Rajan and Prameela, 2004).

Gupta and Verma (1992), Koul and Bhagat (1994), Pareek and Kavadia (1994) and Singh et al. (2000) reported that percentage of fruit damage by the melon fruit fly varied significantly in various cucurbits. Significant differences were reported by Nath (1966) in bottle gourd, sponge gourd and ridge gourd; Dhillon et al. (2005), Nath and Bhushan (2006) and Gogi et al. (2009) have reported significant differences in test genotypes for fruit infestation and larval density per fruit in bitter gourd.

The screening of genotypes for resistance to fruit fly was conducted by Chelliah (1970) in wild melon, *Cucumis callosus*; Pal et al. (1984), Srinivasan (1991), Thakur et al. (1992), Thakur et al. (1994), Thakur et al. (1996) and Tewatia et al. (1997) in bitter gourd; Mahajan et al. (1997) in round melon and Dhillon et al. (2005) in wild bitter melon.

Pal et al. (1983) reported low total soluble solids content in fruit fly resistant wild melon, *Cucumis callosus*.

Dhillon et al. (2005) reported that moisture, potassium and reducing sugars explained 97.4 per cent and moisture, phosphorus, protein, reducing sugars and total sugars explained 85 per cent of the total variation in fruit infestation and larval density per fruit respectively.

Jakhar and Pareek (2005) reported that bitter gourd was a moderately preferred host. Singh et al. (2000) reported that fruit fly showed significantly more preference to bitter gourd fruits than water melon, bottle gourd, musk melon, cucumber and long melon but categorised as moderately preferred host. Nath and Bhushan (2006) reported bitter gourd followed by bottle gourd were the most preferred hosts of *Bactrocera cucurbitae*. Saha et al. (2007) have tested various artificial diets for melon fruit fly, one of which was yeast: Sugar (1:3). *Momordica charantia* var *muricata* landraces are small fruited bitter gourds, it posses unique flavor, taste medicinal properties and fruit fly tolerance (Joseph and Antony, 2008).

Gupta and Verma (1992) reported bitter gourd as a most preferred host of melon fruit fly with damage level from 41 to 89%.

2.2. Genetic components of variability

In the ten lines studied, estimates of heritability and genetic advance were highest for fruit number, fruit weight and yield (Srivastava and Srivastava, 1976).

Heritability estimates were high for fruit fresh weight, fruit length and fruit girth. But it was low for yield per plant. Also high genotypic coefficient of variation values were found for fruit fresh weight, yield per plant and fruit length by Indiresh (1982).

Thakur et al. (1994) reported very high heritability (56.41 to 87.79%) for all the characters including total yield, marketable yield and melon fruit fly infestation. They also reported high genotypic and phenotypic coefficients of variation for total and marketable yield.

Rajput et al. (1996) reported high heritability for the eleven yield components studied. Moreover, large variation was found for yield and its components both at phenotypic and genotypic levels.

Variability studies in bitter gourd revealed that days to first male flower, days to first female flower, number of fruits per plant, mean weight of fruit, fruit yield per plant, fruit length, fruit girth and flesh thickness had high genotypic coefficient of variation and genetic advance except days to first harvest and duration of the crop. But all these traits recorded high heritability. It indicated that majority of the characters in bitter gourd can be improved through selection (Iswaraprasad, 2000).

Rajeswari and Natarajan (2002) reported high heritability for fruit girth, flesh thickness and yield per hill and moderate estimates for fruit length, weight and fruits per hill.

Bhave et al. (2003) reported higher phenotypic coefficient of variation than genotypic coefficient of variation for flowering duration, harvesting span, fruit length, average fruit weight, fruit number per vine and total fruit yield per

vine and high genotypic coefficient of variation and phenotypic coefficient of variation for total fruit yield.

Kutty and Dharmatti (2004) reported appreciable genotypic coefficient of variation and phenotypic coefficient of variation for fruit length, number of fruits per plant, total yield per plant and fruit weight. But phenotypic coefficient of variation was higher than genotypic coefficient of variation and lower than environmental coefficient of variation. They also reported high heritability coupled with high genetic advance (percentage of mean) for number of fruits per plant, fruit weight and total yield per plant. But low heritability was reported for days to first harvest, fruit length and days to first female flower opening.

Ram et al. (2006) reported maximum coefficients of variation for days to male flower emergence, yield per plant, fruit weight and fruit length among 12 different traits studied in bitter gourd.

Raj et al. (2007) reported genotypic coefficients of variation and phenotypic coefficients of variation range of various characters from 6.37 to 37.25 and 8.37 to 38.63 respectively. The highest phenotypic and genotypic coefficients of variation were registered for the number of female flowers per plant followed by fruit weight. They also reported high heritability coupled with high genetic advance for number of female flowers per plant followed by fruit weight and yield per plot. But fruit girth showed moderate heritability with low genetic gain.

2.3. Correlation coefficients

Association analysis indicated that breeding for an increase in total soluble solids will improve the contents of vitamin C, potassium and

phosphorus while maintaining reasonably high protein content in bitter gourd (Ramachandran and Gopalakrishnan, 1980). They also reported based on study of 25 diverse bitter gourd forms that yield per plant was positively correlated with fruit weight, length, number of fruits per plant and number of female flowers per plant at genotypic and phenotypic levels.

According to Indiresh (1982), yield was positively and significantly correlated with fruit fresh weight, length and girth.

Parhi et al. (1995) reported positive and significant correlation of yield per plant with fruit weight, length and days to first harvest.

Thakur et al. (1996) reported that *Bactrocera cucurbitae* infestation was negatively correlated with fruits per plant and total marketable yield. There was significant and positive correlation (r = 0.96) between percentage of fruit infestation and larval density per fruit. These two were positively correlated with flesh thickness, fruit diameter and fruit length. Flesh thickness and fruit diameter explained 93 percent and flesh thickness and fruit length explained 76.3 percent of total variation to fruit fly infestation and larval density per fruit respectively.

Sharma and Bhutani (2001) reported significant correlation for chlorophyll a and b with total chlorophyll content, first female flowering node and fruit length with fruits per plant, fruit length and fruit diameter with average fruit weight, fruits per plant and average fruit weight with total fruit yield per plant.

According to Bhave et al. (2003), the fruit number was highly correlated with total fruit yield per vine in bitter gourd. At the phenotypic and genotypic levels, fruit yield per vine was positively correlated with flowering duration,

harvesting span, biological yield, fruit length, breadth, rind thickness, average weight and number of fruits per vine and negatively correlated with days to first flowering.

Number of fruits and total yield per plant both at phenotypic and genotypic levels were negatively and significantly associated with fruit fly infestation (Dhillon et al., 2005).

Sangeetakutty and Dharmatti (2005) reported that yield per plant showed positive and significant correlation with number of fruits per plant, fruit weight and fruit length at genotypic and phenotypic levels in bitter gourd. Days to first female flower opening was positively and significantly associated with days to first harvest, fruit length and fruit weight at either genotypic or phenotypic levels.

Dhillon et al. (2005) reported that genotypes with low fruit fly infestation had low larval numbers in the fruits in bitter gourd. Protein, reducing sugars, non-reducing sugars and total sugars were negatively and moisture content was positively correlated with fruit fly infestation and larval density per fruit.

2.4. Path coefficient analysis

Paranjape and Rajput (1995) reported that the fruit weight had maximum direct bearing on yield. However fruit length and number of fruits per vine were indirectly contributed towards yield.

The weight per fruit had most important direct effect on yield per plant followed by number of fruits per plant (Xu and Huang, 1995). They also found that the direct effect of fruit length on yield per plant was the lowest, but its

positive indirect effect through weight per fruit was larger. Larger negative effect of number of fruits per plant on yield per plant through weight per fruit was also reported.

Parhi et al. (1995) reported that fruit breadth and days to opening of first male and female flower had maximum positive direct effect on yield in bitter gourd. But fruit weight and fruit length though had significant positive correlation with yield, exhibited low direct effect. Gupta et al. (2007) have reported the same result in bitter gourd.

Direct negative effects on yield were observed for days to first female flower appearance and days to first harvest (Rajput et al., 1996).

Sharma and Bhutani (2001) reported that, fruits per plant had the highest direct contribution towards yield followed by fruit length and diameter. Average fruit weight, diameter and length had high indirect contribution towards yield through number of fruits per plant.

Harvesting span, fruit length, average fruit weight, number of fruits per vine and biological yield had direct positive effects on fruit yield and fruit length had positive and indirect effects on fruit yield in bitter gourd (Bhave et al., 2003).

Number of fruits per plant and fruit weight were the most important factors contributing to the yield per plant as they showed very high positive correlation and high indirect effects through other characters. Even though fruit length showed low positive and direct effect, the high indirect effects through fruit weight and number of fruits per plant explain high genotypic correlation with yield. Fruit fly infestation showed low negative direct effect on yield, but

high negative indirect effects through other characters (Sangeetakutty and Dharmatti, 2005).

Ram et al. (2006) reported that number of fruits per plant and fruit weight together contributed 91.68 per cent, implies the major contribution of these characters to yield in bitter gourd. Fruit weight had contributed 65.82 percent to the total yield.

2.5. D^2 Statistics

Parhi et al. (1993) studied 13 genotypes and grouped them into six clusters. Contribution of fruit length and yield were 14.09 per cent and 9.31 per cent respectively to the total divergence.

Genetic diversity analysis of 50 genotypes of bitter gourd was conducted by Abdul Wahab and Gopalakrishnan (1993) and grouped them into 5 clusters. All the high yielding genotypes were grouped into a single cluster.

Arora (1995) has reported rich genetic diversity in wild and cultivated species of *Momordica*.

Genetic divergence study in bitter gourd revealed high genetic variability with in cluster and it offers scope for improvement by various selection methods. Moreover, maximum inter cluster distance between different clusters showed that hybridization involving genotypes with maximum inter cluster distance as parents may be useful to exploit hybrid vigour in heterosis breeding programme (Manju and Wilson,2002).

Genetic divergence study was conducted using 38 bitter gourd genotypes including two promising gynoecious lines for 17 characters. These genotypes were grouped into six clusters (Dey et al., 2007).

Sundaram and Vadivel (2007) evaluated 22 bitter gourd genotypes and found wide genetic diversity and formed 6 clusters in genetic divergence analysis which included two monogenic clusters also.

Sundaram (2008) evaluated 22 bitter gourd genotypes and reported wide genetic diversity between them and were grouped into six clusters. The clustering pattern revealed that the genetic diversity was independent of the geographical diversity. Among 14 quantitative characters studied, individual fruit weight constituted a maximum of 26.83 percentage contribution to the divergence followed by yield of fruits per vine and length of fruit.

2.6. Selection Index

Selection index involves discriminant function analysis, which is used for making selection on several characters simultaneously and thereby discriminating the desirable genotypes from undesirable ones on the basis of their phenotypic performance.

Parhi et al. (1993) prepared a selection index in the collection of 13 bitter gourd genotypes based on major components of yield namely, 100 seed weight, number of seeds per fruit and yield per plant.

A selection index was formulated in 24 watermelon genotypes by Shibu kumar (1995) using the characters yield per plant, number of fruits per plant, weight of individual fruit and total soluble solids.

Gayathri (1997) prepared selection index in the collection of cucumber genotypes based on major components of yield namely node to first female flower, days to first harvest, fruits per plant, average fruit weight, length, girth, diameter and yield per plant.

Lovely (2001) reported fruit length and fruit girth as important characters for selection in ash gourd.

In ivy gourd, Varghese (2003) reported number of fruits per plant and average fruit weight as important criteria for selection.

Resmi (2004) formulated selection index with better yield, fruit quality, earliness in male and female flowering, narrow sex ratio and mosaic resistance in 25 ash gourd landraces.

Ram et al. (2006) reported that fruit weight and number of fruits are needed to be given more emphasis while selecting high yielding genotypes in bitter gourd.

2.7. Screening for fruit fly resistance

Artificial fruit fly adult rearing method was studied by Lall and Singh (1969).

Srinivasan and Prasad (1980) studied host preference of *Dacus cucurbitae* in terms of incubation period, ovipositional preference, larval period, size, weight of the larvae and pupal period.

Two bitter gourd lines, Faizabad Collection-17 and Kerala Collection-1 were resistant to the melon fruit fly under both field and laboratory conditions (Tewatia, 1994).

Koul and Bhagat (1994) studied ovipositional preference of melon fly in 5 different cucurbits in laboratory conditions and found maximum preference for oviposition on *Momordica charantia*.

Chaudhary and Patel (2007) have developed a technique of artificial rearing of *Bactrocera cucurbitae* on pulp of pumpkin fruits.

Nath (1966) classified genotypes based on damage to fruits as

No damage	-	immune
1-10% damage	-	highly resistant
11-20% damage	-	resistant
21-50% damage	-	moderately resistant
51-75% damage	-	susceptible
76-100% damage	-	highly susceptible

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was conducted in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2009-2010. This experiment was undertaken to estimate genetic variability for yield, different yield attributes and resistance to fruit fly and to identify high yielding fruit fly tolerant genotypes in bitter gourd.

This study involved two experiments, experiment I and II.

Experiment I - Field experiment was carried out to evaluate genotypes / varieties of bitter gourd for yield contributing traits and resistance to fruit fly.

Experiment II - Laboratory screening was done to confirm the fruit fly resistance in bitter gourd genotypes under artificial conditions.

Both these experiments were carried out simultaneously during the same period.

3.1. Field experiment

3.1.1.Materials:

The materials used for this study consisted of 30 genotypes of bitter gourd including 11 accessions received from NBPGR, Thrissur, 16 local varieties collected from different agro-climatic regions of Kerala and three varieties released from Kerala Agricultural University. Details of these genotypes are given in table -1 and plate -1.

3.1.2.Methods - I

3.1.2.1. Design and Layout

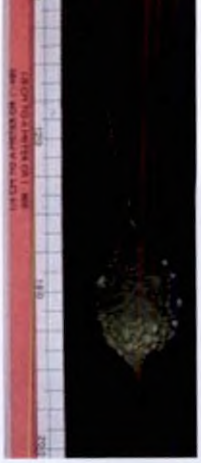
The experiment was laid out in Randomized Block Design with three replications at spacing of 2 x 2 m. Field view is presented in plate – 2.

Table – 1. Details of genotypes used in the study

Sl No.	Genotype /variety	Source/location
1.	IC-68338	NBPGR,Thrissur
2.	IC-68255	NBPGR, Thrissur
3.	Bharanikkavu local	Kollam
4.	Preethi	College of Agriculture,Vellayani
5.	Kallukuthiavila local	Thiruvananthapuram.
6.	Priyanka	Sugarcane Research Station, Thiruvalla
7.	Changanassery local-1	Changanassery
8.	IC-68272	NBPGR, Thrissur
9.	Kollam local	Kollam
10.	Kanakakkunnu local	Idukki
11.	IC-68296	NBPGR, Thrissur
12.	Madhurai local	Tamil Nadu
13.	IC-68237	NBPGR, Thrissur
14.	Priya	Regional Agricultural Research Station, Pattambi
15.	Punnavely local	Idukki
16.	Nedinjal local	Thiruvananthapuram.
17.	Pappanchani local	Thiruvananthapuram.
18.	Changanassery local-2	Changanassery
19.	IC-45341	NBPGR, Thrissur
20.	IC-68250	NBPGR, Thrissur
21.	Adimaly local	Idukki
22.	IC-50516	NBPGR, Thrissur
23.	Eratayar local	Idukki
24.	Palakkadu local	Palakkad.
25.	Kaarikkuzhy local	Thiruvananthapuram.
26.	CL-Coimbatore	National Seeds Corporation, Thiruvananthapuram.
27.	IC-43261	NBPGR, Thrissur
28.	IC-68306	NBPGR, Thrissur
29.	Parathode local	Idukki
30.	IC-68316	NBPGR, Thrissur

Adimaly local

Bharanikkavu local

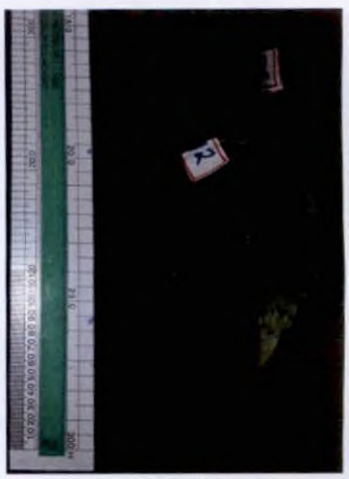


Changanassery local 1

Changanassery local 2

CL Coimbatore

Eratayar local



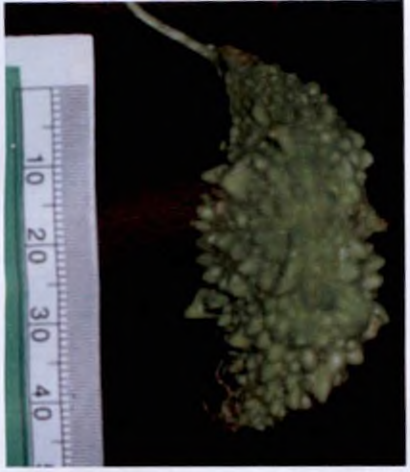
IC -43261

IC -45341

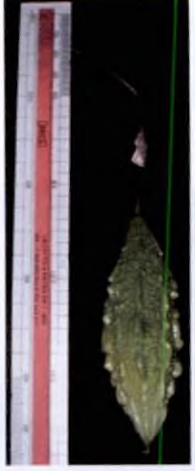
IC - 50516

IC -68237

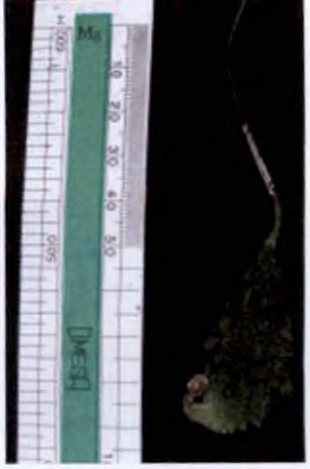
Plate 1 : Fruits of 29 genotypes



IC -68250

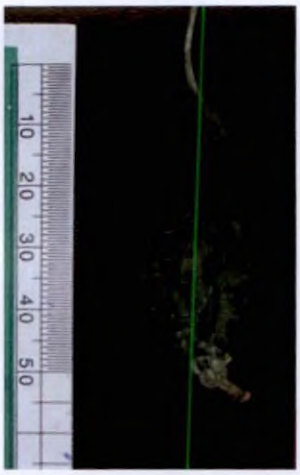


IC -68255



IC -68272

IC -68296



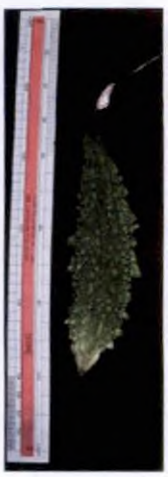
IC -68306

IC -68338

Kaarikhuzhi local

Kallukuthiavilla local

Kanakakunnu local



Kollam local

Plate 1 : Fruits of 29 genotypes continued..

Madhurai local

Nedinjal local

Palakkad local

Pappanchani local

Parathode local

Preethi

Priya

Priyanka

Punnavely local

Plate 1 : Fruits of 29 genotypes continued..

Plate 2 : Field view of experiment I

3.1.2.2. Sowing and cultural operations

Seeds of 30 genotypes were sown directly in pits during September 2009 for evaluation. Agronomic practices adopted were as per the package of practices recommendations of the Kerala Agricultural University for raising the crop (KAU, 2007).

3.1.2.3. Biometric observations

To evaluate genotypes, five plants were selected at random per replication for each treatment and the following observations were recorded. For each observation average was worked out and expressed in corresponding units.

a) Days to first male flower opening (days)

The number of days taken for the blooming of first male flower was recorded in each genotype and expressed in days.

b) Days to first female flower opening (days)

The number of days taken for the blooming of first female flower was recorded in each genotype and expressed in days.

c) Days to first harvest (days)

In each genotype, number of days taken for the first harvest from the date of sowing was recorded and expressed in days.

d) Fruit bearing period (days)

In each treatment the total number of days taken for the harvest of the last fruit from the date of first female flower opening was recorded and expressed in days.

e) Number of fruits per plant

The total number of fruits produced in each plant was recorded and average worked out.

f) Fruit length (cm)

In each treatment replication wise, length of five matured fruits selected at random was measured and the mean fruit length was expressed in centimeter.

g) Fruit girth (cm)

Girth of five matured fruits selected at random in each replication was measured and the mean fruit girth was expressed in centimeter.

h) Individual fruit weight (g)

Five mature fruits selected at random in each replication were weighed and the mean fruit weight was expressed in gram.

i) Yield per plant ($g.plant^{-1}$)

Weight of all the fruits produced in each plant was measured and expressed in gram.

j) Duration (days)

The number of days taken for the harvest of the last fruit from date of sowing was recorded and expressed in days.

k) Flesh thickness (mm)

Middle portion of the fruit sample was cut out with a knife and measured thickness and expressed in millimeter.

l) Incidence of fruit fly (%)

In each plant per replication, total number of fruits produced and number of fruits damaged by the fruit fly were recorded and expressed in percentage.

3.1.2.4. Biochemical characters

Observations regarding the following biochemical characters were taken from the fruit samples collected at three different maturity stages i.e., fruit setting stage (1-7 days) stage I, half maturing stage (8-14 days) stage II and full maturing stage (15-21 days) stage III. Five fruits each at three different stages were collected at random per replication and subjected to chemical analysis and average was worked out and expressed in its corresponding units.

a) Total protein content ($mg.g^{-1}$)

Bradford (1976) method was adopted to estimate protein content in fruit samples.

Procedure

0.5 g of tissues per fruit was taken and extracted with 5-10 ml of the phosphate buffer saline. The extract was centrifuged and the supernatant was collected. 0.2, 0.4, 0.6, 0.8 and 1 ml of the protein standard solution was taken in test tubes. 0.1 ml and 0.2 ml of the sample extract were taken in other two test tubes. In all the test tubes made up the volume to 1 ml with distilled water. 1 ml of water taken in another test tube served as blank. 5 ml of diluted dye binding solution was added to each of the test tubes containing solution and allowed for ten minutes to develop blue colouration in the solution. The absorbance of the coloured solution was measured at 595 nm wavelength against blank.

b) Water content (%)

Air oven method was adopted to determine water content in fruit samples. 2 g tissues per each fruit sample were taken and oven dried for 24 hours. The final weight was taken and water content of fruit samples determined. Loss in weight represented as the weight of water lost due to drying.

$$\text{Water content percentage} = \frac{W_1 - W_2}{W_1} \times 100$$

Where,

W_1 - weight before drying

W_2 - weight after drying

c) Total soluble solids (Brix)

Tissues of equal size were taken from top, middle and bottom portion of a fruit and crushed well to extract juice. The TSS of clear fruit juice was determined with the help of a hand refractometer and the amount of TSS was expressed as Brix.

d) Total sugars ($mg.g^{-1}$)

Total sugars were estimated using Anthrone method (Sadasivam and Manickam, 2002).

Procedure

100 mg of the tissue sample was weighed out in a boiling tube and hydrolyzed it with 5 ml of 2.5N hydrochloric acid for three hours in a boiling water bath and cooled to room temperature. Solid sodium carbonate was added to this until the effervescence ceased. Made up the volume to 100 ml and centrifuged. Supernatant was collected and took 0.5 and 1 ml of aliquots for analysis. Working standards of 0, 0.2, 0.4, 0.6, 0.8 and 1 ml was taken and

'0' served as blank. Each test tube made up to 1 ml with distilled water. 4 ml of anthrone reagent was added to each test tube and then it was heated in a boiling water bath for eight minutes. Test tubes were cooled to room temperature. Absorbance of resultant green to dark green coloured solutions were measured at 630 nm wave length in a colorimeter against blank.

Calculation

The amount of sugars present in the sample was calculated as follows and expressed in $mg.g^{-1}$.

$$\text{Amount of sugars in 100 mg of the sample} = \frac{\text{Weight of glucose (mg)}}{\text{Volume of test sample}} \times 100$$

e) Reducing sugars ($mg.g^{-1}$)

The reducing sugars were estimated by dinitrosalicylic acid method (Miller, 1972).

Procedure

100 mg of the fruit tissues were weighed out and extracted the sugars with 5 ml of hot 80% ethanol twice. Collected the clear supernatant and evaporated it in a water bath at 80°C. Sugars were dissolved in 10 ml of water. 0.5 to 3 ml of extract was taken in test tubes and made up the volume to 3 ml with water. 3 ml of DNS reagent was added to this. The contents were heated in a boiling water bath for 5 minutes.1 ml of 40% Rochelle salt solution was added to it. Then cooled to room temperature and the intensity of dark red colour was measured through 510 nm. A series of glucose (0 to 500µg) served as standard.

Calculation

The amount of reducing sugars present in the sample was calculated using the standard graph.

f) Non- reducing sugars ($mg.g^{-1}$)

Non-reducing sugars were estimated by subtracting the reducing sugars from total sugars.

Non reducing sugars = Total sugars – Reducing sugars

g) Fruit colour (Chlorophyll content) ($mg.g^{-1}$)

Chlorophyll content was estimated by DMSO method.

Procedure

500 mg of the fruit tissues were taken. It was then cut into small bits and put into test tubes.10 ml of DMSO: 80% acetone mixture (1:1) was poured and incubated over night at room temperature. Decanted the coloured solution into a measuring cylinder and made up the volume to 25 ml with the DMSO – Acetone mixture. The absorbance was recorded at 645 nm and 663 nm with a spectrophotometer.

Calculation

$$\text{Total chlorophyll per tissue} = \frac{(20.2\ A_{645} + 8.02\ A_{663}) \times V}{1000 \times W}$$

Where,

A – Absorbance at specific wavelength

V – Final volume of chlorophyll extract in 80% acetone.

W– Fresh weight of tissue extracted.

h) Fiber content ($mg.g^{-1}$)

Procedure

2 g of tissue sample was extracted with ether. The residue obtained was boiled with 200 ml of sulphuric acid for 30 minutes. The extract was filtered and the residue was washed repeatedly with boiling water to remove the acid. It was boiled with 200 ml of sodium hydroxide for 30 minutes and then filtered. The residue was subsequently washed with 25 ml of 1.25% boiling sulphuric acid, three 50 ml of distilled water and 25 ml of ethanol. The residue was transferred to a pre weighed dish (W_1) and dried at 130°C for 2 hours. Cooled the dish in a desiccator and reweighed (W_2). The dish was ignited at 600°C for 30 minutes. The dish was cooled in a desiccator and reweighed (W_3).

Calculation

$$\text{Crude fiber in the sample} = \frac{(W_2-W_1) - (W_3-W_1)}{(W_2-W_1)}$$

Where,

W_1 - Weight of dish

W_2 - Weight of sample before ignition

W_3 - Weight of sample after ignition

i) Epicuticular wax ($mg.10\ cm^{-2}$)

Procedure

Fruit pieces with a surface area of 10 cm^2 were taken from each sample and dipped in a pre weighed 10 ml beaker containing 10ml chloroform and after 10 seconds removed the pieces. The chloroform was allowed to evaporate over night. Reweighed the beaker and expressed the difference in weight as epicuticular wax content.

j) Phenol content ($mg.100g^{-1}$)

Procedure

0.5 to 1 g of fruit tissue sample was taken and extracted with 80% ethanol. Centrifuged the extract and the supernatant was taken and evaporated to nearly dryness. The residue was dissolved in distilled water and made up to known volume 5 ml. A number of aliquots (0.2 to 2 ml) were taken separately into test tubes. In each tube made up the volume to 3 ml with distilled water. 0.5 ml of Folin – Ciocalteu's phenol reagent was added to each test tube. After 3 minutes, 2 ml of 20% sodium carbonate (Na_2CO_3) solution was added to this. Test tubes were placed in a boiling water bath for one minute and cooled to room temperature. The absorbance was then measured through 650 nm wave length in a colorimeter against blank.

3.1.2.5. Statistical analysis

3.1.2.5.1. Analysis of variance (ANOVA) and covariance (ANCOVA)

Analysis of variance and covariance were carried out with replicated data obtained in statistical design, Randomised Block Design (RBD) to test the significance of difference among genotypes with respect to various polygenic traits and to estimate the components of variance, coefficients of variation, correlations and path coefficients, D^2 statistics and selection indices.

Analysis of variance for Randomised Block Design

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Replications	r-1	SSR	MSR	MSR ÷ MSE
Genotypes	g-1	SSG	MSG	MSG ÷ MSE
Error	(r-1)(g-1)	SSE	MSE	
Total	rg-1			

Where,

r = number of replications

g = number of genotypes

SSR= sum of squares for replications

SSG = sum of squares for genotypes

SSE = sum of squares for error

MSR = mean squares for replications

MSG = mean squares for genotypes

MSE = mean squares for error

Critical difference (CD) = $t_{\alpha}(2MSE \div r)^{1/2}$

Where,

t_{α} is the table value of Student's t distribution at error degrees of freedom and α is the level of significance (5% or 1%) (Panse and Sukhatme, 1985).

Analysis of covariance for Randomised Block Design

Source of variation	Degrees of freedom	Sum of products for X and Y	Mean products
Replications	r-1	SPR	MPR
Genotypes	g-1	SPG	MPG
Error	(r-1)(g-1)	SPE	MPE
Total	rg-1		

Where,

r = number of replications

g = number of genotypes

SPR = sum of products for replications

SPG = sum of products for genotypes

SPE = sum of products for error

MPR = mean products for replications

MPG = mean products for genotypes

MPE = mean products for error

The covariance was estimated as follows

Environmental covariance between characters X and Y (σe_{XY}) = MPE

Genotypic covariance between characters X and Y (σg_{XY}) = (MPG-MPE) ÷ r

Phenotypic covariance between characters X and Y (σp_{XY}) = $\sigma g_{XY} + \sigma e_{XY}$

3.1.2.5.2. Estimation of genetic components of variance

From ANOVA, for each character, the phenotypic, genotypic and environmental variances were estimated as follows (Jain, 1982).

Genotypic variance (σg^2) = (MSG- MSE) ÷ r

Environmental variance (σe^2) = MSE

Phenotypic variance (σp^2) = $\sigma g^2 + \sigma e^2$

a) Coefficients of variation

ANOVA permitted estimation of phenotypic, genotypic and environmental coefficients of variation (Burton, 1952).

Phenotypic coefficient of variation (PCV) = (σp ÷ mean) × 100

Genotypic coefficient of variation (GCV) = (σg ÷ mean) × 100

Environmental coefficient of variation (ECV) = (σe ÷ mean) × 100

The PCV and GCV values were classified as follows (Sivasubrahmanian and Madhava Menon, 1973)

Low – Less than 10 percent

Moderate – 10 to 20 percent

High _ More than 20 percent

b) Heritability (in broad sense)

Broad sense heritability (H) was worked out as follows (Hanson et al., 1956).

$H = (\sigma g^2 \div \sigma p^2) \times 100$

Heritability values were categorized as follows as suggested by Johnson et al., (1955)

Low - Less than 30 per cent

Moderate - 30 to 60 percent

High - More than 60 percent

c) Genetic advance as percentage of mean

Genetic advance under selection was estimated by the following method (Johnson et al., 1955).

Genetic advance percent = (Genetic advance ÷ Mean) × 100

Genetic advance (GA) $= (\sigma g^2 \div \sigma p) \times k$

Where,

σp = Phenotypic standard deviation of the original population

k = Selection differential at a particular level of selection intensity

Value of k at 5% level of significance is 2.06, (Miller et al., 1958).

The magnitude of genetic advance as percentage of mean was classified as follows (Johnson et al., 1955)

Low _ Less than 10 per cent

Moderate _ 10 to 20 percent

High – More than 20 percent

3.1.2.5.3. Correlation coefficient

The phenotypic, genotypic and environmental correlations were estimated as follows

Phenotypic correlation coefficient between two variables x and y

$$r_p = \frac{PCov_{xy}}{(PV_x \times PV_y)\ ½}$$

Where,

r_{Pxy} = Phenotypic correlation coefficient

$PCov_{xy}$ = Phenotypic covariances between variables x and y

PV_x = Phenotypic variances for the variable x

PV_y = Phenotypic variances for the variable y

Genotypic correlation coefficient between two variables x and y

$$r_{gxy} = \frac{GCov_{xy}}{(GV_x \times GV_y)\ ½}$$

Where,

r_{gxy} = Genotypic correlation coefficient

$GCov_{xy}$ = Genotypic covariances between variables x and y

GV_x = Genotypic variances for the variable x

GV_y = Genotypic variances for the variable y

Environmental correlation coefficient between two variables x and y

$$r_{exy} = \frac{ECov_{xy}}{(EV_x \times EV_y)\ ½}$$

Where,

r_{exy} = Environmental correlation coefficient

$ECov_{xy}$ = Environmental covariances between variables x and y

EV_x = Environmental variances for the variable x

EV_y = Environmental variances for the variable y

The calculated correlation values were tested for significance of correlation coefficients by comparing it with the table value of correlation values at n-2 degrees of freedom.

3.1.2.5.4. Path coefficient analysis

To study the cause and effect relationship of yield and its component attributes, direct and indirect effects were analyzed using path coefficient analysis as suggested by Wright (1954).

The genotypic correlation between yield and selected component characters were subjected to path analysis and the direct effect of the character on yield as well as the indirect effect through other characters were estimated.

3.1.2.5.5 Selection Index

To discriminate the desirable genotypes from undesirable ones on the basis of their phenotypic performances and thereby for making selection on several characters simultaneously using discriminant function of Fisher (1936), classical selection index model proposed by Smith (1936) was adopted.

The selection index is described by the following functions. The phenotypic performance of various characters is represented by the discriminant function, $I = b_1x_1 + b_2x_2 \ldots\ldots + b_kx_k$ where, $x_1, x_2, \ldots\ldots, x_k$

denoted the phenotypic performance of traits 1,2,.....,k and b_1, b_2.....b_k are the weighing coefficients.

Total genotypic effect of all component effects can be represented by a function, $H = a_1G_1+a_2G_2+.....+a_kG_k$ where, $G_1,G_2,.....,G_k$ are the genotypic values of the plants with respect to the characters 1,2,.....,k and $a_1,a_2,.....,a_k$ are weights and H is the genetic worth of the plant.

To assign weights for genotypic values, it is assumed that all the characters as equally important, then $a_1=a_2=.....=a_k=1$ and b_1, b_2.....,b_k are regression coefficients and these are to be estimated such that the correlation between H and I becomes maximum. The 'b_i' values are estimated as follows

$$b = P^{-1}Ga$$

Where,

b, P, G and a denote the respective matrix representative of the b, P, G, and a values.

3.1.2.5.6. Genetic divergence

Genetic divergence was measured using the technique D^2 statistics developed by Mahalanobis in 1928. Grouping of genotypes into clusters was made based on the relative distances (D^2 values) from each other and it was based on the method suggested by Tocher (Rao, 1952).

3.2. Experiment II – Screening for fruit fly resistance

Screening for fruit fly resistance was done

i) in the field and

ii) in the laboratory.

3.2.1. Field screening

Field screening was carried out to identify fruit fly resistant genotypes under uncontrolled conditions during rabi season (Sept-Oct to Nov-Dec) of 2009-2010. Natural infestation of fruit flies is found high during this period, hence this season is selected for undertaking the study. Application of management practices including insecticides were completely avoided in the experimental plots. Scoring of fruit fly infestation was done as per standard procedure (Nandakumar, 1999).

$$\text{Percentage of fruit fly incidence} = \frac{\text{Number of fruits damaged per plant}}{\text{Total number of fruits per plant}} \times 100$$

3.2.2. Laboratory screening

Fruit fly resistance was confirmed by screening the fruit samples of genotypes under artificial conditions in the laboratory of Department of Agricultural Entomology, College of Agriculture, Vellayani simultaneously with that of field screening during rabi season.

3.2.2.1. Materials

3.2.2.1.1. Melon fruit fly

Different stages like maggot, pupae and adult are presented in plate-3.

3.2.2.1.2. Melon fly rearing cage

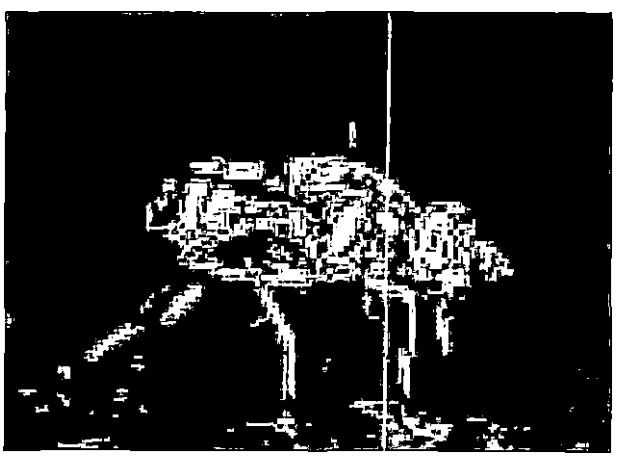
The cages of size 0.5×0.5×0.5 m^3 were used to keep fruit samples for screening (Plate-4).

3.2.2.1.3. Infested fruits

Infested fruits were collected from field time to time for rearing larvae.

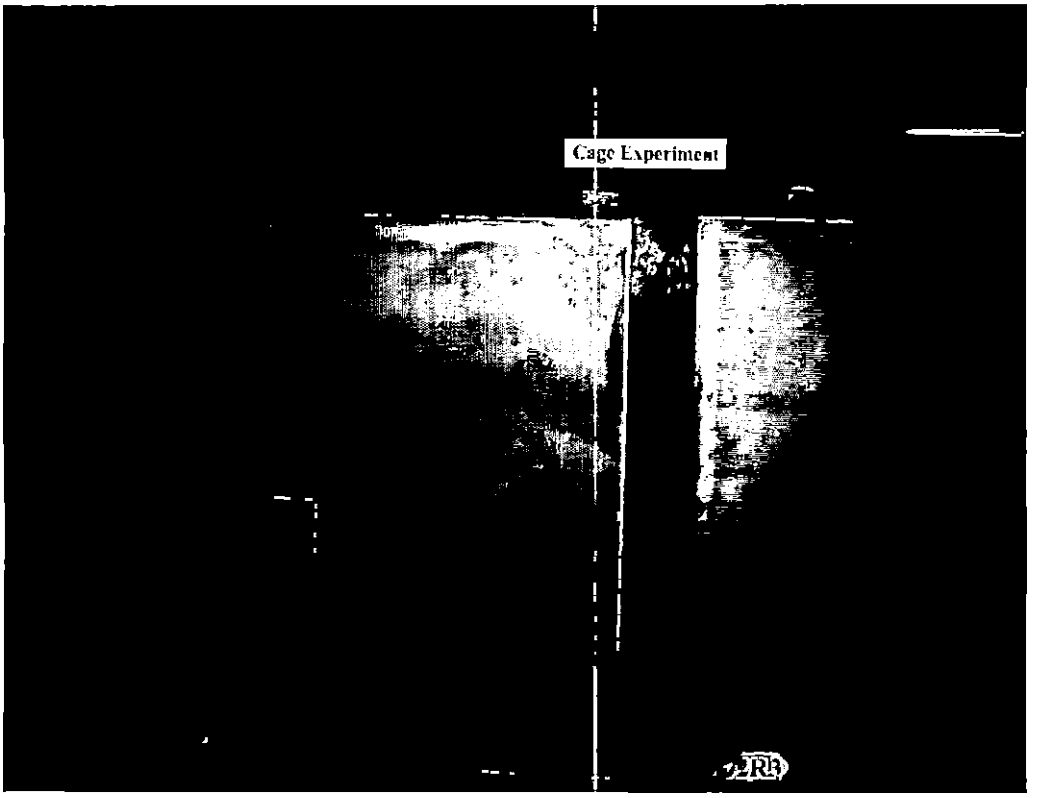
Maggot

Pupae



Adult

Plate 3 : Melon fruit fly - Maggot, Pupae and Adult



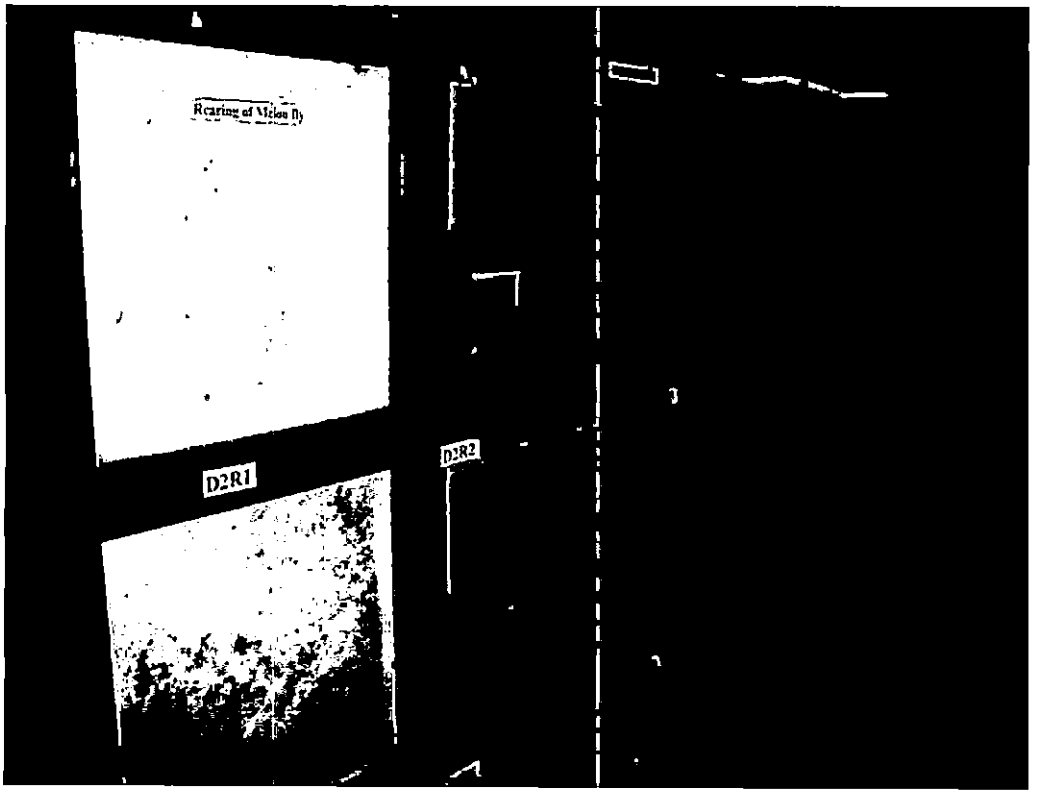


Plate 4 : Melon fruit fly rearing cage

3.2.2.1.4. Fresh fruits

Fresh uninfested fruits were collected at immature, half mature and fully mature stages from field grown plants for laboratory screening.

3.2.2.2. Methods

3.2.2.2.1. Fruit fly rearing and screening of fruit samples

The fruit fly infested bitter gourd fruits were collected from the field and introduced into the troughs, containing soil, for pupation. Uniform sized glass troughs (15cm height and 30 diameter) were used for the study. These troughs were filled with soil to a depth of 4cm and moistened by sprinkling water. The troughs were covered using a muslin cloth and fastened using a rubber band and kept aside for three days. The troughs were constantly examined for the emergence of adult flies.

On the day of adult emergence, the troughs were kept inside the cage to release the adults into the cage. These adults were supplied with a diet of jaggery – yeast solution. The jaggery–yeast solution was prepared by dissolving 20g jaggery and 10g yeast in 100ml distilled water. 25ml of the diet was supplied to fruit flies in the cage. The diet was replenished with fresh solution at three days interval.

Fourteen adult fruit flies (male and female in the ratio 1:1) were introduced into each cage of size 0.5x0.5x0.5 m^3. On the third day of emergence of flies five fruit samples of each genotype were introduced into each cage, providing a congenial condition for oviposition. The fruits were exposed for oviposition for five days and observation was taken on the sixth day. Bitter gourd fruits of three different stages viz. immature (1-7 days old,

stage I), half mature (8-14 days old, stage II) and full mature (15-21 days, stage III) of all the genotypes were used for screening purpose.

3.2.2.2.2. Design

The design used was Completely Randomized Design. Fruit samples of 29 genotypes at three different stages of fruit development were kept in four replications @ 5 fruits per replication.

3.2.2.3. Observations

3.2.2.3.1. Number of ovipositional punctures

The fruits kept for screening were observed for ovipositional punctures on the fruit surface. The number of punctures present on the fruit surface were counted on each fruit and expressed as average of five fruits.

3.2.2.3.2. Number of fruits infested

Number of fruits infested by fruit flies and total number of fruit sample kept for screening were recorded in every replication and expressed in percentage.

$$\text{Percentage of infested fruits} = \frac{\text{Number of fruits infested}}{\text{Total number of fruits kept for infestation}} \times 100$$

3.2.2.3.3. Number of maggots per fruit

The number of larvae per fruit was counted by destructive sampling of oviposited fruits and expressed as average of five fruits.

3.2.2.4. Statistical analysis

3.2.2.4.1. Completely Randomized Design (CRD)

Completely Randomized Design was followed for laboratory screening experiment (Panse and Sukhatme, 1985).

ANOVA for Completely Randomised Design

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F
Between genotypes	g-1	SSG	MSG	MSG ÷ MSE
Error	g(r-1)	SSE	MSE	
Total	rg-1			

Where,

r = number of replications

g = number of genotypes

SSG = sum of squares for genotypes

SSE = sum of squares for error

MSG = mean squares for genotypes

MSE = mean squares for error

Critical difference, $CD = t_{\alpha} (2MSE \div r)^{1/2}$

Where,

t_{α} is the table value of Student's t at error degrees of freedom and α is the level of significance (5% or 1%) (Panse and Sukhatme, 1985).

Pooled ANOVA for CRD

Source of variation	Degrees of freedom	Mean squares	F
Genotypes	g-1	MSG	MSG ÷ MSE
Fruit development stages	s-1	MSS	MSS ÷ MSE
Genotypes × stages	(g-1)(s-1)	MS(G×S)	MS(G×S) ÷ MSE
Error	sg(r-1)	MSE	
Total	rsg-1		

Where,

r = number of replications

g = number of genotypes

s = number of stages

MSS = mean sum of squares for stages

MSG = mean sum of squares for genotypes

MS(G×S) = mean sum of squares for genotype x stage interaction

MSE = mean sum of squares for error

Significance tests for combined analysis of variance in CRD was done to find out the potentials of three different fruit development stages and the performance of genotypes for resistance to fruit fly in the laboratory screening.

Critical difference for comparison between three different fruit development stages for fruit fly resistance

$CD = t_{\alpha} (2MSE \div rg)^{1/2}$

Critical difference for comparison between different genotypes for fruit fly resistance

$CD = t_{\alpha} (2MSE \div rs)^{1/2}$

Critical difference for comparison between genotypes x stages interaction for fruit fly resistance

$$CD = t_{\alpha} (2MSE \div r)^{1/2}$$

Where,

t_{α} is the table value of student's t at error degrees of freedom and α is the level of significance (5% or 1%).

RESULTS

4. RESULTS

4.1. Experiment I

The experiment was conducted using 30 genotypes in RBD with 3 replications. Of these 30 genotypes, one genotype (IC-68316) was not germinated and hence the treatment involved only 29 genotypes. The results obtained are presented below.

4.1.1. Mean performance

The mean performance of 29 genotypes for the different characters is given in table – 2.

Mean days to first male flower opening was lowest in IC-45341(28) and it was on par with IC-43261(31). It was highest in Priya (50.67) which was on par with Parathode local (50.33) and Kanakakunnu local (50).

Mean days to first female flower opening was lowest in IC-45341(35.4) and it was on par with IC-43261 (36.8) and highest in Parathode local (59.17). But it was on par with Kanakakunnu local (57.31) and Punnavely local (58.67).

The minimum days to first harvest was recorded by IC-45341(52.73) and maximum mean by Priya (75.93). But Kanakakunnu local (73.98), Punnavely local (72.8), Adimaly local (73.7) and IC- 50516 (73.18) were on par with Priya.

Maximum fruit bearing period was recorded by Kaarikkuzhi local (85.97). The genotypes Kallukuthiavila local (84.77) and Nedinjal local (84.8)

Table - 2. Mean performance of 29 genotypes for 21 characters

Genotype	Days to first male flower opening (days)	Days to first female flower opening (days)	Days to first harvest (days)	Fruit bearing period (days)	Number of fruits per plant	Fruit length (cm)	Fruit girth (cm)	Individual fruit weight (g)	Yield per plant (g)	Duration (days)	Incidence of fruit fly (%)	Protein content (mg.g^{-1})			Water content (%)			Total soluble solids (mg.g^{-1})		
												Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
1	42.43	48.58	64.53	67.16	11.83	13.15	9.94	23.91	254	115.27	72.66	10.52	13.41	17.20	91.07	91.27	91.83	6.23	4.13	3.07
2	43.57	54.34	66.77	57.15	9.63	13.44	9.94	21.61	130	111.50	77.69	9.29	11.51	14.97	90.93	91.10	91.33	6.32	4.23	3.07
3	42.78	50.43	67.30	63.67	15.25	27.79	**22.69**	72.97	972	113.47	88.41	31.72	36.54	42.65	88.93	91.40	91.93	6.50	3.90	3.20
4	46.90	50.27	66.47	73.27	9.50	21.84	19.20	277.43	4068	123.63	83.31	27.65	34.27	46.68	92.13	**94.13**	93.77	6.17	3.90	3.20
5	43.80	50.07	67.80	84.77	16.42	22.87	18.23	197.74	3645	**134.67**	**98.13**	**56.55**	39.12	47.05	91.90	92.03	**95.53**	7.33	6.23	3.07
6	45.60	53.70	70.07	70.13	12.08	29.64	21.95	333.09	4157	123.83	96.07	29.98	42.43	49.22	88.17	91.10	91.40	8.67	6.90	4.13
7	44.36	50.57	67.07	66.77	19.75	6.57	8.83	5.78	125	123.40	39.53	6.44	12.56	26.91	**85.37**	**88.37**	89.80	**8.90**	7.23	**5.23**
8	42.67	50.07	66.73	64.13	11.83	11.34	8.83	22.29	285	114.53	69.73	10.09	10.85	14.39	88.07	88.90	**89.67**	7.50	6.30	3.27
9	42.31	49.23	66.07	64.30	14.90	19.27	18.54	88.30	1062	114.53	73.13	27.15	35.39	45.00	91.13	92.20	92.60	8.00	6.23	3.07
10	50.00	57.31	73.98	65.03	12.48	24.66	20.20	**353.10**	**4942**	123.67	93.60	35.04	36.71	44.05	92.03	92.40	92.77	6.17	4.17	**3.00**
11	42.56	47.91	67.64	67.33	14.42	16.80	14.58	76.82	1133	115.57	63.07	7.21	9.53	12.75	92.17	92.83	92.77	6.40	**3.17**	**3.00**
12	36.45	42.50	62.53	53.13	**56.53**	**5.82**	**6.80**	**4.72**	321	**93.27**	**38.07**	**3.73**	**4.55**	**7.62**	88.07	89.43	90.50	7.92	**6.96**	5.00
13	43.61	50.03	69.87	65.93	14.83	12.24	9.71	22.72	375	115.97	76.20	22.20	25.34	30.30	90.27	90.30	90.47	6.33	4.07	3.13
14	**50.67**	56.98	**75.93**	67.82	19.83	**33.46**	14.28	117.83	2215	125.33	97.67	31.52	40.09	47.96	**92.40**	92.97	93.27	6.17	4.17	3.23
15	49.00	58.67	72.80	73.73	11.25	19.85	17.95	219.21	1833	132.83	85.47	7.15	10.58	20.12	91.53	92.40	92.33	6.17	4.07	**3.00**
16	41.54	45.87	64.87	84.80	14.28	30.02	17.03	257.41	3851	134.27	92.63	32.85	36.02	41.76	87.60	90.17	91.93	6.13	4.07	3.20
17	45.27	51.27	65.93	81.67	13.42	18.57	22.00	115.94	1447	134.37	82.67	40.94	44.84	49.04	89.70	90.17	90.17	6.25	3.67	3.13
18	48.90	54.37	72.63	70.97	16.31	20.42	20.72	292.91	3852	125.33	94.17	44.64	**51.61**	**60.61**	91.07	91.20	91.67	7.73	5.23	3.13
19	**28.00**	**35.40**	**52.73**	69.27	12.65	12.15	10.94	45.78	558	105.33	66.47	19.28	21.78	25.59	90.90	91.23	92.17	6.23	4.23	**3.00**
20	41.00	47.33	64.33	58.10	11.92	10.19	11.37	15.50	172	105.10	59.80	13.18	17.30	21.39	91.47	91.80	92.20	6.13	4.13	3.13
21	48.83	56.07	73.70	68.30	10.88	26.20	21.12	310.44	2962	124.03	95.27	29.16	34.92	46.47	91.50	92.50	94.20	6.37	4.13	3.07
22	47.83	56.07	70.27	**51.80**	9.87	11.21	19.70	62.51	606	105.80	53.50	31.95	37.15	42.27	90.63	91.50	92.53	6.23	4.07	3.17
23	47.50	54.78	73.18	70.70	13.63	24.80	20.11	335.98	4007	126.07	88.03	18.67	21.78	26.83	91.67	92.93	93.20	7.50	6.00	4.83
24	44.60	49.33	68.67	72.03	15.40	15.25	12.07	73.45	1126	122.03	83.73	6.72	8.40	11.65	91.77	92.27	93.70	8.23	4.80	4.00
25	40.72	46.03	63.37	**85.97**	12.01	20.74	18.18	212.72	2070	133.67	85.03	33.54	37.19	43.93	91.30	91.47	92.13	**6.07**	4.23	3.07
26	40.33	45.60	65.20	82.13	17.70	17.90	13.70	92.78	1302	134.27	92.33	28.88	33.96	36.71	90.47	91.23	91.47	**6.07**	4.17	3.13
27	31.00	36.80	56.80	64.47	10.65	15.62	11.28	20.94	245	101.93	76.53	12.44	15.43	18.97	89.90	90.63	90.80	6.37	4.30	**3.00**
28	**42.63**	**49.74**	**66.74**	51.89	**9.47**	**14.61**	10.24	67.23	540	101.37	79.13	15.86	19.86	24.73	91.30	91.93	91.53	6.37	4.17	**3.00**
29	50.33	**59.17**	72.37	66.07	12.63	19.39	19.93	286.08	3474	125.57	85.13	12.88	15.71	24.67	92.00	91.97	92.17	6.50	4.30	3.07
CD (5%)	3.95	3.54	3.16	4.47	1.45	2.07	1.05	14.43	205	2.56	5.67	4.21	4.43	4.20	1.03	0.70	0.70	0.43	0.43	0.25

Bold – Maximum and minimum values.

Table 2. Mean performance continued.....

Genotype	Total sugars (mg.g^{-1})			Reducing sugars (mg.g^{-1})			Non reducing sugars (mg.g^{-1})			Fruit colour (Chlorophyll content) (mg.g^{-1})			Fibre content (mg.g^{-1})			Flesh thickness (mm)			Phenol content (mg.100g^{-1})		
	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III	Stage I	Stage II	Stage III
1	181.00	227.67	295.33	122.33	148.00	194.00	58.67	79.67	103.33	5.29	3.22	1.41	187.33	273.67	386.67	1.80	2.17	2.80	57.77	86.33	117.60
2	132.67	295.33	349.00	85.67	186.33	227.33	47.00	109.00	121.67	4.53	2.76	0.73	233.33	314.67	371.33	1.93	2.23	3.00	68.90	97.63	151.90
3	44.00	85.33	119.33	26.67	52.00	75.67	17.33	33.33	43.67	4.97	3.31	2.16	162.33	208.67	301.33	2.07	3.20	4.00	39.97	83.07	118.80
4	152.00	231.00	323.67	97.67	148.00	212.00	54.33	83.00	111.67	4.12	2.34	1.29	185.00	250.00	335.00	2.00	3.07	4.17	**35.50**	64.97	90.70
5	152.33	288.33	346.33	94.33	186.33	222.00	58.00	102.00	124.33	2.69	1.46	1.14	148.00	217.67	315.00	**2.43**	3.07	4.23	48.27	85.80	98.17
6	67.00	118.67	138.33	42.33	75.33	89.67	24.67	43.33	48.67	3.64	3.06	1.60	174.33	239.67	387.33	2.20	3.23	**4.27**	52.63	75.73	108.03
7	38.67	51.67	84.33	23.33	**30.67**	**27.67**	9.33	21.00	56.67	4.95	3.90	**2.87**	**268.00**	322.33	357.67	1.50	2.20	2.80	**104.13**	**174.77**	**238.23**
8	145.33	175.00	226.33	94.67	111.00	145.67	50.67	64.00	80.67	3.54	2.26	0.72	137.33	180.33	231.00	1.80	2.43	3.17	37.13	84.93	111.83
9	134.33	288.00	375.33	85.00	188.33	245.00	49.33	99.67	130.33	8.09	5.29	2.42	163.00	232.33	275.67	2.00	3.00	3.50	58.90	83.93	111.87
10	160.00	241.00	282.00	102.33	159.00	186.33	57.67	82.00	35.67	3.73	314	0.84	125.33	186.33	251.00	2.27	**3.40**	3.70	46.27	74.10	101.37
11	**361.67**	**443.67**	**528.67**	**225.67**	**288.00**	**342.33**	**136.00**	**155.67**	**186.33**	4.51	2.53	0.93	174.00	242.00	319.00	2.00	2.80	3.00	62.63	117.83	152.97
12	**23.67**	**54.67**	**73.33**	**16.67**	37.00	50.67	7.00	17.67	22.67	4.61	3.66	1.62	225.00	273.67	339.00	**1.47**	2.40	**2.43**	84.70	156.30	224.10
13	169.67	246.33	288.33	113.33	158.67	188.33	56.33	87.67	100.00	5.93	4.10	1.50	135.00	205.33	300.67	1.73	2.43	3.00	79.50	96.07	106.70
14	150.00	219.00	270.00	100.33	141.67	175.00	49.67	77.33	95.00	6.74	3.47	2.09	175.00	229.33	342.33	1.57	2.57	3.60	54.83	83.37	109.23
15	187.67	227.67	311.33	122.67	149.67	206.00	65.00	78.00	105.33	3.69	2.58	0.77	183.33	265.00	340.67	2.03	3.00	4.17	47.30	61.50	71.27
16	145.67	255.33	354.67	92.67	167.33	235.00	53.00	88.00	119.67	3.16	1.71	0.92	237.00	285.00	385.33	2.00	3.20	**4.27**	57.33	85.37	105.67
17	153.33	182.67	239.67	98.33	115.00	156.67	55.00	67.67	83.00	4.28	1.63	0.52	135.00	192.33	241.67	2.40	3.20	3.87	63.60	94.90	119.90
18	132.33	194.33	289.67	85.33	126.33	190.67	47.00	68.00	99.00	**8.39**	**6.18**	1.06	210.67	208.33	**188.67**	2.13	3.00	4.00	47.83	78.07	108.57
19	149.67	216.33	248.00	99.33	140.33	161.67	50.33	76.00	86.33	4.34	2.86	1.56	160.33	253.33	296.67	1.60	2.27	3.17	78.43	124.00	150.80
20	187.00	242.00	285.33	121.00	152.67	18467	66.00	89.33	100.67	4.34	2.55	0.90	205.00	278.67	353.00	1.80	2.40	3.40	72.97	108.17	148.23
21	54.67	121.33	147.00	32.33	79.67	97.67	22.33	41.67	49.33	**2.57**	**0.78**	**0.27**	**118.00**	**174.67**	217.33	2.17	3.20	**4.27**	43.60	66.97	93.60
22	174.67	217.00	284.67	111.67	138.67	187.33	63.00	78.33	97.33	4.54	2.40	1.02	177.00	227.00	360.67	1.93	3.00	4.20	75.20	94.73	125.47
23	138.67	195.33	227.33	98.33	130.67	149.00	40.33	64.67	78.33	5.32	2.40	2.63	125.33	208.00	306.00	2.10	3.27	**4.27**	71.50	89.37	111.17
24	107.00	170.00	246.00	69.67	112.00	161.00	37.33	58.00	85.00	3.70	2.71	1.21	185.67	211.33	216.67	2.00	3.07	4.00	85.70	148.23	182.13
25	131.67	192.33	255.33	84.00	126.33	168.00	47.67	66.00	87.33	3.21	1.15	0.58	234.33	365.00	483.00	2.00	3.00	4.13	53.30	83.93	118.83
26	129.00	202.00	260.00	83.67	137.00	170.33	45.33	65.00	89.67	3.86	1.36	0.44	143.00	198.33	333.67	2.00	3.00	4.00	**38.33**	**59.23**	**67.10**
27	175.67	222.00	294.33	113.67	145.00	192.33	62.00	77.00	102.00	7.86	5.47	2.19	194.33	271.67	353.67	1.60	2.43	3.43	53.17	84.13	124.97
28	77.67	108.33	137.33	51.33	72.00	90.33	26.33	36.33	47.00	4.17	1.45	0.60	230.33	300.33	409.00	1.80	**2.13**	3.00	72.87	93.63	119.53
29	131.67	148.00	163.00	123.00	131.00	144.00	8.67	**17.00**	19.00	5.43	1.86	0.88	225.33	**456.00**	**603.00**	2.17	3.20	4.20	71.63	96.23	124.70
CD(5%)	15.89	13.66	20.75	12.32	9.72	14.56	10.07	8.36	10.12	1.23	0.41	0.64	15.77	13.02	20.4	0.12	0.10	0.11	6.49	5.72	10.85

Bold – Maximum and minimum values.

were on par with Kaarikkuzhi local. The minimum mean fruit bearing period was recorded by IC-50516 (51.8) and was on par with IC-68306 (51.89).

Average number of fruits per plant was maximum in Madhurai local (56.53) and minimum in IC-68306 (9.47).

Mean fruit length ranged between 5.82 and 33.46 cm in Madhurai local and Priya respectively.

Average fruit girth was minimum in Madhurai local (6.8 cm) and maximum in Bharanikkavu local (22.69 cm). But Bharanikkavu local was on par with Pappanchani local (22 cm) and Priyanka (21.95 cm).

Maximum individual fruit weight was recorded in Kanakakunnu local (353.1g) and minimum in Madhurai local (4.72g).

Average yield per plant ranged from 125 g to 4942.92 g. Genotypes Changanassery local -1 and Kanakakunnu local were the extremes respectively.

Maximum duration of crop was shown by Kallukuthiavila local (134.67 days). This was on par with Nedinjal local (134.27 days), Kaarikkuzhi local (133.67), Pappanchani local (134.37 days) and Punnavely local (132.83 days). Minimum duration was recorded by Madhurai local (93.27 days).

Incidence to fruit fly was highest in Kallukuthiavila local (98.13%) and was on par with Priya (97.67%), Priyanka (96.07%), Adimaly local (95.27%), Changanassery local- 2 (94.17%) and Kanakakunnu local (93.60%). Lowest

infestation was recorded in Madhurai local (38.07%) and it was on par with Changanassery local- 1 (39.53%).

Among all the genotypes, protein content showed an increasing trend from 7 days old fruits to 21 days old fruits. In 7 days old fruits, Kallukuthiavila local (56.55 $mg.g^{-1}$) showed maximum protein content and it was on par with Changanassery local-2 (44.64 $mg.g^{-1}$) and minimum in Madhurai local (3.73 $mg.g^{-1}$). In both 14 days old fruits and 21 days old fruits, Madhurai local showed minimum (4.55 mgg^{-1}, 7.62 mgg^{-1}) and Changanassery local-2 showed maximum (51.61 $mg.g^{-1}$, 60.61 $mg.g^{-1}$) protein content respectively.

Mean water content showed a slight increase with the increase in stage of fruit development from 7-21 days. It was maximum in Priya (92.4%), Preethi (92.97%) and Kallukuthiavila local (95.53%) in 7, 14, and 21 days old fruits respectively and minimum in Madhurai local (85.36% and 88.37%) in 7 and 14 days old fruits and in IC-68272 (89.67 %) in 21 days old fruits.

Mean total soluble solids showed a decrease in trend with increase in fruit maturity. Maximum total soluble solids was recorded in Changanassery local-1 (8.9, 7.23 and 5.23 Brix) in all the three stages and minimum in Kaarikkuzhi local (6.07 Brix) and CL-Coimbatore (6.07 Brix) in 7 days old fruits, IC-68296 (3.17 Brix) in 14 days old fruits and in Kanakakunnu local (3.0 Brix), IC-68296 (3.0 Brix), Punnavely local (3.0 Brix), IC-45341 (3.0 Brix), IC- 43261 (3.0 Brix) and IC-68306 (3.0 Brix) in 21 days old fruits.

Total sugars in 7 days old fruits, ranged from 23.67mgg^{-1} in Madhurai local to 361.67 in IC-68236. In 14 days old fruits the range was 51.67$mg.g^{-1}$ in Changanassery local-1 to 443.67$mg.g^{-1}$ in IC-68296. IC-68296 recorded highest total sugar (528.67$mg.g^{-1}$) and Madhurai local recorded lowest sugar

content (73.33mg.g^{-1}) in 21 days old fruits. Total sugars showed an increasing trend with the increase in maturity of fruits.

Mean reducing sugars showed an increasing trend in bitter gourd fruits according to increase in maturity. In 7 days old fruits it ranged from 16.67mg.g^{-1} in Madhurai local to 225.67 mg.g^{-1} in IC-68296 and in 14 days old fruits it was from 30.67 to 288 mg.g^{-1} in Changanassery local -1 and IC-68296 respectively where as in 21 days old fruits range was from 27.66 mg.g^{-1} in Changanassery local-1 to 342.33 mg.g^{-1} in IC-68296 respectively. In all the three stages, IC-68296 exhibited maximum reducing sugars.

Non reducing sugars showed an increasing trend with maturity of fruits. For immature (3-7days) fruits Madhurai local (7.00 mg.g^{-1}) showed lowest value and IC-68296 (136.00 mg.g^{-1}) showed maximum value. In half mature fruits IC-68296 (155.67 mg.g^{-1}) recorded maximum value and Parathode local recorded minimum value (17.00 mg.g^{-1}). In the case of fully mature fruits Parathode local recorded minimum value (19.00 mg.g^{-1}) and IC-68296 recorded maximum value (186.33 mg.g^{-1}).

Total chlorophyll content showed a decreasing status with increase in maturity of fruits. The lowest content was in Adimaly local (2.57 mg.g^{-1}) and highest in Changanassery local-2 (8.39 mg.g^{-1}) in 7 days old fruits. In half mature fruits the chlorophyll content varied from 0.78 mg.g^{-1} in Adimaly local to 6.18 mg.g^{-1} in Changanassery local-2. In 21 days old fruits it ranged from 0.27 mg.g^{-1} in Adimaly local to 2.87 mg.g^{-1} in Changanassery local-1.

The fiber content showed an increasing trend with fruit maturity. In mature fruits the fiber content varied from 188.69 mg.g^{-1} in Changanassery local-2 to 603 mg.g^{-1} in Parathode local. The half mature fruits showed lower value than mature fruits and ranged from 174.67 mg.g^{-1} in Adimaly local to

456 $mg.g^{-1}$ in Parathode local. In immature fruits a slightly lower value was obtained ranging from 118 $mg.g^{-1}$ (Adimaly local) to 268 $mg.g^{-1}$ (Changanassery local-1).

Average thickness of the flesh also showed an increasing value with maturity. In 7 days old fruits Madhurai local (1.47 mm) showed minimum value and Kallukuthiavila local (2.43 mm) showed maximum thickness. The half mature fruits showed a range of 3.4 mm (Kanakakunnu local) to 2.13mm (IC-68306) in flesh thickness. But in fully mature fruits, thickness ranged from 2.43 mm (Madhurai local) to 4.27 mm (Priyanka, Nedinjal local, Adimaly local and Eratayar local).

Phenol content of fruits showed an increasing trend from immature to mature fruits. In the order of merit, Phenol content was from 35.5 $mg.100g^{-1}$ (Preethi) to 104.13 $mg.100g^{-1}$ (Changanassery local - 1) in 7 days old fruits, 59.25 $mg.100g^{-1}$ (CL - Coimbatore) to 174.77 $mg.100g^{-1}$ (Changanassery local - 1) in 14 days old fruits and 67.1 $mg.100g^{-1}$ (CL -Coimbatore) to 238.23 $mg.100g^{-1}$ (Changanassery local - 1) in 21 days old fruits.

4.1.2. Analysis of variance (ANOVA)

ANOVA was done in RBD for different biometric and biochemical characters and the results obtained were as follows.

4.1.2.1. Biometric characters

The ANOVA revealed highly significant differences among the genotypes for all the biometric and biochemical characters studied (Table - 3) except epicuticular wax content (which was present in undetectable levels and hence not included for further calculations) and hence proceeded to estimate

Table – 3. Analysis of variance of 21 characters

Sl. No.	Character		MSG	MSE	F
1.	Days to first male flower opening (days)		81.75	5.76	14.20**
2.	Days to first female flower opening (days)		98.52	4.63	21.30**
3.	Days to first harvest (days)		74.56	3.69	20.19**
4.	Fruit bearing period (days)		257.82	7.35	35.07**
5.	Number of fruits per plant		214.98	0.78	275.83**
6.	Fruit length (cm)		149.28	1.59	93.95**
7.	Fruit girth (cm)		73.00	0.41	180.10**
8.	Individual fruit weight (g)		43132.08	76.63	562.90**
9.	Yield per plant (kg. plant^{-1})		4682.44	15.56	300.82**
10.	Duration (days)		388.38	2.42	160.37**
11.	Incidence of fruit fly (%)		777.44	11.83	65.73**
12.	Protein content (mg.g^{-1})	Stage I	532.55	6.67	79.81**
		„ II	530.35	7.37	71.90**
		„ III	634.63	6.49	97.75**
13	Water content (%)	Stage I	8.54	0.40	21.12**
		„ II	4.77	0.18	25.91**
		„ III	5.29	0.18	29.10**
14.	Total soluble solids (Brix)	Stage I	2.25	0.07	31.99**
		„ II	3.74	0.07	52.53**
		„ III	1.19	0.02	51.42**
15.	Total sugars (mg.g^{-1})	Stage I	11851.51	94.70	125.15**
		„ II	19130.88	70.02	273.22**
		„ III	28138.80	158.33	177.72**
16.	Reducing sugars (mg.g^{-1})	Stage I	4869.03	56.97	85.46**
		„ II	7949.34	35.50	223.93**
		„ III	12280.46	78.03	157.37**
17.	Non reducing sugars (mg.g^{-1})	Stage I	1797.80	38.03	47.28**
		„ II	2641.22	26.25	100.61**
		„ III	3605.49	37.69	95.65**
18.	Fruit colour (mg.g^{-1}) (chlorophyll content)	Stage I	6.70	0.57	11.81**
		„ II	4.97	0.07	76.43**
		„ III	1.42	0.15	9.23**
19.	Fibre content (mg.g^{-1})	Stage I	4759.44	93.34	50.99**
		„ II	11059.90	63.65	173.76**
		„ III	20851.88	152.99	136.30**
20.	Flesh thickness (mm)	Stage I	0.19	0.01	33.12**
		„ II	0.49	0.00	130.61**
		„ III	0.96	0.00	208.58**
21.	Phenol content (mg.100g^{-1})	Stage I	850.11	15.83	53.70**
		„ II	2217.62	12.29	180.37**
		„ III	4330.28	43.33	99.94**

** Significant at 1% level

genetic components of variance, correlation, path coefficient analysis, D^2 statistics and selection index and the results obtained are presented below.

4.1.2.2. Genetic parameters

The phenotypic, genotypic and environmental variances for the various characters were calculated. Estimation of variances showed that for most of the characters studied, genotypic variance contributed major part of the phenotypic variance.

4.1.2.2.1. Coefficients of variation

The phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were worked out. The PCV, GCV and ECV of the various characters estimated are given in table – 4 and fig. 1.

a) Phenotypic coefficient of variation (PCV)

The PCV was highest for yield per plant (87.82) followed by individual fruit weight (86.5). Moreover PCV was high for total chlorophyll content (59.72), number of fruits per plant (55.82), protein content (45.25), non-reducing sugars (39.56), fruit length (38.58), reducing sugars (38.29), total sugars (37.94), fruit girth (31.96), phenol content (30.74), fiber content (25.36) and incidence of fruit fly (20.72) indicating a high degree of variation. Other characters showed low PCV values. The lowest PCV was obtained for water content (1.49).

Table – 4. Genetic parameters for 21 characters in 29 bitter gourd genotypes

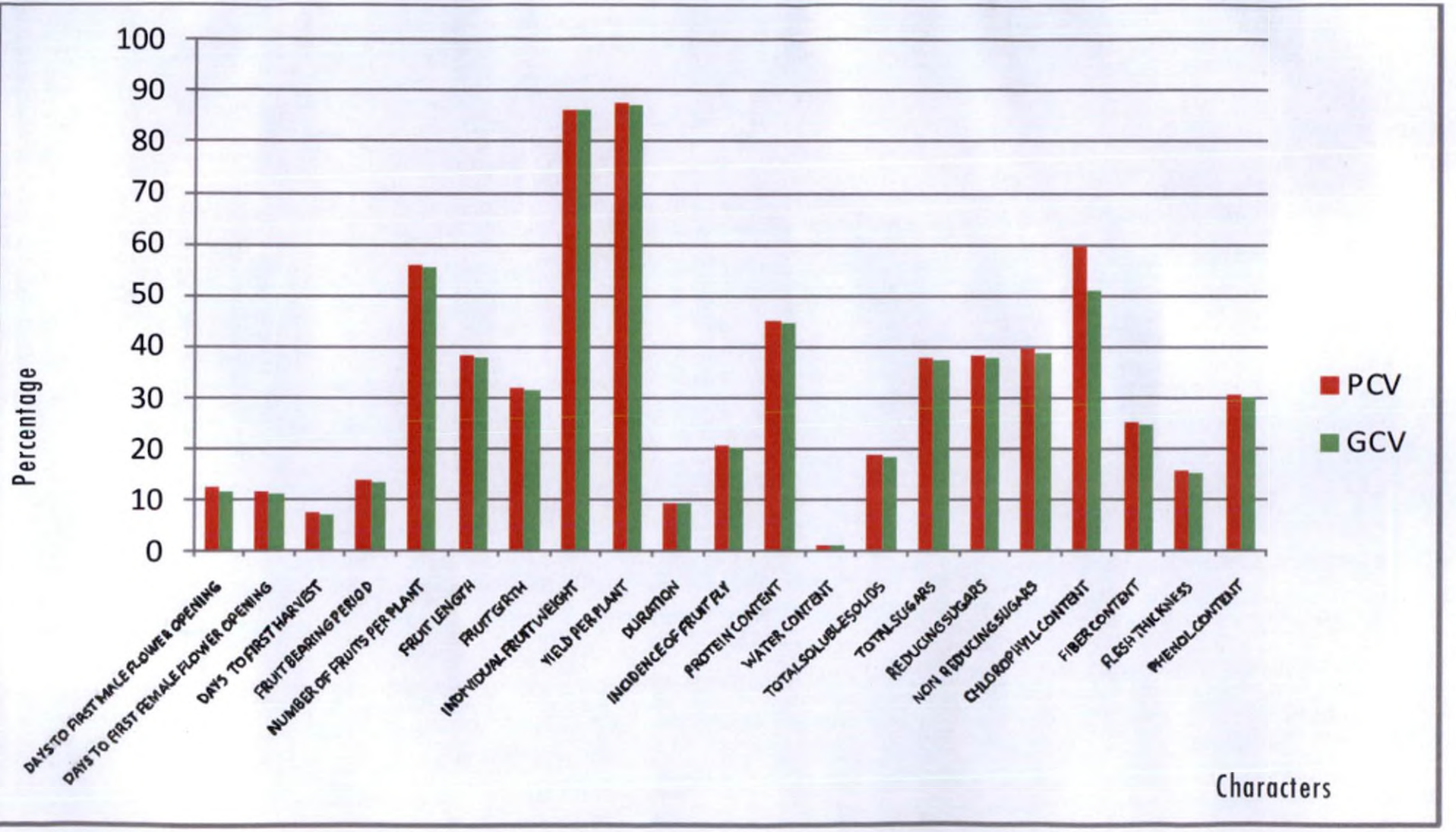
Sl.No.	Character	PCV (%)	GCV (%)	ECV (%)	Heritability (in broad sense)(%)	Genetic advance (% of mean)
1.	Days to first male flower opening (days)	12.78	11.54	1.24	82.00	21.45
2.	Days to first female flower opening (days)	11.92	11.12	0.80	87.00	21.39
3.	Day to first harvest (days)	7.75	7.20	0.55	87.00	13.80
4.	Fruit bearing period (days)	13.94	13.36	0.58	91.00	26.40
5.	Number of fruits per plant	55.82	55.52	0.30	98.92	113.75
6.	Fruit length (cm)	38.58	37.98	0.60	96.87	77.00
7.	Fruit girth (cm)	31.96	31.70	0.26	98.35	64.76
8..	Individual fruit weight (g)	86.50	86.27	0.23	99.47	177.24
9.	Yield per plant ($g.plant^{-1}$)	87.82	87.38	0.43	99.01	179.11
10.	Duration (days)	9.59	9.51	0.08	98.15	19.40
11.	Incidence of fruit fly (%)	20.72	20.26	0.46	95.57	40.79
12.	Protein content ($mg.g^{-1}$)	45.25	44.56	0.68	96.99	90.41
13.	Water content ($mg.g^{-1}$)	1.49	1.42	0.07	90.35	2.78
14.	Total soluble solids ($mg.g^{-1}$)	19.11	18.57	0.54	94.38	37.16
15.	Total sugars ($mg.g^{-1}$)	37.94	37.62	0.31	98.33	76.85
16.	Reducing sugars ($mg.g^{-1}$)	38.29	37.93	0.36	98.12	77.39
17.	Non-reducing sugars ($mg.g^{-1}$)	39.56	38.95	0.61	96.93	78.99
18.	Fruit colour (chlorophyll) ($mg.g^{-1}$)	59.72	51.12	8.59	73.28	90.15
19.	Fibre content ($mg.g^{-1}$)	25.36	25.09	0.27	97.83	51.12
20.	Flesh thickness (mm)	15.57	15.46	0.11	98.58	31.62
21.	Phenol content ($mg.100g^{-1}$)	30.74	30.29	0.45	97.06	61.47

PCV – Phenotypic coefficient of variation

GCV – Genotypic coefficient of variation

ECV – Environmental coefficient of variation

Fig. 1 : Phenotypic and Genotypic coefficients of variation



b) Genotypic coefficient of variation (GCV)

The highest GCV value was obtained for yield per plant (87.38) followed by individual fruit weight (86.27). High GCV was shown by the following characters number of fruits per plant (55.52), total chlorophyll content (51.12), protein content (44.56), non-reducing sugars (38.95), fruit length (37.98), reducing sugars (37.93), total sugars (37.62), fruit girth (31.70), phenol content (30.29), fiber content (25.09) and incidence of fruit fly (20.26).

c) Environmental coefficient of variation (ECV)

ECV was low in all the characters studied as compared to GCV and PCV. Of the characters, ECV was highest for total chlorophyll content (8.59) and lowest for water content (0.07).

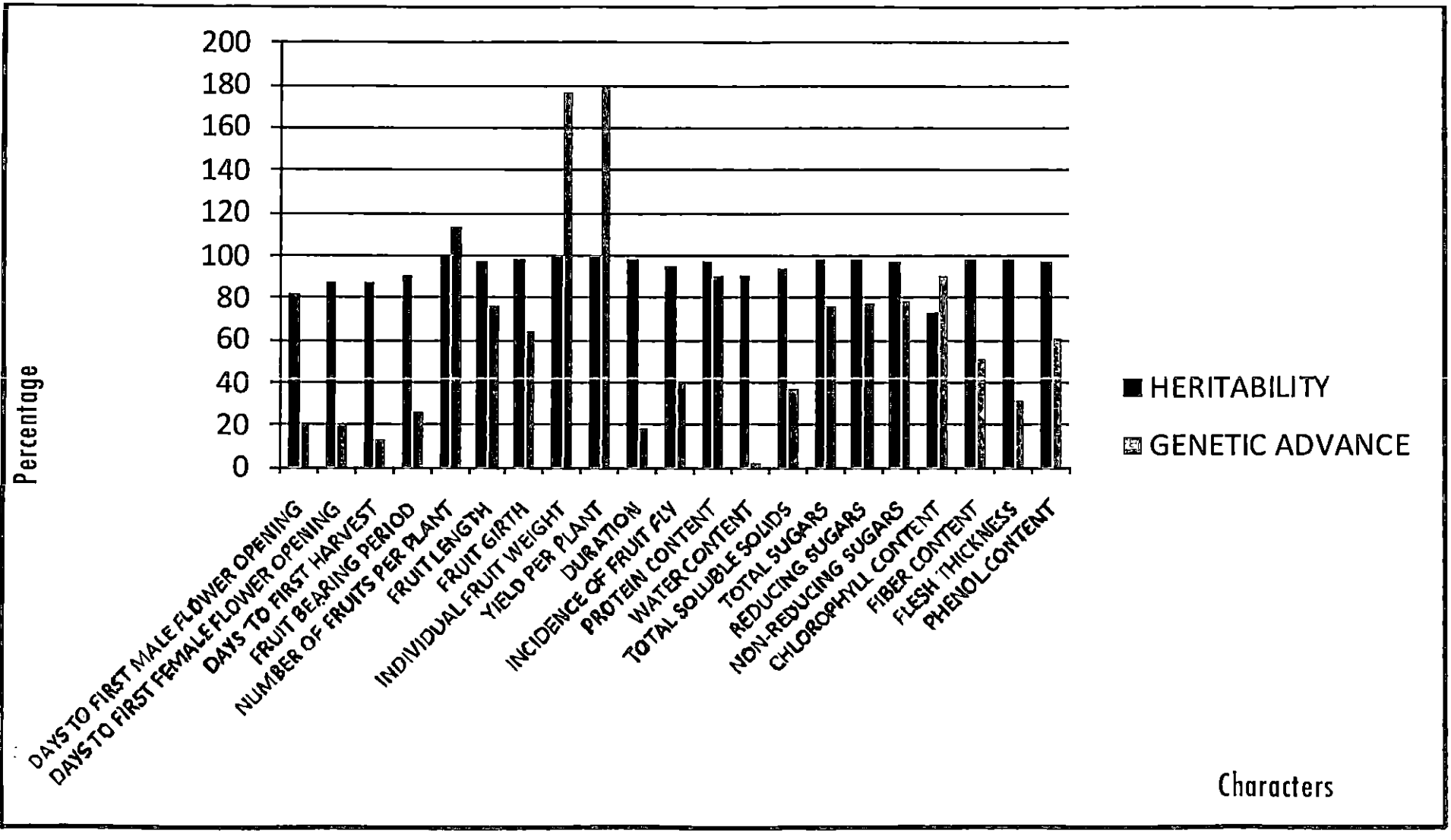
4.1.2.2.2. Heritability (in broad sense)

The heritability values recorded for various characters are presented in table-4 and fig. 2. All the characters exhibited high heritability values. Heritability was maximum for individual fruit weight (0.99) followed by yield per plant (0.99). Minimum heritability was observed for total chlorophyll content (0.73).

4.1.2.2.3. Genetic advance (as percentage of mean)

The estimated genetic advances as percentage of mean for various characters are given in table – 4 and fig.2. All the characters except water content, fruit bearing period and duration exhibited high genetic advance percent. The genetic advance percent for water content alone was low, but for

Fig. 2 : Heritability and Genetic advance



the trait fruit bearing period and duration it was moderate. The highest genetic advance was observed for yield per plant (179.11%) and it was closely followed by individual fruit weight (177.24%) and number of fruits per plant (113.75%).

4.1.2.3. Correlation coefficient

The results pertaining to the estimate of phenotypic, genotypic and environmental correlations of various characters are presented in table – 5, 7, 9.

4.1.2.3.1. Phenotypic correlation

Phenotypic correlation studies revealed that yield per plant had significant positive correlation with days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content and flesh thickness. Yield per plant had significant negative correlation with phenol content and fruit colour only.

The significant phenotypic correlations of each character with others are represented in table- 6, fig. 3 and fig.4.

4.1.2.3.2. Genotypic correlation

Genotypic correlation studies revealed that yield per plant had significant positive correlation with days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content and flesh thickness. Yield per plant had significant negative correlation with fruit colour and phenol content only.

Table – 5. Phenotypic correlation coefficients among twenty one characters

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
X_1	1																				
X_2	0.9487**	1																			
X_3	0.9151**	0.8923**	1																		
X_4	-0.0026	-0.1100*	-0.0407	1																	
X_5	-0.1766*	-0.2314*	-0.1178*	-0.1544*	1																
X_6	0.4038**	0.3588**	0.4405**	0.4547**	-0.2456*	1															
X_7	0.4971**	0.4821**	0.4457**	0.3718**	-0.3026*	0.7063**	1														
X_8	0.5260**	0.4872**	0.5154**	0.4192**	-0.1842*	0.7119**	0.7621**	1													
X_9	0.4987**	0.4282**	0.4858**	0.4596**	-0.0926	0.7345**	0.7142**	0.9578**	1												
X_{10}	0.4638**	0.3894**	0.4086**	0.8463**	-0.2705*	0.5786**	0.5492**	0.6084**	0.6144**	1											
X_{11}	0.3736**	0.3439**	0.3984**	0.5302**	-0.4179**	-0.8250**	0.5943**	0.6659**	0.6707**	0.6364**	1										
X_{12}	0.3700**	0.2964*	0.3188*	0.4058**	-0.1908*	0.6379**	0.7306**	0.5690**	0.6053**	0.5124**	0.5528**	1									
X_{13}	0.2933*	0.2350*	0.2968*	0.2371*	-0.1529*	0.4722*	0.4275**	0.4586**	0.5008**	0.2824*	0.4476**	0.2764*	1								
X_{14}	0.0184	-0.0074	0.0701	-0.1372*	0.5561**	-0.2124*	-0.2068*	-0.0308	-0.0165	-0.0194	-0.4072**	-0.2316*	-0.2162*	1							
X_{15}	-0.0166	-0.0607	-0.0418	0.2481*	-0.3281*	0.0977	0.0513	-0.0078	0.0632	0.1731*	0.1458*	0.0059	0.3156*	-0.5292**	1						
X_{16}	0.0090	-0.0287	-0.0191	0.2428*	-0.3334**	0.1240*	0.0910	0.0429	0.1066	0.1776*	0.1877*	0.0010	0.3323**	-0.5749**	0.9890**	1					
X_{17}	-0.0626	-0.1160*	-0.0812	0.2435*	-0.2993*	0.0437	-0.0248	-0.1005	-0.0201	0.1547*	0.0603	0.0146	0.2667*	-0.4149**	0.9624**	0.9118**	1				
X_{18}	-0.1286*	-0.1486*	-0.0754	-0.1567*	0.2044*	0.0071	-0.1006	-0.1571*	-0.0940	-0.2055*	-0.2346*	-0.0289	-0.0901	0.5049**	-0.1482*	-0.1938*	-0.0557	1			
X_{19}	-0.0171	0.0310	-0.0910	-0.0417	-0.0495	-0.0227	-0.0570	0.0340	-0.0003	-0.0095	-0.0853	-0.1743*	-0.0681	-0.0267	-0.1281*	-0.0629	-0.2406*	0.0291	1		
X_{20}	0.4242**	0.3801**	0.3852**	0.5324**	-0.3634**	0.6852**	0.8294**	0.7406**	0.7016**	0.6563**	0.6794**	0.6126**	0.5144**	-0.1912*	0.0520	0.0978	-0.0352	-0.1850*	0.0235	1	
X_{21}	-0.3039*	-0.2932*	-0.3000*	-0.3945**	0.4959**	-0.6006**	-0.5331**	-0.5104**	-0.4709**	-0.4790**	-0.7547**	-0.5006**	-0.3171**	0.6292**	-0.3113*	-0.3544**	-0.2142*	0.3450**	0.0501	-0.6022**	1

X_1 – Days to first male flower opening

X_2 – Days to first female flower opening

X_3 – Days to first harvest

X_4 – Fruit bearing period

X_5 – Number of fruits per plant

X_6 – Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} – Duration

X_{11} – Incidence of fruit fly

X_{12} – Protein content

X_{13} – Water content

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{17} – Non reducing sugars

X_{18} – Fruit colour (Chlorophyll content)

X_{19} – Fibre content

X_{20} – Flesh thickness

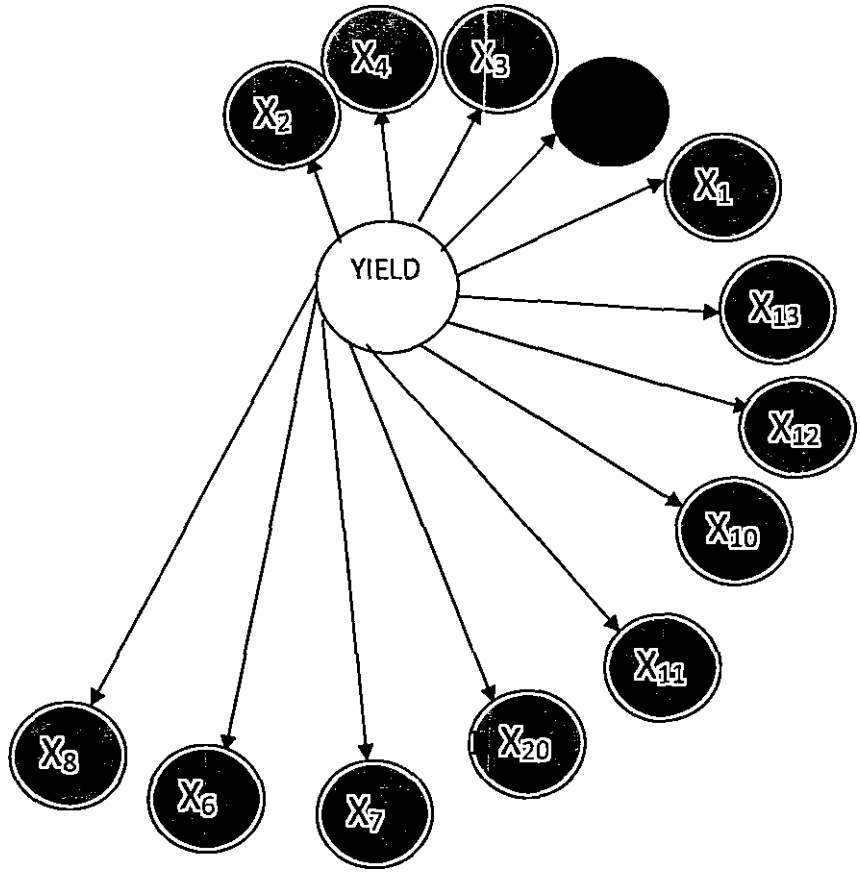
X_{21} – Phenol content

* Significant at 5 per cent level

** Significant at 1 per cent level

Fig. 3. Phenotypic correlation of yield with other characters

Correlation increases with distance



X_1 - Days to first male flower opening

X_2 - Days to first female flower opening

X_3 - Days to first harvest

X_4 -Fruit bearing period

X_5 – Number of fruits per plant

X_6- Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} - Duration

X_{12} – Protein content

X_{13} – Water content

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{18} – Fruit colour (chlorophyll content)

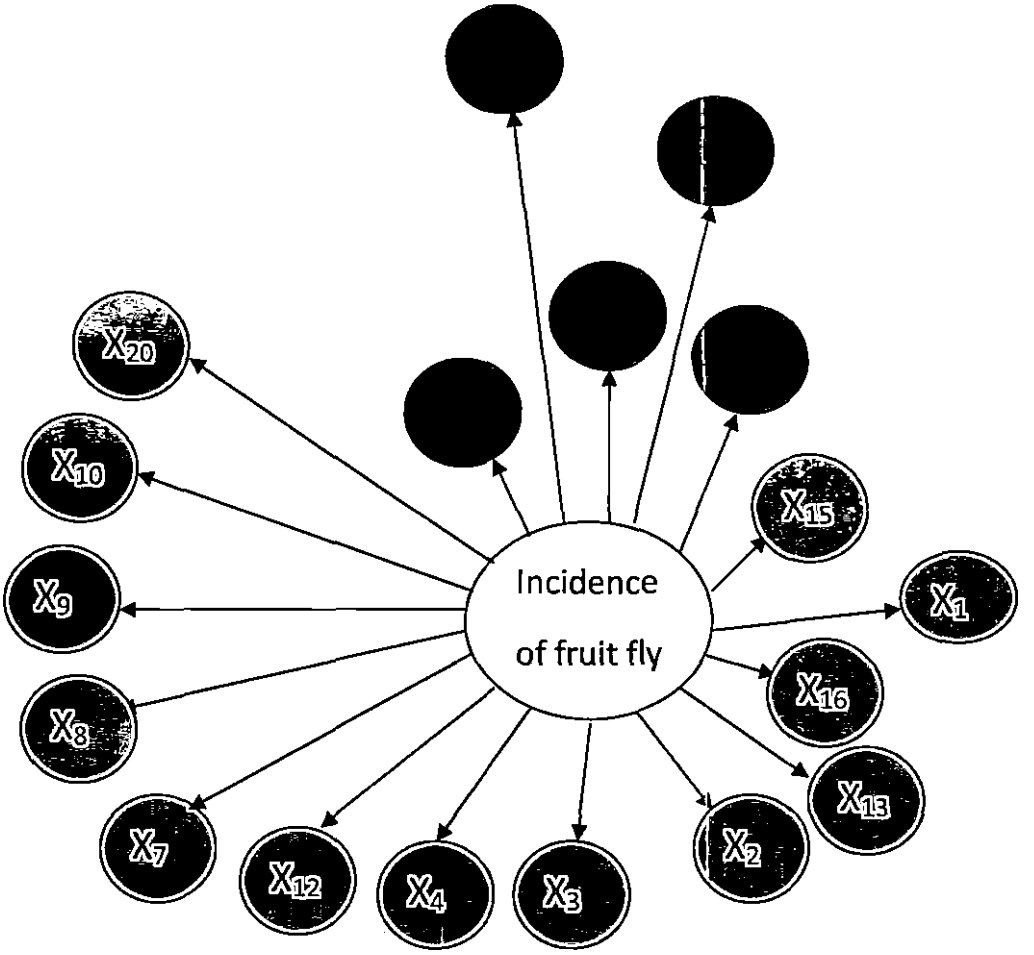
X_{20} – Flesh thickness

X_{21} – Phenol content

→ Significant positive correlation

→ Significant negative correlation

Fig. 4. Phenotypic corrlelation of incidence of fruit fly with other characters



X_1 - Days to first male flower opening

X_2 - Days to first female flower opening

X_3 - Days to first harvest,

X_4 - Fruit bearing period

X_5 – Number of fruits per plant

X_6- Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} - Duration

X_{12} – Protein content

X_{13} – Water content

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{18} – Fruit colour

X_{20} – Flesh thickness

X_{21} – Phenol content

Correlation increases as distance increases

Significant positive correlation

Significant negative correlation

Table -6. Phenotypic correlation of different characters with each other

Sl. No	Character	Significant positive correlation	Significant negative correlation
1	Days to first male flower opening	Days to first female flower opening, days to first harvest, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Number of fruits per plant, fruit colour (chlorophyll content), phenol content
2	Days to first female flower opening	Days to first male flower opening, days to first harvest, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Fruit bearing period, number of fruits per plant, non-reducing sugars, fruit colour(chlorophyll content), phenol content
3	Days to first harvest	Days to first male flower opening ,days to first female flower opening, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Number of fruits per plant, phenol content
4	Fruit bearing period	Fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, total sugars, reducing sugars, non reducing sugars, flesh thickness	Days to first female flower opening, number of fruits per plant, phenol content, TSS, fruit colour (chlorophyll content)
5	Number of fruits per plant	TSS, fruit colour (chlorophyll content), phenol content	Days to first male flower opening , days to first female flower opening, days to first harvest, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content, flesh thickness, total sugars, non reducing sugars
6	Fruit length	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness, reducing sugars	TSS, phenol content
7	Fruit girth	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period,	TSS, phenol content, number of fruits per plant

Table -6. Continued.....

		fruit length, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness,	
8	Individual fruit weight	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness,	Phenol content, fruit colour (chlorophyll content), number of fruits per plant
9	Yield per plant	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content, flesh thickness,	Phenol content
10	Duration	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, incidence of fruit fly, protein content, water content, total sugars, reducing sugars, non reducing sugars, flesh thickness,	Phenol content, fruit colour (chlorophyll content), number of fruits per plant
11	Incidence of fruit fly	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, protein content, water content, total sugars, reducing sugars, flesh thickness,	Phenol content, fruit colour (chlorophyll content), number of fruits per plant, TSS
12	Protein content	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, water content, flesh thickness	Phenol content, crude fiber content, number of fruits per plant, TSS
13	Water content	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period,	Phenol content, number of fruits per plant, TSS

Table -6. Continued.....

		fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, flesh thickness, total sugars, reducing sugars, non reducing sugars	
14	TSS	Number of fruits per plant, fruit colour (chlorophyll content), phenol content	Fruit bearing period, fruit girth, incidence of fruit fly, protein content, water content, total sugars, reducing sugars, non reducing sugars, flesh thickness,
15	Total sugars	Fruit bearing period, duration, incidence of fruit fly, water content, reducing sugars, non reducing sugars	Number of fruits per plant, TSS, fruit colour (chlorophyll content), fiber content, phenol content
16	Reducing sugars	Fruit bearing period, fruit length, duration, incidence of fruit fly, water content, total sugars, non reducing sugars	Phenol content, fruit colour(chlorophyll content), TSS, number of fruits per plant
17	Non reducing sugars	Fruit bearing period, duration, water content, total sugars, reducing sugars	Phenol content, fiber content, TSS, number of fruits per plant
18	Fruit colour (chlorophyll content)	Number of fruits per plant, TSS, phenol content	Days to first male flower opening, days to first female flower opening, fruit bearing period, individual fruit weight, duration, incidence of fruit fly, total sugars, reducing sugars, fiber content , flesh thickness
19	Fiber content		Protein content, total sugars, non reducing sugars
20	Flesh thickness	Days to first male flower opening, days to first female flower opening, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content	Number of fruits per plant, TSS, phenol content, fruit colour(chlorophyll content).
21	Phenol content	Number of fruits per plant, TSS, fruit colour (chlorophyll content)	Days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, total sugars, non reducing sugars, reducing sugars, flesh thickness

The significant genotypic correlations of each character with others are represented in table – 8, fig. 5 and fig. 6.

4.1.2.3.3. Environmental correlation

Environmental correlation studies revealed that yield per plant had significant positive correlation with number of fruits per plant, individual fruit weight, protein content, water content, and fruit colour. Yield per plant had significant negative correlation with fruit girth and incidence of fruit fly.

The significant environmental correlations of each character with others are represented in table – 10, fig. 7 and fig. 8

4.1.2.3.4. Correlation between percentage of fruit infestation due to incidence of fruit fly and biochemical characters of fruits at fruit setting and half- maturing stages in bitter gourd.

Simple correlation was estimated between percentage of fruit infestation and biochemical characters of immature and half maturing stages of fruits in bitter gourd. (Table - 11)

The percentage of fruit infestation (incidence of fruit fly) was significant and positively correlated with protein content, flesh thickness and water content in both immature and half maturing fruits. But it was highly significant and negatively correlated with phenol content. It was also significant and negatively correlated with fiber content of immature fruits.

4.1.2.4. Path coefficient analysis

Yield per plant was taken as the dependent variable for path analysis. The component characters selected for analysis were

X_1 - Days to first male flower opening

X_2 - Days to first female flower opening

X_3 - Days to first harvest

X_4 - Fruit bearing period

X_5 - Fruit length

X_6 - Fruit girth

X_7 - Individual fruit weight

X_8 - Duration

X_9 -Incidence of fruit fly

X_{10}- Protein content

X_{11}- Water content

X_{12} - Flesh thickness

X_{13} - Phenol content

Y - Yield per plant

The direct and indirect effects of these characters on yield per plant were presented in table – 12 and fig. 9

Days to first male flower opening (1.6386), individual fruit weight (0.9081) and duration (0.7039) showed high and positive direct effect on yield.

Indirect effect of individual fruit weight (0.9586) through days to first male flower opening was high and positive.

The maximum positive and significant genotypic correlation coefficient (0.9615) was exhibited between individual fruit weight and yield per plant.

The indirect effects of individual fruit weight through days to first male flower opening had very high and positive effect (0.9586) and indirect

Table – 7. Genotypic correlation coefficients among twenty one characters

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
X_1	1																				
X_2	0.9728**	1																			
X_3	0.9803**	0.9620**	1																		
X_4	0.0732	-0.0610	-0.0046	1																	
X_5	-0.1949*	-0.2511*	-0.1267*	-0.1654*	1																
X_6	0.4614**	0.3988**	0.4882**	0.4814**	-0.2520*	1															
X_7	0.5587**	0.5187**	0.4847**	0.3871**	-0.3056*	0.7254**	1														
X_8	0.5850**	0.5239**	0.5556**	0.4390**	-0.1846*	0.7247**	0.7722**	1													
X_9	0.5571**	0.4629**	0.5269**	0.4793**	-0.0949	0.7517**	0.7265**	0.9615**	1												
X_{10}	0.5379**	0.4303**	0.4584**	0.8722**	-0.2796*	0.5931**	0.5555**	0.6163**	0.6236**	1											
X_{11}	0.4148**	0.3676**	0.4334**	0.5734**	-0.4328**	0.8550**	0.6092**	0.6835**	0.6932**	0.6585**	1										
X_{12}	0.4163**	0.3202*	0.3487**	0.4293**	-0.1985*	0.6569**	0.7557**	0.5763**	0.6131**	0.5247**	0.5756**	1									
X_{13}	0.3286*	0.2664*	0.3286*	0.2635*	-0.1619*	0.5083**	0.4500**	0.4800**	0.5232**	0.3050*	0.4835**	0.3056*	1								
X_{14}	-0.0053	-0.0245	0.0610	-0.1276*	0.5740**	-0.2192*	-0.2160*	-0.0337	-0.0175	-0.0908	-0.4362**	-0.2436*	-0.2393*	1							
X_{15}	-0.0107	-0.0618	-0.0412	0.2563*	-0.3318**	0.0989	0.0534	-0.0063	0.0642	0.1779*	0.1553*	0.0040	0.3378**	-0.5468**	1						
X_{16}	0.0180	-0.0262	-0.0162	0.2510*	-0.3372**	0.1264*	0.0944	0.0444	0.1073	0.1839*	0.1990*	0.0005	0.3591**	-0.5921**	0.9908**	1					
X_{17}	-0.0633	-0.1247*	-0.0853	0.2536*	-0.3057*	0.0431	-0.0251	-0.0997	-0.0188	0.1581*	0.0670	0.0104	0.2821*	-0.4363**	0.9681**	0.9253**	1				
X_{18}	-0.1927*	-0.1791*	-0.1039	-0.1941*	0.2522*	0.0070	-0.1117*	-0.1892*	-0.1177*	-0.2286*	-0.2843*	-0.0430	-0.0944	0.5967**	-0.2064*	-0.2589*	-0.0992	1			
X_{19}	-0.0356	0.0263	-0.1098	-0.0353	-0.0470	-0.0193	-0.0565	0.0344	-0.0007	-0.0071	-0.0889	-0.1751*	-0.0856	-0.0320	-0.1274*	-0.0603	-0.2452*	-0.0343	1		
X_{20}	0.4767**	0.4198**	0.4127**	0.5557**	-0.3657**	0.6965**	0.8415**	0.7486**	0.7104**	0.6668**	0.7030**	0.6220**	0.5517**	-0.1937*	0.0526	0.0981	-0.0341	-0.2251*	0.0226	1	
X_{21}	-0.3330**	-0.3167*	-0.3225*	-0.4084**	0.5073**	-0.6130**	-0.5447**	-0.5204**	-0.4833**	-0.4887**	-0.7819**	-0.5131**	-0.3406**	0.6536**	-0.3199*	-0.6332**	-0.2240*	0.4040**	0.0476	-0.6086**	1

X_1 – Days to first male flower opening

X_2 –Days to first female flower opening

X_3 – Days to first harvest

X_4 – Fruit bearing period

X_5 – Number of fruits per plant

X_6 – Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} – Duration

X_{11} – Incidence of fruit fly

X_{12} – Protein content

X_{13} – Water content

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{17} – Non reducing sugars

X_{18} – Fruit colour (Chlorophyll content)

X_{19} – Fibre content

X_{20} – Flesh thickness

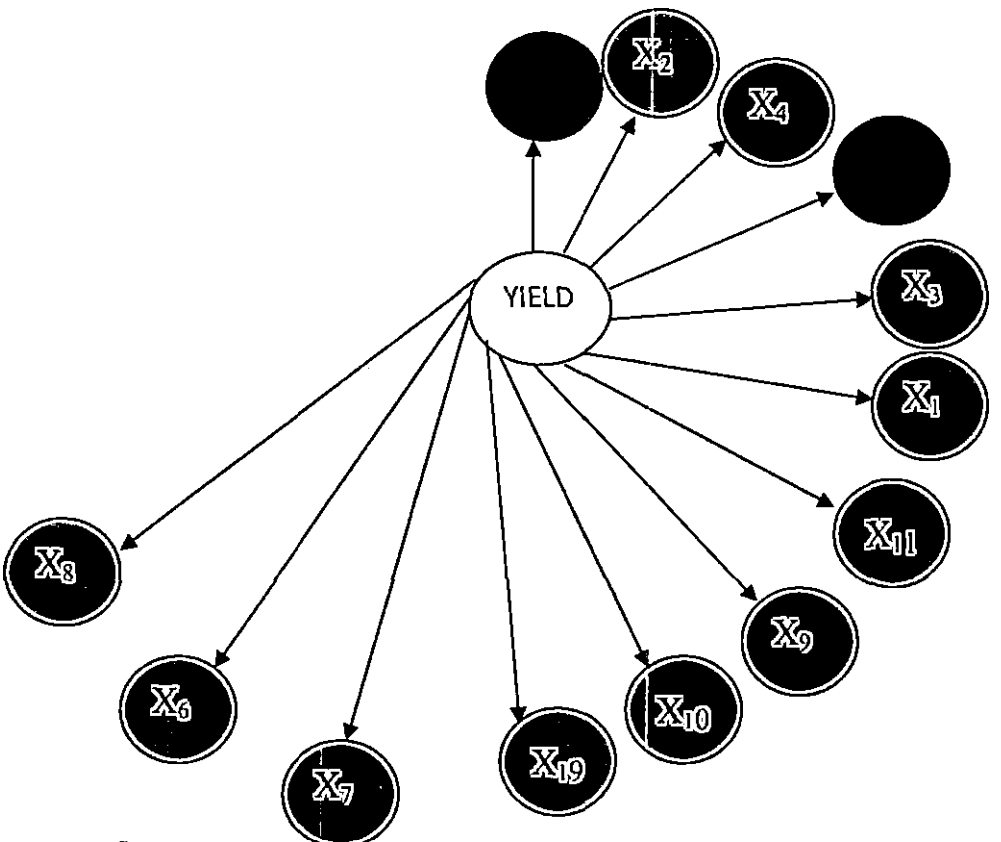
X_{21} – Phenol content

* Significant at 5 per cent level

** Significant at 1 per cent level

Fig. 5. Genotypic correlation of yield with other characters

Correlation increases with distance



X_1 - Days to first male flower opening

X_2 - Days to first female flower opening

X_3 - days to first harvest,

X_4 - fruit bearing period

X_6- Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} - Duration

X_{11} – Incidence of fruit fly

X_{18}–Fruit colour

X_{19}– Fiber content

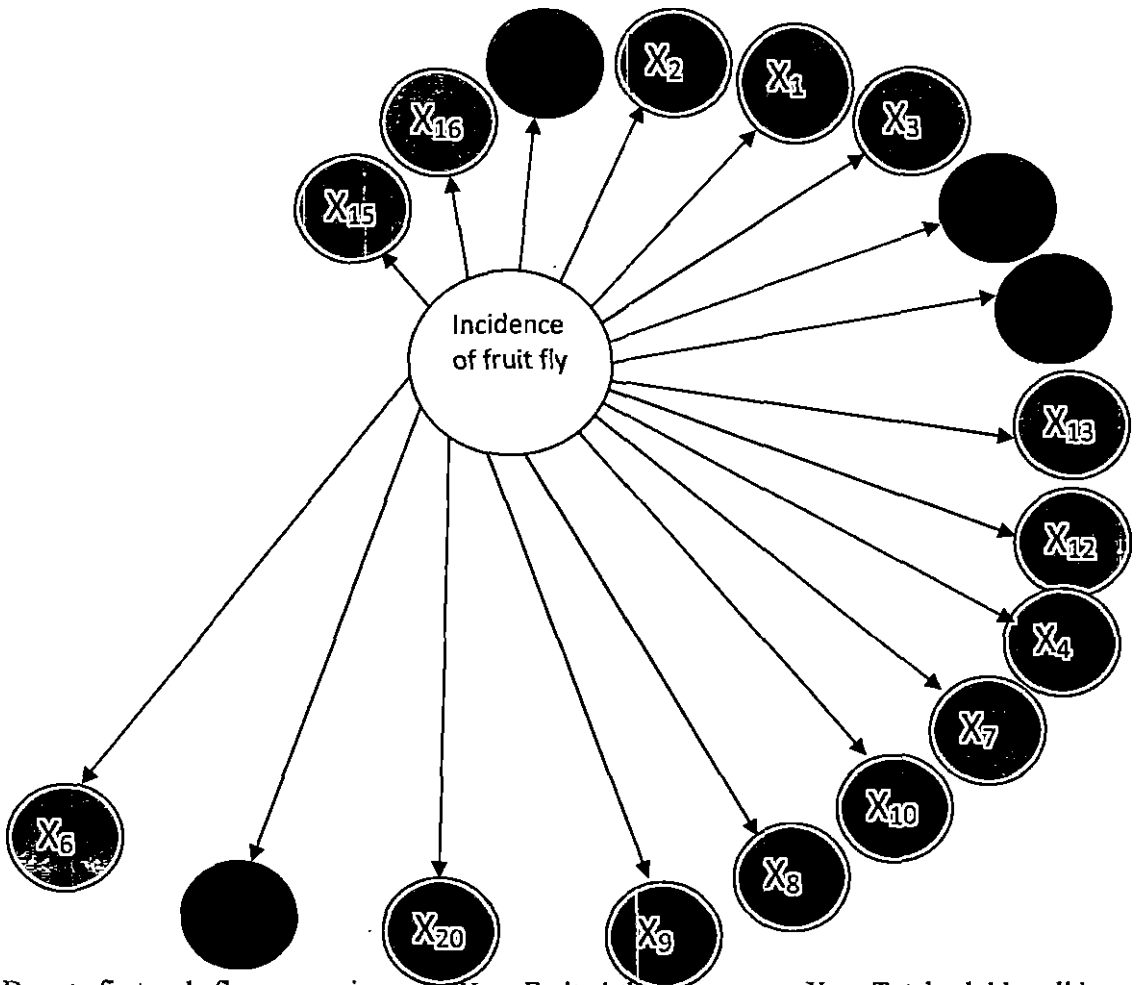
X_{20} – Flesh thickness

Significant positive correlation

Significant negative correlation

Fig. 6. Genotypic correlation of incidence of fruit fly with other characters

Correlation increases as distance increases



X_1 - Days to first male flower opening

X_2 - days to first female flower opening

X_3 - days to first harvest,

X_4 – Fruit bearing period

X_5 – Number of fruits per plant

X_6- Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} - Duration

X_{12} – Protein content

X_{13} – Water content

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{18} – Fruit colour

X_{20} – Flesh thickness

X_{21} – Phenol content

Significant positive correlation

Significant negative correlation

Table – 8. Genotypic correlation of different characters with each other

Sl. No	Character	Significant positive correlation	Significant negative correlation
1	Days to first male flower opening	Days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Number of fruits per plant, fruit colour (chlorophyll content), phenol content
2	Days to first female flower opening	Days to first male flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Number of fruits per plant, non-reducing sugars, fruit colour, phenol content
3	Days to first harvest	Days to first male flower opening, days to first female flower opening, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Number of fruits per plant, phenol content
4	Fruit bearing period	Fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, total sugars, reducing sugars, non reducing sugars, flesh thickness	Number of fruits per plant, phenol content, TSS, fruit colour (chlorophyll content)
5	Number of fruits per plant	TSS, fruit colour (chlorophyll content), phenol content	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content, flesh thickness, total sugars, reducing sugars, non reducing sugars
6	Fruit length	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness, reducing sugars	Number of fruits per plant, TSS, phenol content

Table – 8. Continued.....

7	Fruit girth	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	TSS, phenol content, number of fruits per plant, fruit colour (chlorophyll content)
8	Individual fruit weight	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, yield per plant, duration, incidence of fruit fly, protein content, water content, flesh thickness	Phenol content, fruit colour (chlorophyll content), number of fruits per plant
9	Yield per plant	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content, flesh thickness	Phenol content, fruit colour (chlorophyll content)
10	Duration	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, incidence of fruit fly, protein content, water content, total sugars, reducing sugars, non reducing sugars, flesh thickness	Phenol content, fruit colour (chlorophyll content), number of fruits per plant
11	Incidence of fruit fly	Days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, protein content, water content, total sugars, reducing sugars, flesh thickness	Phenol content, fruit colour (chlorophyll content), number of fruits per plant, TSS
12	Protein content	Days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, water content, flesh thickness	Phenol content, fiber content, number of fruits per plant, TSS
13	Water content	Days to first male flower opening, days to first female	Phenol content, number of fruits per plant, TSS

Table – 8. Continued.....

		flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, flesh thickness, total, reducing and non reducing sugars	
14	TSS	Number of fruits per plant, fruit colour (chlorophyll content), phenol content	Fruit bearing period, fruit length and girth, incidence of fruit fly, protein content, water content, total sugars, reducing sugars, non reducing sugars, flesh thickness,
15	Total sugars	Fruit bearing period, duration, incidence of fruit fly, water content, reducing and non reducing sugars	Number of fruits per plant, TSS, fruit colour (chlorophyll content), fiber content, phenol content
16	Reducing sugars	Fruit bearing period, fruit length, duration, incidence of fruit fly, water content, total and non reducing sugars	Phenol content, fruit colour (chlorophyll content), TSS, number of fruits per plant
17	Non reducing sugars	Fruit bearing period, duration, water content, total sugars, reducing sugars	Days to first female flower opening, phenol content, fiber content, TSS, number of fruits per plant
18	Fruit colour (chlorophyll content)	Number of fruits per plant, TSS, phenol content	Protein content, total sugars, non reducing sugars, fiber content, flesh thickness
19	Fruit fiber content		Protein content, total sugars, non reducing sugars
20	Flesh thickness	Days to first male flower opening, days to first female flower opening, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content	Number of fruits per plant, TSS, phenol content, fruit colour (chlorophyll content)
21	Phenol content	Number of fruits per plant, TSS, fruit colour (chlorophyll content)	Days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, yield per plant, duration, incidence of fruit fly, protein content, water content, total, non reducing and reducing sugars, flesh thickness

Table – 9. Environmental correlation coefficients among twenty one characters

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}	X_{18}	X_{19}	X_{20}	X_{21}
X_1	1																				
X_2	0.8362**	1																			
X_3	0.5824**	0.4340**	1																		
X_4	-0.5387**	-0.5426**	-0.3495**	1																	
X_5	-0.0360	0.0440	-0.0100	0.1114*	1																
X_6	-0.0807	-0.1192*	-0.0900	0.0100	0.0500	1															
X_7	-0.0557	0.0425	-0.0200	0.1000	-0.0800	-0.0700	1														
X_8	-0.0202	-0.0200	0.0000	-0.0200	-0.1327*	0.0400	-0.1749*	1													
X_9	-0.0380	-0.0500	-0.0400	0.0800	0.1286*	-0.0900	-0.2138*	0.4955**	1												
X_{10}	-0.2951*	-0.1700*	-0.2738*	0.4627**	0.3543**	0.0000	0.1998*	-0.0500	-0.0200	1											
X_{11}	0.0841	0.1100*	0.0500	-0.1198*	0.1343*	0.0600	0.1371*	-0.0300	-0.1704*	-0.0400	1										
X_{12}	-0.0017	0.0300	0.0000	0.0000	0.2013*	0.0300	-0.3370**	0.2368*	0.2589*	0.0200	-0.0300	1									
X_{13}	0.0846	-0.0100	0.0500	-0.0300	0.0000	-0.0600	0.0300	0.1552*	0.1930*	-0.1134*	-0.0200	-0.1806*	1								
X_{14}	0.2258*	0.1739*	0.1724*	-0.2722*	0.0500	-0.0600	0.0400	0.1080	0.0150	-0.1263*	0.1426*	0.0300	0.0659	1							
X_{15}	-0.1260*	-0.0700	-0.0800	0.1198*	-0.0600	0.0500	-0.0700	-0.1715*	0.0000	-0.0900	-0.1763*	0.0800	-0.0700	-0.0700	1						
X_{16}	-0.1202*	0.0900	-0.0800	0.1127*	-0.0800	0.0300	-0.0900	-0.1000	0.0500	-0.1537*	-0.1712*	0.0200	-0.1378*	-0.1546*	0.8937**	1					
X_{17}	-0.0851	-0.0200	-0.0400	0.0800	0.0000	0.0600	-0.0110	-0.2061*	-0.0900	0.0210	-0.1149*	0.1490*	0.0400	0.0500	0.7637**	0.3927**	1				
X_{18}	0.0915	-0.0200	-0.0300	0.0100	-0.1923*	0.0100	-0.0800	0.1170*	0.1210*	-0.1644*	0.0300	0.0800	-0.0800	0.0700	0.4044**	0.3621**	0.3078*	1			
X_{19}	0.2316*	0.1283*	0.1842*	-0.1951*	-0.2144*	-0.1489*	-0.0800	0.0000	0.0200	-0.1268*	0.0200	-0.1449*	0.2708*	0.1155*	-0.1689*	-0.1913*	-0.0700	0.0000	1		
X_{20}	-0.5910**	-0.2089*	0.0900	0.1025	-0.1879*	0.2174*	0.0500	-0.0800	-0.0100	0.0200	-0.1191*	0.2132*	-0.1700*	-0.1552*	0.0149	0.0840	-0.0800	0.1020	0.0600	1	
X_{21}	-0.0703	-0.0200	-0.1984*	0.0321	-0.0490	0.0400	0.0300	-0.0300	0.0400	0.0000	0.2274*	-0.1254*	0.1254*	-0.0535	0.1336*	0.1248*	0.0900	0.0000	-0.0300	-0.1369*	1

X_1 – Days to first male flower opening

X_2 –Days to first female flower opening

X_3 – Days to first harvest

X_4 – Fruit bearing period

X_5 – Number of fruits per plant

X_6 – Fruit length

X_7 – Fruit girth

X_8 – Individual fruit weight

X_9 – Yield per plant

X_{10} – Duration

X_{11} – Incidence of fruit fly

X_{12} – Protein content

X_{13} – Water content

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{17} – Non reducing sugars

X_{18} – Fruit colour (Chlorophyll content)

X_{19} – Fibre content

X_{20} – Flesh thickness

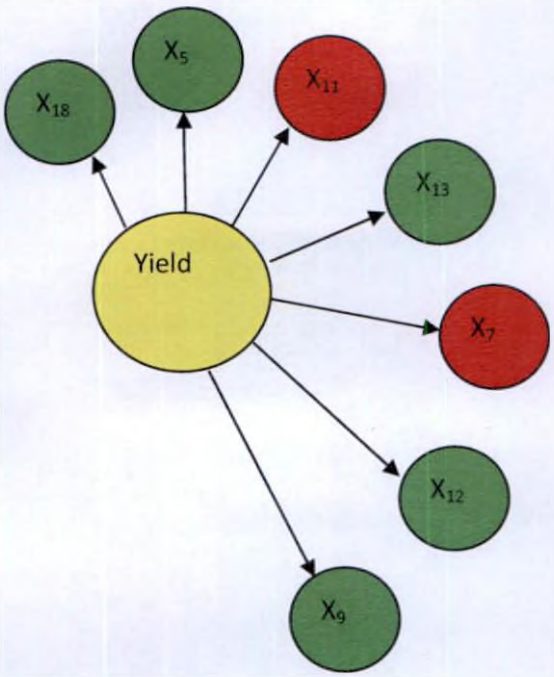
X_{21} – Phenol content

* Significant at 5 per cent level

** Significant at 1 per cent level

Fig. 7. Environmental correlation of yield with other characters

Correlation increases with distance



X_5 – Number of fruits per plant

X_7 – Fruit girth

X_9 – Yield per plant

X_{11} – Incidence of fruit fly

X_{12} – Protein content

X_{13} – Water content

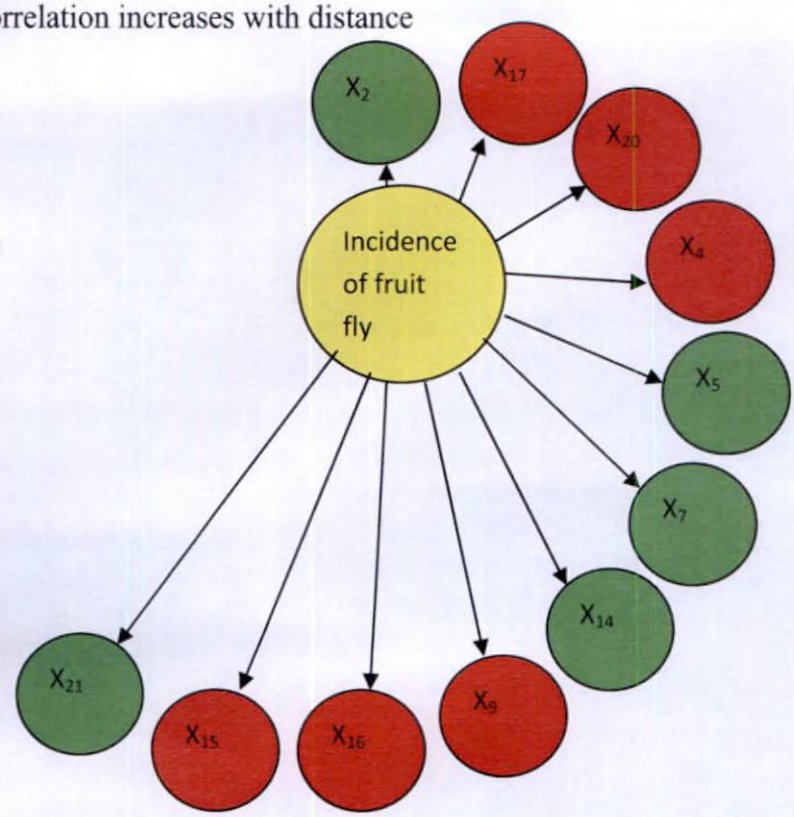
X_{18} – Fruit colour (chlorophyll content)

Significant positive correlation

Significant negative correlation

Fig. 8. Environmental correlation of incidence of fruit fly with other characters

Correlation increases with distance



X_2 - Days to first female flower opening

X_4 -Fruit bearing period

X_5 – Number of fruits per plant

X_7 – Fruit girth

X_9 – Yield per plant

X_{14} – Total soluble solids

X_{15} – Total sugars

X_{16} – Reducing sugars

X_{17} – Non-reducing sugars

X_{20} – Flesh thickness

X_{21} – Phenol content

Significant positive correlation

Significant negative correlation

Table – 10. Environmental correlation of different characters with each other

Sl. No	Character	Significant positive correlation	Significant negative correlation
1	Days to first male flower opening	Days to first female flower opening, days to first harvest, TSS, fiber content	Fruit bearing period, duration, total sugars, reducing sugars, flesh thickness
2	Days to first female flower opening	Days to first male flower opening, days to first harvest, TSS, fiber content	Fruit bearing period, fruit length, duration, flesh thickness, phenol content
3	Days to first harvest	Days to first male flower opening, days to first female flower opening, TSS, fiber content	Fruit bearing period, duration, phenol content
4	Fruit bearing period	Number of fruits per plant, duration, total sugars, reducing sugars	Days to first male flower opening, days to first female flower opening, days to first harvest, incidence of fruit fly, TSS, fiber content
5	Number of fruits per plant	Fruit bearing period , duration, yield per plant, incidence of fruit fly, protein content	Individual fruit weight, flesh thickness, fruit colour (chlorophyll content), fiber content
6	Fruit length	Flesh thickness	Days to first female flower opening, fiber content
7	Fruit girth	Duration, incidence of fruit fly	Individual fruit weight, yield per plant
8	Individual fruit weight	Yield per plant, protein content, water content	Number of fruits per plant, fruit girth, total sugars, non-reducing sugars
9	Yield per plant	Number of fruits per plant, individual fruit weight, protein content, water content, fruit colour (chlorophyll content)	Fruit girth, incidence of fruit fly
10	Duration	Fruit bearing period, number of fruits per plant, fruit girth,	Days to first male flower opening, days to first female flower opening, days to first harvest, water content, fruit colour (chlorophyll content), total sugars, non-reducing sugars, fiber content
11	Incidence of fruit fly	Number of fruits per plant, fruit girth, TSS, phenol content	Total sugars, reducing sugars, flesh thickness, fruit bearing period, yield per plant, non-reducing sugars
12	Protein content	Number of fruits per plant, individual fruit weight,	Fruit girth, water content, phenol content, fiber

Table – 10. Continued.....

		yield per plant, flesh thickness, non-reducing sugars	content
13	Water content	Individual fruit weight, yield per plant, phenol content, fiber content	Duration, protein content, reducing sugars, flesh thickness
14	TSS	Days to first male flower opening, days to first female flower opening, days to first harvest, incidence of fruit fly , fiber content	Fruit bearing period, duration, reducing sugars, flesh thickness
15	Total sugars	Fruit bearing period, reducing sugars, non reducing sugars, phenol content, fruit colour (chlorophyll content)	Days to first male flower opening, individual fruit weight, incidence of fruit fly, fiber content
16	Reducing sugars	Fruit bearing period, total sugars, non reducing sugars, phenol content, fruit colour (chlorophyll content)	Days to first male flower opening, duration, incidence of fruit fly, TSS, fiber content, water content
17	Non reducing sugars	Protein content, total sugars, reducing sugars, fruit colour (chlorophyll content)	Individual fruit weight, incidence of fruit fly
18	Fruit colour (chlorophyll content)	Individual fruit weight, yield per plant, total sugars, non reducing sugars, reducing sugars	Number of fruits per plant, duration
19	Fiber content	Days to first male flower opening, days to first female flower opening, days to first harvest, water content, TSS	Fruit bearing period, number of fruits per plant, fruit length, duration, protein content, total sugars, reducing sugars
20	Flesh thickness	Fruit length, protein content	Days to first male flower opening, days to first female flower opening, number of fruits per plant, TSS, incidence of fruit fly, water content, phenol content
21	Phenol content	Incidence of fruit fly, water content , total sugars, non reducing sugars	Days to first harvest, protein content, flesh thickness

Table – 11. Simple correlation between fruit fly infestation and other characters at stage I and II in bitter gourd

Sl No:	Character	Stage I	Stage II
1.	Protein content	0.6007**	0.5893**
2.	Water content	0.4231*	0.4862**
3.	Total soluble solids	-0.2319	-0.2611
4.	Total sugars	-0.0001	0.1388
5.	Reducing sugars	0.0021	0.1633
6.	Non-reducing sugars	-0.0037	0.0902
7.	Fruit colour (chlorophyll content)	0.0952	-0.2148
8.	Fiber content	-0.3846*	-0.2336
9.	Flesh thickness	0.6501**	0.5994**
10.	Phenol content	-0.6596**	-0.7397**

* Significant at 5 per cent level

** Significant at 1 per cent level

Table -12 . Direct and indirect effects of component characters on yield in bitter gourd

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	Correlation with yield
X_1	1.6386	-1.1737	-0.8303	-0.0614	0.0827	-0.0441	0.5312	0.3786	0.0893	-0.0151	0.0253	-0.0392	-0.0248	0.5571
X_2	1.5940	-1.2066	-0.8148	0.0511	0.0715	-0.0409	0.4757	0.3029	0.0791	-0.0116	0.0205	-0.0345	-0.0236	0.4629
X_3	1.6063	-1.1607	-0.8470	0.0039	0.0875	-0.0383	0.5045	0.3227	0.0933	-0.0126	0.0253	-0.0339	-0.0240	0.5269
X_4	0.1199	0.0736	0.0039	-0.8385	0.0863	-0.0306	0.3987	0.6139	0.1234	-0.0155	0.0203	-0.0457	-0.0304	0.4793
X_5	0.7561	-0.4812	-0.4135	-0.4037	0.1792	-0.0573	0.6581	0.4175	0.1840	-0.0238	0.0392	-0.0572	-0.0456	0.7517
X_6	0.9155	-0.6258	-0.4106	-0.3246	0.1300	-0.0789	0.7012	0.3910	0.1311	-0.0274	0.0347	-0.0691	-0.0405	0.7265
X_7	0.9586	-0.6321	-0.4706	-0.3681	0.1299	-0.0610	0.9081	0.4338	0.1471	-0.0209	0.0370	-0.0615	-0.0387	0.9615
X_8	0.8814	-0.5192	-0.3883	-0.7314	0.1063	-0.0439	0.5597	0.7039	0.1417	-0.0190	0.0235	-0.0548	-0.0364	0.6236
X_9	0.6797	-0.4435	-0.3671	-0.4808	0.1532	-0.0481	0.6207	0.4635	0.2152	-0.0208	0.0372	-0.0578	-0.0582	0.6932
X_{10}	0.6822	-0.3863	-0.2954	-0.3600	0.1177	-0.0597	0.5233	0.3693	0.1239	-0.0362	0.0235	-0.0511	-0.0382	0.6131
X_{11}	0.5384	-0.3214	-0.2783	-0.2209	0.0911	-0.0355	0.4359	0.2147	0.1040	-0.0111	0.0770	-0.0453	-0.0254	0.5232
X_{12}	0.7811	-0.5065	-0.3496	-0.4660	0.1248	-0.0664	0.6798	0.4693	0.1513	-0.0225	0.0425	-0.0822	-0.0453	0.7104
X_{13}	-0.5462	0.3821	0.2732	0.3424	-0.1098	0.0430	-0.4726	-0.3440	-0.1683	0.0186	-0.0262	0.0500	0.0744	-0.4833

Residual effect = 0.1775

Direct effect = Diagonal elements

Indirect effect = Off diagonal elements

X_1 - Days to first male flower opening

X_2 – Days to first female flower opening

X_3 – Day to first harvest

X_4 – Fruit bearing period

X_5 – Fruit length

X_6 – Fruit girth

X_7 – Individual fruit weight

X_8 - Duration

X_9 – Incidence of fruit fly

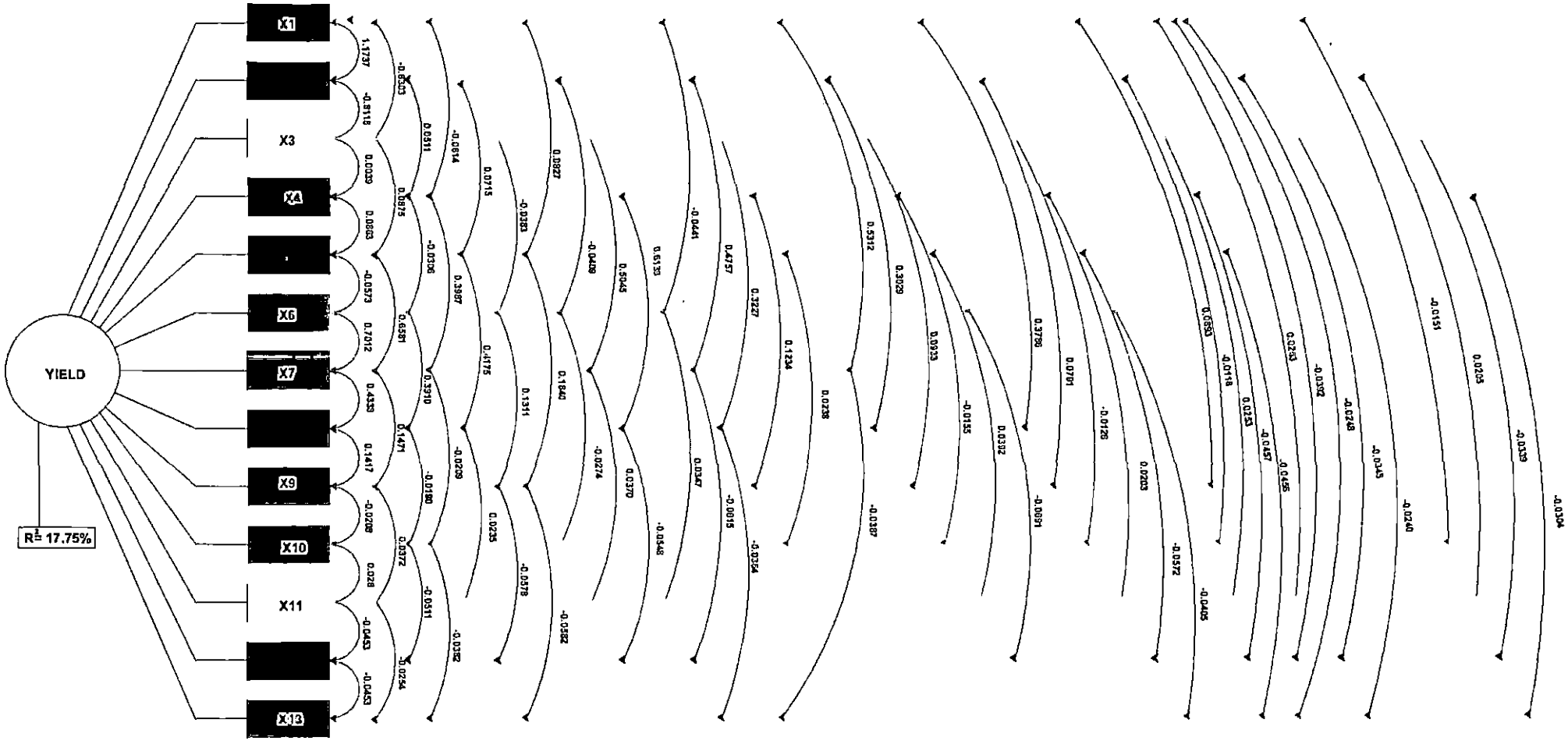
X_{10} – Protein content

X_{11} – Water content

X_{12} – Flesh thickness

X_{13} – Phenol content

Fig. 9 : Path diagram



Straight line indicate direct effect of characters to yield.

Curved lines indicate indirect effect of characters to yield.

effect of individual fruit weight through duration exhibited high and positive effect (0.4338), on yield per plant.

The indirect effects of individual fruit weight through days to first female flower opening (-0.6321), days to first harvest (-0.4706) and number of fruits per plant (-0.3681) on yield per plant had negligible effect.

Fruit length showed second highest significant and positive genotypic correlation (0.7517) with yield per plant.

Fruit girth had the third highest significant and positive total correlation (0.7265).

The incidence of fruit fly had significant and positive genotypic correlation (0.6932) with yield per plant and had moderate and positive direct effect. But the indirect effects of incidence of fruit fly through days to first male flower opening (0.6797), individual fruit weight (0.6207) and duration (0.4635) were high and positive.

The residual effect obtained was 17.75%.

4.1.2.5. D^2 Statistics

As revealed by the D^2 analysis there was wide variability between genotypes. The D^2 values were found highly significant for all the characters studied.

Based on the D^2 values grouping of 29 genotypes into various clusters were done and as a result seven clusters were obtained (Table -13 and fig. 10).

Table – 13. Clusters and genotypes

Cluster no:	Genotypes included	Number of genotypes
I	Kallukuthiavila local, Preethi, Priyanka, Kanakakkunnu local, Punnavely local, Nedinjal local, Changanassery local-2, Adimaly local, Eratayar local, Kaarikkuzhy local, Parathode local	11
II	IC-68338, IC-68255, IC-68272, IC-68296, IC-68237, IC-45341, IC-68250, IC-43261, IC-68306	9
III	Bharanikkavu local, Kollam local, Pappanchani local, IC-50516	4
IV	Priya, CL-Coimbatore	2
V	Changanassery local-1	1
VI	Madhurai local	1
VII	Palakkadu local	1

Table – 14. Average inter and intra cluster distances (D^2 and D values) in 29 genotypes

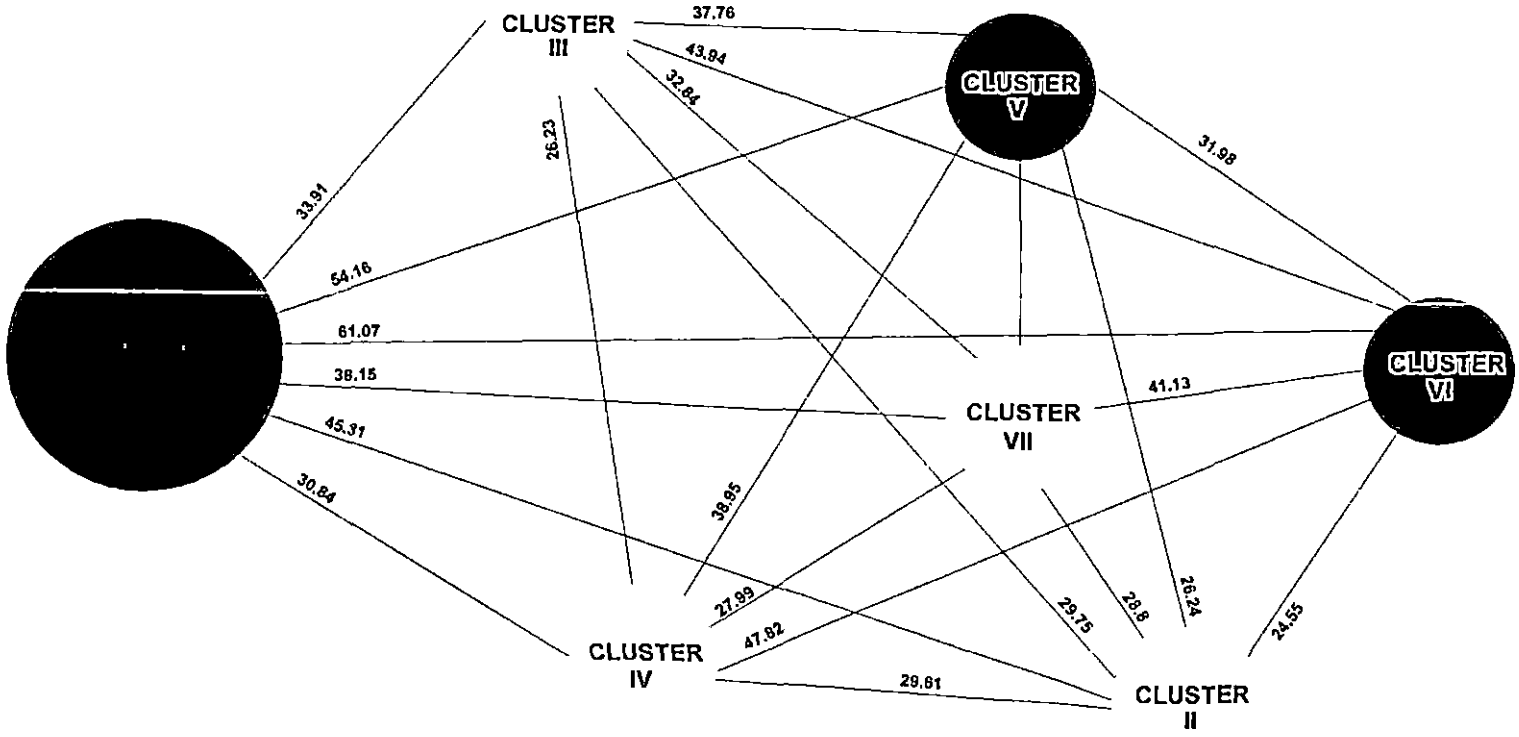
Cluster	I	II	III	IV	V	VI	VII
I	362.64 **(19.04)**	2052.88 **(45.31)**	1150.01 **(33.91)**	951.22 **(30.84)**	2933.44 **(54.16)**	3730 **(61.07)**	1455.35 **(38.15)**
II		196.97 **(14.04)**	885.18 **(29.75)**	877.02 **(29.61)**	688.61 **(26.24)**	602.75 **(24.55)**	829.4 **(28.8)**
III			386.1 **(19.65)**	687.93 **(26.23)**	1426.1 **(37.76)**	1930.7 **(43.94)**	1078.32 **(32.84)**
IV				492.13 **(22.18)**	1516.72 **(38.95)**	2286.89 **(47.82)**	783.44 **(27.99)**
V					0	628.24 **(25.06)**	1022.52 **(31.98)**
VI						0	1691.55 **(41.13)**
VII							0

D values in paranthesis

Diagonal values = intra cluster distances

Off diagonal values = inter cluster distances

Fig. 10 : Cluster diagram



Of these cluster V, cluster VI and cluster VII were monogenotypic clusters. Cluster I had maximum number of genotypes ie. 11 genotypes followed by cluster II with nine genotypes, cluster III had four genotypes and cluster IV had two genotypes.

Estimation of average distance both D^2 and D values at intra cluster and inter cluster levels was done and the results are presented in table - 14.

Of the various clusters (except the monogenotypic clusters) cluster II had minimum intra cluster distance (D^2=196.97 and D=14.04) and cluster IV had maximum intra cluster distance (D^2=492.14 and D=22.18). Highest inter-cluster distance (D^2=3730 and D= 61.07) existed between cluster I and VI and lowest distance between cluster II and cluster VI (D^2=602.75 and D=24.55).

Contribution of individual character towards total divergence was worked out and the results are presented in table – 15 and Fig. 11. Percentage contribution was recorded maximum for individual fruit weight (50) and minimum (0) for days to first female flower opening, days to first harvest and fruit bearing period. For the remaining characters contributions varied from 0.27 to 9.61% to the total divergence.

Average value of different clusters for different characters is given in table - 16.

4.1.2.6. Selection Index

Selection index for the genotypes was computed based on the fourteen characters viz,

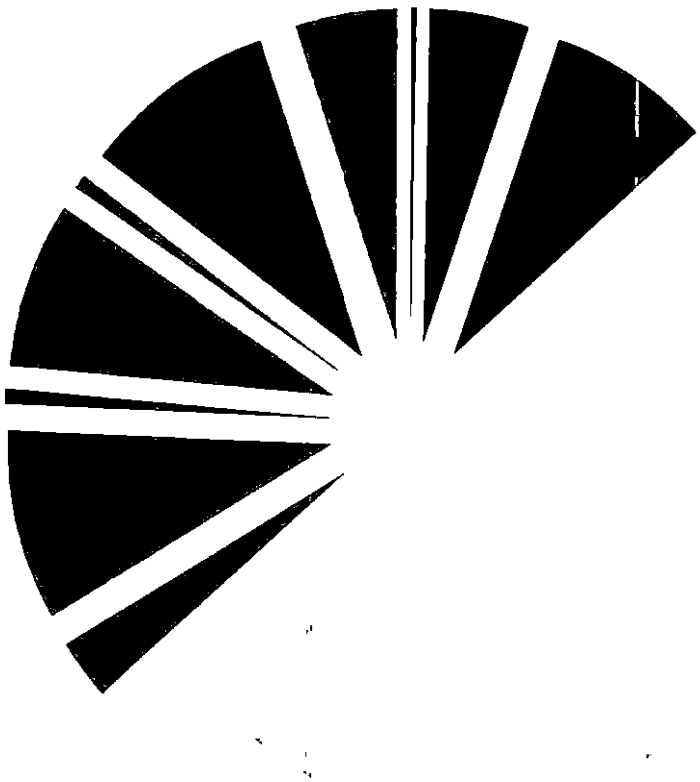
X_1 - Days to first male flower opening

X_2 - Days to first female flower opening

Table – 15. Contribution of characters to total divergence

Sl No	Character	Number of pairs of genotypes giving fixed rating for the characters towards divergence	Contribution (%)
1	Days to first male flower opening	1	0.27
2	Days to first female flower opening	0	0
3	Day to first harvest	0	0
4	Fruit bearing period	0	0
5	Fruit length	20	4.93
6	Fruit girth	33	8.13
7	Individual fruit weight	203	50
8	Yield per plant	12	2.96
9	Duration	38	9.36
10	Incidence of fruit fly	3	0.74
11	Protein content	33	8.13
12	Water content	3	0.74
13	Flesh thickness	39	9.61
14	Phenol content	21	5.17

Fig. 11.CONTRIBUTION OF CHARACTERS TO TOTAL DIVERGENCE



- DAYS TO FIRST MALE FLOWER OPENING
- FRUIT LENGTH
- FRUIT GIRTH
- INDIVIDUAL FRUIT WEIGHT
- YIELD PER PLANT
- DURATION
- INCIDENCE OF FRUIT FLY
- PROTEIN CONTENT
- WATER CONTENT
- FLESH THICKNESS
- PHENOL CONTENT

Table - 16. Vatiation of average values for different characters in seven clusters

Sl No	Character	I	II	III	IV	V	VI	VII
1	Days to first male flower opening (days)	46.65	39.72	44.55	45.50	44.36	36.45	44.60
2	Days to first female flower opening (days)	53.30	46.69	51.75	51.29	50.57	42.50	49.33
3	Days to first harvest (days)	70.11	64.02	67.39	70.57	67.07	62.53	68.67
4	Fruit bearing period (days)	73.98	62.83	65.36	74.98	66.77	53.13	72.03
5	Number of fruits per plant	13.77	11.9	13.36	18.77	19.75	56.53	15.40
6	Fruit length (cm)	23.67	13.28	19.21	25.68	6.57	5.82	15.25
7	Fruit girth (cm)	19.51	10.76	20.73	13.99	8.83	6.80	12.07
8	Individual fruit weight (g)	279.65	35.20	84.93	105.31	5.78	4.72	73.45
9	Yield per plant (g)	3533.37	410.74	1022.08	1759.17	125.00	321.25	1126.25
10	Duration (days)	127.96	109.62	117.04	129.80	123.40	93.27	122.03
11	Incidence of fruit fly (%)	90.62	71.25	74.43	95.00	39.53	38.07	83.73
12	Protein content ($mg.g^{-1}$)	410.40	200.36	447.44	423.42	269.16	76.22	116.57
13	Water content (%)	92.83	91.42	91.81	92.37	89.80	90.50	93.70
14	Total soluble solids (Brix)	3.34	3.07	3.14	3.18	5.23	5.00	4.00
15	Total sugars ($mg.g^{-1}$)	258.06	294.74	254.75	265.00	84.33	73.33	246.00
16	Reducing sugars ($mg.g^{-1}$)	172.76	191.85	166.17	172.67	27.67	50.67	161.00
17	Non reducing sugars ($mg.g^{-1}$)	85.30	102.89	88.58	92.33	56.67	22.67	85.00
18	Fruit colour (Chlorophyll content) ($mg.g^{-1}$)	1.09	1.17	1.53	1.27	2.87	1.62	1.21
19	Fibre content ($mg.g^{-1}$)	346.58	335.67	294.83	338.00	357.67	339.00	216.67
20	Flesh thickness (mm)	4.15	3.11	3.89	3.80	2.80	2.43	4.00
21	Phenol content ($mg.100g^{-1}$)	102.92	131.61	120.51	88.17	238.23	224.10	182.13

X_3 - Days to first harvest

X_4 - Fruit bearing period

X_5 - Fruit length

X_6 - Fruit girth

X_7 - Individual fruit weight

X_8 - Yield per plant

X_9 - Duration

X_{10} - Incidence of fruit fly

X_{11} - Protein content

X_{12} - Water content

X_{13} - Flesh thickness

X_{14} - Phenol content

The selection index was worked out as follows

$$I=-20.355X_1+7.201X_2+11.205X_3-2.817X_4+1.522X_5+9.057X_6+1.335X_7+ 0.943X_8+5.943X_9+1.742X_{10}+0.887X_{11}+2.908X_{12}-26.354X_{13}+1.054X_{14}$$

Selection index values are presented in ascending order in table - 17. Highest selection index value was recorded by the genotype Kanakakunnu local and it was closely followed by the genotypes Priyanka, Changanassery local-2, IC-50516 and Preethi.

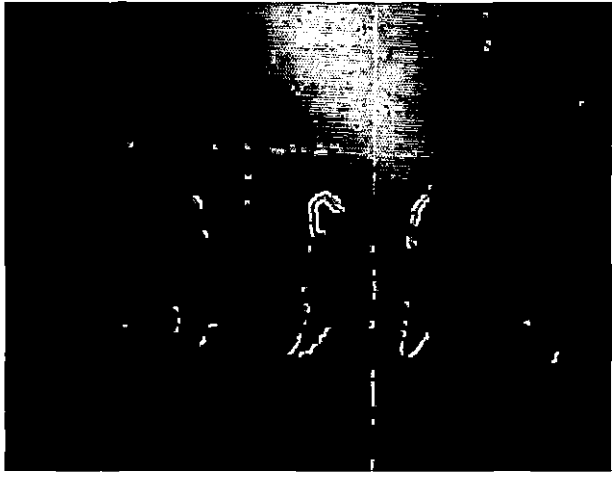
Lowest selection index value was recorded by the genotype Madhurai local.

4.2. Experiment -2

Laboratory screening was done to confirm the fruit fly resistance among genotypes under artificial conditions. Results are presented in plate-5,6,7.

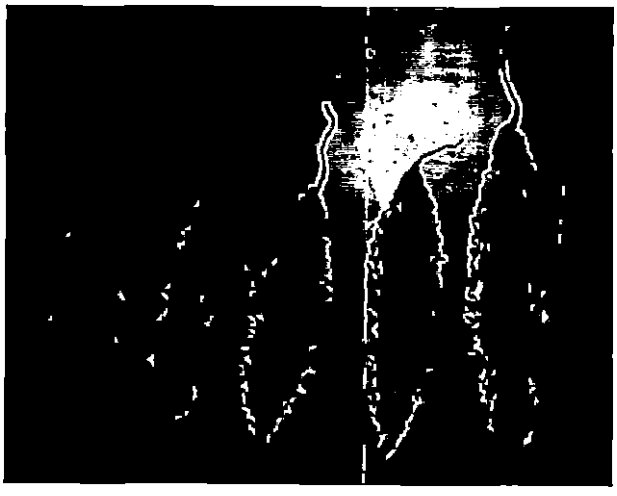
Table - 17. Selection index

Sl. No	Accession number	Genotype	Selection Index
1	12	Madhurai local	1557.72
2	20	IC–68250	1586.48
3	2	IC–68255	1606.85
4	8	IC–68272	1626.08
5	1	IC–68338	1635.45
6	27	IC–43261	1640.64
7	7	Changanassery local-1	1696.16
8	13	IC–68237	1877.47
9	28	IC–68306	1977.02
10	19	IC–45341	1993.39
11	22	IC–50516	2195.53
12	11	IC- 68296	2424.32
13	24	Palakkadu local	2427.77
14	3	Bharanikkavu local	2639.7
15	9	Kollam local	2677.5
16	26	CL- Coimbatore	2780.62
17	17	Pappanchani local	3095.56
18	15	Punnavely	3252.63
19	25	Kaarikkuzhi local	3629.14
20	14	Priya	3679.82
21	21	Adimaly local	4499.42
22	29	Parathode local	4641.83
23	5	Kallukuthiavila local	4862.25
24	16	Nedinjal local	5018.25
25	4	Preethi	5145.41
26	23	Eratayar local	5156.65
27	18	Changanassery local - 2	5248.37
28	6	Priyanka	5478.9
29	10	Kanakakunnu	6029.67



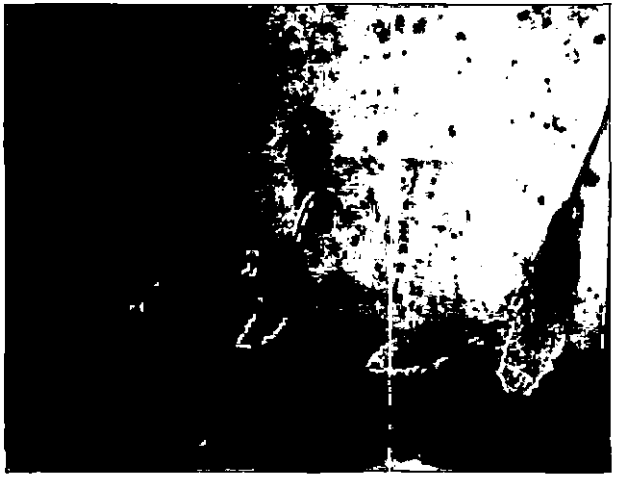
Stage I

Stage II



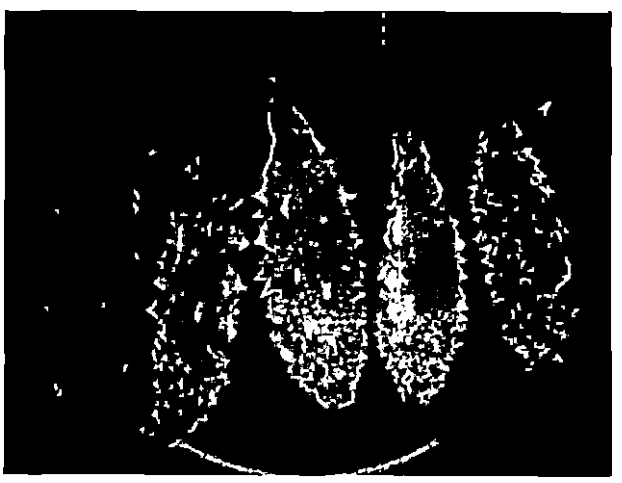
Stage III

Plate 5 : Laboratory screening - Fruits before release of adult fruit flies



Stage I

Stage II



Stage III

late 6 : Laboratory screening - Fruits after exposure to adult fruit flies

Stage I

Stage II

Stage III

Plate 5 : Laboratory screening - Fruits before release of adult fruit flies

Stage I

Stage II

Stage III

Plate 6 : Laboratory screening - Fruits after exposure to adult fruit flies

Plate 7 : Gallery formation consequent to fruit fly infestation

The experiment was conducted using fruit samples of 29 genotypes collected at three different fruit development stages such as fruit setting stage (3-7 days), half maturing stage (8-14 days) and full maturing stage (15-21days) in CRD with 4 replications.

The results obtained are presented as follows.

4.2.1. Number of ovipositional punctures

The results are presented in Table - 18. In fruit samples of fruit setting stage (stage I), Changanassery local-1 (0.05) showed the lowest mean number of ovipositional punctures. Genotypes Madhurai local (0.06), IC- 68338 (0.3), IC – 68255 (0.3) and Preethi (0.3) were on par with Changanassery local-1. However, the genotype CL-Coimbatore recorded the highest number of ovipositional punctures (1.10). In half maturing stage, Changanassery local-1 (0.10), Madhurai local (0.10) and Priya (0.10) showed the lowest incidence of ovipositional punctures. Kollam local (0.15) and IC – 50516 (0.20) were also on par with them. But the genotype Kallukuthiavila local recorded the highest number of ovipositional punctures (0.75).

At full maturing stage Priya (0.10) showed the lowest number of ovipositional punctures and the genotypes Changanassery local-1 (0.20), Kollam local (0.20) and Madhurai local (0.20) were also on par with Priya. Whereas, the genotype Preethi showed maximum number of ovipositional punctures (0.80).

In the pooled analysis, the accessions Changanassery local-1 (0.12), Madhurai local (0.12), Priya (0.18) and Kollam local (0.20) showed minimum number of ovipositional punctures and all these were on par with each other. CL-Coimbatore (0.80) recorded the maximum number of ovipositional

Table – 18. Mean number of ovipositional punctures in three stages

Sl No:	Genotype	Stage I	Stage II	Stage III	Mean value of genotypes over stages
1.	IC-68338	0.30	0.45	0.35	0.37
2.	IC-68255	0.30	0.30	0.50	0.37
3.	Bharanikkavu local	0.50	0.40	0.60	0.50
4.	Preethi	0.30	0.50	0.80	0.53
5.	Kallukuthiavila local	0.50	0.75	0.60	0.62
6.	Priyanka	0.65	0.50	0.50	0.55
7.	Changanassery local -1	0.05	0.10	0.20	0.12*
8.	IC- 68272	0.60	0.35	0.35	0.43
9.	Kollam local	0.35	0.15	0.20	0.20
10.	Kanakakunnu local	0.45	0.55	0.60	0.53
11.	IC-68296	0.50	0.45	0.40	0.45
12.	Madhurai local	0.06	0.10	0.20	0.12*
13.	IC – 68237	0.50	0.30	0.50	0.43
14.	Priya	0.35	0.10	0.10	0.18
15.	Punnavely local	0.60	0.50	0.50	0.53
16.	Nedinjal local	0.70	0.55	0.75	0.67
17.	Pappanchani local	0.60	0.40	0.55	0.52
18.	Changanassery local- 2	0.63	0.55	0.60	0.59
19.	IC- 45341	0.60	0.45	0.55	0.53
20.	IC- 68250	0.55	0.30	0.45	0.43
21.	Adimaly local	0.55	0.50	0.55	0.53
22.	IC- 50516	0.35	0.20	0.50	0.32
23.	Eratayar local	0.60	0.50	0.65	0.59
24.	Palakkadu local	0.55	0.35	0.50	0.47
25.	Kaarikkuzhi local	0.75	0.50	0.70	0.65
26.	CL- Coimbatore	1.10	0.55	0.75	0.80
27.	IC – 43261	0.70	0.35	0.50	0.52
28.	IC – 68306	0.65	0.40	0.45	0.50
29.	Parathode local	0.70	0.45	0.65	0.60
	CD (5%)	0.27	0.18	0.22	0.18
	Mean value of stages over genotypes (Not significant)	0.52	0.40	0.50	

* Minimum value

punctures and Kallukuthiavila local (0.62), Kaarikkuzhi local (0.65) and Nedinjal local (0.67) were on par with each other.

4.2.2. Number of fruits infested (% of fruit infestation)

The results showed that there was no significant interaction between stages and genotypes, but significant difference was observed between stages and between genotypes (table-19).

For seven days old fruits the accessions Madhurai local and Changanassery local-1 recorded low infestation percentage of 12.60 and 10.00, respectively, and these two were on par with each other. The highest fruit fly infestation was recorded in CL-Coimbatore (80.00%). In the second stage low incidence of fruit fly infestation was recorded in Madhurai local (10.00%), Changanassery local-1(10.00%) and Priya (10.00%) and these were on par. Kollam local (15.00%) and Adimaly local (15.00%) were also on par with them. Percentage of fruit infestation was maximum in Kallukuthiavila local (65.00%). In the third stage, minimum infestation was recorded in Priya (10.00%) which was on par with Changanassery local-1 (20.00%), Kollam local (20.00%) and Madhurai local (20.00%) and maximum infestation was recorded in Preethi (75.00%).

Of the three stages mean percentage of infestation was minimum in half mature stage and maximum in full mature stage.

In the pooled analysis Changanassery local-1 recorded minimum infestation (11.20%) which was on par with Madhurai local (11.60%). The maximum infestation was seen in CL-Coimbatore variety (66.60%).

Table – 19. Mean performance of 29 genotypes for number of fruits infested at three fruit development stages (Angular transformation values in paranthesis) (* Minimum value)

Sl No:	Genotype	Stage I		Stage II		Stage III		Mean value of genotypes over stages	
1	IC- 68338	35.00	(34.65)	45.00	(44.95)	35.00	(34.18)	38.40	(37.88)
2	IC-68255	30.00	(29.50)	30.00	(29.50)	50.00	(50.00)	36.60	(36.10)
3	Bharanikkavu local	35.00	(34.65)	40.00	(39.50)	55.00	(55.50)	43.40	(43.15)
4	Preethi	30.00	(29.50)	45.00	(44.48)	75.00	(75.48)	50.00	(50.00)
5	Kallukuthiavila local	40.00	(39.50)	65.00	(65.35)	55.00	(55.05)	53.20	(53.35)
6	Priyanka	55.00	(55.50)	50.00	(50.00)	50.00	(50.00)	51.60	(51.82)
7	Changanassery local-1	10.00	(5.25)	10.00	(5.25)	20.00	(15.38)	11.20*	(8.10*)
8	IC-68272	40.00	(39.50)	35.00	(34.18)	35.00	(34.65)	36.60	(36.10)
9	Kollam local	35.00	(35.05)	15.00	(11.62)	20.00	(15.38)	20.00	(19.80)
10	Kanakakunnu local	45.00	(44.95)	50.00	(50.00)	60.00	(60.48)	51.60	(51.80)
11	IC-68296	40.00	(39.50)	45.00	(44.95)	40.00	(39.50)	41.60	(41.35)
12	Madhurai local	12.60	(3.85)	10.00	(5.25)	20.00	(20.00)	11.60	(8.50)
13	IC-68237	50.00	(50.00)	30.00	(29.50)	55.00	(50.00)	45.00	(42.95)
14	Priya	30.00	(29.50)	10.00	(5.25)	10.00	(5.28)	16.60	(11.50)
15	Punnavely local	55.00	(55.05)	45.00	(44.95)	50.00	(50.00)	50.00	(50.00)
16	Nedinjal local	65.00	(65.65)	55.00	(55.05)	70.00	(70.50)	63.20	(63.85)
17	Pappanchani local	60.00	(60.45)	35.00	(34.65)	55.00	(55.50)	50.00	(50.25)
18	Changanassery local - 2	62.60	(62.95)	55.00	(55.05)	55.00	(55.05)	56.60	(57.68)
19	IC-45341	55.00	(55.50)	40.00	(39.50)	55.00	(55.50)	50.00	(50.25)
20	IC-68250	50.00	(50.48)	30.00	(50.00)	45.00	(44.95)	41.60	(41.48)
21	Adimaly local	60.00	(60.95)	50.00	(15.35)	55.00	(55.02)	55.00	(55.35)
22	IC-50516	35.00	(35.05)	20.00	(15.38)	50.00	(50.00)	31.60	(32.52)
23	Eratayar local	60.00	(60.45)	50.00	(34.65)	65.00	(65.80)	58.20	(58.85)
24	Palakkadu local	55.00	(55.50)	35.00	(50.00)	50.00	(50.00)	46.60	(46.62)
25	Kaarikkuzhi local	60.00	(60.45)	50.00	(50.00)	75.00	(75.38)	61.60	(62.25)
26	CL- Coimbatore	80.00	(84.65)	50.00	(34.65)	70.00	(70.50)	66.60	(69.25)
27	IC-43261	60.00	(60.45)	35.00	(34.65)	50.00	(50.00)	48.20	(48.35)
28	IC-68306	65.00	(65.82)	40.00	(39.50)	45.00	(44.95)	50.00	(50.15)
29	Parathode local	65.00	(65.82)	45.00	(44.95)	70.00	(70.50)	60.00	(60.65)
	CD (5%)		(15.48)		(13.06)		(15.79)		(2.72)
	Mean value of stages over genotypes		(46.51)		(36.18)		(48.55)	CD (5%) = 2.71	

4.2.2. Number of maggots per fruit

The results are presented in Table - 20. Minimum number of larvae per fruit was observed in Madhurai local (0.13) in stage-1. This was on par with Changanassery local-1 (0.25), Kollam local (1.5), Priya (1.45) and Bharanikkavu local (2.05). Maximum number of larvae was seen in CL Coimbatore (6.60). This was on par with the following accessions such as Kaarikkuzhi local (4.85), Palakkadu local (4.2), Eratayar local (5.5), Changanassery local-1(4.44), Pappanchani local (4.9) and Nedinjal local (5.25).

In the second stage Madhurai local (0.35) showed the lowest number of larvae per fruit. This was on par with IC – 68255 (4.45), Changanassery local-1 (0.5), IC- 68272 (3.95) and Kollam local (0.7). The number of larvae per fruit was maximum in CL-Coimbatore (24.55) and this was on par with Eratayar local (20.70) and Nedinjal local (19.80)

In the third stage minimum number of larvae per fruit was observed in Kollam local (0.5). This was on par with Changanassery local-1(0.6), Priya (0.85), Madhurai local(0.9), IC-68306 (1.55), IC-68272(2.8), IC-50516(3.2), IC-68237(3.3), IC-68338(3.4), IC-68255(3.95), Palakkadu local (4.3), IC-43261(4.85), IC-68250(4.4),IC-45341(6.05), IC-68296(7.2) and Bharanikkavu local(7.3). Maximum number was observed in Kaarikkuzhi local (39.25).

In the pooled analysis of the three stages accessions Adimaly local, Parathode local, Erataya local, Nedinjal local, Preethi, Kallukuthiavila local and CL-Coimbatore had maximum susceptibility and all these were on par with each other. Minimum infestation was observed in Madhurai local (0.45), followed by Changanassery local-1 (0.75), Kollam local (0.77), Priya (1.48), IC-50516(2.33), IC-68272(3.1), IC-68250 (3.23), IC-68237(3.43), IC-68306

Table – 20. Mean number of maggots per fruit in three stages

Sl No:	Genotype	Stage I	Stage II	Stage III	Mean value of genotypes over stages
1	IC- 68338	2.40	7.10	3.40	4.30
2	IC-68255	2.35	4.45	3.95	3.58
3	Bharanikkavu local	2.05	6.35	7.30	5.28
4	Preethi	2.75	18.05	31.55	17.45
5	Kallukuthiavila local	2.80	21.00	32.50	18.77
6	Priyanka	3.40	13.15	20.95	12.50
7	Changanassery local-1	0.25	1.40	0.60	0.75*
8	IC-68272	2.55	3.95	2.80	3.10
9	Kollam local	1.50	0.70	0.50	0.77
10	Kanakakunnu local	3.85	12.95	21.70	12.83
11	IC-68296	3.40	5.45	7.20	5.35
12	Madhurai local	0.13	0.35	0.90	0.45*
13	IC-68237	3.55	3.45	3.30	3.43
14	Priya	1.45	2.15	0.85	1.48
15	Punnavely local	3.70	6.05	9.15	6.30
16	Nedinjal local	5.25	19.80	24.05	16.37
17	Pappanchani local	4.90	10.05	21.00	11.98
18	Changanessery local - 2	4.44	12.80	17.55	11.52
19	IC-45341	2.95	3.00	6.05	4.00
20	IC-68250	2.85	2.45	4.40	3.23
21	Adimaly local	3.85	13.20	26.95	14.67
22	IC-50516	1.63	2.70	3.20	2.33
23	Eratayar local	5.50	20.70	22.75	16.32
24	Palakkadu local	4.20	2.85	4.30	3.78
25	Kaarikkuzhi local	4.85	14.85	23.65	14.48
26	CL- Coimbatore	6.60	24.55	39.25	23.47
27	IC-43261	3.20	4.65	4.85	4.23
28	IC-68306	3.65	5.50	1.55	3.57
29	Parathode local	5.95	11.05	29.90	15.63
	CD (5%)	2.08	5.47	7.77	4.5
	Mean value of stages over genotypes	3.32	8.75	12.97	CD (5%) = 1.02

* Minimum value

(3.57), IC-68255 (3.58), Palakkadu local (3.78), IC-45341(4.0), IC-43261 (4.23) and IC-68338 (4.3).

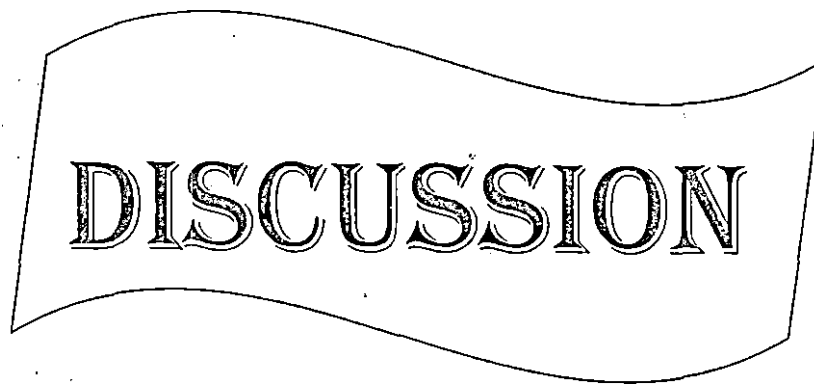
The lowest percentage of fruit infestation was seen in the second stage. Maximum infestation was in the third stage but it was on par with first stage. Ovipositional punctures were minimum in second stage and maximum in first stage. All the three stages were on par with each other for number of ovipositional punctures. Number of larvae per fruit was maximum in third stage and minimum in first stage. Number of larvae per fruit exhibited highly significant difference in stage 3 as compared to stage1 and stage 2.

According to the categorization of Nath (1966) the genotypes were classified as follows (Table 21).

Table-21. Classification of genotypes based on Nath's (1966) categorization

Damage (%)	Category	Categories based on field experiment	Categories based on laboratory screening
0%	Immune	—	—
1-10%	Highly resistant	—	7,12
11-20%	Resistant	—	9,14
21-50%	Moderately resistant	7,12	1,2,3,4,8,11,13,15,20, 22,24,27
51-75%	Susceptible	1,8,9,11,17,19,20,22	5,6,10,16,17,18,19,21,2 3,25,26,28,29
76-100%	Highly susceptible	2,3,4,5,6,10,13,14,15,1 6,18,21,23,24,25,26,27, 28,29,	—

Both under field and laboratory screening, the genotypes Madhurai local and Changanassery local -1 were categorized as highly resistant ones as compared to remaining 27 genotypes.


DISCUSSION

5. DISCUSSION

The success of a crop improvement programme depends solely on the identification and selection of suitable genotypes. The efficiency of selection largely depends on the extent of genetic variability present in a population and the heritability of the concerned character. An insight into the magnitude of variability present in a crop species is of utmost importance as it provides the basis for effective selection. The total variation, i.e. phenotypic variation present in a population arises due to genotypic and environmental effects. Of these, the genotypic variation is the main concern of plant breeders. It is the component of variation which is due to the genotypic differences among individuals with in a population. The variability present in the breeding population can be assessed in the following three ways.

1) Using simple measures of variability
2) By estimating the various components of variance and
3) By studying the genetic diversity.

Selection is more effective for characters with high heritability than those having low heritability. Evans (1968) reported that selection based on yield and its component traits was found to be more efficient than selection for yield alone. It is because, generally yield has low heritability. Yield is regarded as a complex character or super character, which is influenced by many components on contributing traits both in positive and negative direction.

Generally, direct selection for yield is not sufficiently effective due to its low heritability, and it is desirable to select indirectly for improved yield. Biometrical techniques provide information about the relative contribution of the various component traits to yield. These help in the isolation of superior

yielding genotypes from genetically variable population by providing information in indirect selection for yield. These techniques are

1) Correlation coefficient
2) Path coefficient and
3) Discriminant function analysis

In cucurbits, several research works have been carried out to screen and find out resistance sources for melon fruit fly. But in bitter gourd, such type of works are seldom reported and hence the present study was carried out in RBD with three replications using 29 genotypes of bitter gourd to gather information regarding yield, relative contribution of the various component traits to yield and fruit fly resistance and the results obtained are discussed below.

5.1. Mean performance

In the present study, days to first male flower opening was minimum in IC-45341 and maximum in Priya. Days to first female flower opening, was minimum in IC-45341 and maximum in Parathode local. Moreover days to first harvest, was minimum in IC-45341 and maximum in Priya. But fruit bearing period was minimum in IC-50516 and maximum in Kaarikkuzhi local. So IC-45341 was the early flowering, fruit bearing and maturing genotype and Priya was the late flowering, fruit bearing and maturing genotype. But shortest fruit bearing period was observed in IC-50516 and longest in Kaarikkuzhi local.

Genotype Madhurai local was recorded minimum mean fruit length, fruit girth and individual fruit weight but it was recorded maximum mean number of fruits per plant. Moreover it was the short duration one among 29 genotypes.

Longest fruits were observed in Priya but genotype Bharanikkavu local was recorded maximum fruit girth. Genotype Kanakakunnu local was recorded the highest mean individual fruit weight and yield per plant as compared to other genotypes. So Kanakakunnu local was the high yielding genotype and Changanassery local-1 was the low yielding genotype in this study.

Genotype Kallukuthiavila local was the long duration one among the 29 genotypes.

Madhurai local recorded the lowest fruit fly infestation where as Kallukuthiavila local recorded the highest infestation.

Changanassery local-2 recorded the highest protein content and Madhurai local recorded the lowest protein content in three fruit development stages.

In accordance with the fruit maturity stages, water content varied among the genotypes ie. in the fruit setting stage and half maturing stage, highest water content was observed in Priya and lowest in Changanassery local-2 where as in the full maturity stage highest and lowest water content was observed in Kallukuthiavila local and IC-68272 respectively.

Changanassery local-2 showed the highest total soluble solids content in three fruit development stages. But lowest total soluble solids content was observed in different genotypes in different fruit development stages. In fruit setting stage, both Kaarikkuzhi local and CL-Coimbatore recorded the minimum total soluble solids content where as in half maturing stage IC-68296 and full maturity stage Kanakakunnu local and IC-68296 recorded minimum total soluble solids content. IC-68296 recorded highest total sugars,

reducing and non-reducing sugars in three fruit development stages and Madhurai local recorded the lowest total sugars in three fruit development stages.

Lowest sugar content varied in different genotypes in different fruit development stages. Bharanikkavu local, Madhurai local and Changanassery local-1were recorded the minimum values.

Fruit colour in terms of chlorophyll content varied according to the stage of fruit development. In immature stage, Changanassery local-2, half maturing stage Kollam local and full maturing stage Changanassery local-1 recorded highest chlorophyll content where as Adimaly local recorded lowest chlorophyll content in all the three stages. Adimaly local also recorded lowest crude fiber content in immature and half mature fruit development stages. But Changenassery local-2 was recorded lowest fiber content in full mature stage. Changanassery local-1, Kaarikkuzhi local and Parathode local recorded highest fiber content in immature, half mature and full mature stages of fruit development.

Kallukuthiavila local and Madhurai local, IC-68296 and IC-68306 were recorded the maximum and minimum flesh thickness values in the immature and half mature stages respectively. In full maturing stages Changenassery local- 1, Adimaly local and Eratayar local were recorded highest values and Madhurai local recorded lowest value.

Preethi and Changanassery local- 1, Punnavely local and Changanassery local- 1, CL-Coimbatore and Changanassery local-1were recorded the maximum and minimum phenol content in fruit setting, half maturing and full maturing stages respectively.

5.2. Variability parameters

Significant differences among the genotypes were observed for all the 21 characters analysed statistically suggesting the presence of sufficient variability among the genotypes for these traits. These results were in corroborated with the findings of several authors, Kale et al. (1991), Ram et al. (1996), Xiang et al. (2000), Kore et al. (2003), Dhillon et al. (2005), Nath and Bhushan (2006), Panda et al. (2007), Murlee et al. (2008) and Gogi et al. (2009).

5.3. Components of variability

5.3.1. Coefficient of variation (PCV, GCV and ECV)

In general, estimates of phenotypic coefficient of variation (PCV) were higher than the corresponding estimates of genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) for all the 13 characters including biochemical traits and incidence of fruit fly studied and also comparatively narrow differences between the estimates of PCV and GCV for all the 21 traits indicated non-significant effect of environment on the expression of all these traits. These results were in accordance with those of other workers (Srivastava and Srivastava, 1976; Indiresh, 1982; Lingaiah et al., 1993; Thakur et al., 1994; Rajput et al., 1996; Bhave et al., 2003; Rajeswari and Natarajan, 2002; Kutty and Dharmatti, 2004 and Raj et al., 2007).

5.3.2. Heritability

Very high estimates of heritability in broad sense were observed for all the characters under study. But high heritability in broad sense alone was observed for days to first harvest and duration. Therefore, these two traits do

not guarantee large gain from selection unless sufficient genetic advance in present. These results were in accordance with Srivastava and Srivastava, 1976; Indiresh, 1982; Lingaiah et al., 1993; Thakur et al., 1994; Rajput et al., 1996; Rajeswari and Natarajan, 2002; Bhave et al., 2003 and Kutty and Dharmatti, 2004.

5.3.3. Genetic advance (% of mean)

High values of heritability in broad sense coupled with high genetic advance were recorded for all the characters except days to first harvest, duration and water content. These results were in accordance with those of Srivastava and Srivastava, 1976; Indiresh, 1982; Lingaiah et al., 1993; Thakur et al., 1994; Rajput et al. , 1996; Rajeswari and Natarajan, 2002; Bhave et al., 2003 and Kutty and Dharmatti,2004; and contradiction with that of Kutty and Dharmatti, 2004.

The highest heritability in broad sense (0.99) and genetic advance as percent of mean (179.11) were observed for yield per plant.

Knowledge of heritability coupled with expected genetic advance of a trait is necessary for assessing the scope of its improvement through selection. Genetic advance values indicated the genetic progress for a particular trait under a suitable selection system. Estimates of PCV and heritability determine the extent of genetic advance and the genetic advance, in turn, measures the extent of improvement under a certain level of selection process. So the results of the above traits offers scope for improvement through selection.

5.4. Correlation coefficient

The genotypic, phenotypic and environmental correlation coefficients among 21 characters were worked out in the present studies. (Table – 5, 6, 7).

Out of 13 significant phenotypic correlation coefficients of yield, 12 were positive and 1 was negative.

Yield per plant showed highly significant and positive phenotypic correlations with days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, girth and weight, duration, protein content, water content, flesh thickness and fruit fly infestation. Also it exhibited negative correlation with fruit colour and phenol content. But number of fruits per plant, total soluble solids, total sugars, reducing and non reducing sugars and fiber content did not exhibit significant correlation with other traits at phenotypic level.

Similar results were reported by Ramachandran and Gopalakrishnan, 1980; Indiresh, 1982; Thakur et al., 1994; Parhi et al., 1995; Paranjape and Rajput, 1995; Rajput et al., 1996; Singh et al.,1996; Bhave et al., 2003 and Sangeetakutty and Dharmatti, 2005.

Correlation between fruit fly infestation and biochemical traits revealed that highly significant and positive phenotypic correlations were observed for protein content and water content with fruit fly infestation. Similar results have been reported by Dhillon et al. (2005) for water content. But he reported contradictory result for protein content.

Of the several traits studied only phenol content had exhibited significant and negative correlation in all the three stages of fruit development with fruit fly infestation.

Dhillon et al. (2005) have also reported negative correlation of reducing and non reducing sugars and total sugars with fruit fly infestation. But contradictory to this no significant correlation was reported for reducing and non reducing sugars and total sugars with fruit fly infestation.

A breeding programme, directed towards improving many traits simultaneously, positive correlations among them would be considered as desirable. In the present study, traits namely days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, girth and weight, yield per plant, protein content and water content were significantly and positively related with yield per plant. These component characters were also positively and significantly associated among themselves. Hence selection for these characters would bring out an improvement of total yield per plant and incidence of fruit fly.

5.5. Path coefficient analysis

Path coefficient analysis was carried out taking yield per plant as dependent and selected characters viz. days to first male flower opening, days to first female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, incidence of fruit fly, protein content, water content, flesh thickness and phenol content as independent variables.

Highest direct and positive effect at genotypic level on yield per plant was exhibited by days to first male flower opening followed by individual fruit

weight and duration. This was in conformity with the findings of Xu and Huang (1995), Bhave et al. (2003) and Ram et al. (2006). Maximum positive and significant genotypic correlation coefficient between individual fruit weight and yield per plant was mainly due to its high and positive direct effect on yield.

Followed by individual fruit weight, other characters such as fruit length and fruit girth exhibited significant and positive correlation with yield per plant. This was attributed mainly due to high and positive indirect effect through days to first male flower opening, individual fruit weight and duration.

Incidence of fruit fly also had moderate direct effect which shows that as the infestation is high, the yield will be affected directly and also had indirect effect through biometric traits. Sangeetakutty and Dharmatti (2005) have reported that fruit fly infestation had low negative direct effect on yield but had high negative indirect effect through other characters.

Xu and Huang (1995); Bhave et al. (2003) and Ram et al. (2006) have reported that fruit weight, days to first male flower opening and duration had high direct effect on yield per plant. Major emphasis should be given on these characters while selecting for higher yield.

Positive indirect effect on yield per plant was also observed via. fruit weight, days to first male flower opening and duration.

The residual effect obtained was only 17.75%, which indicated that 82.25% of the variation in yield was mainly attributed by the characters selected for the study. Bhave et al. (2003) have reported based on their correlation and path analyses that selection for flowering duration, harvesting

span, fruit length, breadth and rind thickness, average fruit weight, number of fruits per plant, dry fruit weight, biological yield, dry matter per vine and harvest index could improve the yield of bitter gourd.

In the light of these results, while selecting for high yielding types, major emphasis should be given to fruit weight and duration with due consideration to characters exhibited positive indirect effect such as fruit weight, days to first male flower opening and duration.

Similar result was also obtained by Rajput et al. (1996).

5.6. D^2 Statistics

D^2 analysis was carried out to ascertain the nature and magnitude of genetic diversity to identify suitable donors having wider genetic distances. It is because genetically divergent parents are likely to produce heterotic effects and desirable segregants.

In the present study all the 29 genotypes were grouped into seven clusters. Among these cluster I had most of the commercially cultivated genotypes whereas cluster V and cluster VI had the fruit fly resistant genotypes.

Of the characters used for D^2 analysis maximum divergence was contributed for individual fruit weight. Moreover flesh thickness, duration, fruit girth and protein content were also significantly contributed to total divergence. Sundaram (2008) also reported maximum divergence for fruit weight.

The highest inter cluster D^2 values were observed between cluster I and VI and it was closely followed by cluster I and V which showed that

genotypes from these three clusters could be used as donors in hybridization programme to obtain wide spectrum of variation among the suitable segregants for high yield and fruit fly resistance. Because most of the cultivated genotypes were grouped into cluster I and fruit fly resistant genotypes were grouped into two monogenotypic clusters V and VI.

Based on the above results cluster I had high yielding genotype Kannakakunnu local and cluster V and VI had fruit fly resistant genotypes Madhurai local and Changanassery local – 1 respectively.

So the present study provides worthwhile information as the diverse clusters I, V and VI hold good promise for various breeding programmes thereby providing large variability for the traits used in the study.

5.7. Selection indices

In the present investigation, selection indices for various character combinations have been constructed using the characters days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, yield per plant, incidence of fruit fly, protein content, water content, flesh thickness and phenol content.

The grouping of genotypes by selection indices followed almost the same pattern as their clustering in D^2 analysis.

Kanakakunnu local had exhibited highest selection index followed by Priyanka. Kanakakunnu local had recorded maximum yield per plant (table-17).

At the same time Madhurai local had recorded the minimum value of selection index followed by IC-68250 and IC-68255. This indicates that improvement of the yield contributing traits on the genotype, Madhurai local is not a promising one. Even though the selection index for this genotype was low the resistance to fruit fly was maximum. Another genotype Changanassery local-1 had recorded higher yield than Madhurai local but the resistance to fruit fly was on par with Madhurai local.

Lawande and Patil (1989) concluded that to give higher yields the ideal plant should have heavier fruits, more fruits per vine and longer harvest duration.

Paranjape and Rajput (1995) had reported that early genotypes produced higher yield and hence selection for such genotypes is possible in bitter gourd for improvement.

5.8. Laboratory screening

Laboratory screening revealed that of the three developmental stages of fruits namely immature, half mature and full mature stages, fruits in the half mature stage were the least infested while fruits in the mature stage were highly infested with fruit fly. This may be due to the tenderness of the immature and full mature fruits than half mature stage. Less prominence of tubercles on the fruit surface during immature and full mature stages may attribute to the increased oviposition during these stages. Madhurai local and Changanassery local-1 had the least infestation in all the three stages. Priya and Kollam local showed on par values for infestation with the tolerant ones in half and full mature stages. Changanassery local-1 was having the lowest infestation of all.

Minimum number of ovipositional punctures were observed in Changanassery local-1, Madhurai local, Priya and Kollam local. The punctures were minimum in half mature stage and maximum in immature stage in the pooled analysis of stages.

Number of larvae per fruit was the lowest in Madhurai local in immature and half mature stages and the lowest in Kollam local in the full mature stage. In the three stages, immature fruits had the minimum larvae and full mature fruits had maximum number. Moreover moisture content showed a positive association with fruit fly infestation and larval density per fruit (Dhillon et al., 2005).

Fang and Chang (1987) reported that oviposition took place on the fruits at any stage of their development and the largest fruits were most heavily infested.

Moisture, potassium and reducing sugar content explained 97.4% of the total variation in the fruit infestation, while moisture, phosphorous, protein, reducing and non-reducing sugars explained 85.7% variation for larval density per fruit (Dhillon et al., 2005) .

From the observations, in general we can find that small fruited types like Changanassery local- 1 and Madhurai local had low percentage of fruit infestation, ovipositional punctures and number of larvae per fruit while common cultivated types had high values for all these observations.

In field, percentage of infestation was the lowest in Changanassery local –1 and Madhurai local.

According to the categorization of Nath (1966), genotypes Madhurai local and Changanassery local-1 were categorized as moderately resistant under field screening and highly resistant under laboratory screening. Hence these two genotypes can be selected for further breeding programme.

In the light of the present study, Kanakakunnu local was observed to have highest individual fruit weight and yield per plant and it was closely followed by Priyanka. However, these two genotypes were significantly different for the above traits. The genotypes Madhurai local and Changanassery local -1 recorded the lowest fruit fly infestation where as CL-Coimbatore and high yielding genotype Kanakakunnu local recorded the highest fruit fly infestation.

Wild bitter gourd accessions can be used as a source of resistance to melon fruit fly, *Bactrocera cucurbitae* breeding programme (Dhillon et al., 2005).

In the present study we can utilize the above small fruited genotypes as potent donors in an appropriate breeding programme for improving fruit yield and quality character like resistance to fruit fly in bitter gourd.

Plate 8 : Kanakakunnu local

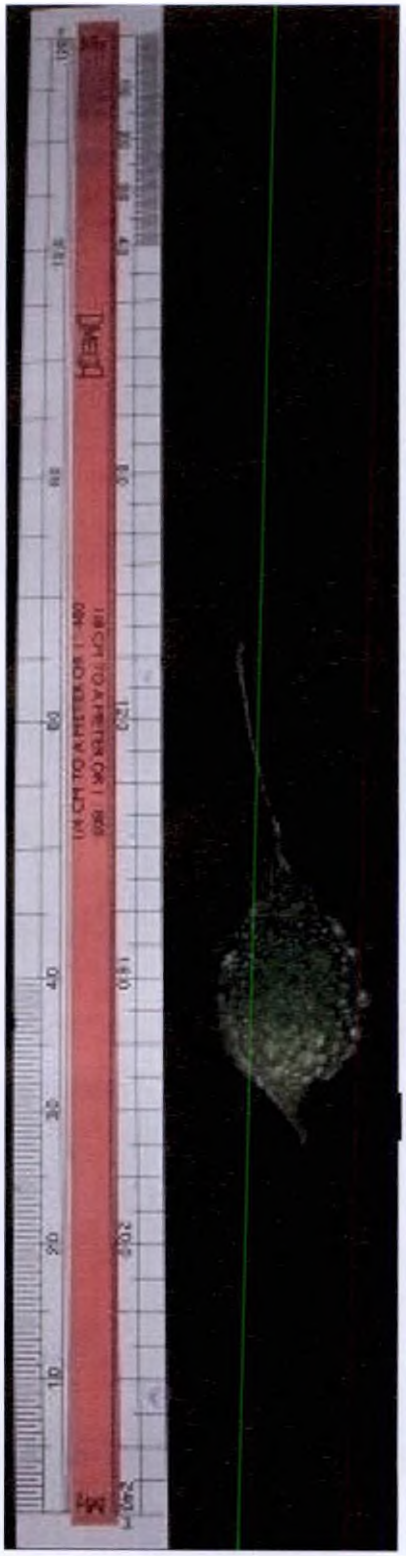


Plate 9 : Changanassery local 1

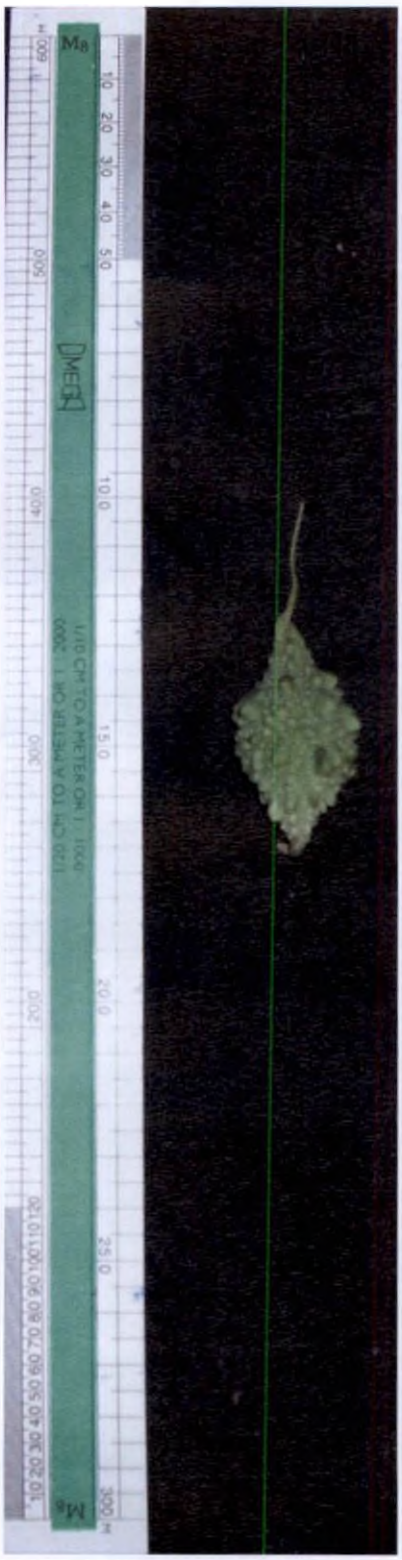
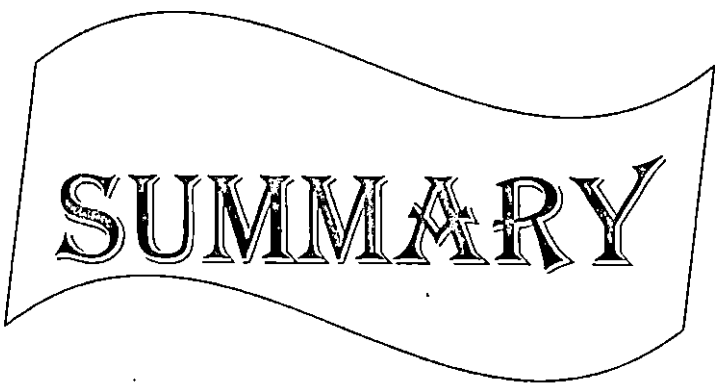


Plate 10 : Madhurai local


SUMMARY

6. Summary

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period 2009-2010 to assess the genetic variability for different yield attributes and resistance to fruit fly in bitter gourd and to identify high yielding genotypes tolerant to fruit fly. To attain these objectives field and laboratory experiments were conducted simultaneously. 29 genotypes procured from NBPGR, KAU, NSC and farmers of different regions of Kerala were raised in RBD with three replications in field. Simultaneously artificial screening of fruits of 29 genotypes was carried out in the Laboratory of Department of Agricultural Entomology. Screening was conducted in CRD with 4 replications.

The salient findings are summarized below.

- Of the 29 genotypes evaluated, IC-45341 was the early flowering and bearing type. Madhurai local was the genotype having maximum number of fruits per plant, minimum incidence of fruit fly and short duration. Priya and Bharanikkavu local had maximum fruit length and girth respectively. Kanakakunnu local had maximum fruit weight and yield per plant. Kallukuthiavila local was the long duration genotype. Priyanka had maximum protein content. Changanassery local -1 had maximum TSS, fruit colour (chlorophyll content) and phenol content. IC- 68296 had maximum total sugars, reducing and non reducing sugars.
- Analysis of variance revealed significant genotypic differences for all the characters included in the present study.
- The PCV and GCV were high for yield per plant, individual fruit weight, number of fruits per plant, fruit length, fruit girth, protein content, total sugars, reducing and non reducing sugars, fruit colour (chlorophyll content), crude fiber content, phenol content and

incidence of fruit fly indicating scope for improvement of these characters through selection.

- Very high estimates of heritability in broad sense coupled with high genetic advance were recorded for all the characters except days to first harvest, duration and water content indicating the scope for genetic improvement through selection.
- Significant positive correlations were obtained for yield with days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, flesh thickness, incidence of fruit fly, protein content and water content indicating that selection of these characters would bring out an improvement in total yield per plant.
- Significant negative correlations were obtained for incidence of fruit fly with phenol content and number of fruits per plant which suggest that selection of genotypes based on these characters would improve the fruit fly resistance in bitter gourd.
- Path coefficient analysis revealed positive and direct effect of days to first male flower opening, individual fruit weight and duration on yield per plant, emphasizing the importance of selection for these characters for improvement on yield per plant. All the remaining characters involved in the path coefficient analysis had significant and indirect effect on yield per plant through these three characters.
- In the D^2 statistics, 29 genotypes were grouped into 7 clusters
- High yielding genotype Kanakakunnu local was grouped into cluster I where as fruit fly resistant genotypes Madhurai local and Changanassery local – 1 were grouped into cluster V and VI respectively. This emphasizes scope for further improvement by selecting donor parents from these clusters.

- Of all the traits studied, individual fruit weight contributed maximum to total divergence followed by flesh thickness, duration, fruit girth and protein content.
- Selection indices revealed that Kanakakunnu local had maximum index value and Madhurai local had minimum index value.
- Laboratory screening for fruit fly resistance revealed mature fruit development stage as most susceptible one for infestation.
- Changanassery local-1 and Madhurai local had minimum level of fruit fly infestation. CL-Coimbatore had maximum level of infestation followed by Kanakakunnu local.
- Kanakakunnu local, Changanassery local-1 and Madhurai local were identified as potent donors for appropriate breeding program for improving fruit yield and quality character like resistance to fruit fly.
- As per the techniques and rating system of Nath (1966), minimum percentage of fruit damage was in Madhurai local and Changanassery local-1, under both natural screening and artificial screening. So these two genotypes were rated as resistant/highly resistant genotypes against fruit fly infestation.
- In the light of the present study the high yielding genotype Kanakakunnu local and fruit fly resistant genotypes Madhurai local and Changanassery local-1 were identified as potent donors for improving fruit yield and quality character like resistance to fruit fly in future breeding programme.

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GENETIC VARIABILITY STUDIES FOR YIELD AND FRUIT FLY RESISTANCE IN BITTER GOURD (*Momordica charantia* L)

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Abstract

A study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture ,Vellayani during the period 2009-2010 to assess the genetic variability for different yield attributes and resistance to fruit fly in bitter gourd and to identify high yielding genotypes tolerant to fruit fly. To attain these objectives field and laboratory experiments were carried out simultaneously.

Of the 29 genotypes evaluated IC-45341 was the early flowering and bearing type. Madhurai local was the genotype having maximum number of fruits per plant. Priya and Bharanikkavu local had maximum fruit length and girth respectively. Kanakakunnu local had maximum fruit weight and yield per plant. Kallukuthiavila local and Madhurai local were the long duration and short duration genotypes respectively. Priyanka had maximum protein content. Changanassery local -1 had maximum TSS, fruit colour and phenol content. IC- 68296 had maximum total sugars, reducing and non reducing sugars. Madhurai local had minimum incidence of fruit fly.

Analysis of variance revealed significant differences for all the characters. Genotypic and phenotypic coefficients of variation were high for yield per plant, individual fruit weight, number of fruits per plant, fruit length, fruit girth, protein content, total sugars, reducing sugars, non reducing sugars, fruit colour, crude fibre content, phenol content and incidence of fruit fly. High heritability coupled with high genetic advance were noticed for all characters except days to first harvest, duration and water content which had high heritability and low genetic advance.

Correlation studies revealed that out of the 13 significant phenotypic correlation coefficients of yield, twelve were positive and one was negative. Significant and positive correlations were obtained for yield with days to first male and female flower opening, days to first harvest, fruit bearing period, fruit length, fruit girth, individual fruit weight, duration, flesh thickness, incidence of fruit fly, protein content and water content. Significant negative correlations were obtained for incidence of fruit fly with phenol

content and number of fruits per plant. Protein content, water content, phenol content and flesh thickness of immature, half mature and full mature fruits had significant correlation with incidence of fruit fly. Path coefficient analysis revealed high direct and positive effects of days to first male flower opening, fruit weight and duration on yield.

D^2 analysis grouped the 29 genotypes into seven clusters. Individual fruit weight contributed maximum to total divergence followed by flesh thickness, duration, fruit girth and protein content. High yielding genotype, Kanakakunnu local, was grouped into cluster I where as fruit fly resistant genotypes Madhurai local and Changanassery local – 1 were grouped into cluster V and VI respectively. This emphasizes scope for further improvement by selecting donor parents from these clusters. Selection indices revealed that Kanakakunnu local had maximum index value and Madhurai local had minimum index value.

Kanakakunnu local, Changanassery local-1 and Madhurai local were identified as potent donors for appropriate breeding program for improving fruit yield and quality character like resistance to fruit fly. As per the techniques and rating system of Nath (1966) the percentage of fruit damage was minimum in Madhurai local and Changanassery local-1 under both natural screening and artificial screening. So these two genotypes were rated as resistant/highly resistant genotypes.