GENETIC ANALYSIS OF SEGREGATING GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO FRUIT AND SHOOT BORER (*Earias vittella* Fab.) IN BHINDI (*Abelmoschus* spp.)

By

DIVYA BALAKRISHNAN

THESIS

Submitted in partial fulfilment of the requirement for the degree of

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Faculty of Agriculture
Kerala Agricultural University, Thrissur

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE
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KERALA, INDIA

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DECLARATION

I, **DIVYA BALAKRISHNAN** hereby declare that the thesis entitled "**GENETIC ANALYSIS OF SEGREGATING GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO FRUIT AND SHOOT BORER** (*Earias vittella* Fab.) **IN BHINDI** (*Abelmoschus* spp.)" is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or society.

18/10/08

Place: Vellanikkara **(DIVYA BALAKRISHNAN)**

Date: 18.10.2008

CERTIFICATE

Certified that the thesis entitled "**GENETIC ANALYSIS OF SEGREGATING GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO FRUIT AND SHOOT BORER** (*Earias vittella* Fab.) **IN BHINDI** (*Abelmoschus* spp.)" is a bonafide record of research work done independently by Smt. **DIVYA BALAKRISHNAN** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

18/10/2008

Place: Vellanikkara

Date: 18.10.2008

(Dr. E. SREENIVASAN)
Chairman, Advisory Committee
Associate Professor
Dept. of Plant Breeding & Genetics
College of Horticulture
Vellanikkara

CERTIFICATE

We, the undersigned members of the Advisory Committee of Smt. **DIVYA BALAKRISHNAN**, a candidate for the degree of Master of Science in Agriculture with major in Plant Breeding and Genetics, agree that the thesis entitled "**GENETIC ANALYSIS OF SEGREGATING GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO FRUIT AND SHOOT BORER** (*Earias vittella* Fab.) **IN BHINDI** (*Abelmoschus* spp.)" may be submitted by Smt. **DIVYA BALAKRISHNAN**, in partial fulfilment of the requirement for the degree.

18/10/2008

Dr. E. SREENIVASAN
Chairman, Advisory Committee
Associate Professor
Department of Plant Breeding and Genetics
College of Horticulture, KAU Vellanikkara

18/10/08

Dr. V.V. RADHAKRISHNAN
(Member, Advisory Committee)
Professor and Head
Dept. of Plant Breeding & Genetics
College of Horticulture, KAU
Vellanikkara

18/10/08

DR. SURESH BABU K.V
(Member, Advisory Committee)
Professor,
Department of Olericulture,
College of Horticulture, KAU
Vellanikkara

18/10/08

Dr. R. SUJATHA
(Member, Advisory Committee)
Assistant Professor
Dept. of Plant Breeding & Genetics
College of Horticulture, KAU
Vellanikkara

18/10/08

EXTERNAL EXAMINER
(S. MANONMANI)

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-: In the lotus feet of Lord Krishna:-

Dedicated to my

Parents, Brother and beloved Sreej

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INTRODUCTION

1. INTRODUCTION

Bhindi, *Abelmoschus esculentus* (L.) Moench (syn. Okra, bhendi, lady's finger and gumbo) is an important warm season vegetable crop grown for its tender pods in tropical and sub tropical regions. It is also cultivated in the warmer parts of temperate regions and having a wide acceptability around the world. Attention has been given for growing the crop at greenhouses in protected condition during recent years.

Okra is valued for its immature fruits and are used as vegetable. It is a nutritive vegetable with rich source of calcium, iron, vitamin A and fibre content. It also posses medicinal qualities like diuretic properties. The processed products like dehydrated pods, canned and frozen forms are used for preservation. It is a potential export earner and provides high returns to farmers. Okra seeds form a nutritious ingredient of cattle feed and is a source of vegetable oil. The oil is edible and has a pleasant taste and odour, and it is abuntant in unsaturated fat such as oleic and linoleic acid. Okra genotypes with colourful flowers are grown as ornamental plants. *Abelmoschus esculentus* is one of the most heat and drought tolerant vegetable species in the world.

India is a major producer of okra in the world with an annual production of 32 lakh tonnes (NHB, 2005). Incidence of pest and diseases is the most serious production constraint faced by the farmers all over the world. Among the pests of okra, the shoot and fruit borer (*Earias* species) is the major pest causing high yield reduction. The larvae of the pest bore into the growing shoot, flower buds, flowers and fruits of okra, either killing the plant or causing heavy shedding of fruits (Bairwa *et al.*, 2005). The fruits become distorted and they are rendered unfit for human consumption as well as for the procurement of seeds. This results in drastic decrease (37 – 76%) in yield. So far, no cultivar is known to be resistant to this pest. Thus to evolve or identify a new resistant variety is of paramount importance.

In India, both from public and private sector many okra varieties have been released so far, but most of the released varieties are observed to be susceptible to fruit and shoot borer (*Earias vittella).* The conventional plant protection measures using chemicals for the control of this pest is undesirable from the point of view of residual effects and health hazards, as the tender pods are used for consumption. The regular pesticide usage will results in the development of resistance in insects, resurgence and environmental pollution (Suneetha *et al.,* 2007). Because of these factors an emphasis is always being given to develop insect resistant varieties of Bhindi, in a country like India where a considerable area is under cultivation with this crop.

Though, breeding for shoot and fruit borer resistance in okra has been identified as one of the priority areas of research, intensive efforts in this direction are lacking (Sidhu, 1998). Genetic improvement in okra especially with focus on fruit and shoot borer resistance has been conducted only to a very limited extent in India. Karuppaiyan (2006) screened 144 okra germplasm lines of Indian and exotic origin for shoot and fruit borer resistance and reported a number of resistant and moderately resistant genotypes. In the present study these genotypes were used as donors of resistance to develop high yielding resistant varieties. The present research programme on "Genetic analysis for yield attributes and resistance to shoot and fruit borer (*Earias vitella* Fab.) in Bhindi (*Abelmoschus* spp.)" become relevant on this context and hence this study was taken up with following objectives:

1. To study the nature of gene action governing fruit and shoot borer resistance and yield attributes.
2. To identify the resistant genotypes with desirable yield attributes.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

A detailed review of earlier works related to present study entitled "Genetic analysis of segregating generations for yield attributes and resistance to fruit and shoot borer (*Earias vittella* Fab) in bhindi (*Abelmoschus* spp.)" are discussed in this section.

2.1 VARIABILITY AND GENETIC DIVERSITY IN OKRA

Variation is the basic requirement on any selection programme, aimed at improving some desirable traits like yield and resistance. An understanding of precise magnitude of variability present in a population with respect to these attributes is important in formulating the most appropriate breeding techniques for population improvement.

In case of okra, India has been considered as one of the important centre of diversity and Africa is considered to be the primary centre of origin. Okra belongs to the genus *Abelmoschus* of family Malvaceae. *Abelmoschus esculentus* is the major cultivated species along with a number of semi domesticated and wild species like *Abelmoschus angulosus, Abelmoschus crinitus, Abelmoschus ficulneus, Abelmoschus manihot, Abelmoschus moschatus, Abelmoschus tetraphyllus,* and *Abelmoschus tuberculatus.* Among the cultivated species *Abelmoschus esculentus* and the semi domesticated species *Abelmoschus caillei* were considered in this research work and a review of their genetic diversity is given below.

2.1.1 Variability and genetic diversity in the species *Abelmoschus esculentus*

The extent of variability for 29 characters in 296 okra accessions collected from 15 countries was studied by Chheda and Fatokun (1982). The accessions were divided into 10 groups of three major agronomic types. Girenko and Pugachev (1983) analyzed 300 genotypes from 32 countries for 18 morpho-metric traits. The accessions were grouped into 13 clusters. They noticed that the morphological differences among Indian and North American varieties were lesser, but the differences were more among genotypes from Africa, suggesting that okra originated in that continent. Bisht *et al.* (1995) conducted an experiment with 260 okra accessions collected from India, Bangladesh, Nepal and Sri Lanka for 18 morphological characters including shoot and fruit borer resistance. The accessions were divided into eight clusters. Characters like days to flowering, plant height and fruit characters were the important components of variability.

Deo *et al.* (1996) reported high GCV and PCV for pod yield, number of pods, plant height and number of branches per plant. They observed that selection based on number of pods per plant, length of pod and plant height helps to evolve high yielding genotypes. Joshi (2004) conducted a study on variability components of okra and estimated that almost all the characters are highly heritable and they are easily amenable to selection. Chandra *et al.* (2004) studied the genetics of yield and yield traits and revealed that number of pods per plant, pod yield and pod weight showed high GCV and PCV.

2.1.2 Variability and genetic diversity in the species *Abelmoschus caillei*

This is a semi-wild or partially-domesticated species, cultivated in West Africa for its fruits, seeds and leaves (Martin, 1982b). This entity was named as *Abelmoschus caillei* in 1988 (Hamon *et al.,* 1991). The erstwhile Plant Introduction Division of the ICAR (Now NBPGR) introduced this species (Accession No EC 31830 or 'Asumtemkoko') into India from Ghana in late seventies. Later this was found to be a source of resistant to yellow vein mosaic virus (YVMV) and hence supplied to major okra research centers (Thomas *et al.,* 1990).

Studies on parameters of variability in *Abelmoschus caillei* revealed that characters such as number of branches per plant, number of nodes per plant, plant height and fruit length had maximum coefficient of variation (Reena *et al.*, 1999). Using *Abelmoschus caillei* accessions, studies were conducted on four directions such as i) assessment and creation of variability for agronomic and quality traits

(Thambi and Indira, 2000); ii) improvement through selection as exemplified from the release of Susthira (Gopalakrishnan, 2004); iii) cytogenetic studies (Sheela, 1994); and iv) gene transfer from *Abelmoschus caillei* to *Abelmoschus esculentus* (Arumugam *et al.,* 1975; Kousalya *et al.*, 2006).

Ariyo (1993) studied 30 accessions of *Abelmoschus caillei* for 25 qualitative and quantitative traits. The extent of variability for pigmentation on various parts, fruit shape, fruit colour, number of pods per plant, pod weight and number of seeds per pod were reported to be high. Velayudhan *et al.* (1996) reported its cultivation in the homesteads of Kerala.

Chacko *et al.* (1998) reported high GCV, PCV and heritability for number of fruits and fruit yield per plant. On the basis of D^2 analysis, 22 genotypes of *Abelmoschus caillei* were grouped into three clusters. Kehinde and Adeniji (2003) pointed out that the response to genetic improvement would be rapid in *Abelmoschus caillei* as this species exhibited high variability for agronomic traits. An investigation involving 101 accessions of okra by Sindhumole *et al.* (2006) observed high GCV, PCV, heritability and genetic advance for the characters like yield and yield attributes.

2. 2 THE SHOOT AND FRUIT BORER OF OKRA

The shoot and fruit borer infesting okra and cotton belongs to the genus *Earias* (Noctuidae: Lepidoptera). Under this genus five species namely, *E. vittella* Fabricius, *E. insulana* Boisduval, *E. biplaga* Sehans, *E. cupreoviridis* Walker and *E. huegeli* have been described (Reed, 1994). Among these, *E. vittella* and *E. insulana* are predominant species in Asia, while *E. vittella* is more common in India (Lal, 1991). Naresh *et al.* (2004) conducted a study on the biology of shoot and fruit borer and found that it is having high fecundity with a life cycle averaged 24.8 days, which is high enough to cause severe damage to the crop. It is the most serious pest of okra and the caterpillars of the pest not only bore the pods but also attack the shoots, buds and flowers (Mohapatra, 2007). The extent of infestation in okra caused by shoot and fruit borers in different parts of India was compiled and presented in Table 2.1.

Table 2.1 Shoot and fruit borer infestation in okra

Year	Reference	Distribution	%FI	% SI
1976	Krishnaiah *et al.*	Delhi	49.00 74.00	
1980	Krishnaiah	Karnataka	36.00	
1981	Radke and Undirwade	Maharashtra	88.00- 100.00	
1984	Dhamdhere *et al.*	Madhya Pradesh	25.93(RS♣) 40.91(SS)	5.50(RS) 23.90(SS)
1985	Dhandapani	Tamil Nadu	30.47	
1986	Prasad *et al.*	Andhra Pradesh	58.00	
1988	Kumar and Urs	Madhya Pradesh	12.00 - 46.70	2.00- 5.00
1989	Kumar	Kerala	27.50	
1989	Chaudhary and Dadheech	Rajasthan	54.04*	
1994	Singh and Brar	Punjab	32.06- 40.84*	
1997	Shukla *et al.*	Madhya Pradesh	41.20	8.5
1999	Ghosh *et al.*	West Bengal	30.81*	
2000	Suryawanshi *et al.*	Maharashtra	50.77*	
2000	Das *et al.*	West Bengal	44.26	
2003	Pareek and Bhargava	Rajasthan	52.33 - 70.75	
2006	Karuppaiyan	Kerala	56.58	36.58

* Estimated yield loss due to combined infestation by sucking pests and fruit borer

♣ RS-Rainy season; SS-Summer season

2.2.1 The Extent of Damage Caused By Shoot and Fruit Borer

In okra pest control, resistant varieties have been deployed as an ecofriendly pest management tool conferring resistance to insect pests compared to several conventional insecticides. The requirement for production of resistant varieties had arisen considering the most damaging pest namely fruit and shoot borer in bhindi. The yield potential of okra (*Abelmoschus esculentus*) is hardly realized because of regular pest infestation. After flowering fruit borer damages the healthy fruit by boring, rendering the fruit unfit for consumption and reduces the marketability by 76% (Dhawan and Sidhu, 1984).

Combined infestation of sucking pest and fruit borer caused 45.0 to 46.2 per cent reduction in leaf number, 49.8 to 74.1 per cent reduction in plant height, 50.77 to 67.7 per cent reduction in fruit yield, 70.15 per cent reduction in seed yield (Rawat and Sahu, 1973; Suryawanshi *et al.,* 2000). Dhawan and Sidhu (1984) reported damage of flower buds to the extent of 52.4 per cent. The estimated fruit loss in okra due to *Earias* was 0.76 t/ha in Gwalior (Dhamdhere *et al.,* 1984), 2.66 t/ha in Karnataka (Srinivasan and Krishnakumar, 1983) and 7.33 t/ha in Jabalpur (Rawat and Sahu, 1973).

Sahoo and Pal (2003) studied the effect of use of pesticide on shoot and fruit borer of okra. About 13 -14 % of total pesticides used in the country are consumed in vegetable crops and the produce harvested at short intervals is consumed fresh in many cases. Frequent pesticide sprays resulted in high level of pesticide residues (Awasthi and Ahuja, 1997; Agnihotri, 1999; Sardana *et al.*, 2005) and reported that chemical control of the pest is very difficult as it needs alternate use of different pesticides in high dozes and repeated spraying are required to reduce the damage and cause more environmental pollution. In a screening study conducted by Neeraja *et al.* (2004) reported that the fruit borer incidence ranged from 21.7 percent to 27.6 in number of okra hybrids from private and public sector.

2.3 RESISTANCE IN OKRA TO SHOOT AND FRUIT BORER

The reviews related to shoot and fruit borer resistance in okra are listed in the Table 2.2 under the headings, resistance in germplasm lines, resistance in commercial varieties, resistance in F_1 hybrids and advanced breeding lines, and resistance in wild and semi-wild okra.

Table 2.2 Resistance in okra to shoot and fruit borer

Sl. no.	year	Reference	no. of genotypes in the study	resistance			
				varieties	%SI	varieties	%FI
2.3.1 Resistance in germplasm lines							
1	1961	Srinivasan and Narayanaswamy	18 okra genotypes	Red I, Red II, Red wonder I Red wonder II	3.5		
2	1977	Nawale and Sonone	14 germplasm	AE 22 ,AE 52 ,Wonderful Pink	11- 15		
3	1978	Gupta andYadav	60 germplasm	Kalyanpur Bonia, Accession Nos. 5325, 6327, 6701, 6901, 6903, 6904, 6908 and 7117	<15		
4	1979	Raut and Sonone	21 genotypes	AE 22, 57 ,Wonderful pink	20.1	AE 71	19.21
5	1983	Kashyap and Verma	68 germplasm	Bhindi 6 Dhari, All Season 2, Sel 2, Faizabadi Green, IC 6497, IC 12930, IC 12938	high MFY	Selection Round	<15
6	1989	Bhalla *et al*	1000 accessions NBPGR	50 accessions moderately resistant	6- 15		
7	1990	Thomas *et al*					
8	1989	Sharma and Dhankhar		Long green smooth, All Season I , Sel 2-2	<14.4		
9	1991	Kumbhar *et al.*	40 lines	AE 79, AE 69 and AE 22			
2.3.2 Resistance in commercial varieties							
10	1966	Shehata	Four commercial varieties	less damage in early flowering varieties.			

11	1985	Madav and Dumbre	resistance varied from season to season	Pusa Sawani, Long Green, Koparwadi Local, White Velvet			
12	1985	Mahadevan and Dhandapani		Arka Anamika, Bhindi 6 Dhari, Gujarat Okra 1, Kamadhenu, P-7 Wonderful Pink			
13	1988	Gupta					
14	1989	Sardana and Dutta					
15	1991	Vyas and Patel					
16	1993	Raj *et al*					
17	1996	Khambete and Desai					
18	1999	Ghosh *et al*					
2.3.3 Resistance in F_1 hybrids and advanced breeding lines							
19	1981	Teli and Dalaya	21 varieties	AE 22, 52, 69, 79 ,Sel 1-1 x AE 79	9 to 20	AE 22, 52, 69	22-31
20	1983	Kishore *et al*	44 lines	HB 22 and HB 53			
21	1998	Shukla *et al.*	seven F_1 hybrids	AROH 2 and Komal	4 to 5	Ankur 35 and Parbhani Kranti	7.5 and 8.0
22	2001	Srinivasa and Sugeetha	seven okra varieties	Arka Anamika, Arka Abhay, KS 410, Line 1999, Parbhani Kranti, Pusa Sawani and Varsha Upahar	all susceptible		
23	2004	Neeraja *et al.*		hybrids were equally damaged by fruit borer as that of varieties			
24	2005	Bairwa *et. al.*					
2.3.4 Resistance in wild and semi-wild okra							
25	1983	Kashyap and Verma		*A. caillei*	11.1		

2.3.4 Resistance in wild and semi-wild okra

Very few studies have been conducted on the response of wild species of *Abelmoschus* to shoot and fruit borer. Bisht *et al.* (1997) grouped *Abelmoschus tuberculatus* in 'less susceptible' category based on three point visual score. The extent of shoot or fruit infestation was not quantified by the above workers. Raut and Sonone (1979) estimated 7.5 per cent shoot damage and 51.4 per cent fruit damage in *Abelmoschus tetraphyllus*. Chelliah and Srinivasan (1983) reported that *Abelmoschus manihot* was resistant to shoot borer. Kashyap and Verma (1983) reported *Abelmoschus ficulneus* was susceptible to fruit borer (21 per cent) but *Abelmoschus caillei* was moderately resistant to fruit borer (11.1 per cent).

2.4 CROSSABILITY AMONG *Abelmoschus* spp.

Review of available literature (Table 2.2) indicates that a few *Abelmoschus esculentus* varieties and *Abelmoschus caillei genotypes* are identified to be resistant to shoot borer but information on transfer of shoot and fruit borer resistance gene from these species to other cultivated okra is limited. The review of literature about effective gene transfer through conventional breeding, and earlier studies about crossability are discussed below:-

2.4.1 Crossability between *Abelmoschus esculentus* (2n =130) and *Abelmoschus caillei* (2n =92, 194)

Hybridization between *Abelmoschus esculentus* and *Abelmoschus caillei* was reported first by Arumugam *et al.* (1975) and subsequently by Thakur (1976), Dhilllon and Sharma (1982), Siemonsma (1982), Martin (1982a), Sharma and Dhillon (1983), Sharma and Sharma (1984), Hamon and Yapo (1986) and Fatokun (1987). In all the above reports, hybridization was effected to transfer YVMV resistance gene from *Abelmoschus caillei* to *Abelmoschus esculentus*. The reports revealed that it was easy to obtain F_1 plants. But the F_1 were mostly sterile. Pod set in the F_1 ranged from 0 to 72 per cent while seeds per pod were reduced (0 to 28 seeds / pod). The seeds produced by F_1 plants were empty. However, backcrossing helped to restore fertility. Therefore, gene transfer from *Abelmoschus caillei* to *Abelmoschus esculentus,* though difficult, appears to be feasible (Karuppaiyan, 2006). The African variety Winter Bush (Martin, 1982a) and Indian variety Punjab Padmini (Sharma and Sharma, 1984) are the product of *Abelmoschus esculentus* x *Abelmoschus caillei* cross.

2.5 COMBINING ABILITY STUDIES

Combining ability of the genotypes is becoming increasingly important in plant breeding especially for exploitation of heterosis. It is useful in studies and comparisons of performance of lines in hybrid combination. Information on the gca and sca will be helpful in the analysis and interpretation of the genetic basis of important traits. Many biometrical procedures have been developed to obtain information on combining ability. Diallel analysis is one among them which is widely used to study the combining ability of the parents to be chosen for heterosis breeding.

Sivagamasundari *et al.* (1992a) reported that gca and sca variances were significant in case of fruit weight and fruit length from the combining ability studies conducted by them. Rajani *et al.* (2001) estimated the combining ability of six genetically divergent parental strains of *Abelmoschus esculentus* and their 30 F_2 hybrids. The numerical and graphical analysis indicated over dominance for all most all characters except incidence of shoot and fruit borer for which complete dominance was seen. The Vr-Wr graph also indicated the presence of epistasis for weight of fruits per plant, number of seeds per fruits, fruiting phase & height of plant.

Suresh Babu *et al.* (1994) evaluated F1 hybrids of okra for various quantitative traits and estimated high heterosis in case of number of fruits and fruit yield.

Ravishankar (2002) crossed fifteen lines with two testers in a line x tester mating design and obtained 30 hybrids. Based on the per se performance and gca effect the genotypes AE264, AE214 and AE190 were identified as best combiners. They reported that significant variances due to gca, sca and reciprocal effects were obtained in case of fruit weight, fruit length and plant height number of branches etc.

Thirugunakumar *et al.*, 2004 conducted study with 6x6 complete diallel analysis and found that the component of variation due to additive gene effects were important for most of the quantitative traits studied in okra. Heterosis was studied in okra through 6x8 diallel analysis and the degree of heterosis was higher for yield per plant, fruit length, internodal length, leaf area and yield per plant (Boragaonkar *et.al*, 2005).

A line x tester analysis in okra carried out with six lines and three testers to estimate combining ability and variances indicated the preponderance of non additive gene action for all the characters (Senthil kumar *et al.*, 2006). A number of studies on combining ability for yield and yield attributes are available. Brief information on gene action, parents with good *gca* and cross combinations with high *sca* for yield and yield contributing traits are presented in Table 2.3.

Table 2.3 Nature of gene action, parents with good *gca* and hybrids with high *sca* for yield and yield attributes in okra

Year	**Reference**	**No. of parents & mating design**	**Nature of gene action**	**Parents with high *gca* effects**	**Hybrid with high *sca* effects**
1.Days to flowering					
1978	Sharma and Mahajan	16 x 4 LT*	NA	Pusa Makhmali	Dwarf Green x Pusa Sawani
1980	Partap and Dhankhar	7 x 7 DA	A & NA	IC 6653	IC 12930 x Dwarf Green Smooth

1986a	Vijay and Manohar	10 x 10 DA	A	Pusa Sawani	Pusa Sawani x Clemson Spineless
1989	Shukla *et al.*	15 x 4 LT	NA	Parbhani Kranti	IC 12205 x Parbhani Kranti
1990	Jawili and Rasco	6 x 6 DA	A	86-40	-
1991	Chaudhary *et al.*	5 x 3 LT	NA	Pusa Sawani	Sel 6-2 x Parbhani Kranti
1992	Mandal and Das	8 x 8 DA	A & NA	Sel 4	Parbhani Kranti x Sel 10
1994	Chavadhal and Malkhandale	9 x 9 DA	A	Parbhani Kranti	Parbhani Kranti x TRO
1995	Sivakumar *et al.*	4 x 4 DA	A & NA	AE 129	P 7 x AE 129
1995	Wankhade *et al.*	12 x 12 DA	NA	Vaishali Vadhu	IC 12934 x Punjab Padmini
2001	Sood and Kalia	8 x 8 DA	A	IC 9856	P 7 x Arka Abhay
2001	Singh *et al.*	15 x 15 DA	NA	7310	6305 x 6308
2003	Mitra and Das	10 x 10 DA	NA	Ankur 40	Parbhani Kranti x Indam 9821
2003a	Rani and Arora	8 x 8 DA	NA	P 8	HRB 9-2 x VB 9101
2004	Saeed *et al.*	6 x 6 DA	A	Green Velvet	No. 8 x Green Velvet
2005	Kumar *et al.*	6 x 6 DA	NA	Azad bhindi 1	Azad bhindi 2 x Azad bhindi1
2. Plant height					
1976	Kulkarni	6 x 6 DA	NA	AE 107	Sevendhari x Dwarf Green
1978	Sharma and Mahajan	16 x 4 LT	NA	Verma's Jewel	American 7 dhari x Pusa Sawani
1979	Singh and Singh	10 x 2 LT	NA	6313	7107 x 6313
1990	Jawili and Rasco	6 x 6 DA	A	Smooth Green	-
1991	Chaudhary *et al.*	5 x 3 LT	NA	Pusa Sawani	Sel 2 x P 7
1992	Mandal and Das	8 x 8 DA	A & NA	Parbhani Kranti	Parbhani Kranti x Sel 10
1994	Chavadhal and Malkhandale	9 x 9 DA	NA	*Abelmoschus ficulneus, Abelmoschus manihot*	*Abelmoschus ficulneus* x *Abelmoschus manihot*
1995	Sivakumar *et al.*	4 x 4 DA	A	P 7	P 7 x AE 129
1996	Singh *et al.*	8 x 8 DA	NA	Punjab Padmini	P 7 x P 5
2001	Dhankhar and Dhankhar	20 x 4 LT	NA	MR 15	MR 12 x Raj 12

2001	Singh *et al.*	15 x 15 DA	NA	7310, 6313	6305 x 6308
2001	Rajani *et.al.*	6x6 DA	A & NA	NBPGR/TCR 861	NBPGR/TCR 893 x NBPGR/TCR 864
2003	Mitra and Das	10 x 10 DA	A	Ankur 40	Indam 9821 x Ankur 40
2003a	Rani and Arora	8 x 8 DA	NA	P 8	VRO 03 x KS 404
2005	Kumar *et al.*	6 x 6 DA	NA	Parbhani Kranti	Azad bhindi 2 x Parbhani Kranti
3. Number of fruits per plant					
1978	Sharma and Mahajan	16 x 4 LT	NA	Pusa Sawani	Pusa Sawani x Smooth Long Green
1980	Partap and Dhankhar	7 x 7 HD	A & NA	Sel 2	IC 12930 x Pusa Sawani
1991	Chaudhary *et al.*	5 x 3 LT	NA	Pusa Makhmali	Pusa Sawani x P 7
1994	Chavadhal and Malkhandale	9 x 9 DA	NA	*Abelmoschusficulneus, Abelmoschus tetraphyllus*	Parbhani Kranti x *Abelmoschus ficulneus*
1995	Sivakumar *et al.*	4 x 4 DA	NA	P 7	P 7 x AE 129
1995	Wankhade *et al.*	12 x 12 DA	NA	Local Akola	IC 18960 x Local Akola
2001	Dhankhar and Dhankhar	20 x 4 LT	NA	MR 15	MR 10-1 x Varsha Upahar
2001	Singh *et al.*	15 x 15 DA	NA	7310	6305 x 6308
2002	Indurani *et al.*	7 x 7 DA	NA	Varsha Upahar	MF 3 x Varsha Upahar
2003a	Rani and Arora	8 x 8 DA	NA	P 8, Punjab Padmini	VRO 03 x KS 404
2005	Kumar *et al.*	6 x 6 DA	NA	Azad bhindi 1	Azad bhindi 2 x Azad bhindi 1
2005	Senthil kumar *et.al*	4 x 4 DA	A	Parbhani kranti	Arka Abhay xPunjab Padmini
2005	Panda and Singh	4 x 2 LT	A&NA	Pusa Sawani	BO1X Arka Anamika
4.Single fruit weight					
1978	Sharma and Mahajan	16 x 4 LT	NA	Crimson Spineless	Okra Red x Smooth Long Green
1980	Partap and Dhankhar	7 x 7 HD	NA	IC 12930 & Narnaul Colln	
1991	Chaudhary *et al.*	5 x 3 LT	NA	Pusa Makhmali	Sel 6-2 x Parbhani Kranti

1994	Chavadhal and Malkhandale	9 x 9 DA	NA	Sel 2-2, Pusa Sawani	Sel 2-2 x *Abelmoschus ficulneus*
1995	Sivakumar *et al.*	4 x 4 DA	A & NA		EMS 8 x AE 129
2002	Indurani *et al.*	7 x 7 DA	NA	Varsha Upahar	MF 3 x OHD 1
2003a	Rani and Arora	8 x 8 DA	NA		Pusa Makhmali x P 8
5. Fruit yield					
1978	Sharma and Mahajan	16 x 4 LT	NA	Pusa Sawani	Pusa Sawani x Smooth Long Green
1979	Singh and Singh	10 x 2 LT	A	KB, 6302	7107 x 6313
1980	Partap and Dhankhar	7 x 7 HD	A	Sel 2	Dwarf Green Smooth x Sel 2
1981a	Elangovan *et al.*	14 x 4 LT	NA	AE 1068, AE 180	-
1986a	Vijay and Manohar	10 x 10 DA	A	Pusa Sawani	Pusa Sawani x Clemson Spineless
1989	Shukla *et al.*	15 x 4 LT	NA	KS 301 & 310	IC 12205 x Parbhani Kranti
1990	Jawili and Rasco	6 x 6 DA	A	Smooth Green	Smooth Green x 86-40
1991	Chaudhary *et al.*	5 x 3 LT	NA	Punjab Padmini	Pusa Sawani x P 7
1991a	Veeraraghavathatham and Irulappan	7 x 7 D	NA	AE 974	AE 824 x AE 180
1992	Mandal and Das	8 x 8 DA	A & NA	Pusa Sawani	Punjab Padmini x Sel 10
1992a	Sivagamasundhari *et al.*	6 x 6 DA	NA	Arka Abhay	Arka Abhay x Arka Anamika
1993	Arora	10 x 10 DA	A & NA	Foam Barelley	Pusa Sawani x Vaishali Vadhu
1995	Vasaline and Ganesan	10 x 5 LT	A & NA	AE 110, AE 118	Pusa Sawani x CO 2
1994	Chavadhal and Malkhandale	9 x 9 DA	A	*Abelmoschus ficulneus*, KO	Pusa Sawani x KO
1994	Patel *et al.*	10 x 10 DA	NA	Gujarat Okra	-
1995	Shinde *et al.*	8 x 8 DA	NA	No. 168, Japan	Japan x Parbhani Tillu
1995	Sivakumar *et al.*	4 x 4 DA	A & NA	Punjab 7	P 7 x AE 129
1995	Wankhade *et al.*	12 x 12 DA	NA	Vaishali Vadhu	Vaishali Vadhu x Local Akola

1996	Singh *et al.*	8 x 8 DA	NA	Punjab Padmini	Punjab Padmini x P 7
1998	Pathak *et al.*	6 x 3 LT	NA	Arka Abhay	IC 9275 x HB 55
2001	Singh *et al.*	15 x 15 DA	NA	7310 & 6313	6305 x 6308
2001	Sood and Kalia	8 x 8 DA	A	Parbhani Kranti	P 7 x Arka Abhay
2002	Indurani *et al.*	7 x 7 DA	NA	Varsha Upahar	MF 3 x Varsha Upahar Varsha Upahar x Arka Anamika
2002	Prakash *et al.*	7 x 3 LT	NA	Pusa Makhmali	Punjab Padmini x Pusa Makhmali
2003	Mitra and Das	10 x 10 DA	A	Ankur 40	Parbhani Kranti x Indam 9821
2003a	Rani and Arora	8 x 8 DA	NA	P 8, HRB 9-2	Pusa Makhmali x P 8 VRO 03 x KS 404
2004	Saeed *et al.*	6 x 6 DA	A	Parbhani Kranti, Green Velvet	No. 8 x Green Velvet
2005	Kumar *et al.*	6 x 6 DA	NA	Azad bhindi 1	Azad bhindi 2 x Azad bhindi 1
2006	Karuppaiyan	6 x 6 DA	NA	Arka Anamika	KL9x Arka Anamika
6.Shoot and fruit borer resistance					
2006	Karuppaiyan	6 x 6 DA	NA	AC 5	KL9x AC 5

DA - to diallel mating, LT - to Line x Tester, A- Additive, NA- Non additive gene action

2.6 STUDIES ON HETEROSIS

Varying levels of heterosis over mid parent and better parent has been reported in okra for number of characters. In okra, hybrid vigour over mid parent was reported first by Vijayaraghavan and Warrier (1946), later by Venkatramani (1952), Joshi *et al.* (1959), Raman and Ramu (1963) and Jalani and Graham (1973). Shukla *et al.* (1989) and Singh and Singh (1979) have reported heterosis for yield in okra ranging from 27.32- 71.84 percentage. Elmaksoud *et al.* (1986) reported that exploitation of heterosis has been attempted and hybrid vigour has been identified with as much as 86% increased yield in okra.

Patel *et al.* (1994) have reported that heterosis for lowest number of seeds over better parents ranged from 40.78 to 16.21 percentage. The hybrids synthesized by the above workers (*eg.* H 398 x Pusa Sawani, H 398 x Pusa Makhmali, Malaysian Local 5 x Emerald, Local 7 x Gold Coast) manifested earliness, tallness, high fruit weight, high fruit number and high yield (Peter, 1998). Singh and Syamal (2006) crossed twelve promising varieties of diverse origin and crossed in all possible combinations to study the extent of heterosis. They have reported heterosis of 53.28 percentage for number of pods and 54.54 percentage for yield per plant.

There is a high potential for exploitation of hybrid vigour in okra due to the ease in emasculation, high fruit set and high number of seeds per pods. At present, some of the private seed companies, ICAR institutes and State Agricultural Universities have their own proprietary F_1 hybrids. The relative heterosis for fruit yield ranged was from 0.03 to 68.03 per cent. However, this wide range of heterosis may not be of practical use unless heterosis is expressed in comparison with better parent (*i.e.* heterobeltiosis) or with check variety (*i.e.* standard heterosis). Therefore, heterobeltiosis and standard heterosis reported by the various workers for yield and yield attributes are summarized in Table 2.4.

Table 2.4 Promising F_1 hybrids reported in okra for yield and yield attributes

Year	**Reference**	**Outstanding heterotic crosses**	**Mean**	**d_i %***	**d_{iii} %**
1. Days to first flowering					
1975	Singh *et al.*	7107 x KB	48.83	-1.02	
1977	Kulkarni and Virupakshappa	Dwarf green x AE 107	43.64	-4.37	-3.46
1979	Singh and Singh	6319 x KT1	51.33	-9.95	
1981b	Elangovan *et al.*	AE 711 x AE106	49.65		-5.31
1986b	Vijay and Manohar	Pusa Sawani x Sel 6-1	46.30	-13.06	
1990	Shukla and Gautam	AE 100 x Pusa Sawani	41.30		-8.70

d_i-heterobeltiosis d_{iii}- standard heterosis

1993	Mandal and Dana	EMS 8 x Punjab Padmini		-	
2004	Singh *et al.*	Sel 4 x Parbhani Kranti		-9.63	
2004	Surendirakumar *et al.*	TCR 2056 x Mohanur local			67.10
2. Plant height (cm)					
1977	Kulkarni and Virupakshappa	Sevandhari x AE 107	83.67	19.19	19.19
1979	Singh and Singh	7106 x 6313	99.33	28.16	
1981b	Elangovan *et al.*	AE 800 x AE 142	116.68		20.35
1984	Maksoud *et al.*	Balady x Gold Coast	112.5	43.87	
1993	Mandal and Dana	Sel 10 x Punjab Padmini		-	
2004	Singh *et al.*	VRO 04 x VRO 05		59.69	
3. Number of fruits per plant					
1975	Singh *et al.*	6302 x FC	27.96		13.52
1977	Kulkarni and Virupakshappa	Sevendhari x AE 107	13.50	4.65	4.65
1979	Singh and Singh	7114 x 6313	29.61	71.46	
1981b	Elangovan *et al.*	AE 1068 x AE 100	24.12		19.90
1990	Shukla and Gautam	KS 310 x Pusa Sawani	25.20		31.20
1992b	Sivagamasundhari *et al.*	Arka Abhay x Arka Anamika			11.75
1993	Mandal and Dana	Sel 10 x Punjab Padmini		-	
1994	Babu *et al.*	F_1-1A (Ankur seeds)	21.30		83.60
1997	More and Patil	Vaishali Vadhu x AE 1	-	24.33	
1999	Sood	P7 x Arka Abhay	16.20	1.84	59.8
2004	Singh *et al.*	No 315 x IIVR 10	19.60	81.23	
2004	Surendirakumar *et al.*	TCR 2056 x Mohanur local	-	67.00	8.67

4 Fruit yield per plant (g)					
1975	Singh *et al.*	7170 x FC	321.16		32.71
1979	Singh and Singh	7114 x Pusa Sawani	304.72	70.28	-
1981b	Elangovan *et al.*	AE 1068 x AE 180	-	31.42	-
1986b	Vijay and Manohar	Pusa Sawani x Clemson Spineless	365.20	64.93	
1990	Shukla and Gautam	KS 310 x Pusa Sawani	491.60		44.1
1991b	Veeraragavathatham and Irulappan	AE 974 x AE 180	317 .00		
1992b	Sivagamasundhari *et al.*	Arka Abhay x Arka Anamika		24.51	-
1993	Kumbhani *et al.*	Padra 18-6 x KS 312	341.00		
1994	Babu *et al.*	F_1-1A (Ankur seeds)	573.90	134.6	
1995	Poshiya and Vashi	New Selection X AE 91	420.62	27.77	
1996	Singh *et al.*	Pusa Makhmali x Parbhani Kranti			103.20
1997	More and Patil	Vaishali vadhu x Sel 6-2	321.05	28.94	
1997	Wankhade *et al.*	Vaishali Vadhu x Local Akola	386.52		
2001	Sood and Sharma	P7 x Arka Abhay	293.00	68.00	80.00
2003b	Rani and Arora	Pusa Makhmali x VRO 03	162.49	276.76	
2004	Singh *et al.*	No 315 x IIVR 10		67.57	

d_i-heterobeltiosis d_{iii}- standard heterosis

2.7 CORRELATION AND PATH COEFFICIENT ANALYSIS

Information regarding association of characters like earliness, quality, yield and its component characters is very useful for plant breeder in developing a commercial variety or hybrid. Many of these characters are inter related in desirable and undesirable direction. Correlation study measures the natural relationship between various characters and helps in determining the component characters on which selection can be based for improvement in yield.

Jaiprakashnarayanan and Ravindra, (2004) carried out correlation and path analysis in 69 okra genotypes using growth, earliness and yield traits. The results indicated the negative relationship between growth and earliness characters but significant association between growth and yield characters. Akinyele and Osekita (2006) reported that seed yield per plant showed significant positive correlation with number of pods per plant, height etc.

Path coefficient analysis revealed that number of pods per plant, pod weight and height had the highest direct effect on yield. Singh *et al.*, (2007) conducted an investigation to assess genetic variability, association of different characters and to study the path coefficient analysis for yield improvement in okra. They reported that fruit yield in okra could be improved by selecting for more number of fruits, branches per plant and short internodal length.

2.8 GENERATION MEAN ANALYSIS

The knowledge of gene action controlling the traits related to yield is desirable, before undertaking yield improvement for the effective planning of breeding programme.

2.8.1 Gene action for fruit borer resistance

Ghai *et al.* (1990) studied percentage fruit damage (by *Heliothis armigera*) in two parents (Punjab Padmini and Pusa Sawani) and their F_1 advanced to 21 generations reported that resistance was not an outcome of simple additive dominance or digenic interactions but of more complexities and higher order gene interactions like trigenic might be involved. Generation mean analysis of five crosses of west African okra (*Abelmoschus caillei)* was conducted by Adeniji *et al.*

(2007). They reported that additive gene effects were contributed to seed yield and 100 seed weight.

2.8.2 Gene action for fruit yield in inter varietal crosses of *Abelmoschus esculentus*

Randhawa (1989) and Jawili and Rasco (1990) reported that additive gene effects were higher in relation to dominance for fruit weight, fruits per plant, plant height and yield per plant. According to Randhawa (1989) three parameter model was adequate to explain the variation for days to first flowering, plant height and fruit weight but inadequate for number of fruits and fruit yield. He suggested simple selection during early generation to develop high yielding varieties. Other workers have reported non-additive gene action for yield and yield contributing traits in okra (Partap and Dhankhar, 1980; Veeraragavathatham and Irulappan, 1991b; Indurani *et al.* 2002).

Panda and Singh (2001) attributed additive gene effects for pod number, dominance effect and additive x additive effects for pod yield. Korla and Sharma (1987) reported the prevalence of epistasis for fruit yield in Vaishali Vadhu x EC 68475, Sel 6-2 x EC 68475 and Pusa Sawani x EC 68475. Rajani and Manju (1999) reported over dominance for fruit yield. Tripathi *et al.* (2002) reported the prevalence of duplicate type of epistasis for all economic traits in AG-26 x Pb-8.

Senthilkumar *et al.* (2005) reported that days to first flowering, number of nodes, plant height, single fruit weight, fruit length and fruit weight in the cross Arka Anamika x Punjab Padmini were predominantly controlled by dominance x dominance interaction. However, fruit yield per plant in the cross Punjab Padmini x Parbhani Kranti was predominantly determined by additive gene action.

Kumar *et al.* (2005). studied six okra generations derived from Arka anamika x Punjab Padmini and Punjab Padmini x Parbhani kranti and found that fruit weight, fruit length, plant height were mainly controlled by dominance gene effects and these effects can be exploited through heterosis breeding. Panda and Singh, (2007) undertaken genetical studies in okra and the higher magnitude of additive genetic variance assessed consistently for almost all the characters under study.

2.8.3 Gene action for fruit yield in *Abelmoschus esculentus* x *Abelmoschus caillei* crosses

Arumugam and Muthukrishnan (1979) estimated gene effects through five parameter model in the cross Co-1 x *Abelmoschus caillei* and Pusa Sawani x *Abelmoschus caillei* (African & Japanese source). Complementary gene action for plant height and duplicate gene action for days to flowering were reported. In an another study involving parents, F_1, F_2, BC_1 and BC_2 generations of cross Pusa Sawani x *Abelmoschus caillei* var. Ghana, Reshmi x *Abelmoschus caillei* var. *Ghana*, Dhillon and Sharma (1982) observed dominance for days to flowering, internode length and resistance to the YVMV. Kehinde and Adeniji (2003) reported that in *Abelmoschus caillei, sca* variance was greater than the *gca* variance for pod yield due to non-additive gene action.

2.9 BASIS OF RESISTANCE IN OKRA TO SHOOT AND FRUIT BORER

2.9.1 Biochemical basis of resistance

Biochemical constituents in different parts of okra fruits namely epicarp, fruit axil, seeds and whole fruit was found to affect the development behaviour and reproductive potential of shoot and fruit borer resistance (Vishwapremi and Krishna, 1974; Singh, 1987). The reproductive potential of *E. vittella* on the epicarp and fruit axil was found to be poor due to less number of free amino acids and lower concentration of soluble protein as compared to seeds (Mani *et al.,* 1986). Singh (1987) reported that primary phytochemicals like protein, free amino acids, total sugars, and non-reducing sugars were positively correlated with survival of *Earias vittella* but expressed optimism that these chemicals could not be definitely attributed to host resistance due to non-significant correlation. However, tannin content in okra fruits was reported to have negative correlation (r = -0.46 to- 0.81) with larval survival.

Thus the above review reveals the need of production of the shoot and fruit borer resistant varieties

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present research work for the thesis study entitled "Genetic analysis of segregating generations for yield attributes and resistance to fruit and shoot borer (*Earias vittella* Fab.) in bhindi (*Abelmoschus* spp.)" was conducted at the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara from 2006 to 2008.

The whole research work was grouped into four experiments and were conducted: (i) to effect crosses between resistant and high yielding parent, to get F_1s in all possible combinations (ii) to raise F_1s to develop F_2 and back cross progenies (BC_1 and BC_2) (iii) to Raise the F_2 generations of selected crosses along with check variety in RBD with suitable replications for evaluating F_2s against shoot and fruit borer and (iv) to evaluate six generation materials (Parents, F_1, F_2, BC_1 and BC_2) against shoot and fruit borer and other yield attributes. Field trials were laid out at the experimental plots of the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara. The area is located at latitude of 10°31' N, longitude of 76°30' E and an elevation of 22.2 m above MSL. Details of individual experiments are given below;

3.1 EXPERIMENT NO. 1: HYBRIDISATION

3.1.1 Materials

The materials for the present study consist of three high yielding varieties and three resistant genotypes (Table 3.1) of okra germplasm representing four cultivated species *Abelmoschus esculentus* and two semi-domesticated species *Abelmoschus caillei,* (Plate.1) which were selected based on the screening studies conducted by Karuppaiyan, 2006. The materials were obtained from National

i. Arka anamika

ii. AC 5

iii. KL 9

iv. Salkeerthy

v. Sel 2

vi. Susthira

Salkeerthy, Sel2, KL9, Susthira Arka Anamika, AC5

Plate 1. Parents used in the study

Bureau of Plant Genetic Resources and Department of Olericulture, College Of Horticulture, Kerala Agricultural University.

Table 3.1 List of *Abelmoschus* accessions used in the study

High yielding genotypes			Resistant genotypes		
1	Arka Anamika	*Abelmoschus esculentus*	4	KL-9 (IC 45818)	*Abelmoschus esculentus*
2	Salkeerthy	*Abelmoschus esculentus*	5	SEL 2	*Abelmoschus esculentus*
3	Susthira	*Abelmoschus caillei*	6	AC-5 (EC 305760)	*Abelmoschus caillei*

3.1.2 Methodology

The experiment was conducted using the shoot and fruit borer resistant genotypes identified in earlier studies conducted at KAU and were raised along with high yielding varieties and were crossed to get fruit and shoot borer resistant high yielding F_1s. The crossing was done in a 6 x 6 full diallel mating design involving four genotypes in the species *A. esculentus* and two genotypes from *A. caillei* as detailed in Table 3.1.

Flowers are solitary and they appear on leaf axils and the flower bud takes about 22-26 days from initiation to anthesis. The time of anthesis ranges from 8 a.m to 10 a.m depending on the cultivar and temperature. The dehision of anthers occurs 15-20 minutes after anthesis and it extends for 5-10 hours. The flowers remain open for a short term and they wither late in the afternoon. The stigma is receptive at the time of anthesis. For the purpose of crossing, the mature flower buds that are expected to be open on next day are emasculated on the previous day using the hood

i.

ii.

iii.

iv.

v.

vi.

Plate. 2 Emasculation of female flowers

method (Plate.2). A circular incision is made about two by third from top of the corolla using a sharp blade without disturbing the staminar column. The cut portion of the corolla tube is lifted up carefully in the form of hood. All the anthers are scraped off using scalpel. The corolla hood is kept back and the emasculated flower bud is protected using butter paper cover. Pollination is done on the next day morning between 8a.m to 10 a.m. Mature pollen is collected from the male parent using a small brush and smeared on the stigma of the emasculated flower of the female parent and tagging is done (Plate.3). Selfing is done by covering the matured unopened flower bud with butter paper covers and tagging is done with labels.

The parents were raised from February 2007 to May 2007 in pots in the green house to avoid pest attack and get maximum seeds for further generation (Plate.4). Cultural and manuarial practices were done as per Package of practices recommendations of the Kerala Agricultural University (KAU, 2007). The present study was undertaken with a view to assess the combining ability of six genotypes of okra in diallel analysis.

The six parents were crossed in diallel fashion and 27 hybrids were developed successfully. Since three F_1's of interspecific cross *i.e. A. esculentus* x *A. caillei* did not set seeds on crossing as shown in fig 4.2 so that three of the F_1s could not be advanced to next generation. The data generated were utilized to estimate the combining ability as suggested by Griffing (1956).

3.1.3 Observations Recorded From Field Experiments

The observations on yield, yield attributes, flowering characters and fruit and shoot borer incidence were recorded for experiment no. II, III, and IV. Observations taken on the following characters;

3.1.3.1 Qualitative data

The qualitative characters were recorded on the basis of the scale given in Table 3.2

i.

ii.

iii.

iv.

v.

vi.

Plate .3 Pollination of female flowers for hybridisation

Table 3.2 Scale for the classification of qualitative characters

Sl. No.	Character	Score
I. Vegetative character		
1	Growth habit	1-Erect 2-Medium 3-Procumbent
2	Stem pubescence	1-Glabrous 2-Slight 3-Conspicuous
3	Leaf colour	1-Green 2- Dark green 3-Green leaf with light red veins 4-Green leaf with deep red veins 5-Purple blotched
4	Petiole colour	1-Green 2-Green with purple 3-Purple 4-Rose
5	Internodal length	1-Congested (<5cm) 2-Short(5-10cm) 3-Medium(10-15cm) 4-Long(>15cm)
II. Fruit characters		
6	Fruit colour	1-Pale white 2-Light green 3-Green 4-Dark green 5-Yellowish green 6-Red 7- Green with purple striation 8- Purple
7	Fruit ridges	1-Non-ridged 2- Five ridges 3- > Five ridges
8	Fruit pubescence	1- Downy 2- Slight 3- Rough 4- Prickly
9	Fruit quality score	Score 1 to 3: Non consumable Score 3-5: Consumable but low quality Score Score 6-7: Medium Score 8-9: Good quality

3.1.3.2 Quantitative data

Yield and yield contributing characters

a) **Days to first flowering:** Duration between sowing and first flower opening was expressed in days.

b) **Plant height:** Measured from soil level to the tip of the plant at the time of final harvest and expressed in centimetre.

c) **Number of leaves:** Number of well formed leaves remaining in the plant between 65 and 75 days after sowing was counted.

d) **Number of internode**: Total internode in the main stem was counted.

e) **Internode length:** Three measurements at top, middle and bottom of a plant at final harvest were made and the average was expressed in centimeter.

f) **Fruit yield:** Tender pods were harvested at seven days intervals from the plants of two replications leaving two replications of each treatment for seed purpose; pods were sorted, counted and weighed. Tender to dry pod weight conversion ratio was calculated. It was used to estimate weight of tender pods from dry pod weight which were kept for seed production. To derive fruit yield per plant, cumulative fruit weight from all harvest were divided by the number of plants in a replication and expressed in gram.

g) **Number of fruits:** The cumulative figure from all harvests was divided by the number of plants and expressed in per plant basis.

h) **Average fruit weight:** Arrived from total fruit weights and fruit number.

i) **Fruit length**: Measured at the time of harvest and expressed in centimeter.

j) **Fruit girth:** Measured at the time of harvest and at the point of maximum bulging expressed in centimeter.

Plate 4. Experiment No. I

Plate 5. Experiment No. II

3.2 EXPERIMENT NO.2: EVALUATION OF F_1

3.2.1 Experiment Materials and methodology:

The materials included in this trial were F_1s obtained from experiment No.1. twenty seven F_1s were raised along with their parents in pots in green house with three replications for each treatment. The materials were raised at the farm under Dept. of Plant Breeding and Genetics during June 2007 to November 2007 (Plate.5). All cultural . operations were carried out as per the package of practices recommendations of KAU, 2007. No seed germination was there in two of the inter specific crosses with AC5 as the female parent as shown in Fig. 4.3.

Biometrical observations were recorded from three randomly selected plants from each replication. All the crosses were selfed as well as back crossed to their female parents (referred as BC_1) and male parents (BC_2) to generate F_2 and backcross generations, respectively and methodology followed as in the experiment No. I.

3.2.2 Observations Recorded From Field Experiments

In addition to the observations on qualitative and quantitative data as recorded in the experiment No. I, observations were also recorded on the following aspects:-

Shoot damage: Number of shoots damaged by *Earias* spp. was counted from all the plants in a replication and the percent shoot infestation (SI) was calculated as given below.

$$\text{Shoot infestation (\%)} = \frac{\text{Number of plants with damaged shoots per genotype}}{\text{Total number of plants per genotype}} \times 100$$

Fruit damage: Percent fruit infestation (FI) on number basis was calculated based on infestation data recorded.

$$\text{Fruit infestation (\%)} = \frac{\text{Number of damaged fruits per genotype}}{\text{Total number of fruits per genotype}} \times 100$$

Marketable fruit yield: Weight of healthy fruit divided by total fruit (healthy + damaged) weight and expressed in grams as well as in percentage.

$$\text{Marketable fruit yield (g)} = \frac{\text{Weight of healthy fruits per plant}}{\text{Weight of healthy + damaged fruits per plant}}$$

3.3 EXPERIMENT NO.3: EVALUATION OF F_2

3.3.1 Experiment Materials and Methodology

Selfed seeds of the selected crosses of F_1 were sown on 7.12.2007 in open field condition. Fifteen F_2s were selected on the basis of their F_1 performance and the performance of their parents in earlier studies and they are raised along with check variety Salkeerthy following a spacing of 50x 40 cm (Plate.6). The treatments were raised in randomized block design (RBD) replicated thrice with 15 plants in each replication. The crop is grown in ridges and furrow system. Recommended package of practices of KAU was followed to grow a successful crop of okra. The crop was left open for natural infestation by fruit and shoot borer and no pesticides were sprayed. Fruit borer susceptible variety Salkeerthy was raised in border rows.

Observations were recorded from three randomly selected plants from each replication, on nine qualitative traits *viz.*, growth habit, stem pubescence, stem colour, leaf colour, petiole colour, fruit colour, fruit ridges, fruit pubescence and fruit quality. Similarly observations on quantitative traits as listed in experiment No. I and II were also recorded

3.3.2 Observations Recorded From Field Experiments

In addition to the observations on qualitative and quantitative data as recorded in the experiment No.I and No.II observations were also recorded on the following aspects:-

Rating shoot and fruit infestation in resistance scale

The relative degree of resistance to shoot and fruit borer infestation was judged on the basis of percentage shoot and fruit infestation in each genotype. The classification suggested by Kumbhar *et al.* (1991) was adopted in the present study.

Table 3.3 Resistance scale based on intensity of infestation

Sl.No	**Resistance category**	**Shoot infestation**	**Fruit infestation** (number basis)
1	Immune	0 %	0 %
2	Highly resistant	1-10.99 %	1-10.99 %
3	Moderately resistant	11-20.99 %	11-20.99 %
4	Susceptible	21-30.99 %	21-30.99 %
5	Highly susceptible	>31 %	>31 %

Incidence of Yellow Vein Mosaic Virus (YVMV)

The number of plants infected by YVMV was counted and the percent disease index (PDI) was worked out as shown below.

$$\text{Per cent Disease index} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

Incidence of Powdery Mildew

The number of plants infected by Powdery mildew was counted and the percent disease index (PDI) was worked out as shown below.

$$\text{Per cent Disease index} = \frac{\text{Number of infected plants}}{\text{Total number of plants observed}} \times 100$$

3.4 EXPERIMENT NO.4: GENERATION MEAN ANALYSIS

3.4.1 Experiment Materials and Methodology

Two crosses namely, the inter-specific cross *A. esculentus* cv. Sel 2 x *A. caillei* cv. AC 5 and the inter varietal (*A. esculentus*) cross KL 9 x Salkeerthy, as well as their six generations (P_1, P_2, F_1, F_2, BC_1 and BC_2) were raised in RBD with four replications during December 2007(Plate.7). The biometrical data obtained were subjected to generation mean analysis by six parameter model as suggested by Hayman and Mather (1955). The susceptible variety Salkeerthy was grown along the borders for enhancing fruit and shoot borer infestation. All cultural operations were carried out as per the package of practice recommendations of KAU 2007. In each block single rows of parents F_1, F_2, BC_1 and BC_2s were raised and at a spacing of 60 x 40 cm. Pesticides were not sprayed in the plot and the crop was left for natural infestation. Observations were recorded as in the experiment No. I and No. II

3.5 STATISTICAL ANALYSIS OF DATA

There are basically four applications of biometrical techniques in plant breeding and genetics, namely., i) to assess the variability ii) to select elite genotypes, iii) to identify suitable parents and breeding procedures and iv) to assess varietal adaptation (Singh and Narayanan, 2006).

In the present study first three applications were utilized. Measures of dispersion and components of genetic variances were studied to assess the variation. Correlation and Path analysis was done to select elite genotypes. Diallel cross is done to analyse several single crosses in first filial generation and generation mean analysis was done to study individual crosses for the purpose of identification of breeding procedures and choice of parents.

Plate 6. Experiment No. III

Plate 7. Experiment No. IV

3.5.1 Analysis of variance and estimation of co-efficient of variation

Data on quantitative characters were analyzed for variances and significance of treatments. The genotypic co-efficient of variation (GCV) and phenotypic co-efficient of variation (PCV) were estimated as per Singh and Chaudhary (1985).

$$\text{Phenotypic coefficient of variation} = \frac{\sqrt{\text{Phenotypic variance}}}{\text{Mean of the character under study}} \times 100$$

$$\text{Genotypic coefficient of variation} = \frac{\sqrt{\text{Genotypic variance}}}{\text{Mean of the character under study}} \times 100$$

The estimates of PCV and GCV were classified as,

less than 10 per cent = low

10 –20 percent = moderate

more than 20 percent = high

3.5.2 Heritability

Heritability in the broad sense was calculated according to the formula suggested by Johanson *et al.* (1955).

$$\text{Heritability} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

The heritability was categorised as,

60 – 100 per cent = high

30 – 60 percent = moderate

Less than 30 percent = low

3.5.3 Genetic advance

The expected genetic advance under selection was estimated by the formula suggested by Johanson *et al.* (1955).

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

Vg = genotypic variance

Vp = phenotypic variance

K = Selection differential at 5% level (2.06)

3.5.4 Genetic gain

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

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

Genetic gain was categorised as

More than 20 per cent = high

10-20 per cent = moderate

Less than 10 percent = low

3.5.5 Combining ability

The data recorded from 5 x 5 diallel crosses was analysed for *gca* and *sca* effects and variance following Method I and Model I of Griffing's approach (1956). Variance components such as additive variance (σ^2A), dominance variance (σ^2D) and environmental variance (σ^2e) were estimated as per Sharma (1998). Combining ability studies were conducted to evaluate the genetic value of inbreds, to identify superior cross combinations and to assess the gene action involved in the expression of various quantitative characters.

i) ***Combining ability through Griffing's approach***

a. General combining ability

b. Specific combining ability

The significance of gca, sca and reciprocal effects are also tested

ii) ***Estimate of additive and dominance components through Hayman's numerical approach***

E - The expected environmental component of variation

D - Variation due to additive effect

H_1 - Components of variation due to the dominance effect of the genes

F - The mean of 'Fr' over the arrays

H_2 - Proportion of positive & negative genes in the parents

$H_2 / 4H_1$ - Proportion of positive (increasing) & negative (decreasing) genes among the common parents of arrays

D/R - Proportion of Dominant and Recessive Genes in the Parents

MDD - Mean degree of dominance

Hn - Heritability in narrow-sense

Vp - Variance of parents

Vr - Variance over the arrays

Wr - Covariance between parents and offsprings over the arrays

If $H_2 / 4H_1 = 0.25$ indicates symmetrical distribution of genes, deviation from this value shows asymmetrical distribution. If D/R is equals to unity means it shows symmetrical distribution and deviation from this value shows asymmetrical distribution of genes.

If MDD = 1 – Complete dominance,

< 1 – Partial dominance,

>1 – Over Dominance

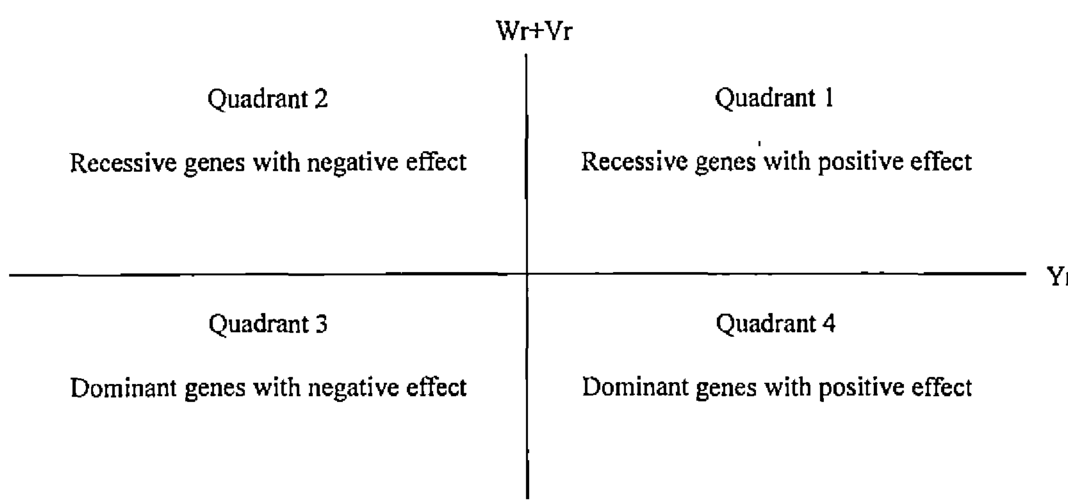
iii) ***Vr – Wr graph: Graphical analysis of diallel crosses as suggested by Hayman (1954)***

The Vr – Wr graph was drawn using a regression relation ship between Wr and Vr. If the regression line passes through the origin (i.e. a =0), it can be taken as an indication of complete dominance. But if it passes above the origin (i.e. a >0), it can be an indication of partial dominance, while the line passing below the origin (i.e. a <0) indicates the presence of over dominance.

iv) ***Standardised deviation graphs***

Standardised deviation graphs were plotted for each character with standardised values of Wr + Vr on Y axis and those of Yr (mean of the common parent array) on X axis in order to determine the type of genes possessed by the parents (Fig.3.1).

Fig.3.1 Position of genes in the Standardised deviation graph



3.5.6 Heterosis and inbreeding depression

Standard heterosis and inbreeding depression were computed and their significance was tested using standard error (Singh and Narayanan, 2006). Different types of heterosis namely, heterorobeltiosis (in relation to better parent value, BP) and standard heterosis (in relation to standard parent value, SP) were estimated for all the characters recorded in the F_1 generation and their significance tested.

$$\text{Heterobeltiosis} = \frac{F_1 - BP}{BP} \times 100$$

$$\text{Standard heterosis} = \frac{F_1 - SP}{SP} \times 100$$

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

F_1	=	Mean F_1 value for the character
BP	=	Mean Better Parent value for the character
SP	=	Mean Standard Parent value for the character
MP	=	Mean Mid Parent value for the character

3.5.7 Genotypic correlation and Path analysis

To assess the association between shoot and fruit borer resistance with other quantitative traits, genotypic correlation was worked out as per Singh and Chaudhary (1985). It also gives information about relationship between a pair of variables and the direction of their relationship. Direct and indirect effects of yield attributes on yield through path analysis were also done.

3.5.8 Generation mean analysis

The generation mean analysis were done using six generations *viz.*, P_1, P_2, F_1, F_2, B_1 and B_2 of the crosses Sel 2 x AC 5 and KL 9 x Salkeerthy. A scaling test of

Hayman and Mather (1955) was applied to detect the presence of epistasis. The estimates of mean (m), additive gene effects (d) and dominant gene effects (h) were calculated through three parameter model (additive dominance model) of Jinks and Jones (1958). If epistasis was present, digenic non-allelic interaction model was resorted and six parameters namely, m, d, h, i, j and l were estimated as per Hayman (1958). A joint scaling test was also carried out to test the adequacy of three or six parameter model.

3.6 BIOCHEMICAL ANALYSIS

Analysis of fruit samples were conducted to understand the biochemical basis of resistance in okra to shoot and fruit borer, The samples from resistant and susceptible lines used in the study were analysed for phenol and tannin content. Total phenol as per Malick and Singh (1980) and tannin by Folin-Denis method (Burns, 1971) were estimated. The dried samples of fruits and shoots of *A. esculentus* and *A. caillei* were taken and used for biochemical analysis. Total phenol estimation was carried out with Folin-Ciocalteau reagent. Phenols react with phosphomolybdic acid in Folin- Ciocalteau reagent in alkaline medium and produce blue coloured complex. The absorbance was measured at 650 nm using a spectrophotometer. From the standard curve prepared using different concentrations of catechol, phenols in the test sample were estimated (Malick and Singh, 1980).

Tannins were estimated by Folin Denis method. Tannin like compounds reduces phosphotungstomolybdic acid in alkaline solution to produce a highly coloured blue solution, the intensity of which is proportional to the amount of tannins. The intensity was measured in a spectrophotometer at 700 nm. A standard graph was plotted using 0-100 ug of tannic acid and tannin content of the samples were calculated, as tannic acid equivalents from the standard graph.

RESULTS

4. RESULTS

In Okra damages caused by shoot and fruit borer (*Earias vittella*) is very severe affecting both market preference and export potential of the product and it causes losses over 30 per cent. The improvement of the varieties is an effective way to reduce the losses in the crop. For a successful breeding programme, it is necessary to screen the germplasm for resistance source and to combine the identified resistance to the existing high yielding varieties is necessary. Therefore, the present study was undertaken to combine the already identified resistant sources to existing high yielding varieties and the results are presented below;

4.1. SELECTION OF PARENTS FOR CROSSING PROGRAMME

On the basis of results from earlier research works and by taking into account the resistance of genotypes to shoot and fruit borer and yield potential the following parents (Table 4.1) were selected for crossing programme to develop a high yielding strain with inbuilt resistance to shoot and fruit borer.

Table 4. 1

Genotypes selected for crossing programme

High yielding genotypes			**Resistant genotypes**		
1	Arka Anamika	P1	4	KL 9 (IC 45818)	P2
2	Salkeerthy	P3	5	SEL 2	P4
3	Susthira	P5	6	AC 5 (EC 305760)	P6

4.2 TRANSFER OF SHOOT AND FRUIT BORER RESISTANCE TO A HIGH YIELDING VARIETY

Hybridization was conducted among genotypes moderately resistant to shoot and fruit borer (KL 9, AC 5 and Sel 2) and high yielding genotypes (Arka Anamika, Salkeerthy and Susthira) and the observations were recorded. Direct and reciprocal crosses were made involving all the six parents as shown in Fig. 4.1

4.2.1. Crossability between *A. esculentus* x *A. caillei* and nature of F_1 hybrids

Since the 5 x 5 diallel mating involves genotypes belonging to two species namely, *A. esculentus* and *A. caillei*, the crossability between these species needs mention here. Most of the crosses between *A. esculentus* and *A. caillei* resulted in pods with germinable seeds in both direct as well as reciprocal crossing. Fruit shapes in the *A. esculentus* x *A. caillei* hybrid appeared intermediate between parents. However, the hybrid either appeared intermediate or resembled to that of *A. caillei* in case of floral, foliar and other vegetative characters. The direct and reciprocal crosses between all the six parents were made but a few crosses using AC 5 as one of the parent were not successful Fig 4.2. Most of the F_1s were highly vigorous and heterotic.

4.2.2. Fertility of inter-specific hybrids

In this study both *A. esculentus* and *A. caillei* were used and all are crossed randomly. In case of crosses Arka Anamika x AC5, AC 5 x Salkeerthy and AC 5 x Susthira there was no fruit set. In other crosses like AC 5 x Arka Anamika and AC 5 x Sel 2 fruit set was there and resulted in pod formation but seed setting was very poor and the obtained seeds were empty and did not have embryo or cotyledons. No seed germination was there in two of the inter specific crosses with AC5 as the female parent as shown in Fig. 4.3

Fig.4.1 6 x 6 Full Diallel crossing

	Arka Anamika	Salkeerthy	Susthira	AC5	KL9	Sel2
Arka Anamika	*	*	*	*	*	*
Salkeerthy	*	*	*	*	*	*
Susthira	*	*	*	*	*	*
AC5	*	*	*	*	*	*
KL9	*	*	*	*	*	*
Sel2	*	*	*	*	*	*

*- effective crossing

Fig 4.2 Fruit set for the crosses in 6 x6 Full Diallel mating

	Arka Anamika	Salkeerthy	Susthira	AC5	KL9	Sel2
Arka Anamika	*	*	*	o	*	*
Salkeerthy	*	*	*	*	*	*
Susthira	*	*	*	*	*	*
AC5	*	o	o	*	*	*
KL9	*	*	*	*	*	*
Sel2	*	*	*	*	*	*

*- Effective crossing

0- No Fruit set

Fig. 4.3 Seed germination in 6 x6 Full Diallel mating

	Arka Anamika	Salkeerthy	Susthira	AC5	KL9	Sel2
Arka Anamika	*	*	*	o	*	*
Salkeerthy	*	*	*	*	*	*
Susthira	*	*	*	*	*	*
AC5	#	o	o	*	*	#
KL9	*	*	*	*	*	*
Sel2	*	*	*	*	*	*

*- Effective crossing

0- No fruit set

- No seed germination

4.3 EXTENT OF VARIABILITY IN F_1 AND F_2 GENERATIONS

In this study three high yielding and three resistant varieties are crossed in all possible combinations in the experiment I. The seeds of these crosses i.e. F_1s along with their parents were raised in experiment II. From the F_1 population, selfing and back crossing to both the parents are done to obtain F_2, BC_1 and BC $_2$ respectively. Selected F_2s and the six generations of selected crosses were raised further separately in Experiment No.III and IV. The genetic variability for the important economic traits was assessed. The extent of genetic variability with respect to ten characters in 30 genotypes in F_1 and fifteen characters in 15 genotypes in F_2 were estimated. The variability estimates of ten qualitative characters for both the generations were also taken. The mean performance of crosses and the parents are given in the Tables 4.6 and 4.8.

4.3.1 Variability for Qualitative Traits

Ten qualitative characters namely growth habit, stem pubescence, fruit pubescence, petiole colour, leaf colour, fruit colour, fruit shape, fruit ridges, fruit pubescence and fruit quality were recorded from the parents F_1s, F_2s and from the genotypes raised for generation mean analysis is given in tables 1 to 4 in appendix I. In case of F_2 data observations were recorded for the qualitative characters namely growth habit, fruit colour, fruit ridges, fruit quality, fruit pubescence, shoot pubescence, petiole colour, leaf colour and number of branches.

4.3.1.1 Growth habit

The study materials exhibited only two traits out of three growth habits namely, erect, procumbent and intermediate (Table 4.2). None of the accessions were procumbent, most of the accessions (More than 90 per cent) were erect especially the genotypes belongs to A. *esculentus* and the remaining few *i.e. A. caillei* and its crosses were exhibited intermediate trait (main stem was erect while branches procumbent).

Table 4.2
Number of accessions in each descriptor state for growth habit

Code	Descriptor states	*A. esculentus*	*A. caillei*	Total
1	Erect	37	-	37(82.2%)
2	Medium	-	8	8 (17.7%)
3	Procumbent	-	-	- (0 %)

Table 4.3
Number of accessions in descriptor state for pigmentation on petiole, leaf, and fruit

Code	Descriptor states	*A. esculentus*	*A. caillei*	Total
Leaf colour (F_2)				
1	Green	6	-	6(40%)
2	Dark green	6	-	6(40%)
3	Green leaf with light red veins (dot like)	1	1	2(13.3%)
4	Green leaf with deep red veins	-	1	1(6.7%)
5	Purple blotched	-	-	-(0 %)
Petiole colour(F_2)				
1	Green	9	1	10(66.67%)
2	Green and purple	4	-	4(26.7%)
3	Purple	-	-	-(0 %)
4	Red	-	1	1(6.6%)
Fruit colour(F_1 +F_2)				
1	Pale white	2	2	4(8.9%)
2	Light green	16	3	19(42.2%)
3	Green	10	4	14 (31.1%)
4	Dark green	7	-	7(15.6%)
4	Yellowish green	-	-	- (0 %)
5	Red	-	-	- (0%)
6	Green and purple striation	1	-	1(2.2%)
7	Beige pink or rose			(0%)

Plate 8. Variability in pod characteristics

Plate 9. Variability in pigmentation of fruits

4.3.1.2 Pigmentation on leaf, petiole, and fruit

Observations for the petiole colour were taken in F_2 data only. Petiole colour ranged from green to purple (Table 4.3). Green petiole was found in 10 genotypes (66.67per cent), green with purple markings in four accessions (26.7 per cent), purple petiole was not found in any of the genotypes and rose petiole was only in one F_2 generation. Leaf lamina colour varied from green to red through various grades of green and red mix such as green lamina with feeble red veins and green lamina with deep red veins (Table 4.3). Six F_2s had dark green leaves, six F_2s with green leaves, 2 F_2s with green leaf with red veins and a single F_2 with green leaf with deep red veins.

Fruit colour of F_1s and F_2s ranged from pale white to purple (Plate.8). Pale white fruits were recorded in 4 crosses (8.9 per cent), light green fruits in 19 crosses (42.2 per cent), green in 14 F_1 genotypes (31.1 per cent), dark green fruits in 7 genotypes (15.6 per cent), and green with purple striation in only one cross (2.2 per cent). No yellowish green or red fruits were found in these generations (Table 4.3).

4.3.1.3 Pubescence on stem and fruit

Stem pubescence was classified into glabrous, slight and conspicuous. There was no F_1s and F_2s with conspicuous stem pubescence. Few *A. caillei* had slight pubescence and all others had glaborous stem only. Trichomes present on fruit were classified into i) downy (soft), ii) slight iii) rough and iv) prickly (Table 4.4). Downy fruits were found in 9crosses, slight trichomes in 36 crosses and no rough and prickly fruits were found in any of the accessions.

4.3.1.4 Fruit ridges and fruit quality

Number of ridges in fruits varied from zero to ten (Table 4.5). Five ridged fruits were predominant in the materials studied (27 crosses or 60 per cent) followed by multi-ridged fruits (14 accessions or 31.1 per cent). A few caillei genotypes produced non-ridged fruits. With regard to fruit quality, no accessions produced non-edible spiny fruits, only AC 5 produced low quality fruits, 29 genotypes bear

Table 4.4
Number of accessions across descriptor state for pubescence on stem and fruit

Code	Descriptor states	*A. esculentus*	*A. caillei*	Total
Stem pubescence				
1	Glabrous	4	4	8 (17.8 %)
2	Slight	26	11	37 (82.2 %)
3	Conspicuous	-	-	- (0%)
Fruit pubescence				
1	Downy	4	5	9(20 %)
2	Slight	32	4	36(80 %)
3	Rough	-	-	- (0%)
4	Prickly	-	-	- (0%)

Table 4.5
Number of accessions across descriptor state for fruit ridges and fruit quality

Code	Descriptor states	*A. esculentus*	*A. caillei*	Total
Fruit ridges				
1	Non- ridged		4	4(8.9%)
2	Five ridged	25	2	27(60%)
3	>Five ridged	11	3	14(31.1%)
Fruit quality score				
1	Non consumable(score 0-3)	-	-	- (0%)
2	Consumable but low quality (score 4-5)	1	-	1 (2.2 %)
3	Medium quality(score 6-7)	21	8	29(64.4%)
4	Good quality(score 8-9)	14	1	15(33.3%)

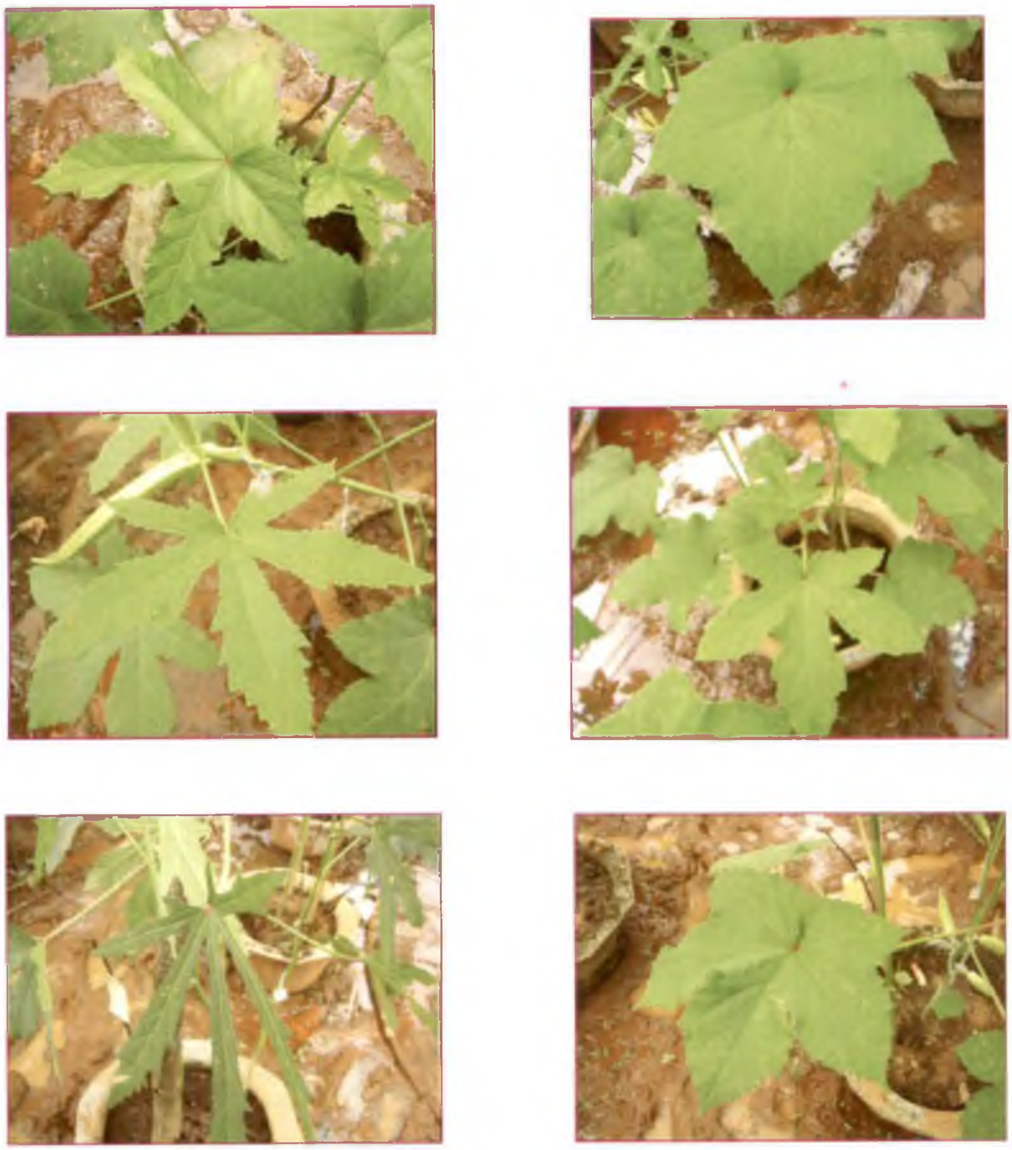


Plate 10. Variability in foliar characteristics

Plate 11. Variability in floral characteristics

medium quality fruits and 15 crosses produced better quality fruits (Table 4.5). Variability was also observed in Pod characteristics, foliar and floral characteristics (Plate.8 to Plate.11)

4.3.2 Variability for Quantitative Traits;

4.3.2.1. Variability among parents

In case of yield and yield contributing characters in parents, early flowering was detected in KL 9 (29 days) and with highest value was scored by AC 5 (54.5 days) gca effects were significant for Arka Anamika and KL 9 in desirable negative direction for this trait. The Parent Sel 2 registered highest for plant height (140.5c.m) and had positive and significant gca effects. Number of internode ranged from 13.5 in parent KL 9 to 19 in Salkeerthy. Internodal length was shortest (6.1 cm) in Salkeerthy. Number of fruits per plant varied from 6 in Arka Anamika to in 11.5 in Susthira, gca was high and significant in Sel 2 for fruit weight and in Salkeerthy for fruit length in positive direction. Fruit yield per plant ranged between 243 g in KL 9 and 75.5 g in AC 5. (Table 4.6).

4.3.2.2 Variability among F_1 and F_2hybrids for yield and yield attributes

Quantitative data recorded from field experiment II and III (Table 4.8 to 4.11) were analyzed for GCV, PCV, heritability and genetic advance. They showed significant differences among genotypes for days to first flowering, flowering period, plant height, internode number, internodal length, fruits per plant, average fruit weight, fruit length, fruit girth, fruit yield per plant, per cent shoot and fruit infestation and marketable fruit yield (Table 4.6 to 4.8). The range, mean performance and co-efficient of variation for the F_1 and F_2 are given in Table 4.7 and 4.9 respectively. The Salient results alone from field experiment-II and experiment-III are presented below.

4.3.2.2.1 Days to first flowering

The range for days to first flowering in 6 parents and 24 F_1 s varied from 26.00 to 54.5 days (Table 4.7). Among the F_1 s in Sel 2 x Arka Anamika flowered early

Table 4. 6
Mean performance of F_1 progenies and the parents in greenhouse conditions

F1/ Parents	Pht	Dff	LNo	IN	IL	FN	Nr	FW	FY	FL
P1	139	34.5	15	14	10.05	6	5	21	151.5	14.5
P2	104.25	29	12.5	13.5	9.8	6.5	7	16.975	243	16.85
P3	120.5	42	17.5	19	**6.1**	7.5	5	35	181.5	28.75
P4	140.5	39.5	19	17	12.25	8.5	5	18	75.5	17.5
P5	114.5	50.5	18	15.5	9.95	11.5	7	19.165	80.5	15.4
P6	132	54.5	15.5	15	12.75	7.5	5	14.5	75.5	10.8
P1x P2	99.5	31.5	12.5	11	8.6	5.5	7	17	297.85	16.6
P1 x P3	101	30.5	15	14.5	13.4	6	5	10.62	67.72	13.1
P1 x P4	105.5	31	11	11.5	10.15	**5**	5	13.54	170.52	13
P1 x P5	110	29.5	17.5	16.5	10.85	6	5	12.58	157.98	12.4
P2 x P1	96.5	29.5	**10.5**	12.5	10.25	5.5	7	13.9	75.85	20.6
P2 x P3	109	32.5	**10.5**	**10.5**	11.1	5.5	8	14.745	76.225	14.8
P2 x P4	104	31.5	**10.5**	**10.5**	11.35	6	8	11.915	66.99	18.8
P2 x P5	123	30.16	10.83	13.16	10.21	7.66	7.33	10.37	80.09	19.93
P2 x P6	138.5	30	12	14.5	11.5	5.5	8	10.84	**58.54**	19.8
P3 x P1	103	41	13.5	13.5	9.75	6.5	5	17.4	135.9	24
P3 x P2	113	42.5	12	13	6.7	5.5	5	24.745	141.22	21.5
P3 x P4	126.5	40.5	14.5	15.5	8.05	7.5	5	13.795	102.56	21.5
P3 x P5	131	39	15	16	12.75	7.5	5	24.09	200.72	14.75
P3 x P6	144	42	21	21.5	8.15	5.5	7	22.5	110.5	21.5
P4 x P1	149	**26**	16.5	16	11.7	8.5	5	12.61	74.02	18.65
P4 x P2	194	38.5	19.5	18.5	16.1	8.5	5	14.225	120.52	20.5
P4 x P3	150.5	38	19	19	15.65	6.5	5	12.095	71.665	20.75

P4 x P5	122	38	16.5	17.5	13.2	6.5	5	16.78	81.96	17.5
P4 x P6	162	36	17.5	17	11.8	11	5	**9.57**	68.99	17.5
P5x P1	163.5	49.5	12.5	11	12.95	7.5	5	12.64	170.96	12
P5x P2	**80.5**	46.5	13.5	15.5	7.75	5.5	5	12.9	179.6	17.9
P5x P3	98.73	45	12.5	16	6.7	8	6	14.92	165.36	13.2
P5x P4	165.5	50	20	16	10.05	8.5	5	14.59	136.81	**10.5**
P5x P6	88.5	49	13	13.5	10.9	10	6	14.79	164.57	15.6
MEAN	124.31	38.255	14.811	14.938	10.683	7.105	5.777	21.06	126.15	17.339
SD	26.311	7.762	3.165	2.718	2.422	1.674	1.118	28.887	59.097	4.156
VARIANCE	692.30	60.25	10.01	7.38	5.86	2.80	1.25	834.46	3492.5	17.27
CD at 5 %	38.07	11.23	4.58	3.93	3.50	2.42	1.62	41.79	85.50	6.01
CD at 1 %	29.77	8.78	3.58	3.07	2.74	1.89	1.26	32.68	66.86	4.70

P1- Arka Anamika (A.A), **P2** - KL9, **P3**– Salkeerthy(Sal), **P4** - Sel 2, **P5**-Susthira (Sus), P6 - AC5

Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant
Values in bold and underlined refers to the minimum and maximum respectively

(26 days) followed by KL 9 (29 days), Arka Anamika x Suthira, KL 9 x Arka Anamika (29.5 days) whereas AC 5, Susthira and Susthira x Sel 2 flowered late (54.5days, 50.5 days, 50 days respectively) (Table 4.6). The mean for Days to first flowering was 38.26 days. SCA effects was high and significant in desirable direction (-ve) for Arka Anamika x Sel2.

The range for days to first flowering in 14 F_2 s and check variety Salkeerthy varied from 36.00 to 51 days (Table 4.8). Among the F_2s also Sel 2 x Arka Anamika flowered early (36.00 days) followed by Arka Anamika x Susthira, KL 9 x AC 5 (38 days), Salkeerthy x Arka Anamika (35 days) whereas Susthira x Sel 2, Arka Anamika x Salkeerthy and Susthira x AC5 flowered late (51 days, 47 days and 45days respectively) (Table 4.6). The mean for days to first flowering was 42.13 In case of F_2s days to first flowering ranged from 36.00 to 51.00 days.

4.3.2.2.2 Flowering period

Flowering period in F_2 generation extended from 25.96 to 32.33 days and the mean was 28.92 days (Table 4.9). In crosses, the minimum value was (25.96 days) recorded in KL 9 x Susthira whereas the maximum value by cultivated variety Salkeerthy (32.33 days).

4.3.2.2.3 Plant height

The mean value for plant height ranged from 80.5 to 194.00 cm (Table 4.7). Among the F_1s, Susthira x KL 9 recorded the minimum value for plant height (80.5 cm) whereas Sel 2 x KL 9 recorded the maximum value (194.00 cm) for this trait. KL 9 x Sel 2 showed high significant positive sca effects. Among F_2 Sel 2 x Arka Anamika was taller (74.6cm) while Susthira x Sel 2 was shorter (25.6 cm) (Table 4.8). The mean for plant height was 124. 31 in case of F_1 and 52.74 in case of F_2.

4.3.2.2.4 Number of leaves per plant

The range for number of leaves per plant in case of F_1 varied between 21.0 (in Salkeerthy x AC 5) and 10.5 in F_1 s with KL 9 as the female parent and the mean

Table 4. 7.
Range, mean, standard deviation , coefficient of variation in F_1 generation for different quantitative traits

Sl no	Characters	Range	Mean	SD	GCV (%)	PCV (%)	heritability (%)	Genetic Advance (%)	Genetic gain
1	Pht	194 -80.5	124.31	26.31	20.64	21.64	91.0	50.55	40.66
2	Dff	54.5 - 26	38.25	7.76	19.40	21.29	83.0	13.92	36.39
3	LNo	10.5 - 21	14.81	3.16	20.56	22.04	87.0	5.86	39.57
4	IN	10.5 -21.5	14.93	2.71	16.72	19.22	75.7	4.49	30.06
5	IL	16.1-6.1	10.68	2.42	21.33	24.13	78.1	4.14	38.75
6	FN	11.5- 5	7.10	1.67	21.57	25.67	70.6	2.66	37.44
7	FW	35 - 9.57	21.06	28.88	46.60	46.66	99.7	121.17	96.05
8	FY	297.85 -58.54	126.15	59.09	11.01	54.37	58.27	1.90	9.02
9	FL	28.75 -10.5	17.33	4.15	23.20	24.82	87.4	7.76	44.75

Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW- fruit weight (g), FL-Fruit length (cm), FY-Fruit yield (g)/ plant was14.81 (Table 4.6). In case of F_2 the range for number of leaves per plant varied between 25 (in Susthira x AC 5) and 7.00 in Arka Anamika x Salkeerthy and the mean was 12.26 (Table 4.8).

4.3.2.2.5 Internode number

Number of internodes in main stem ranged between 21.5 and 10.5 (Table 4.6). The mean for F_1 genotypes was 14.94 whereas the mean for F_2 genotypes were 11.26 (Tables 4.6 to 4.8). The accessions registered high value for this character was Salkeerthy x AC 5 (21.5 internode) Sel 2 x KL 9 (18.5internode) and minimum value of KL 9 x Arka Anamika (10.5 internodes). Arka Anamika x Salkeerthy showed high SCA effects in desirable direction (negative) and Salkeerthy x Arka Anamika showed high significant reciprocal effects for this trait.

4.3.2.2.6 Length of internode

Length of internode varied between 6.1 cm and 16.1 cm in F_1 genotypes (Table 4.6). The lowest value among the F_1 was registered by Salkeerthy. In F_1 highest value was recorded for Sel 2 x KL 9 (16.1 cm) SCA effects were significant for KL 9 x Salkeerthy in positive direction and Arka Anamika x Sel 2 in negative direction (Table 4.8). Among F_2, Arka Anamika x Susthira recorded the lowest value *i.e.* 2 c.m (Table 4.6). KL 9 x AC 5 showed the highest internodal length (8.00cm) (Table 4.8).

4.3.2.2.7 Average fruit weight

The minimum value for average fruit weight in F_1 population was recorded by Sel 2 x AC5 (9.57 g / fruit) whereas the maximum value was recorded by Salkeerthy (35.00 g / fruit) (Table 4.6). The mean value was 21.06 g. High and a positive effect for this trait was recorded by Arka Anamika x KL9 and KL 9 x Salkeerthy.

The minimum value for average fruit weight in F_2 population by Susthira x AC5 (25 g / fruit) whereas the maximum value was recorded by KL9 x AC 5 (60.00

Table 4. 8
Mean performance of F_2 progenies and the parents in natural field condition

F2	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FY	FL	SI	FI	FG	Flp	MFY
P3 x P2	49.2	40	11	11	5	**5.8**	5	35	203	17.8	18.18	27.5	**8.5**	28.44	147.17
P3 x P1	40.5	39	**7**	13	4	5.6	5	42.5	238	16.2	18.18	31.5	6	31.49	163.03
P3 x P5	56.24	45	20	9	4	4.8	6	30	144	20	16.66	20.8	6	29.85	114.04
P2 x P4	38.8	42	13	9	4	3.4	7	50	170	**21.9**	20	**11.76**	7.5	26.27	150.08
P2 x P6	42.2	38	15	10	3	3.8	**8**	**60**	228	**15.2**	8.33	36.84	7.5	26.7	144.04
P2 x P5	59.6	46	15	10	3	5	5	47.5	237.5	17.66	25	20	8	**25.96**	**190**
P1 x P2	69.2	40	16	9	**7**	5	5	42.5	212.5	21.6	0	24	8	27.6	161.5
P1 x P3	65	47	**7**	13	4.6	5.4	5	45	**243**	20	0	29.6	7	31.49	171.07
P1 x P5	61.2	38	14	10	**2**	5	5	42.5	212.5	18	**30**	36	6.1	29.02	136
P1 x P4	63	41	8	13	4	5.2	5	45	234	18.2	0	34.6	6.5	29.33	153.03
P4 x P3	70.2	42	8	12	5	3.8	5	42.5	161.5	17.5	11	42	6.5	30.16	93.67
P4 x P1	**74.6**	**36**	10	14	**7**	5.4	5	40	216	20.2	0	33.33	6	29.33	144.07
P5 x P6	36.2	45	**25**	14	5	3.8	5	40	152	19.2	0	21.05	7.5	28.12	120.04
P5 x P4	**25.6**	**51**	**7**	**7**	5	**1.4**	6	**25**	**35**	17.2	0	14.2	6.5	27.69	**30.03**
P3	39.6	42	8	**15**	6	3.8	5	50	190	15.6	28.57	**80**	7.5	**32.33**	38
MEAN	52.74	42.13	12.26	11.26	4.57	4.48	5.46	42.5	191.8	17.21	11.72	30.87	7.01	28.91	130.38
SD	14.85	4.01	5.33	2.34	1.39	1.15	0.91	8.39	54.35	4.59	11.36	16.12	0.83	1.93	45.63
VARIANCE	220.76	16.12	28.49	5.49	1.95	1.33	0.83	70.53	2953.95	21.14	129.07	259.94	0.70	3.74	2082.78
CD at 5 %	21.49	5.81	7.72	3.39	2.02	1.67	1.32	12.15	78.63	6.65	16.43	23.32	1.21	2.79	66.02
CD at 1 %	16.81	4.54	6.04	2.65	1.58	1.30	1.04	9.50	61.49	5.20	12.85	18.24	0.94	2.18	51.63

P1- Arka Anamika (A.A), **P2** - KL9, **P3**– Salkeerthy(Sal), **P4** - Sel 2, **P5**-Susthira (Sus), **P6** - AC5

Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%), Flp- flowering period (days). Values in bold and underlined refers to the minimum and maximum respectively g / fruit), (Table 4.8). The mean value for average fruit weight in F_2 population was 42.05 g.

4.3.2.2.8Number of fruits per plant

The data on number of fruits per plant ranged from 5.00 to 11.5 in the materials studied (Table 4.6). Among F_1s largest number of fruits was given by Susthira and in F_2 it is Salkeerthy x KL 9. The mean for F_1 was 7.11 fruits per plant while it was 4.48 fruits per plant in F_2 generations and this difference is contributed by the seasonal variation in the F_1 crop and F_2 crop(Tables 4.6 to 4 8).

4.3.2.2.9 Fruit length

Fruit length varied between 10.5 cm and 28.75 cm (Table 4.9). F_1 genotypes Susthira x Sel 2 and AC 5 produced small fruits (10.5 to 10.8 cm long), whereas Salkeerthy (28.75 cm), Salkeerthy x Arka Anamika (24 cm), produced lengthy fruits (Table 4.7). SCA effects were high for Arka Anamika x KL 9 in positive direction. In F_2 fruit length was short in KL 9 x AC 5 (15.2 cm) and long (21.9) in KL 9 x Sel 2. In F_2 mean of the fruit length was 17.21 c.m.

4.3.2.2.10 Fruit girth

Fruit girth varied from 6.00 cm to 8.5 cm in the F_2 genotypes under study (Table 4.8). The mean value for fruit girth was 7.01 mm. The minimum girth (6cm) was recorded in Sel 2 x Arka Anamika and the maximum value (8.5c.m) in Salkeerthy x KL 9.

4.3.2.2.11 Fruit yield per plant

Fruit yield per plant in the F_1 genotypes varied from 58.54 to 297.85 g (Table 4.8). The genotype Arka Anamika x Salkeerthy registered high fruit yield (297.85 g / plant) (Table 4.6). It was on par with Salkeerthy x Susthira (200.72 g / plant) and minimum value by KL 9 x AC 5 (58.54 g). The sca effects were significant for Arka Anamika x Salkeerthy. Among F_2 population, Arka Anamika x Salkeerthy registered

Table 4. 9

Range, mean, standard deviation, coefficient of variation in F_2 generation for different quantitative traits

Sl. no.	characters	range	mean	SD	GCV (%)	PCV (%)	Heritability (%)	Genetic Advance(%)	genetic gain
1	Pht	74.6-25.6	52.74	14.85	28.21	28.42	98.5	30.28	57.41
2	Dff	51-36	42.13	4.01	9.57	10.50	83.1	7.52	17.85
3	LNo	25 -7	12.26	5.33	26.95	36.59	54.3	4.63	37.75
4	IN	15-7	11.26	2.34	11.37	26.15	18.9	1.05	9.32
5	IL	7-2	4.57	1.39	20.70	35.35	34.3	1.11	24.27
6	FN	5.8-1.4	4.48	1.15	14.81	45.29	10.7	0.42	9.38
7	Nr	8 - 5	5.46	0.91	7.07	35.41	4.0	0.15	2.74
8	FW	60-25	42.5	8.39	28.30	28.32	99.9	111.60	58.19
9	FY	243-35	191.8	54.35	19.42	19.89	95.4	16.51	38.85
10	FL	21.9-15.2	17.21	4.59	7.74	19.08	16.4	1.18	6.85
11	SI	30-0	11.72	11.36	97.27	98.54	97.4	22.69	73.48
12	FI	80 -11.76	30.87	16.12	51.81	52.14	98.7	32.47	63.46
13	FG	8.5 -6	7.01	0.83	0.47	26.78	26.9	0.00	0.00
14	Flp	32.33-25.96	28.91	1.93	4.99	8.04	38.5	1.83	6.33
15	MFY	190-30.03	130.38	45.63	35.09	35.12	99.8	93.98	72.08

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days)

high yield (243g / plant) and minimum value by Susthira x AC 5 (35 g).The mean for fruit yield per plant was 191.8 g (Table 4.8).

4.3.2.2.12 Shoot infestation (SI)

Shoot borer infestation in F_2 hybrids ranged between 0.00 and 30.00 per cent and the mean was 11.728 per cent (Table 4.8). The minimum shoot infestation (0.00 per cent) was observed in Arka Anamika x KL 9, Arka Anamika x Salkeerthy, and Arka Anamika x Sel 2. Sel 2 x Arka Anamika, Susthira x AC 5, Susthira x Sel 2. The maximum was observed in F_2 generation of Arka Anamika x Susthira (30) and the check variety Salkeerthy (28.57).

4.3.2.2.13 Fruit infestation (FI)

Fruit borer infestation varied from 11.76 to 80 per cent and the grand mean was 30.87 per cent (Table 4.8). F_2s of KL 9 x Sel2 (11.76 per cent) and Susthira x Sel 2 (14.2 per cent) registered low fruit infestation. The maximum infestation was observed in the check variety Salkeerthy (80 per cent).

4.3.2.2.14 Marketable fruit yield

It was observed that fruit borer damaged 30.87 per cent of the total harvested fruits. Hence, the remaining 69.12 percent were marketable (Table 4.8). Marketable fruit yield ranged from 30.03 to 190 g per plant. The highest marketable fruit yield was recorded by KL 9 x Susthira (190 g / plant) followed by Arka Anamika x Salkeerthy (171.07 g / plant) and minimum fruit yield was recorded by Susthira x AC 5 (30.03).

4.4 GENOTYPIC AND PHENOTYPIC CO-EFFICIENT OF VARIATIONS (GCV AND PCV)

The co-efficient of variations at genotypic (GCV %) and phenotypic level (PCV %) calculated for 10 quantitative characters observed in 30 F_1 s are presented in Table 4.7. In general, the PCV was higher than the corresponding GCV for all the traits under study. Genetic advance was also higher in case fruit weight and plant height. In case of F_1 the percentage of GCV was higher for fruit weight and was less for fruit yield and number of internodes. The percentage of GCV was less than 20 percent for days to first flowering. The GCV and PCV were calculated for 15 quantitative characters observed in 15 F_2s. The percentage of GCV was less than 20 percent (low variability) for days to first flowering, no. of fruits and fruit yield; 20 to 25 per cent (medium variability) for internode number, average fruit weight and fruit length; above 25 per cent (high variability) for plant height, number of leaves per plant, number of internodes etc in F_2 generation.

Heritability was higher for fruit weight (99.7), shoot infestation (97.4) and fruit infestation (98.7). In case of F_1 heritability values ranged from 99.7 to 58.27. The maximum heritability was observed over fruit weight (99.7) and lowest for fruit yield (58.27). In case of F_2, heritability ranged from 99.9 to 26.9.The maximum was scored by fruit weight and minimum by fruit girth.

4.5 COMBINING ABILITY ANALYSIS

Combining ability of parents and specfiic parental combinations are of principal importance in plant breeding especially in hybrid production. It is useful in studying and comparing the performance of lines in hybrid combinations. Combining ability analysis was done using methods suggested by Hayman's numerical and graphical approach as well as Griffing's method I model I.

The general combining ability and specific combining ability were significant for six characters namely plant height, days to first flowering, number of internodes, fruit yield, fruit length and fruit weight. The mean squares for reciprocal effects were significant for days to first flowering, plant height, fruit length and fruit weight. The estimates of the gca effects of the six parents and the s.ca effects of the F_1 hybrids and reciprocal crosses are presented in table 4.11. The gca effect was significant for plant height, days to first flowering leaf number, internodal number,

Table 4. 10
Skeleton of ANOVA for 5 x 5 full diallel progenies based on Griffing's method I model I

Source	df	Pht	Dff	LNo	IN	IL	FN	FW	FL	FY
i) Combined ANOVA for Parents and crosses										
Replications	1	151.24**	24.50**	7.22**	0.08**	3.33**	1.62*	1.50**	9.25**	11293888.54**
Treatments	24	1395.46**	106.20**	19.26**	13.38**	13.18**	4.48*	7298.42**	36.24**	5971587.41**
Error	24	76.17	13.29	1.35	2.04	1.55	1.08	8.93**	2.61	5967505.52
ii) ANOVA for combining ability effects										
gca	4	393.01**	14.48**	5.24	3.67*	4.69	1.52	3412.46**	16.39**	3598036.39**
sca	10	1013.23**	144.18**	23.58	15.36*	8.59	5.98	4525.38**	41.76**	1041088.03**
reciprocals	10	1193.57**	72.72**	11.86	8.72*	10.79	2.20	5272.48**	17.09**	4838800.71**
Error	24	38.08	6.65	0.67	1.02	0.78	0.54	4.46	1.30	2983752.76
iii) Variance components										
$\sigma^2 A$		207.79	58.56	6.14	4.10	1.20	32.15	4.20	1.20	4985.48
$\sigma^2 D$		976.76	75.13	21.49	4.16	21.49	45.63	5.92	8.75	7754.37
$\sigma^2 r$		39.59	6.87	0.79	0.81	0.79	1.44	0.55	0.20	4.31

Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW- fruit weight (g), FL-Fruit length (cm), FY-Fruit yield (g)/ plant

* $P<0.05$ and ** $P<0.01$ $\sigma^2 r$ refers to variance due to reciprocals

internodal length, fruit number, fruit weight and fruit length. The gca effect was significant for plant height, days to first flowering leaf number, internodal number, internodal length, fruit weight, fruit weight and fruit length.

4.5.1 Plant height

The combing ability analysis for plant height showed that gca, sca and reciprocal effects were significant for this character. Significant gca effect was exhibited by two parents KL9 and Salkeerthy where KL9 showed negative effect of (9.21) and Salkeerthy showed positive effect (16.84). However four of the F_1 hybrids showed significant sca effects, P1 x P2 (-13.39), P1 x P3 (-13.01), P3 x P4 (-10.19) and P2 x P4 (18.41), P4 x P1 (-21.75), P4 x P2 (-45.00) P4 x P3 (-12.00) have shown significant negative reciprocal effects.

4.5.1.2 Days to first flowering

Significant gca and sca effects were noticed, all in negative direction except sca effect of P4 x P1 (2.50). Arka Anamika (-3.67) and KL9 can be considered as best general combiners for this trait and Arka Anamika x Sel2 was considered as the best specific combination for this character.

4.5.1.3 Fruit Number

Arka Anamika has shown significant gca effects for this character. None of the combinations has shown sca effects for this trait. Reciprocal effects were shown by P4 x P1 (-1.75) and P4 x P2 (-1.25).

4.5.1.4 Fruit length

Significant positive gca effect was enhibited by only one parent Salkeerthy (2.69) while Arka Anamika has shown signification negative gca effect (-1.49) for this trait.The crosses Araka anamika x KL9 have shown positive gca effect (1.60) for the character and KL9 x Salkeerthy have shown negative sca effect for this character. Significant negative sca effects were shown by KL9 x Arka Anamika (-

Table 4.12

Estimation of Components of Variation for F1 Population

Components	plant height	days to first flowering	number of leaves	internodal length	no. of internodes	number of ridges	fruit length	fruit no	fruit weight	fruit yield
E	39.59	6.87**	0.79**	0.81**	0.98	0.00	1.44	0.55**	0.20**	4.31
D	207.79**	58.56**	6.14**	4.10**	4.09**	1.20**	32.15**	4.20**	1.20	4985.48**
F	54.92	17.63	-0.77	2.29	0.54	0.70**	28.72**	2.78**	7.49	5639.26**
H_1	976.76**	75.13**	21.49**	4.16**	16.05**	2.33**	45.63**	5.92**	8.75	7754.37**
H_2	856.28**	73.92**	21.63**	3.60**	15.42**	1.96**	36.22**	5.58**	7.20	5628.94**
h^2	1644.64**	226.64**	65.04**	1.85**	45.39**	4.19**	60.50**	17.22**	3.28	4765.04**
MDD	2.17	1.13	1.87	1.01	1.98	1.39	1.19	1.19	1.15	1.24
P/N	0.22	0.25	0.25	0.22	0.24	0.21	0.20	0.24	0.15	0.18
D/R	1.13	1.31	0.25	1.77	1.07	1.53	2.20	1.77	0.31	2.65
Hn	0.35	0.45	0.35	0.41	0.30	0.47	0.38	0.31	-0.24	0.34

- E- The Expected Environmental Component of Variation, D - Variation Due To Additive Effect, H_1 - Components of Variation Due To The Dominance Effect of The Genes, F - The Mean of 'Fr' Over The Arrays , H_2- Proportion of Positive & Negative Genes In The Parents, D/R -Proportion of Dominant and Recessive Genes in the Parents, h^2 -Dominance Effect, MDD- Mean Degree of Dominance, Hn- Heritability in Narrow-Sense

2.00) Salkeerthy x Arka Anamika (-5.45), Salkeerthy) x KL9 (-3.35) and Sel2 x Arka anamika (-2.23).

4.5.1.5 Fruit Weight

None of the parents are good general combiners for this character. The cross combination Arka Anamika x Salkeerthy have shown high significant positive sca effect and Salkeerthy x Arka Anamika have shown high negative sca effect for this trait.

4.5.1.6Fruit Yield

Arka Anamika (12.86), KL9 (20.57) and Sel2 (34.92) have shown significant gca effect for fruit weight. And the entire cross combinations have shown significant gca and sca effect for the entire cross combinations.

4.5.2 Components of variation for F1 population

The components of variation were tested using Hayman's numerical approach and given in the table 4.12 . The analysis using parents and F_1 s indicated significance for D, H1, H2 and h2 for all the characters except fruit weight. While those of E and F was not significant for all the characters. The value of H1 was greater than D for almost all the characters like plant height, days to first flowering, number of leaves, number of internodes, fruit length, fruit weight and fruit yield indicating the presence of over dominance but the value of H1 was almost equal to D for characters like internodal length, number of ridges and fruit number indicating complete dominance for these traits. The mean degree of dominance for internodal length (1.01) equals to unity indicating complete dominance and all others having mean degree dominance greater than unity indicating over dominance.

The H2/ 4H1 ratio was 0.25 for characters like days to first flowering, number of leaves and close to maximum attainable value 0.25 for characters like plant height (0.22), internodal length (0.22), no. of internodes (0.24) and fruit number (0.24) indicating symmetrical distribution of positive and negative genes.

Table 4.11
GCA, SCA and reciprocal effects of parents and F1s

	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FY	FL
General Combining Ability Effects										
P1	-2.36	-3.67**	-0.72	-1.27**	0.18	-0.73**	-0.28	298.52	12.86**	-1.49**
P2	-9.21**	-3.42**	-2.12**	-1.42**	-0.48	-0.63	0.92	-476.82	20.57**	1.07
P3	-5.59	1.88	0.08	0.88	-0.96**	-0.18	-0.28	303.53	-0.09	2.69**
P4	16.84**	-0.17	1.93**	1.13**	1.48**	0.42	-0.38	-63.16	34.92**	0.20
Specific Combining Ability Effects										
P1x P2	-13.39**	0.17	-0.28	-0.28	-0.87	-0.12	0.68	-298.36	20.90**	1.60**
P1 x P3	-13.01**	0.12	0.27	0.27	1.76**	0.18	-0.12	2796.85**	-43.48**	-0.07
P1 x P4	-10.19**	-5.08**	-2.08**	-2.08**	-1.33**	0.08	-0.02	-714.40	11.81**	-0.31
P2 x P3	2.84	1.62	-1.33**	-1.33**	-0.25	-0.67	0.18	-299.08	-44.28**	-3.03**
P2 x P4	18.41**	1.17	0.57	0.57	2.13**	0.48	0.28	60.93	-24.42**	0.96
P3 x P4	4.29	0.12	0.12	0.12	0.74	-0.22	-0.02	-719.54	10.40**	0.82
Reciprocal Effects										
P2 x P1	1.50	1.00	1.00**	-0.75	-0.83	-	-	1.55	111.00**	-2.00**
P3 x P1	-1.00	-5.25**	0.75	0.50	1.83**	-0.25	-	-3880.39**	-34.09**	-5.45**
P3 x P2	-2.00	-5.00**	-0.75	-1.25**	2.20**	-	1.50	-5.00	-32.50**	-3.35**
P4 x P1	-21.75**	2.50**	-2.75**	-2.25**	-0.78	-1.75**	-	0.47	48.25**	-2.83**
P4 x P2	-45.00**	-3.50**	-4.50**	-4.00**	-2.38**	-1.25**	1.50	-1.16	-26.77**	-0.85
P4 x P3	-12.00**	1.25	-2.25**	-1.75**	-3.80**	0.50	-	0.85	15.45**	0.38

P1- Arka Anamika (A.A), **P2** - KL9, **P3**– Salkeerthy(Sal), **P4** - Sel 2, Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant

The proportion of dominant and recessive genes are near to unity for number of inter nodes and plant height indicates the symmetrical distribution of the dominant and recessive genes for this trait.

4.5.3 Graphical analysis

4.5.3.1 *Vr- Wr Graph*

The observations with respect to each of the 10 characters were subjected to graphical analysis. Vr.values and values at the intercept are given in Table 9 of appendix III. Since the regression of Wr on Vr is unity, additive dominance model is satisfactory. For this the linear regression line should have a unit slope. They also depict the average level of dominance for each character. The Wr-Vr graph showed the regression line intercepts the Wr axis below the origin for most of the characters like plant height, fruit length, fruit number, fruit yield and number of leaves (Fig.5.1). Hence overdominance is involved in the action of genes governing the inheritance of these traits.

For days to first flowering and number of ridges, the regression of Wr on Vr for parents and F_1s showed the adequacy of the additive-dominance model. In the graph the line on regression line was seen passing through the origin or near to the origin. The Vr-Wr graph also indicated the presence of epistasis for plant height, fruit weight and fruit number.

4.5.3.2 Standardised Deviations graph

This graph is plotted from the standardised values of parental means and (Wr+Vr) values for five arrays. The S.D graph reveals that the parental lines posses most of the genes with recessive expression and with negative influence on characters like plant height, days to first flowering, number of leaves, number of internodes, internodal length. In case of characters like fruit length, fruit weight and fruit yield have some parental lines possess the dominant genes with positive effect. These lines may therefore be employed for hybridization.

4.6 CORRELATION BETWEEN SHOOT AND FRUIT BORER RESISTANCE WITH OTHER TRAITS

To determine the inter-relationship between shoot and fruit borer resistance with yield and yield attributes, data recorded from 15 F_2s in field experiment III were subjected to correlation analysis. The genotypic correlation co-efficient among 15 traits are presented in Table 4.13. Characters like internode number (r = 0.89), flowering period (r = 0.67) and internodal length (r = 0.62) had significant positive correlation with shoot infestation. On the other hand, fruit length (r =-0.67) and fruit infestation (r = -0.94) had negative correlation with shoot infestation. Phenotypic correlation coefficient was given in Table 4.14.

Plant height, fruit number and fruit yield showed significance but negative correlation with fruit infestation. Both shoot borer infestation and fruit borer infestation were negatively inter-related (r =-0.94). In the present study, fruit yield per plant was positively correlated with fruit number(r = 0.89), (number of internodes (r = 0.76), fruit weight (r = 0.66) and plant height (r = 0.52) and fruit yield was negatively correlated with days to first flowering(r =-0.65) and fruit infestation (r = -0.61). Correlation of the characters studied in F_1 generations and Generation mean analysis were also analyzed and given in appendix II.

4.7 DIRECT AND INDIRECT EFFECTS

For estimating the direct and indirect effect of constituent characters on yield the genotypic correlation of all characters under study was included. The estimates of direct and indirect effect of these characters on yield are presented in Table 4.15. Among parents and F_1s the high positive direct effect on fruit yield per plant was contributed by fruit number (0.985) followed by marketable fruit yield (0.941) fruit length (0.059) and fruit number (0.045). The plant height (-0.143), days to first flowering (-0.076) and internodal length (-0.143) showed direct effect on yield in a negative direction.

Table 4.13
Genotypic correlation coefficients among 15 qualitative traits in F2 generation

	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FY	FL	FG	SI	FI	Flp	MFY
Pht	1.000**														
Dff	-0.40	1.000**													
L.no.	-0.15	0.18	1.000**												
IN	0.41	-0.55*	-0.82**	1.000**											
IL	0.02	-0.18	-0.05	0.97**	1.000**										
FN	1.04	-1.19	0.54*	0.48	-0.04	1.000**									
Nr	-0.29	-0.31	0.57*	-0.58*	-0.81**	-0.72**	1.000**								
FW	0.07	-0.51*	0.04	0.38	-0.12	-0.11	0.24	1.000**							
FY	0.52*	-0.65**	-0.12	0.76**	-0.20	0.89**	-0.91**	0.66**	1.000**						
FL	0.28	0.27	0.66**	-0.65**	-0.75**	0.30	-0.94**	-0.32	-0.01	1.000**					
FG	-0.17	-0.24	0.27	-0.34	-0.32	-0.15	-0.65**	0.18	0.16	0.15	1.000**				
SI	0.06	-0.41	-0.25	0.89**	0.62**	-0.29	-0.34	0.36	0.26	-0.67**	0.31	1.000**			
FI	-0.99**	-1.02	0.34	-0.54*	0.95**	-0.63**	-0.31	0.94**	-0.61*	-0.06	-0.13	-0.94**	1.000**		
Flp	0.13	-0.26	-0.19	0.15	0.61*	-0.76**	-0.94**	-0.37	0.10	-0.31	-0.10	0.67**	-0.56*	1.000**	
MFY	0.48	-0.35	0.10	0.08	-0.58*	0.38	-0.11	0.38	0.71**	0.45	-0.04	-0.41	0.63**	-0.38	1.000**

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days), * P<0.05 and ** P<0.01

Table 4.14
Phenotypic correlation coefficients among 15 qualitative traits in F2 generation

	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FY	FL	FG	SI	FI	Flp	MFY
Pht	1.000**														
Dff	-0.31	1.000**													
L.no.	-0.13	0.07	1.000**												
IN	0.18	-0.20	-0.36	1.000**											
IL	0.00	-0.12	-0.10	0.03	1.000**										
FN	0.45	0.03	0.00	0.11	-0.08	1.000**									
Nr	-0.14	0.35	0.10	-0.18	-0.17	0.55	1.000**								
FW	0.09	-0.37	0.00	0.17	-0.08	0.17	0.26	1.000**							
FY	0.52**	-0.58**	-0.10	0.33	-0.12	0.45	-0.15	0.65	1.000**						
FL	0.11	0.08	0.26	-0.07	-0.20	-0.01	-0.13	-0.14	0.00	1.000**					
FG	-0.15	-0.15	0.17	-0.14	-0.20	0.10	0.03	0.21	0.16	0.05	1.000**				
SI	0.07	-0.32	-0.20	0.39	0.35	0.01	-0.16	0.38	0.26	-0.27	0.32	1.000**			
FI	0.00	0.40	0.06	-0.12	-0.01	0.70**	0.77**	0.23	0.02	-0.06	0.07	-0.06	1.000**		
Flp	0.18	0.18	-0.19	0.34	0.17	0.59**	0.28	-0.05	0.09	-0.12	0.07	0.50**	0.31	1.000**	
MFY	0.48	-0.30	0.07	0.04	-0.34	0.49**	0.02	0.38	0.77	0.18	-0.03	-0.40	0.14	-0.20	1.000**

* P<0.05 and ** P<0.01

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days)

Table 4.15
Matrix Of Direct And Indirect Effects: Direct Effects On Main Diagonal

	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FL	SI	FI	Flp	MFY	Total correlation
Pht	**-0.143**	0.030	0.006	-0.028	-0.002	0.047	0.032	-0.001	0.016	0.035	0.055	-0.006	0.481	0.522
Dff	0.056	**-0.076**	-0.007	0.037	0.025	-0.053	0.008	0.010	0.016	0.049	-0.370	0.013	-0.353	-0.645
L.no.	0.021	-0.014	**-0.041**	0.055	0.007	0.024	-0.039	-0.001	0.039	-0.054	-0.229	0.010	0.097	-0.125
IN	-0.059	0.042	0.033	**-0.067**	-0.139	0.021	0.063	-0.008	-0.038	0.068	0.812	-0.057	0.084	0.755
IL	-0.002	0.013	0.002	-0.065	**-0.143**	-0.002	0.020	0.002	-0.044	0.065	0.559	-0.030	-0.577	-0.202
FN	-0.149	0.091	-0.022	-0.032	0.005	**0.045**	0.141	0.002	0.018	0.030	-0.266	0.038	0.985	0.886
Nr	0.184	0.023	-0.064	0.173	0.116	-0.256	**-0.025**	-0.005	-0.055	0.133	-1.221	0.195	-0.109	-0.911
FW	-0.010	0.039	-0.002	-0.026	0.017	-0.005	-0.006	**-0.020**	-0.019	-0.037	0.330	0.018	0.376	0.655
FL	-0.040	-0.021	-0.027	0.043	0.108	0.013	0.023	0.007	**0.059**	-0.030	-0.604	0.016	0.448	-0.005
SI	0.024	0.018	-0.011	0.023	0.046	-0.007	0.016	-0.004	0.009	**-0.203**	0.281	0.005	-0.037	0.16
FI	-0.009	0.031	0.010	-0.060	-0.088	-0.013	0.033	-0.007	-0.039	-0.063	**0.908**	-0.033	-0.410	0.26
Flp	-0.019	0.019	0.008	-0.077	-0.088	-0.034	0.097	0.007	-0.018	0.020	0.606	**-0.050**	-0.377	0.094
MFY	-0.068	0.027	-0.004	-0.006	0.082	0.062	0.003	-0.008	0.026	0.008	-0.371	0.019	**0.941**	0.711

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days)

4.8 SELECTION OF CROSS COMBINATIONS FOR FURTHER STUDIES

Considering the performance of yield and yield attributes and resistance to fruit infestation and shoot infestation the following crosses were selected for Generation Mean Analysis

1. Inter-specific hybrid *A. esculentus* **cv. Sel 2 x** *A. caillei* **cv. AC 5:** This cross combination manifested more fruit number, fruit yield, moderate degree of resistance to both shoot and fruit borer. Both the parents of this cross were moderately resistant to shoot borer.

2. Intra-specific cross of *A. esculentus*: **KL 9X Salkeerthy:** This cross combination showed high fruit number, high yield, field resistance to YVMV and moderate degree of resistance to shoot and fruit borer. Its parent KL 9 was moderately resistant to shoot borer and Salkeerthy showed high yield and high fruit number.

4.9 GENERATION MEAN ANALYSIS

The two promising crosses mentioned above were advanced to F_2, $BC_1$and BC_2 to isolate high yielding segregants showing inbuilt resistance to shoot and fruit borer. To elucidate the nature of gene action for shoot and fruit borer resistance, generation mean analysis was carried out using the data recorded from P_1, P_2, F_1, F_2, BC_1 and BC_2 generations of the above two cross combinations. The generation mean Analysis consists of two main steps i) testing for epistasis and ii) estimation of gene effects and variances. The testing of epistasis determines the presence or absence of inter allelic interaction and their type (Hayman and Mather, 1955).

4.9.1 Generation mean analysis in the cross *A. esculentus* cv. Sel 2 x *A. caillei* cv. AC 5

The data recorded from field experiment IV were subjected for generation mean analysis. The performance of six generation materials P_1, P_2, F_1, F_2, BC_1 and BC_2 of the inter specific cross Sel 2x AC 5 for 15 quantitative traits are presented in

Table 4. 16

Mean Performance of six generation materials of inter specific cross Sel2 x AC 5 for various quantitative traits

	Pht	Dff	L.no.	IN	IL	FN	Nr	SI	FI	Flp	MFY	FG	FW	FY	FL
P1	37.8	47.75	20.12	9.14	6.03	5.88	5	31.92	26.8	28.16	74.43	7.55	17.28	101.03	22
P2	24.55	50.25	26.02	8.49	5.06	2.73	5	2.87	19.88	31.98	29.24	8.13	13.54	36.86	15.45
F1	89.8	39.5	30.14	13.37	6.19	10.25	5	12.78	4.25	29.23	152.41	7.13	15.49	163.11	20.5
F2	50.29	45	21.97	10.15	5.9	7.4	5	14.75	18.88	29.87	98.84	7.05	15.54	115.58	21.13
BC1	46.82	41.75	22.67	10.42	5.62	5.67	5	15.88	24.13	29.59	56.95	6.63	13.33	75.98	21.75
BC2	35.71	49.25	21.35	9.66	5.77	3.92	5	29.4	17.83	29.42	45.12	7.38	13.77	54.37	21
di	0.727	-0.272	0.137	0.365	0.183	0.734	0.000	0.775	-3.678	-0.094	0.808	-0.140	0.126	0.774	0.246
ID	0.440	-0.139	0.271	0.241	0.047	0.278	0.000	-0.154	-3.442	-0.022	0.351	0.011	-0.003	0.291	-0.031

di- heterobeltiosis –(F1- BP) / F1, ID- Inbreeding Depression – (F1- F2) / F1

Table 4.17

Estimates of gene effects based on six generation means

	Pht	Dff	L.no.	IN	IL	FN	Nr	SI	FI	Flp	MFY	FG	FW	FY	FL
m	40.86	43.50	22.23	9.88	5.78	5.01	5.00	17.27	20.20	30.50	54.38	6.88	13.62	68.13	21.75
d	11.12	-7.50	1.31	0.76	-0.15	1.76	0.00	-13.53	6.30	0.17	11.83	-0.75	-0.44	21.61	0.75
h	22.52	-7.50	7.22	4.11	-0.16	-4.46	0.00	26.97	-10.68	-2.31	-90.67	-0.91	-7.89	-107.43	2.78
i	-36.12	2.00	0.15	-0.45	-0.81	-10.41	0.00	31.58	8.41	-1.47	-191.24	-0.20	-7.98	-201.60	1.00
j	4.50	-6.25	4.26	0.43	-0.63	0.19	0.00	-28.05	2.83	2.08	-10.77	-0.46	-2.31	-10.48	-2.53
l	113.01	-7.00	18.24	4.66	1.49	20.34	0.00	-61.80	-37.16	2.06	395.61	2.13	15.59	405.00	-8.05

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days)

Table 4.16. The results of scaling test are presented in Table 4.20 and the estimates of gene effects [m, d, h, i, j, l] are given in Tables 4.17. Salkeerthyient results are highlighted below.

4.9.1.1 Plant height

Plant height in F_1 (89.8c.m) was much higher than both the parents, Sel 2 (37.80) and AC 5 (24.55). The hybrid exhibited a heterobeltiosis of 72.7 percent and inbreeding depression was 44 percent. Scaling test was significant only for Scale B; hence epistasis was assumed to be present. For the interacting crosses, six parameter model was adopted, the non-additive effects [h+l=135.53] were greater than additive effects [d+i=-25]. The sign of [h] and [l] are on the same direction and interaction is complementary epistasis.

4.9.1.2 Days to first flowering

F_1 flowered earlier (39.5 days) compared to both the parents Sel 2 (47.75) and AC 5 (50.25 days). The F_1 manifested 27.2 percent heterobeltiosis in desirable direction (-). The estimates of scales A, B and D were significant showing presence of epistasis. The non additive effects [h+l = -14.5] were larger than additive effects [d+i =-5.5].Since the sign of [h] and [l] were on the same direction (-), there is the presence of complementary epistasis.

4.9.1.3 Number of fruits per plant

F_1 hybrid recorded maximum value for this trait (10.25 no. of fruits / plant). The hybrid had shown a heterobeltiosis of 73.4 per cent and an inbreeding depression of 27.8. The estimates of scales A, B, C and D were insignificant suggesting the absence of inter allelic interaction. The additive effect was low [d =1.76] and there was a dominance effect of h= -4.46.

4.9.1.4 Fruit weight

Fruit weight of F_1 hybrid (15.4g) was less compared to better parent Sel 2 (17.28g). The heterobeltiosis was 12.6 that is in negative direction and with an inbreeding depression of 0.3 percent. Scales A, B and D were significant. The additive effects and additive x additive interaction effects [d+i = -8.42] were in almost equal magnitude as that of dominance, dominance x dominance effects [h+l=7.70]. Therefore, both additive and dominance effects were important for this character. The interaction was of duplicate epistasis as [h] and [l] are in opposite direction.

4.9.1.5 Fruit yield

The F_1 hybrid recorded maximum fruit yield of 163.11, compared to parents Sel 2 (101.03) and AC 5 (36.86). The heterosis of F_1 over better parent Sel 2 was 77.4 per cent. Scaling test was significant over scale B and showed presence of epistasis. The estimates of dominance effect was high [h= -107.43] compared to the additive effects [I = 21.61]. The values of dominance and dominance x dominance interaction were in opposite direction hence the interaction was duplicate dominance.

4.9.1.6 Shoot infestation

Shoot borer infestation in moderately resistant parent (Sel 2) was 31.92 per cent (Table 4.27), whereas in *A. caillei* parent AC 5 shoot infestation was 2.87 per cent. Shoot borer damage in the F_1 was 12.78 per cent. The mean shoot infestation in the segregating generation *i.e.* F_2, B_1 and B_2 were within the range of parents. Shoot borer infestation shown a heterobeltiosis of 77.5 percent over better parent and with an inbreeding depression of 15.4 per cent in negative direction. Scaling test was insignificant suggesting inter allelic interaction. The additive effect was negative [d= -13.53] whereas the dominance effect was positive [h=26.97].

4.9.1.7 Fruit infestation

Fruit borer infestation among six generation materials varied from 4.25 to 26.8 per cent. The F_1 manifested 78.62 per cent heterobeltiosis in desirable direction (-). Infestation in the F_2 and backcross progenies (B_1 and B_2) falls within their parental values *i.e.* 24.13 to 17.83 per cent. The genes interact as evident from the significance of scales A and B. The non additive effects [h+l=-47.84] were larger than additive effects [d+i=14.71]. The sign of [h] and [l] were in the same direction (+) and hence the interaction is complementary epistasis.

4.9.2 Generation mean analysis in the cross KL 9 x Salkeerthy

The observations recorded from field experiment IV were subjected for generation mean analysis. The performance of six generation materials P_1, P_2, F_1, F_2, B_1 and B_2 of the inter specific cross KL 9 x Salkeerthy for 15 quantitative traits are presented in Table 4.18. The results of scaling test are presented in Table 4.21 and the estimates of gene effects [m, d, h, i, j, l] are given in Tables 4.19. Salkeerthyient results are presented below.

4.9.2.1 Plant height

The F_1 manifested 3.9 percent heterosis over better parent in negative direction. But the F_2 segregants (mean = 45.17 c.m) having more plant height than F_1s (945.29) but further reduction in height was noticed in the back cross progenies (934.43 to 37.49). The scale B was significant, hence the epistasis assumed to be present. The duplicate digenic non allelic interaction model is found to be adequate to explain the gene action.

4.9.2.2 Days to first flowering

Salkeerthy flowered earlier (38.25days) than KL 9 (40.25). The F_1 flowered earliest i.e. 34.75 days, but the derivatives from these parents i.e. F_2, BC_1 and BC_2 have flowered later than both the parents (38.75, 41 and 44.33 respectively). The hybrid manifested heterobeltiosis of 10.1 per cent in desirable direction (-) for this trait. Scales A and B were significant epistasis is present. Both additive (d = -3.33) and additive x additive effects (l =15.67) were significant.

4.9.2.3 Number of fruits per plant

The F_1 hybrids showed more number of fruits (10.26) that both the parents and F_2 had (11.3). Heterobeltiosis was 2.5 percent and having an inbreeding depression

Table 4.18

Mean Performance of six generation materials of inter specific cross KL9X Salkeerthy for various quantitative traits

	Pht	Dff	L.no.	IN	IL	FN	Nr	SI	FI	Flp	MFY	FG	FW	FY	FL
P1	39.02	40.25	22.58	7.61	4.22	8.78	5.75	29.68	27.93	26.63	124.07	6.88	19.39	174.2	21.63
P2	44.27	38.25	23.64	7.95	4.29	10	8	27.01	27.02	28.94	156	8	20.56	205.04	17.38
F1	42.59	34.75	21.46	8.42	4.19	10.26	7	15.86	22.37	30.42	157.03	7.93	19.38	197.58	19.13
F2	45.17	38.75	19.67	8.21	3.96	11.3	7.25	26.03	26.58	25.78	150.72	7.5	18.6	209.57	18.88
BC1	37.49	41	17.5	7.35	4.29	6.29	8	28.42	28.71	28.45	77.33	7.5	17.32	108.81	19.5
BC2	34.43	44.33	16.58	7.19	3.33	6.75	8.67	19.7	33.64	29.68	82.35	7.5	17.91	120.92	17
di	-0.039	-0.101	-0.102	0.056	-0.024	0.025	-0.143	-0.703	-0.208	0.049	0.007	-0.009	-0.061	-0.038	0.091
ID	-0.061	-0.115	0.083	0.025	0.055	-0.101	-0.036	-0.641	-0.188	0.153	0.040	0.054	0.040	-0.061	0.013

di- heterobeltiosis –(F1- BP) / F1, ID- Inbreeding Depression – (F1- F2) / F1

Table 4.19

Estimates of gene effects based on six generation means

	Pht	Dff	L.no.	IN	IL	FN	Nr	SI	FI	Flp	MFY	FG	FW	FY	FL
m	35.57	41.25	16.06	7.08	4.46	5.92	8.00	24.44	33.16	27.40	70.87	7.75	17.76	104.36	19.00
d	3.05	-3.33	0.91	0.16	0.96	-0.46	-0.67	8.72	-4.93	-1.23	-5.01	0.00	-0.59	-12.11	2.50
h	-35.90	11.17	-12.15	-3.12	-0.64	-18.24	4.46	-20.37	13.27	15.77	-266.53	0.49	-4.55	-370.86	-2.88
i	-36.84	15.67	-10.50	-3.76	-0.58	-19.11	4.33	-7.89	18.37	13.13	-283.53	0.00	-3.95	-378.83	-2.50
j	5.68	-4.33	1.44	0.34	1.00	0.15	0.46	7.39	-5.38	-0.08	10.95	0.56	-0.01	3.31	0.38
l	61.48	-38.33	31.48	7.07	2.23	32.33	-9.92	0.07	-43.38	-12.97	558.29	0.73	12.21	693.77	6.75

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days)

of -10.1 per cent. Scaling test indicated presence of inter allelic interaction with significance on scales A and B. The joint scaling test indicated the presence of duplicate epistasis.

4.9.2.4 Fruit weight

Fruit weight ranged between 17.91 to 20.56 g. Next to F_1 (19.38) fruit weight was high in F_2 (18.6) and it was reduced in back crosses. Scales A and D were significant indicating the presence of epistasis. The additive effects and additive x additive interaction effects [d+i =- 4.54] were lesser than the dominance and dominance x dominance effects [h+l = 7.66]

4.9.2.5 Fruit yield

The F_1 manifested a fruit yield of 197.58 g and was intermediate between both the parents KL 9 (174.2) and Salkeerthy (205.04). But F_2 showed a higher yield compared to F_1 *i.e.* 209.57 g. The heterosis was 3.8 percent in negative direction. Scale A was significant. The estimates of [h] and [l] showed opposite sign hence it was duplicate epistasis.

4.9.2.6 Shoot infestation

Shoot infestation in parent KL 9 was 29.68 and in Salkeerthy it was 27.01. The hybrid showed 15.86 per cent of shoot damage with high heterobeltiosis of 70.3 in the desirable direction (-). The estimates of scales A, B, C and D were insignificant suggesting the absence of inter allelic interaction. The additive effect was 8.72 and the dominance effect was -20.37.

4.9.2.7 Fruit infestation

Fruit borer infestation was low in F_1 hybrid i.e. 22.37 compared to all other five generations where infestation ranged from 33.64 to 26.58 per cent. Scales A and B were significant, thereby suggesting the presence of interallelic interaction of all kinds. Additive effects [d = -4.93] were low and negative, while additive x additive interaction effects were high and positive [i = 18.37]. Similarly dominance effects

Table 4.20
Scaling test to detect the presence epistasis in the cross Sel2 x AC 5 for various quantitative traits

Traits	Scale A	Scale B	Scale C	Scale D	χ^2
Plant height	0.02	-2.77*	-0.97	0.34	50.80
Days to first flowering	2.69*	10.95*	0.85	6.57*	94.02
Leaf no.	1.10	-2.25*	-2.82*	0.96	21.27
No. of internodes	0.77	1.94	1.02	0.45	10.71
Internodal length	1.18	2.58*	0.52	0.81	33.97
No. of fruits	1.14	-0.11	0.90	0.01	44.28
No. of ridges	1.29	2.04*	33.06*	1.31	23.21
shoot infestation	0.30	0.55	0.69	0.58	15.45
fruit infestation	-2.11*	-3.22*	-0.98	1.28	84.92
fruit girth	0.69	0.42	0.42	0.95	60.33
Fruit weight	2.25*	5.59*	1.76	4.32*	23.06
Fruit yield	-1.66	-3.17*	-0.67	1.02	48.37
Fruit length	0.83	1.24	0.66	0.70	33.14

Table 4.21
Scaling test to detect the presence epistasis in the cross KL9 x Salkeerthy for various quantitative traits

Traits	Scale A	Scale B	Scale C	Scale D	χ^2
Plant height	-1.62	-2.53*	-1.88	1.29	30.81
Days to first flowering	3.64*	6.09*	1.28	1.02	37.29
Leaf no.	1.08	-3.87*	-2.51*	0.03	3.88
No. of internodes	0.44	0.72	0.38	0.06	50.42
Internodal length	1.58	1.81	0.04	1.05	1.28
No. of fruits	-2.57*	2.52*	-0.21	-1.74	.73
No. of ridges	1.54	1.35	0.62	-0.26	8.87
shoot infestation	0.64	0.32	0.50	0.38	62.44
fruit infestation	-2.57*	-2.12*	-0.08	1.26	5.18
fruit girth	1.44	0.54	66.00*	0.08	46.7
Fruit weight	3.73*	1.13	0.13	2.57*	12.54
Fruit yield	-2.09*	-1.78	0.01	1.29	26.81
Fruit length	0.28	1.30	1.38	0.18	23.17

were positive [h = 13.27] while dominance x dominance interaction effect was positive [l = -43.88]. Thus the interaction happened to be duplicate epistasis.

4.10 HETEROSIS AND INBREEDING DEPRESSION

The mean values of the parents and hybrids were used to determine the heterosis manifested by the F_1 generations for each character. The F_1s of Sel 2 x AC5 and KL9 x Salkeerthy were taken to study the various heterosis for different traits. Heterosis refers to the superiority of F_1 hybrid in one or more characters over its parents or the improvement of F_1 in fitness and vigor over the parental values. Relative heterosis was higher for plant height, number of fruits, fruit infestation, fruit girth and fruit yield. Fruit yield scored highest heterosis for both the crosses. Sel 2 x AC5 and KL9 x Salkeerthy. There was also a high inbreeding depression noticed for this character which indicates the presence of non-additive gene action either dominance or epistasis (Table.4.22 and Table. 4.23).

The high heterosis is an indication the same alleles one fined in one parent and other alleles in the second parents. Heterosis can be fully exploited in the form of hybrids. In case of days to first flowering, number of fruits, number of ridges, fruit weight and fruit length there was the presence of negative heterosis in the cross Sel 2 x AC 5, which are not in the desirable direction. In case of KL9 x Salkeerthy negative heterosis was observed in characters like days to first flowering, number of ridges, shoot infestation, fruit girth which are in desirable direction.

4.11 BIOCHEMICAL BASIS OF RESISTANCE

Resistance to the crop pests is either based on physical characteristics or based on the biochemicals in the plant parts. In this study the phenol and tannin content in the dried samples of fruit and shoot borer resistant and susceptible

Table 4.22
Estimation of heterosis and inbreeding depression in the cross Sel 2 x AC 5

Character	Het (FP)	Het (SP)	Het (MP)	ID
Plant height	15.23	8.38	11.81	10.74
Days to first flowering	-6.75	-5.000	-5.88	53.50
Leaf no.	5.71	4.32	5.02	9.97
No. of internodes	2.33	1.46	1.90	1.77
Internodal length	3.93	2.93	3.43	3.04
No. of fruits	-11.74	-22.96	-17.35	-12.75
No. of ridges	-6.21	-10.3	-8.26	-5.36
shoot infestation	4.52	-.81	1.86	1.92
fruit infestation	76.38	49.62	63.00	63.39
fruit girth	1.05	.68	.86	.3
Fruit weight	1.10	-1.49	-0.20	.63
Fruit yield	82.49	40.19	61.34	63.27
Fruit length	-2.38	.38	-1.00	0.00

Table 4.23
Estimation of heterosis and inbreeding depression in the cross KL 9 x Salkeerthy

Character	Het (FP)	Het (SP)	Het (MP)	ID
Plant height	52.01	62.25	58.63	39.51
Days to first flowering	-8.25	-10.75	-9.50	-5.50
Leaf no.	10.02	4.12	7.07	8.17
No. of internodes	4.23	4.88	4.56	3.22
Internodal length	4.38	7.52	5.95	2.86
No. of fruits	-19.14	9.91	-4.61	-1.97
No. of ridges	-22.56	-15.63	-19.09	-14.63
shoot infestation	1.07	-1.46	-0.20	-0.64
fruit infestation	77.98	123.17	100.57	53.57
fruit girth	-0.43	-1.00	-0.71	0.07
Fruit weight	-1.78	1.95	0.08	-0.05
Fruit yield	62.08	126.26	94.17	47.54
Fruit length	-1.50	5.05	1.77	-0.62

Het (FP) - Heterosis with first parent, Het (SP) - Heterosis with second parent, Het (MP) - Heterosis with mid parent, ID - Inbreeding depression genotypes is done to reveal any correlation between the resistance and presence of these biochemicals in the plant parts.

Phenols are the aromatic compounds with hydroxyl group which occur in most of the plant parts. Phenols are said to offer resistance to diseases and pests in plants. Tannins and tannin like substances are also widespread in nature and probably present in all plant materials and offers pest resistance by lower digestibility and impaired nutritional quality.

4.11.1 Phenol and Tannin content

Phenol in the fruits of moderately resistant *A. caillei* (220.2 µg per gram) was significantly higher than Susceptible species *A. esculentus* (82.5 µg per gram) (Table 4.24). Phenol in the shoots of moderately resistant species *A. caillei* was 156 µg per gram while it was significantly high (64.8 µg) in Susceptible species *A. esculentus* (Table 4.24).

Table 4. 24

Contents of some selected phytochemicals in the fruits of resistant and susceptible *Abelmoschus* species

Sl.no.	Species	Resistant class	Phenol (µg/g)		Tannin (µg/g)	
			fruit	shoot	fruit	shoot
1	*Abelmoschus esculentus*	Highly susceptible	82.5	64.8	685.8	68.44
2	*Abelmoschus caillei*	Highly resistant	220.2	156	715.2	92.2

Tannin content was significantly higher (715.2 µg per gram) in moderately resistant *A. caillei* shoots than in Susceptible *A. esculentus* shoots (76.31 µg per gram) and susceptible *A. esculentus* shoots (685.8 µg per gram) (Table 4.24). Shoot borer susceptible species *i.e. A. esculentus* and moderately resistant species *A. caillei* recorded 68.4 and 92.2 µg per gram of tannin in shoot. It reveals that there is a significant and direct relation between presence of biochemicals and fruit and shoot borer resistance.

4.12 CLASSIFICATION OF GENOTYPES BASED ON THEIR RELATIVE DEGREE OF RESISTANCE

Kumbhar *et al.* (1991) was given a rating scale to classify the genotypes based on resistance and it is followed to group the germplasm based on their shoot and fruit infestation into five resistance classes namely, i) immune (0 per cent infestation), ii) highly resistant (1-10 per cent shoot or fruit infestation), iii) moderately resistant (11-20 per cent infestation), iv) susceptible (21-30 per cent infestation) and v) highly susceptible (>31 per cent infestation). The mean infestation data was used for the classification. The genotypes grouped according to their resistance reactions are shown in Table 4.26. Data on percentage shoot infestation, fruit infestation and marketable fruit yield recorded from F_2s and Generation mean analysis studies in field experiment III and IV are presented in Tables 4.25. Salient results are given below.

4.12.1 Genotypes resistant to shoot borer (E. vittella)

Out of the 15 F_2s tested, six were immune to shoot borer (Table 4.26). Only one entry *i.e.* KL 9 x AC 5 was highly resistant. Five F_2s were moderately resistant. The remaining two F_2s, which includes KL 9 x Susthira (25 percent) and Arka Anamika x Susthira (30 per cent), were either susceptible or highly susceptible to shoot borer. The damage symptoms observed in susceptible varieties are shown in the Plate.12. The F_1, F_2 and BC_1 generation of Sel2x AC 5 were moderately resistant to shoot borer.

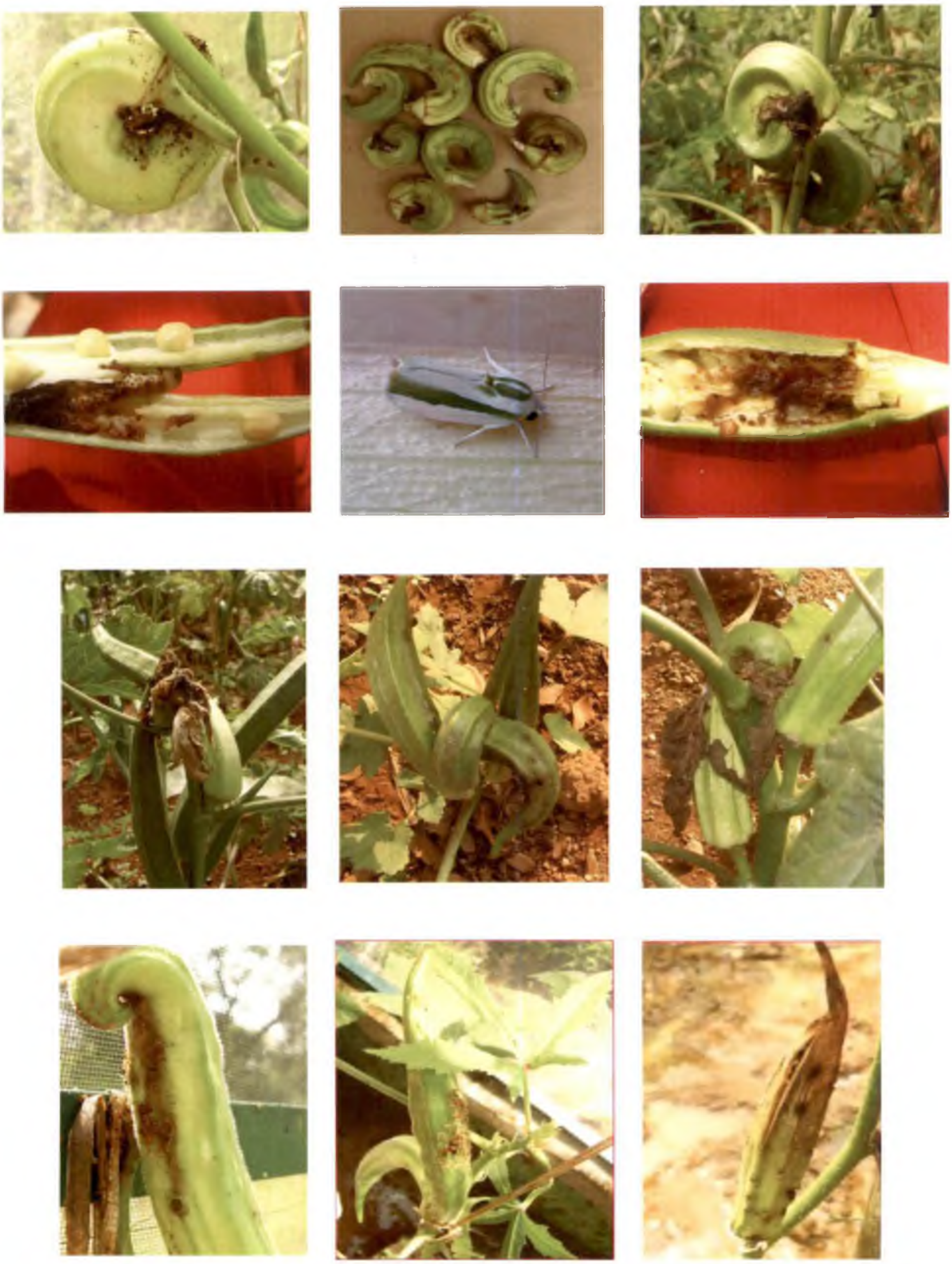


Plate 12. Shoot and Fruit Borer (*Earias vittella*) damage symptoms

Table 4.25

Percentage shoot infestation (SI), Fruit infestation (FI) and Marketable Fruit Yield in 15 F2 and six generations of Sel 2xAC 5 and KL 9X Salkeerthy

Sl. no.	Genotype	%SI	%FI	FY	MFY
1	Salkeerthy x KL9	18.18	27.50	203.00	147.17
2	Salkeerthy x Arka Anamika	18.18	31.50	238.00	163.03
3	Salkeerthy x Susthira	16.66	20.80	144.00	114.04
4	KL9 x Sel 2	20.00	11.76	170.00	150.08
5	KL9 x AC5	8.33	36.84	228.00	144.04
6	KL9 x Susthira	25.00	20.00	237.50	190.00
7	Arka AnamikaxKL9	0.00	24.00	212.50	161.50
8	Arka AnamikaxSalkeerthy	0.00	29.60	243.00	171.07
9	Arka AnamikaxSusthira	30.00	36.00	212.50	136.00
10	Arka AnamikaxSel 2	0.00	34.60	234.00	153.03
11	Sel 2xSalkeerthy	11.00	42.00	161.50	93.67
12	Sel 2xArka Anamika	0.00	33.33	216.00	144.07
13	SusthiraxAC5	0.00	21.05	152.00	120.04
14	SusthiraxSel 2	0.00	14.20	35.00	30.03
15	Salkeerthy	28.57	80.00	190.00	38.00
	<u>Sel2 x AC 5</u>				
16	P_1	31.92	26.80	101.03	74.43
17	P_2	2.87	19.88	36.86	29.24
18	F_1	12.78	4.25	163.11	152.41
19	F_2	14.75	18.88	115.58	21.13
20	BC_1	15.88	24.13	75.98	56.95
21	BC_2	29.40	17.83	54.37	45.12
	<u>KL9xSalkeerthy</u>				
22	P_1	29.68	27.93	174.20	124.07
23	P_2	27.01	27.02	205.04	156.00
24	F_1	15.86	22.37	197.58	157.03
25	F2	26.03	26.58	209.57	150.72
26	BC_1	28.42	28.71	108.81	77.33
27	BC_2	19.70	33.64	120.92	82.35

4.12.2 Genotypes resistant to fruit borer (E. vittella)

No genotype was immune to fruit borer (Table 4.26). F1 of Sel2 x AC 5 was observed to be highly resistant to fruit borer. KL 9 x Sel 2(11.76 per cent), Susthira x Sel 2 (14.2 per cent) and KL 9 x Susthira(20 per cent) showed less than 20 per cent fruit infestation hence treated as moderately resistant to fruit borer. The remaining F_2 generations of crosses were susceptible or highly susceptible to fruit borer.

Table 4.26
Classification of germplasm based on their relative degree of resistance to shoot and fruit borer

Group	Category	Percentage of infestation	Shoot Borer	Fruit Borer
I	Immune	0 %	Susthira x Sel 2, Susthira x AC 5, Sel2 x Arka Anamika, Arka Anamika x Sel2, Arka AnamikaxSalkeerthy, Arka AnamikaxKL9	Nil
II	Highly resistant	1 - 10.99%	AC5, KL9xAC5	Sel 2xAC5 (F_1)
III	Moderately resistant	11 - 20.99%	Sel 2xSalkeerthy, KL9xSel 2, SalkeerthyxKL9, SalkeerthyxArka Anamika,SalkeerthyxSusthira, Sel 2xAC5 (F_1, F_2, BC_1), Kl 9 x Salkeerthy (F_1, BC_2)	KL 9 x Sel 2, Salkeerthy x Susthira, KL 9 x Susthira, Susthira x Sel 2, AC 5, Sel 2 x AC 5 (F_2, BC_2), AC 5
IV	susceptible	21 - 30.99%	KL 9 x Susthira, KL 9, KL 9 x Salkeerthy (BC_1), Sel 2 x AC 5 (BC_2)	Sel 2, KL9, SalkeerthyxKL9, Arka AnamikaxKL9, Arka AnamikaxSalkeerthy, SusthiraxAC5, Sel 2xAC5(BC_1), Kl 9 x Salkeerthy (F_1, F_2, BC_1)
V	Highly susceptible	> 31 %	Salkeerthy	Salkeerthy, SalkeerthyxArka Anamika, KL9xAC5, Arka AnamikaxSusthira, Arka AnamikaxSel 2, Sel 2xSalkeerthy, Sel 2xArka Anamika, Kl 9 x Salkeerthy(BC_2)

DISCUSSION

5. DISCUSSION

From the ancient era itself there existing the selection of genotypes based on the level of resistance, otherwise the people could save only those plants which did not succumb to pest depredation during the domestication of crops. In the early years of 20^{th} century, with the help of genetics based plant breeding, breeders produced new crop varieties with improved resistance to major diseases and insect pests. After the second world war and at the time of green revolution there was a tremendous usage of pesticides. Due to the awareness of ecological and health hazards associated with pesticides, Integrated Pest Management (IPM) emerged as an eco friendly option to pest control and the resistant variety is the most important and basic component of a successful IPM. The genetically engineered genes also proved to provide resistance nowadays. The little knowledge about consequences and negative effects of the genetically modified organisms is paving way to more acceptance of resistance breeding in classical or conventional plant breeding methods.

Okra shoot and fruit borer is a serious pest of the crop and causes losses over thirty percent which is equivalent to seven tonnes per ha (Rawat and Sahu, 1973; Krishnaiah *et al.*, 1976; Dhamdhere *et al.*; 1984). As okra is grown in an area of three lakh ha with an annual production of 32 lakh tonnes in India, it is of a prime importance to control this pest. Resistant varieties are preferred because the use of pesticides will cause the residual problems as it is harvested and consumed as tender pods.

5.1 SELECTION OF PARENTS FOR BREEDING PROGRAMME

The main objective of the research programme is to combine the shoot and fruit borer resistance to the existing high yielding varieties like Arka Anamika, Salkeerthy and Susthira from the resistant genotypes like Sel 2, KL 9 and AC 5. Both the high yielders and resistant types are consists of cultivated species *A. esculentus* and semi domesticated species *A. caillei*. The seeds of these genotypes were collected from National Beauro of Plant Genetic Resources and Kerala Agricultural University. Both the species under study have shown high variability among them for many characters. *Abelmoschus caillei* was having long flowering period and takes more number of days to first flowering and having small non ridged fruits, large leaves and flowers compared to *Abelmoschus esculentus.*

5.2 CROSSABILITY AND FERTILITY OF INTERSPECIFIC HYBRIDS

Considering the time of anthesis and anther dehiscence *A.caillei* was late compared to *A. esculentus* genotypes. Difference in the flowering period and the time of flower opening was a constrain during the crossing of the parents to obtain F_1s and crossing of the F_1s with parents to obtain back cross progenies; problem of difference in flowering period was overcome by sowing the replications in one week interval. Repeated pollination and crossing is done to obtain maximum number of F_1s for higher seed set. Crosses were made in all possible combinations but fruit set was not there in crosses like Arka Anamika x AC 5, AC 5 x Salkeerthy and AC 5 x Susthira.

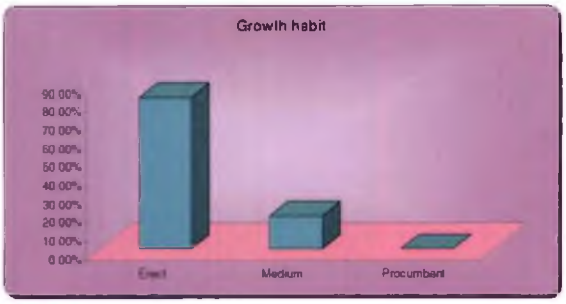
Most of the crosses with *A. esculentus* as female parent are appeared to be successful and showed good germination percentage but in case of interspecific crosses with *A.caillei* as the female parent, a few crosses appeared to be unsuccessful. This is mainly because of the difference in chromosome number and the difference in other characteristics. The crossed fruits appeared to be intermediate in character to the female parent and pollen parent. Seed set was very low and seeds appeared as shriveled in interspecific crosses. Similar results were also reported by Sindhu (1993) and Sheela (1994). The dried fruits were harvested for seeds and extracted seeds were again dried under the shade. The seeds were sown as F_1 along with parents in replication. The seeds were also treated with gibberelic acid at a rate of 100 ppm for improving germination. The seeds obtained from the few interspecific crosses like AC 5 x Arka Anamika, AC 5 x Sel 2 and AC 5 x KL 9 showed zero percent germination even on repeated sowing. Thus very few crosses involving AC 5 could be obtained from this breeding programme.

The present study was undertaken to transfer shoot and fruit borer resistance present in semi domesticated species to cultivated okra. Most of the crosses between *A. esculentus* and *A.calliei* were successful in either direction and also reported by Dhillion and Sharma (1982), Hamon and Yapo (1986) but Chacko *et al* (1998) and Kousalya *et al* (2006) reported failure of *A.esculentus* x *A.caillei* crossing.

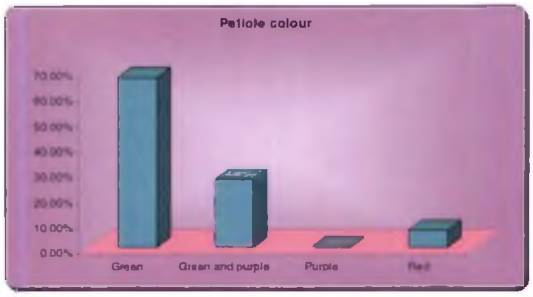
5.3 VARIABILITY OF GERMPLASM FOR QUALITATIVE TRAITS

The knowledge about the extend of variability is the basic need to develop an effective plant breeding programme. The efficiency of selection largely depends upon the magnitude of genetic variability present in the population. Extend of variability for qualitative traits made based on the descriptor status or based on the scores. Variability was high among the genotypes from different species *A. caillei* and *A. esculentus* but showed comparatively less variability within the species.

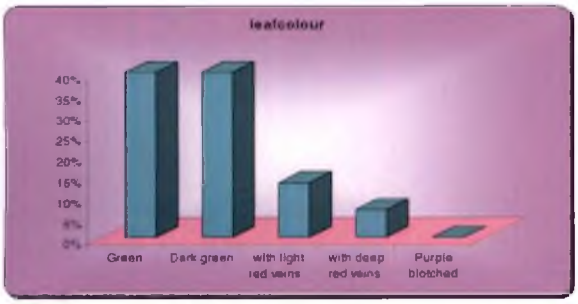
In case of growth habit most of the F_1 s and F_2 s shown erect characters (> 90%) and a few *A. caillei* F_1 s showed intermediate growth habit. Regarding the pigmentation on plant parts, the F_1 s and F_2 s showed highest variability. Leaf lamina colour varied from green to purple and all the *A. esculentus* showed various shades of green but *A. caillei* genotypes had shown green leaves with veins of red shades. Petiole colour also ranged from green to red and the *A. caillei* species only showed a wide variability. Regarding fruit colour it showed a wide variability from pale white to pink with seven descriptor status. But most of the fruits have close resemblance to green and an interspecific cross of KL9 x Salkeerthy have shown green with purple striations Fig.5.1. Kirtisingh *et al.* (1974) investigated variability in species and found out that a large number of okra characters such as pigment



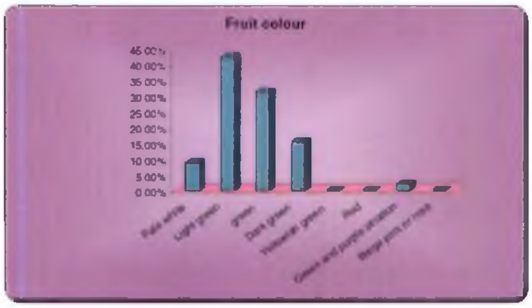
i. Growth habit



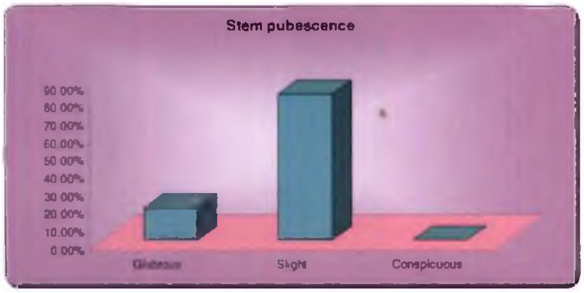
ii. Petiole colour



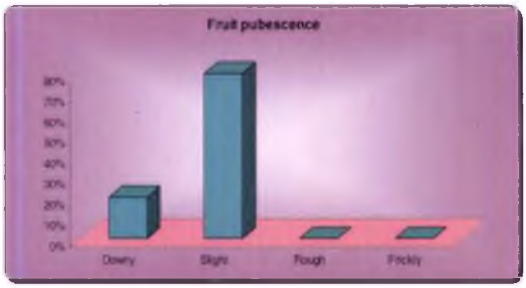
iii. Leaf colour



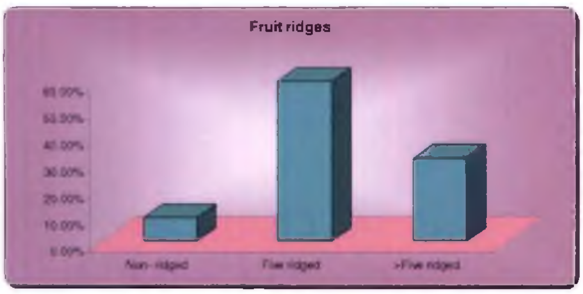
iv. Fruit colour



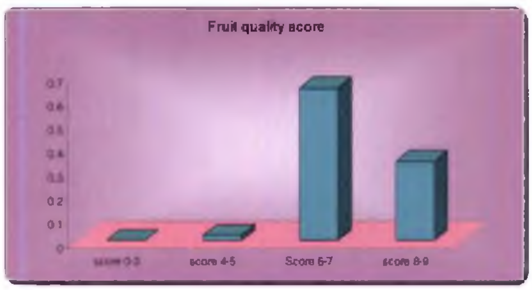
v. Stem pubescence



vi. Fruit pubescence



vii. No. of ridges on fruits



viii. Fruit quality score

Fig. 5.1 Variability for qualitative characters

colour and fruit pubescence are inherited in simple fashion, suggesting that these characters are controlled by relatively few genes. The results also agree with those of Girenko and Pugachev(1983), Ariyo(1993) and Karuppaiyan(2006) who reported high variability for leaf colour and fruit colour in okra.

In case of stem and fruit pubescence variability was very less and most of the F_1 s and F_2 s have shown glabourous or slight pubescence on fruit surface and downy slight pubescence on the stem surface. This is mainly because the germplasm was obtained from either domesticated or semi domesticated species of okra and the genetic make up of the parents were almost similar. Fruits exhibited high degree of variation for number of ridges four *A. caillei* species having non ridged *fruits to 14* genotypes having more than five ridges. Five ridged fruits were the most common type found in 60% of the population.

Fruit quality score assessed based on the fruit colour, tenderness, surface texture and market preference showed the entire genotypes are having consumable fruits with varying quality. This is mainly because the parents are the cultivated and semi-wild varieties. Similar results were reported by Hamon and Charrier (1983), Bisht *et al.* (1995), Ariyo (1993) and Nizar *et al.* (2004). The good quality genotypes can be used as donors for improving fruit quality.

5.4 VARIABILITY OF GERMPLASM FOR QUANTITATIVE TRAITS

Variability refers to the presence of differences among the individuals of plant population. It results due to differences either in the genetic constitution of the individuals of a population or in the environment in which they are grown. Hence, insight into the magnitude of genetic variability present in a population is of paramount importance to the plant breeder for starting a judicious breeding programme (Singh and Narayanan, 2006). The variability for days to first flowering, internode number, number of ridges fruit girth and flowering period was low as it is evident from low GCV (< 15 per cent) and high variability was shown by plant height, marketable fruit yield, fruit weight, shoot infestation and fruit infestation

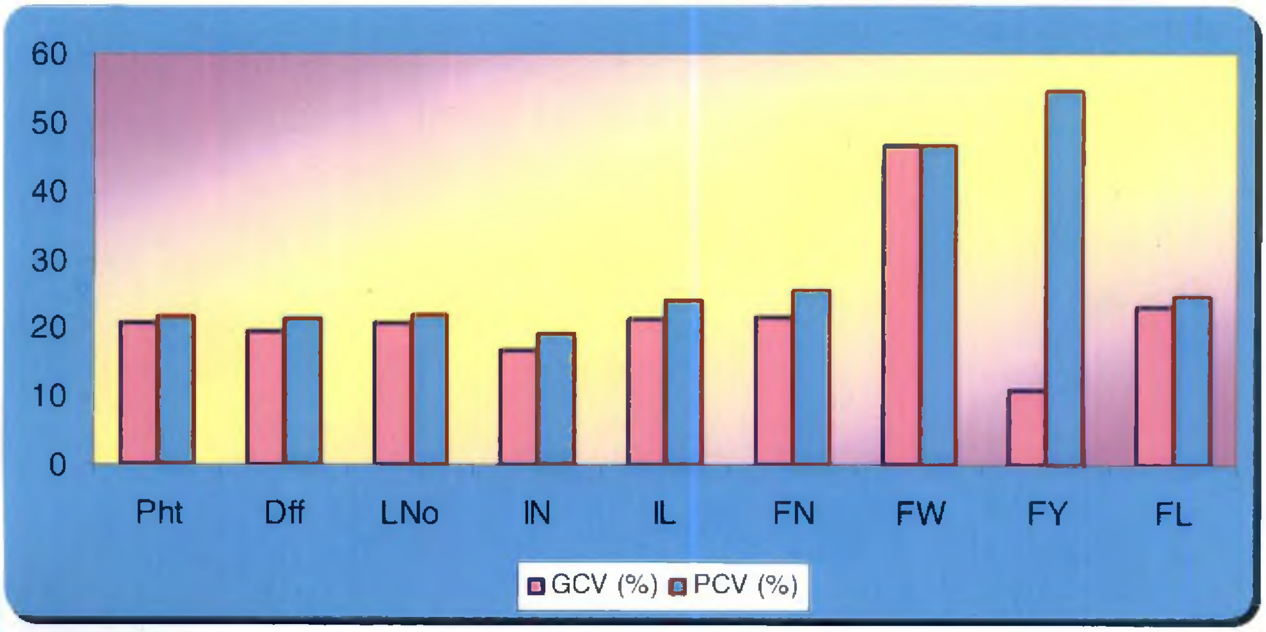


Fig.5.2 Genotypic coefficient of Variation and Phenotypic coefficient of Variation of F_1

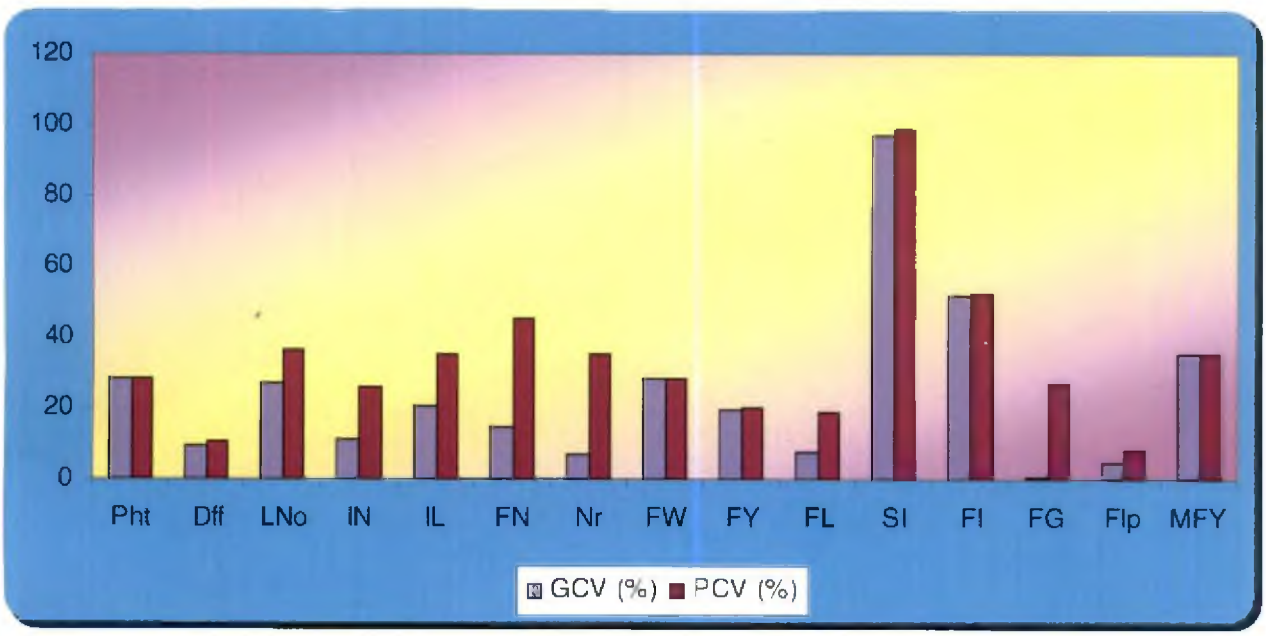


Fig.5.3 Genotypic coefficient of Variation and Phenotypic coefficient of Variation of F_2

(GCV>30 per cent) (Fig.5.2 and Fig. 5.3). All other characters have shown an intermediate genotypic component of variation. The high GCV gives an indication of justifiable variability among the genotypes with respect to these characters and therefore gives scope for improvement through selection.

The minor variation between values of GCV and PCV, incase of fruit weight, days to first flowering and fruit length shows the limited role of environment in these characters and the heritability was very high for these traits. Selection for improvement of such characters will be rewarding in this situation. But in case of characters like fruit number, number of ridges there is high influence of environmental factors as evident from high difference between GCV and PCV and recombination breeding is the best method to improve these traits. This finding also agrees with the observation of Majumder *et al.* (1974), Kirtisingh *et al.* (1974), Dhall *et al.* (2003) and Karuppaiyan (2006) who reported low GCV for days to first flowering and fruit girth, medium GCV for fruit yield, fruit weight and high GCV for marketable fruit yield, fruit and shoot borer infestation and plant height.

High heritability followed by low genetic advance was found in all characters in F_1 except fruit weight. This is the indication of predominance of epistasis and dominant gene action. But in F_2 generation fruit weight, fruit yield per plant, plant height, days to first flowering, shoot infestation, fruit infestation and marketable fruit yield exhibited high heritability (Fig.5.4 and Fig. 5.5). Fruit weight, plant height, shoot infestation and fruit infestation recorded simultaneous higher heritability and genetic advance compared to other traits. It shows that these characters can be improved through selection. Chacko and Babu (1999) reported similar results.

5.4.1 Performance of genotypes for yield and yield attributes

From this study it is revealed that F_1 s derived from *A. esculents* flowered 20-25 days earlier then *A. caillei* genotypes. KL9 (29 days) scored low for this trait and can be used as donor for earliness and the maximum value for flowering period was secured by Salkeerthy (32-33 days). Plant height and number branches are

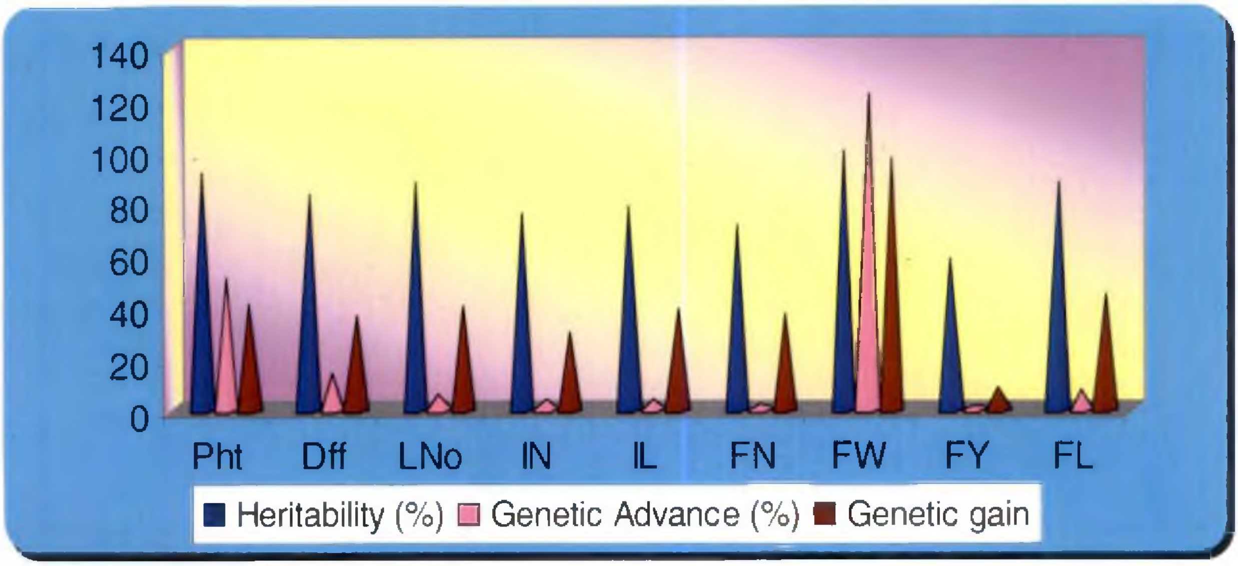


Fig.5.4 Heritability, Genetic advance, Genetic gain of various traits in F_1

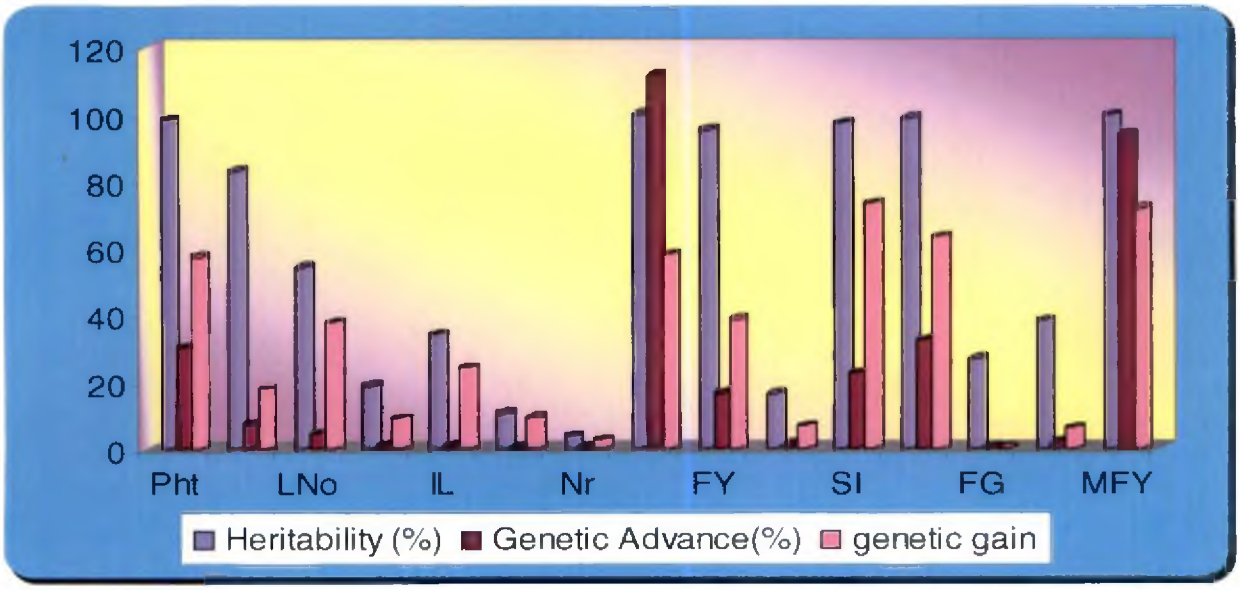


Fig.5.5 Heritability, Genetic advance, Genetic gain of various traits in F_2

Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%), Flp- flowering period (days).

important yield contributing characters in okra (Vijay and Manohar, 1990) F_1 of Sel 2 x KL9 recorded 194 cm for this character. In okra as each leaf axil produces a single fruit, low intermodal length and high internode number are desirable in increasing the number of fruits per plant (Singh and Singh, 1979). Salkeerthy x AC 5 shown highest internode number and Arka Anamika x Salkeerthy displayed shortest internodal length and can be used for further generations. *A. caillei* genotypes have shown short internodes and reduced plant height.

Considering the length of the fruits, Salkeerthy and F_1 s with Salkeerthy as female parent produced lengthy fruits. Average fruit weight was also higher for F_1 of Salkeerthy (35.00 g) and F_2 of KL9 x AC5. The fruit weight of Salkeerthy was mainly contributed by high fruit length and that of KL9 derivates due to high fruit girth. Highest fruit yield in F_1 was given by Arka Anamika x Salkeerthy followed by Salkeerthy and can be further multiplicated for varietal development for high fruit yield. In case of marketable fruit yield KL9 x Susthira ranked top followed by Arka Anamika x Salkeerthy.

It is observed that even the fruit yield was highest in *A.esculentus* genotypes the difference between fruit yield and marketable fruit yield was minimum in *A. caillei* genotypes due to less susceptibility to pest and diseases. The F_2 generations of interspecific crosses of *A. caillei* and *A. esculentus* have shown less coefficient of infection for Yellow Vein Mosaic Virus and Salkeerthy and its progenies were highly susceptible to YVMV. These were previously observed by and Chheda and Fatokun (1982), Karuppaiyan (2006) and Kousalya *et al.* (2006) and they reported that *A. caillei* was highly resistant to YVMV. Among the characters observed in both F_1 and F_2 generation there is a difference in degree of variability for the same character as the selection reduces the variability in further generations and segregants were also found in F_2 generations for different characters.

5.4.2 Performance of genotypes for resistance to shoot and fruit borer

The parents used in the study were already screened for fruit and shoot borer resistance, and it is found that parents namely Sel 2, AC 5 and KL9 were moderately

Plate 13. The F_1 of KL 9 x Salkeerthy along with parents

Plate 14. The F_1 of Sel 2 x AC 5 along with parents

resistant (Karuppaiyan, 2006). Considering the cross compatibility of these parents with cultivated high yielding varieties these parents are preferably selected over resistant wild species for the purpose of resistant donors in this breeding programme. The performance of genotypes were assessed in the open field condition, comparing the percentage of shoot infestation, fruit infestation and marketable fruit yield. The results of the study were discussed below.

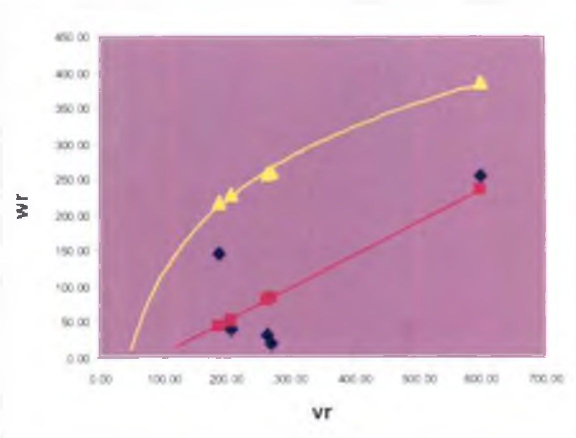
In the experiment No. I and II, there was little scope in studying the shoot and fruit borer infestation as the parent and F_1s were grown under protected green houses in pest free conditions. Therefore 15 selected F_2s and genotypes of generation mean analysis of Sel 2 x AC 5 and KL9 x Salkeerthy (Plate.13 and Plate.14) were screened for pest infestation in open field conditions with susceptible variety in border rows to raise the pest population for better screening.

Differential response to fruit and shoot borer infestation was observed in all genotypes even the pest causing the damage was same. The study revealed that minimum shoot infestation was shown by F_2s of Arka Anamika x KL9, Arka Anamika x Sel 2, Sel 2 x Arka Anamika, Susthira x AC5 and Susthira x Sel 2. AC5 has shown minimum shoot infestation among the parents.

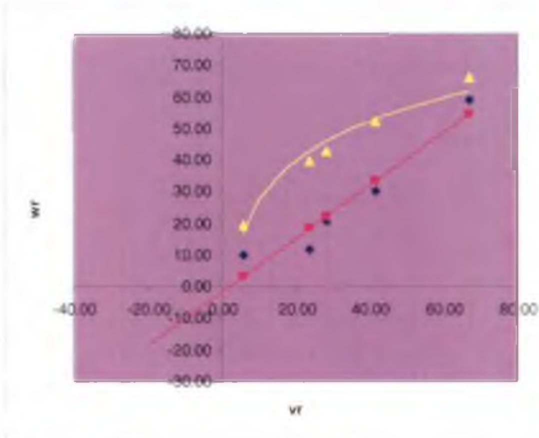
In case of fruit infestation F_1 of Sel 2 x AC 5, F_2 s of KL9 x Sel 2 and Susthira x Sel 2 shown high resistance or low infestation. In case of marketable fruit yield KL9 x Susthira secured the highest. It is evident from the result that the progenies of resistant parents have shown preferable traits for further selection. These results are consistent with the findings of workers like Bairwa *et al.* (2005) and Karuppaiyan (2006).

5.5 DIALLEL ANALYSIS

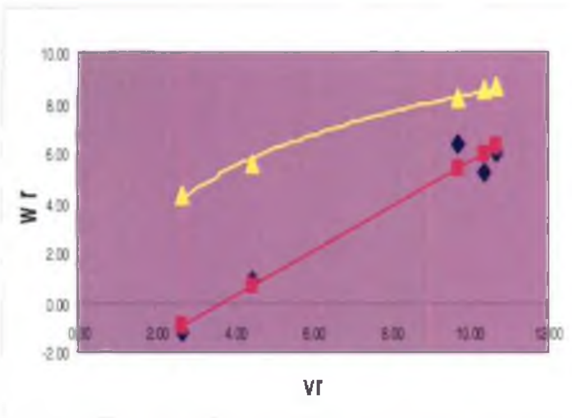
The estimate of gca variance and genetic parameters in the diallel analysis will give an idea about the gene action. Combining ability analysis for the 5x5 full diallel cross revealed the gene action for every trait under the study. Components of



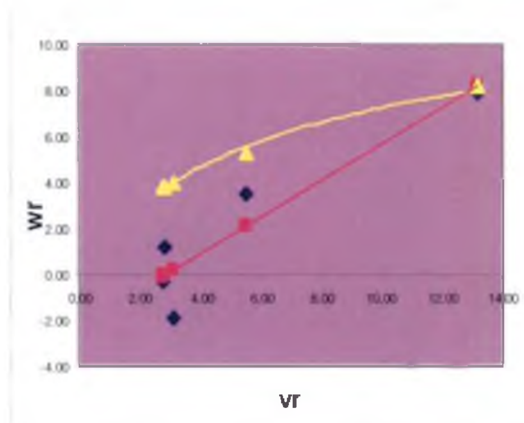
i. Plant height



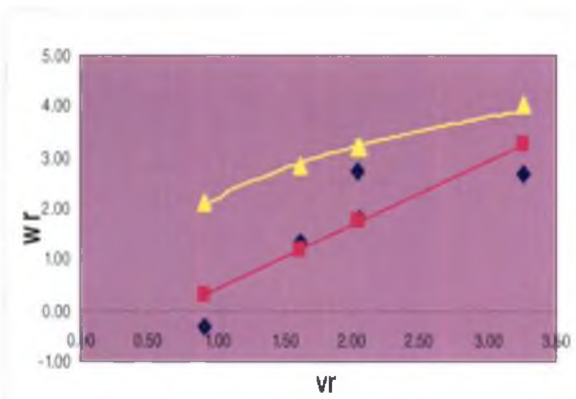
ii. Days to first flowering



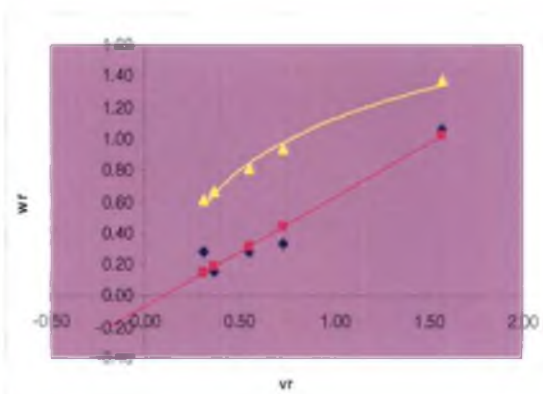
iii. Number of leaves



iv. Number of internodes

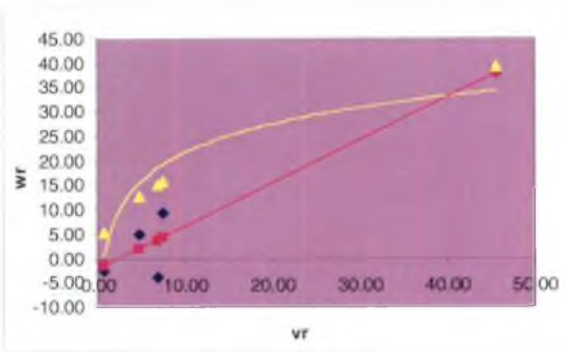


v. Length of internodes

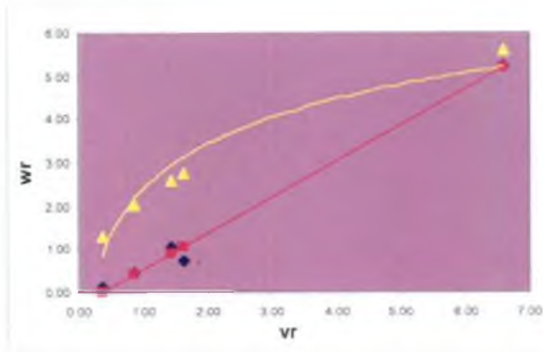


vi. Number of ridges

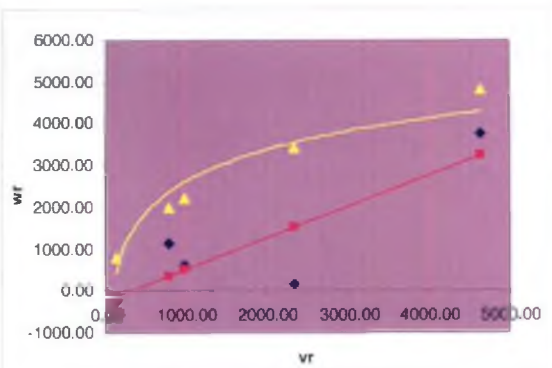
Fig.5.6 Wr-Vr graphs



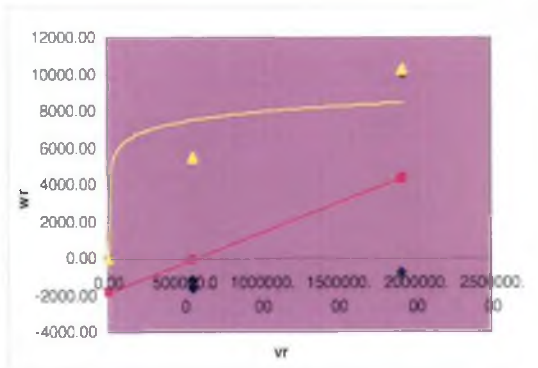
vii. Fruit length



viii. Fruit number

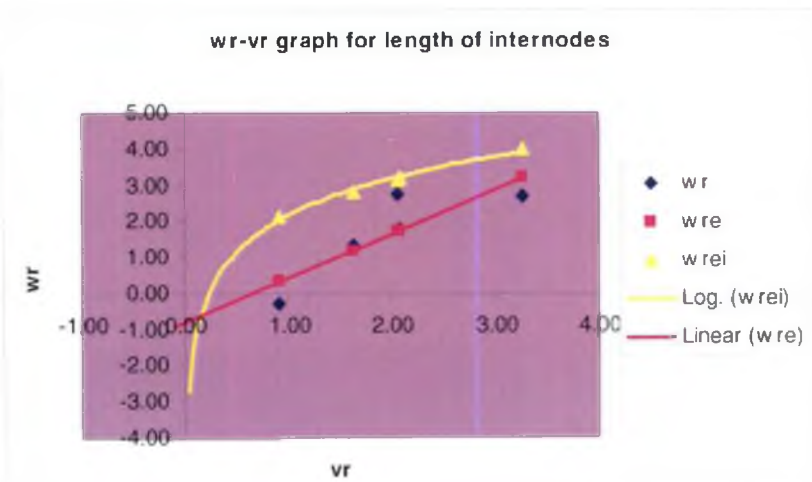


ix. Fruit weight



x. Fruit yield

Fig.5.6 Wr-Vr graphs



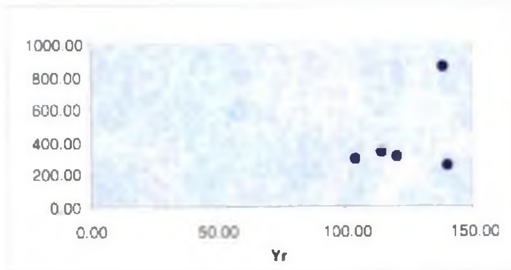
variation due to the dominance effect of the genes were greater than components of variation due to additive effect of the genes for all characters except internodal length. This signifies the importance of non-additive effects of these characters indicating the presence of over dominance. Consequently it is suggested that these traits could be improved through heterosis breeding rather than selection.

Therefore yield could be enhanced through the improvement of these component traits like plant height days to first flowering, number of leaves number of internodes, fruit length, fruit number and fruit yield by recombination or heterosis breeding. In okra presence of non additive gene action for most of the characters like days to first flowering, plant height, number of fruits per plant, single fruit weight and fruit yield were reported by Sharma and Mahajan (1978), Shukla *et al.* (1989), Cahudhary *et al.* (1991) Singh *et al.* (2001) and Kumar *et al.* (2005).

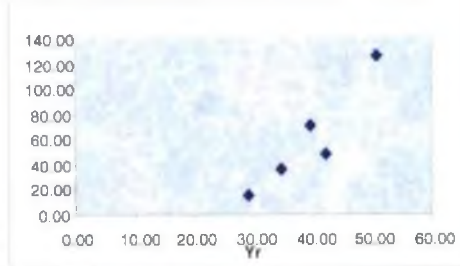
The numerical and graphical analysis indicated overdominance for almost all characters in okra (Rajani and Manju, 1999). In case of Internodal length both additive and non additive gene action showed equivalent magnitude indicating the presence of complete dominance (Fig.5.6). The standard deviation graph shows the prescence of recessive genes with positive effect for almost all the characters (Fig.5.7). This character can be inherited through breeding programmes like biparental mating followed by recurrent selection. From the components of variation it is concluded that characters like days to first flowering, number of leaves, plant height, internodal length, number of internodes and fruit number having symmetrical distribution of positive and negative genes but others with asymmetrical distribution of these genes (Table.4.11). A number of scientists such as Sivakumar *et al* (1995), Partap and Dhankar (1980) and Rani and Arora (2003a) reported the same.

5.5.1 General combining ability effects of parents

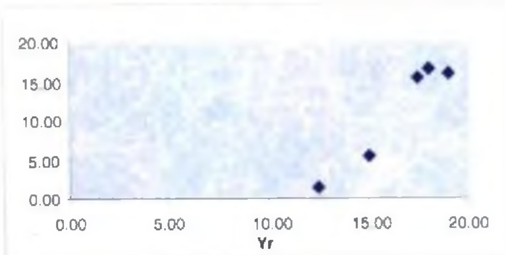
The average performance of a genotype in a series of hybrid combination is termed as general combining ability and these genotypes with high general combining ability are called as good general combiners for particular trait. The gca is a measure of additive genetic variance (Sprague and Tatum, 1942). On the basis



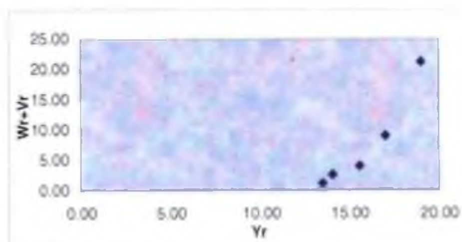
i Plant Height



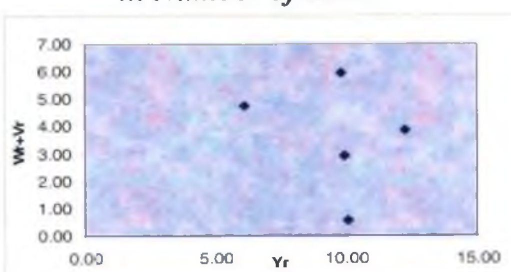
ii Days to first flowering



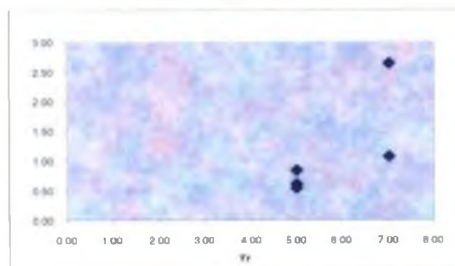
iii Number of leaves



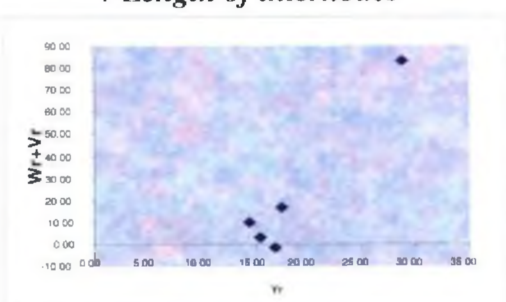
iv Number of internodes



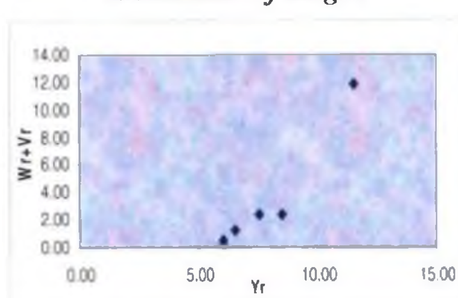
v Length of internodes



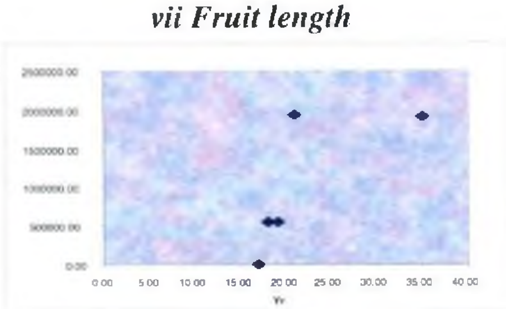
vi Number of ridges



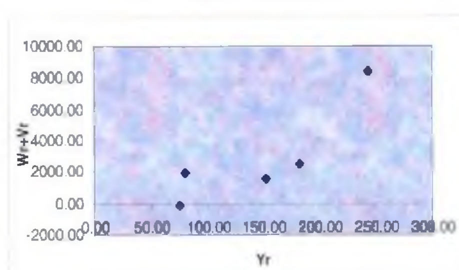
vii Fruit length



vii Fruit Number



ix Fruit weight



x Fruit Yield

Fig.5.7 Standard deviation graphs

of direction and magnitude of gca effects, it was found that Arka Anamika was good general combiner for fruit number, fruit weight and fruit length. The genotype KL9 was a good general combiner for plant height, days to first flowering, leaf number, Internodal number and fruit weight.

5.5.2 Performance of hybrids for yield and other attributes

The cross combination Arka Anamika x Sel2 was found to be good specific combiners in case of magnitude and direction for the traits like plant height, days to first flowering, leaf number, internodal number and internodal length. In case of fruit weight all the cross combinations have shown significant specific combining ability. Regarding fruit length Arka Anamika x Salkeerthy has shown significant positive specific combining ability and Arka Anamika x KL9 have shown significant negative combining ability. The cross combination Arka Anamika x Salkeerthy has manifested high significant gca effects for fruit yield and can be considered as good specific combiner for improving fruit yield.

The variances for sca were greater than gca variances for most of the characters studied indicating the predominant role of dominance gene action governing the epistasis. In case of some traits parents with high gca effects produced hybrids with low sca effects maybe due to lack of complementation of parental genes. Whereas some hybrids with high sca effects had parents with poor gca which can be due to complementary gene action. This is in line with the findings of Rajani *et al.* (2001).

5.5.3 Reciprocal Differences

The ANOVA revealed the significance of reciprocal effects for all the traits under study except for leaf number, internode length and fruit number. Therefore, during selection of crosses in addition to sca, importance may be give to reciprocal difference also. In case of fruit yield per plant, considering the magnitude and direction of reciprocal effects, it is understood that Arka Anamika x Salkeerthy will give better progenies only when Arka Anamika was taken as female parent. Similarly in case of other traits also these differences should be taken into account while making the crosses. The reciprocal differences are mainly due to difference in chromosome number in interspecific crosses and may be due to cytoplasmic inheritance.

5.6 CORRELATION AND PATH ANALYSIS

Correlation and Path Analysis are the important tools useful for getting information regarding association of characters. Correlation study estimates the mutual relationship between various characters and helps in determining the component characters on which selection can be based for improvement in yield. The interpretations from correlation studies become more evident when correlations are partitioned into the components in path analysis in order to determine the relative magnitude of various attributes contributing to correlation (Jaiprakashnarayanan and Ravindra, 2004).

The correlation studies have shown that characters like flowering period, internode number, internode length has significant positive association with shoot infestation and negative association between fruit length and shoot infestation. Therefore it can be concluded that selecting genotypes with short flowering period, short internode length and short fruits are preferable to reduce shoot borer infestation. Plant height, internodal number, fruit number, fruit yield and flowering period showed a negative association with fruit infestation, so selection of genotypes with early flowering, enhanced plant height, and more internode number will reduce fruit borer infestation. Similar results were obtained by Karuppaiyan (2006). The fruit yield was positively correlated with plant height, number of internodes, fruit weight and marketable fruit yield but negatively correlated with days to first flowering and fruit infestation. Therefore selection of genotypes with enhanced plant height, increased number of internodes, high fruit weight and high marketable fruit yield will be the basic steps towards the development of high yielding resistant bhindi varieties. These findings are in accordance with Mishra and Singh (1985) Vijay and Manohar (1990) Sood *et al.* (1995) and Deo *et al.* (1996) observed positive correlation of fruit yield with fruit weight, number of internodes and plant height.

Path coefficient analysis was worked out to determine the true component on fruit yield and it was found that highest genotypic correlation coefficient was contributed by fruit number. The plant height showed a positive correlation coefficient on yield with its indirect effect on yield through fruit number. The fruit length and marketable fruit yield showed a positive direct effect on yield. The characters like days to first flowering, internodal length, leaf number and number of ridges on fruits showed negative direct effect on yield. Mishra and Singh (1985), Lakshmi *et al.* (1996), Chacko and Babu (1999), Jaiprakashnarayan and Ravindra (2004) and Singh *et al.* (2007) obtained similar direct and indirect effect of components on yield.

Hence direct selection for fruit weight and number of fruits per plant is suggested for getting yield improvement. In situations where there is positive association of major yield characters, component breeding would be very effective but when these characters are negatively associated, it would be difficult to exercise simultaneous selection for them in developing a variety (Akinyele and Osekita, 2006).

5.7 GENERATION MEAN ANALYSIS

In the present study, two promising crosses were selected to study the nature and magnitude of additive, dominance and epistatic effects for shoot and fruit borer resistance, yield and its other attributes from the elite crosses identified in the study (Plate.15 and Plate.16). The values of individual scaling tests and estimates of m, d, h, i, j and l and parameters of different characters in two crosses namely Sel 2 x AC 5 and KL9 x Salkeerthy were estimated. Information on the genetic architecture of the various traits is essential for proper selection of parents and breeding methodology.

KL9x Salkeerthy BC1

Salkeerthy x KL 9

Sel 2 x AC 5

Susthira x AC5

KL 9 x Salkeerthy F1

Arka Anamika x Sel 2

Susthira x Sel 2

KL9 x Susthira

KL9 x AC5

Plate 15. Elite Crosses Identified in the Study

Plate 16 Elite Crosses Identified in the Study

5.7. 1 Gene action for various characters the intra-specific cross Sel 2 x AC5

Gene action refers to the behavior or mode of expression of genes in a genetic population. The non allelic interaction or epistasis was absent for number of internodes, shoot infestation, fruit girth and fruit length in the cross Sel 2 x AC5. Non additive variance was high for number of internodes shoot infestation fruit length and fruit girth. As these traits with high dominance variance are non fixable, selection for this traits is ineffective. Therefore heterosis breeding programme will be useful for improving these traits.

Epistasis was observed for plant height, days to first flowering, leaf number, internodal length, fruit infestation, flowering period, marketable fruit yield, fruit weight and fruit yield. The digenic non-allelic interaction model was found adequate to explain the gene action in these traits. The interaction was complementary for plant height, days to first flowering, leaf number, fruit infestation but duplicate epistasis was observed for Internodal length, flowering period, fruit weight and fruit yield.

In duplicate epistasis, due to negative dominance in some locus, mutual cancellation of positive and negative effects may take place. In such situation additive effects would be important in deciding the net effects. Hence Karuppaiyan, (2006) reported that heterosis breeding is not desirable is case of duplicate epitasis but it would be possible to isolate segregants as good as that of F_1 in the subsequent filial generations. More reliance should be placed on selection between families and lines for the traits with relatively high epistatic variance. The figures of flowers and pods of parents and F_1s of Sel2 x AC5 are given in the Plate .17.1 and Plate.17.2.

5.6.2 Gene action for various characters in the cross KL9 x Salkeerthy

Inter allelic interaction (epistasis) was present for most of the traits except number of internodes, internodal length, number of ridges, shoot infestation and fruit length. Non Additive variance was high for internodal length, number of ridges, shoot infestation, fruit length but additive variance was high for internode number (Fig.5.8). The breeding objective should be towards development of hybrids for

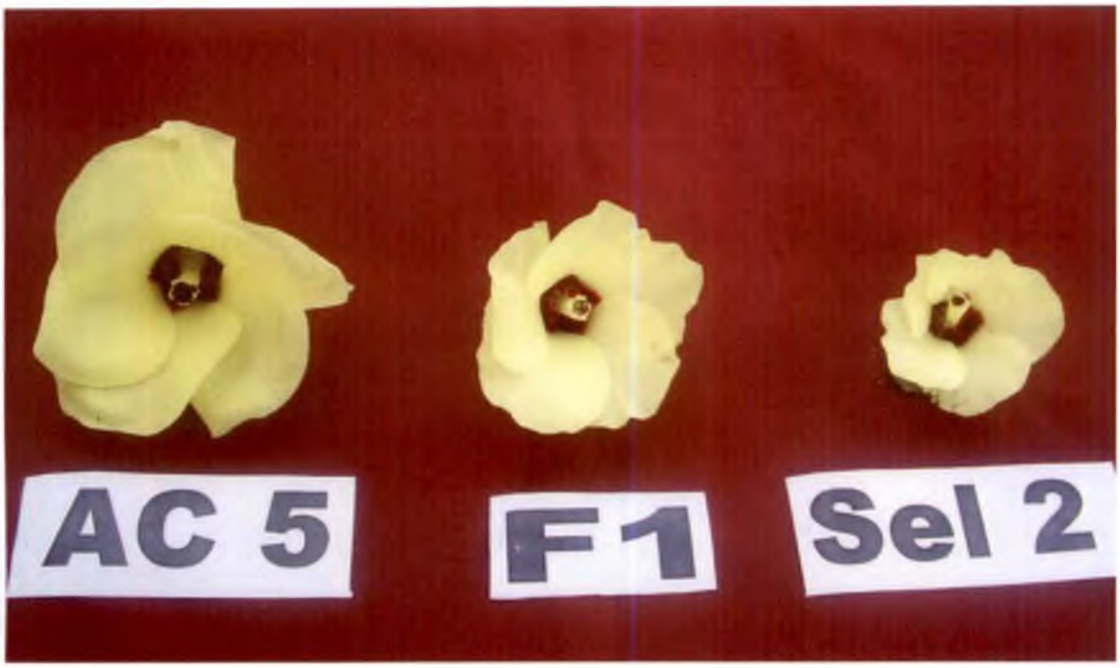


Plate 17. 1 Flowers of the parents and hybrid of interspecific cross
Sel 2 x AC 5

Plate 17.2 Sel 2 x AC 5

Plate 17.3 KL 9 x Salkeerthy

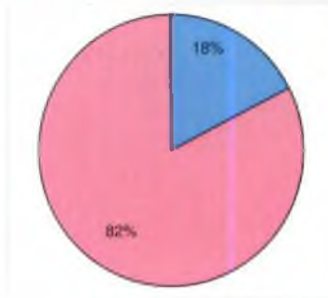
commercial purpose in case of the traits with high dominance variance. Selection is the reliable breeding method for improving varieties for the characters with high additive variance. When non additive gene effects are greater than additive gene effects biparental mating or recurrent selection can be done to get more heritable variation for simultaneous improvement of fruit yield and its components. The dominance (h), additive x additive (i) and dominance x dominance (l) gene effects were important for most of the traits in two crosses under generation mean analysis.

Duplicate epistasis was observed for plant height, days to first flowering, leaf number, fruit number, fruit infestation, flowering period, fruit weight and fruit yield. Hence it would be desirable to go for recombination breeding to isolate useful segregants. The duplicate dominant epistasis in the inheritance of the characters studied was earlier reported by Arumugam and Muthukrishnan (1979), Korla and Sharma (1987) and Panda and Singh (2005) in okra. In case of fruit girth complementary digenic non-allelic model was found adequate and these are fixable and can be exploited effectively for the improvement of traits by pedigree method of selection. The figures of pods of parents and F_1s of KL9 x Salkeerthy are given in the Plate.17.3.

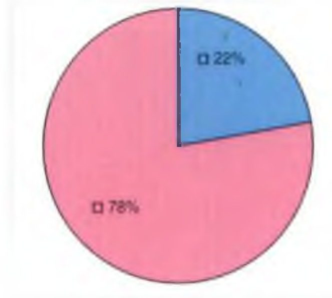
5.7 HETEROSIS AND INBREEDING DEPRESSION

Heterosis was observed in the both the selected crosses of Sel2 x AC5 and KL9 x Salkeerthy. High heterosis was followed by inbreeding depression in case of characters like plant height, fruit infestation and fruit yield indicates the presence of non-additive gene action. Negative heterosis was observed in case of days to first flowering, number of ridges, shoot infestation and fruit girth. In okra hybrid vigour over mid parent was reported by Vijayaraghavan and Warrier (1946), Vekataramani (1952), Joshi *et al.* (1959) and Peter (1998). Jawli and Rasco (1990) reported that F_1 hybrids flowered earlier than the parents. The crosses with significant heterotic values for desirable traits, in desired direction could be utilized to exploit hybrid vigour commercially. Low inbreeding depression suggests that increased vigour of

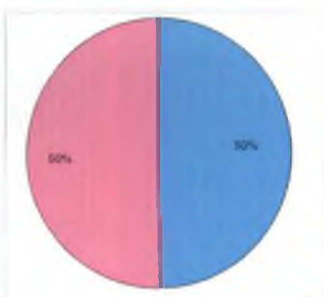
i. Days to flowering



ii. Plant height

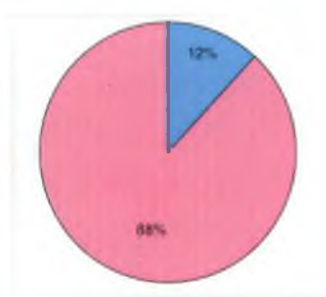


iii.Number of Leaves

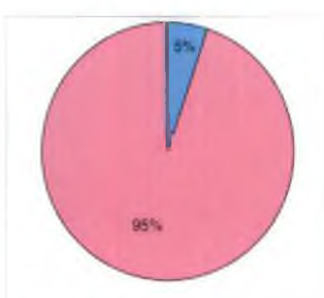


iv. Internode number

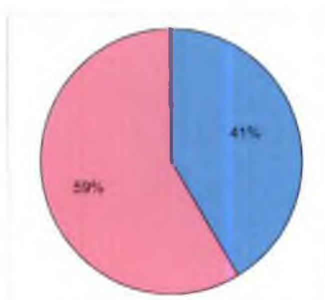
v. Fruit weight



vi. Fruit length



vii. Internode length



viii. Fruits/plant

ix. Fruit yield/plant

- refers to additive variance

- refers to non-additive variance

Fig.5.8 Proportion of additive and non-additive variance for quantitative traits

F_1s in such cases is expected to be mainly due to accumulation of favourable additive genes (Shukla and Gautam, 1990). The extend of heterosis in okra in relation to yield and its components have earlier been reported by Kumbhani *et al.*(1993), Poshiya and Vashi (1995), Wankhede *et al.*(1997), Panda and Singh (2001) and Borgaonkar *et al.* (2005).

5.8 BIOCHEMICAL BASIS OF RESISTANCE

To identify the influence of biochemicals in imparting the resistance to fruit and shoot borer chemical analysis were done. Resistant genotypes like *A. caillei* had high phenol content in fruit and shoot than susceptible *A. esculentus* genotypes. It is reported that phenolic compounds were known to provide resistance to *Earias* in cotton (Sharma and Agarwal, 1984). Previous reports by Arumugam and Muthukrishnan (1979) and Karuppaiyan (2006) confirm the presence of higher phenol content in *A.caillei* than *A.esculentus*. Another feeding inhibitor present in the genotypes was tannin and which is also present in higher percentage in *A. caillei* than *A.esculentus*. This is in agreement with Sharma *et al.* (1982) who reported prescence of high tannin in the shoot and fruit borer resistant cotton genotypes.

5.9 CLASSIFICATION OF GENOTYPES BASED ON THE DEGREE OF RESISTANCE

Based on the rating scale given by Kumbhar *et al.* (1991) the genotypes were classified for degree of resistance. Twenty seven genotypes of different crosses and different generations are screened in the present study. Performance of parents for yield and resistance are given in the graph in Fig.5.9. The study revealed that F_1s of Susthira x Sel 2, Susthira x AC 5, Sel 2 x Arka Anamika, Arka Anamika x Sel 2, Arka Anamika x Sal and Arka Anamika x KL9 were found immune to shoot borer but none of them were immune to fruit borer. AC5 and KL9 x AC5 were highly resistant to shoot borer and F_1 of Sel 2 x AC5 was highly resistant to fruit borer.

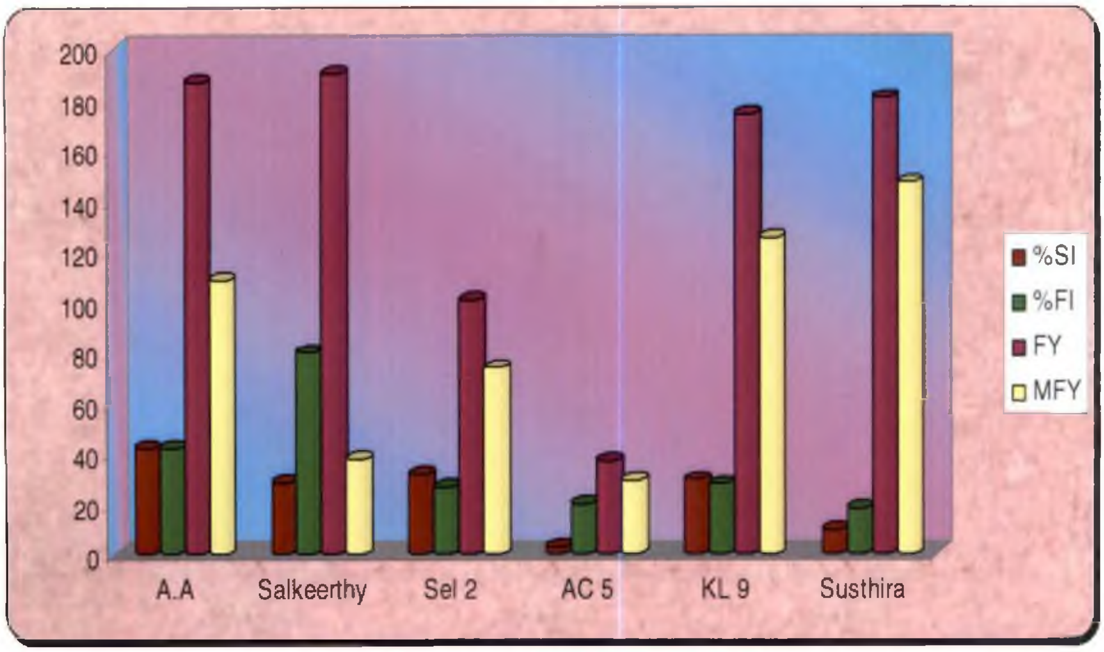


Fig. 5.9 Performance of Parents for yield and resistance

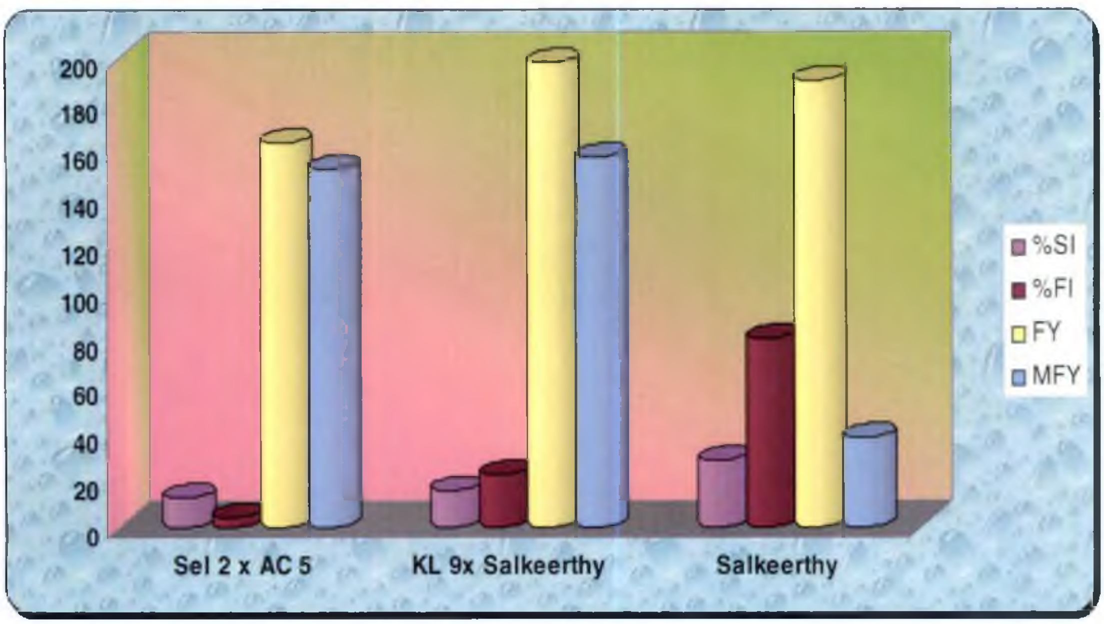


Fig. 5.10 Performance of superior hybrids for yield and resistance with check variety Salkeerthy

Salkeerthy was found highly susceptible for both shoot borer and fruit borer infestation. Previous workers like Mahadevan and Dhandapani (1985), Gupta (1988),. Vyas and Patel (1991), Srinivasa and Sugeetha (2001), and Neeraja *et al.* (2004) reported the susceptibility of many cultivated varieties to fruit borer. Comparative information about yield and resistance of parents and superior hybrids can be obtained from the graphs in Fig 5.9 and Fig. 5.10.

The F_1 of Sel 2 x AC 5 was found to be the best genotype which was showing highest degree of resistance to both fruit borer (highly resistant) and shoot borer (moderately resistant) compared to all other genotypes under study (Fig.5.10). This is having comparatively high fruit yield (163.11 g) and marketable fruit yield (152.41g). Therefore this genotype can be considered as an elite genotype with both high yield and resistance to fruit and shoot borer. This F_1 has shown field resistant to yellow vein mosaic virus also. The field view of the crop in different stages is given in Plate.18.

5.10 FUTURE LINE OF WORK

The present research work reveals that the parents AC 5 and KL 9 are the potential donors of shoot and fruit borer resistance. But many of the crosses using parent AC 5 (*Abelmoschus caillei*) genotype were not successful. Crossing barriers like cross incompatibility and hybrid sterility was found in the generation of F_1 plants of interspecific crosses involving *A. caillei* and *A. esculentus* genotypes. Embryo culture and genetic engineering methods are suggested in future to minimize the constrains in the gene transfer between these species and this will open new avenues for further research. Secondly promising F_1s like Sel 2 x AC 5, KL 9 x Salkeerthy (resistant high yielding genotypes) and other outstanding genotypes from F_1, F_2, BC_1 and BC $_2$ generations can be further advanced to obtain elite varieties with desirable economical characters.

Plate 18. The Field view of crop at different stages

SUMMARY

6. SUMMARY

The present investigation of "Genetic analysis for yield attributes and resistance to shoot and fruit borer (*Earias Vittella* Fab.) in Bhindi (*Abelmoschus* spp.) was conducted in the Department of Plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara during 2006-2008. The study was aimed to understand the genetics of fruit and shoot borer resistance and yield attributes. The ultimate objective was to transfer shoot and fruit borer resistance to genotypes with desirable yield attributes and finally to identify best crosses with both these economic characters.

The experimental materials included three high yielding (Arka Anamika, Salkeerthy and Susthira) varieties and three resistant genotypes (KL 9, Sel 2 and AC 5) which were previously evaluated at the Department of Plant Breeding and Genetics, College of Horticulture, Vellanikkara. The parents were crossed in all possible combinations. The seeds of these crosses were raised in green houses along with the parents. The selfing of the F_1 s and backcrossing of the F_1 s with corresponding parents were done. F_2 s and six generations of two selected crosses (Sel 2 x AC5 and KL9 x Salkeerthy) were raised in open field condition in RBD with four replications. Evaluation of F_1, F_2 and six generations of selected crosses were done during February 2007 to March 2008 and observations were taken for various characters. Biochemical and statistical analysis were employed to understand the genetics of various characters.

The salient findings of the study are summarized below:

1. The magnitude of variability in the material studied was high for qualitative traits like leaf colour, fruit colour and petiole colour whereas it was low for growth habit, fruit and shoot pubescence, fruit ridges, fruit quality and number of branches. The extent of variability was high for quantitative traits like plant height, number of leaves per plant and number of internodes in F_1.

2. In the F_2 variability was higher for shoot infestation, fruit infestation, marketable fruit yield, fruit weight and plant height. Direct selection can be done for most of the yield attributing traits since it exhibited high genetic variability and high range of variation.

3. A high PCV over GCV for the characters studied in F_1 and F_2 generation indicated that environment influences the expression of these characters under study.

4. Fruit weight showed highest heritability in broad sense for both F_1 (99.7 percentage) and F_2 (99.9 percentage) generations. High genetic advance genetic gain and heritability were recorded for shoot infestation, fruit infestation and plant height indicated that selection can be resorted for the improvement of these characters.

5. The F_1 and F_2 generations of Sel2 x Arka Anamika flowered earliest whereas maximum flowering period was recorded by Salkeerthy. Susthira and mean of F_2 of Salkeerthy x KL9 were given highest number of fruits per plant. The F_1 hybrid and mean of F_2 of Arka Anamika x Salkeerthy scored highest fruit yield.

6. In the diallel crossing there was no fruit set for the crosses Arka Anamika x AC5, AC5 x Salkeerthy and AC5 x Susthira. No germination was observed in the F_1 seeds of AC5 x Arka Anamika, AC5 x Sel 2 and AC5 x KL9.

7. Arka Anamika was identified as a good general combiner for fruit number, fruit weight and fruit length and KL9 was identified for plant height, days to first flowering, leaf number, internodal number and fruit weight.

8. Arka Anamika x Sel 2 for good specific combination for the characters plant height, days to first flowering, leaf number, internodal number and internodal length. The F_1 hybrid of Arka Anamika x Salkeerthy identified as the best specific combination for fruit yield.

9. The characters like plant height, days to first flowering, number of leaves, number of internodes, fruit length and fruit yield was controlled mainly by non additive genes indicating the presence of overdominance and can be exploited for development of hybrids.

10. Fruit yield was positively associated with number of fruits, number of internodes, fruit weight and fruit length. Selection of genotypes with short growth habit, short flowering period and short fruit length will help to minimize the shoot and fruit borer infestation.

11. Generation mean analysis of Sel 2 x AC5 indicated the presence of complementary epistasis for plant height and fruit infestation and duplicate epistasis for fruit number, fruit weight and fruit yield.

12. In the inter varietal cross KL9 x Salkeerthy it was observed that duplicate epistasis govern the fruit borer resistance and duplicate epistasis for fruit weight, fruit yield and days to first flowering. Digenic non-allelic interaction model was inadequate to explain shoot borer infestation.

13. Relative heterosis was higher for plant height, number of fruits, fruit infestation, fruit girth and fruit yield. High inbreeding depression noticed for these characters which indicated the presence of non-additive gene action of either epistasis or dominance.

14. Presence of biochemical factors like high phenol and tannin content in the fruits and shoots of resistant genotypes compared to susceptible genotypes indicated that the biochemical constituents play a role in fruit and shoot borer resistance.

15. The F_1 hybrid of Sel 2 x AC5 identified as the best hybrid for both high marketable fruit yield and resistance to fruit and shoot borer, and it also showed field tolerance to Yellow Vein Mosaic Virus.

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Originals not seen*

APPENDICES

Appendix I

Table. 1
Characterization data for parents and F1s for seven qualitative characters

F1/ PARENTS	GH	FC	FR	FQ	ILr	FP	SP
P1	1	2	2	9	3	2	2
P2	1	2	3	8	2	2	2
P3	1	4	2	8	3	2	2
P4	1	2	2	8	3	2	2
P5	1	3	2	8	3	2	2
P6	1	2	3	7	3	2	2
P1x P2	1	2	3	7	3	2	2
P1 x P3	1	2	3	7	3	2	2
P1 x P4	1	2	3	7	3	2	2
P1 x P5	1	4	3	7	3	2	2
P2 x P1	1	4	3	7	3	2	2
P2 x P3	1	3	2	7	3	2	2
P2 x P4	1	4	2	7	3	2	2
P2 x P5	1	2	2	7	3	2	2
P2 x P6	1	3	2	7	4	2	2
P3 x P1	1	2	2	8	3	2	2
P3 x P2	1	3	2	5	3	2	2
P3 x P4	2	1	1	8	3	1	1
P3 x P5	1	2	2	8	2	2	1
P3 x P6	1	2	2	7	2	2	1
P4 x P1	1	3	3	8	2	2	2

P4 x P2	1	3	2	8	2	2	2
P4 x P3	1	1	2	7	3	2	1
P4 x P5	1	1	2	7	3	2	2
P4 x P6	2	3	1	7	2	2	1
P5x P1	2	1	3	7	2	1	1
P5x P2	2	3	3	7	2	1	1
P5x P3	2	2	2	7	2	2	2
P5x P4	2	3	1	7	3	2	2
P5x P6	2	3	1	7	3	2	2

Abbreviation: P1- Arka Anamika (A.A), **P2** - KL9, **P3–** Salkeerthy(Sal), **P4** - Sel 2, **P5**-Susthira (Sus), **P6** - AC5

GH-Growth habit, SP-Stem pubescence, PeC-Petiole colour, FC-Fruit colour, FR-Fruit ridges, FP- Fruit pubescence, SP-Shoot Pubescence,FQ-Fruit quality score, ILr – internodal length scoring

NB: For details of descriptor code refers to section 3.5.1

Table. 2
Characterization data for F2s and check variety for seven qualitative characters

F2	GH	FC	FR	FQ	ILr	FP	SP	PeC	LC	NBR	YVM	PM
T1	1	4	2	8	1	2	2	1	2	1	28	0
T2	1	4	2	7	1	2	2	2	2	1	16	0
T3	1	3	3	7	1	1	2	1	1	1	0	0
T4	1	4	3	8	1	2	2	1	2	1	0	0
T5	1	3	3	7	1	2	2	1	2	1	0	0
T6	1	7	2	7	1	2	2	2	3	1	0	8.33
T7	1	2	2	7	1	2	2	1	1	1	0	7.69
T8	1	2	2	9	2	1	2	2	1	1	0	11.11
T9	1	2	2	7	1	1	2	1	1	1	0	20
T10	1	2	2	7	2	1	2	2	1	1	0	33.33
T11	1	3	2	8	2	2	2	1	2	1	0	22.22
T12	1	3	2	8	1	2	2	1	2	1	0	0
T13	1	2	2	7	1	1	2	1	3	1	0	0
T14	2	2	3	6	1	1	1	4	4	1	0	0
T15	1	2	2	7	1	2	2	1	1	1	72	0

Abbreviation: P1- Arka Anamika (A.A), **P2** - KL9, **P3**– Salkeerthy(Sal), **P4** - Sel 2, **P5**-Susthira (Sus), **P6** - AC5, T1-SalxKL9,T2- SalxA.A,T3- SalxSus,T4-KL9xSel 2,T5-KL9xAC5,T6-KL9xSus,T7-A.AxKL9,T8-A.AxSal,T9-A.AxSus,T10- A.AxSel 2,T11-Sel 2xSal,T12-Sel 2xA.A,T13-SusxAC5,T14-SusxSel 2,T15-Salkeerthy,

GH-Growth habit, SP-Stem pubescence, PeC-Petiole colour, FC-Fruit colour, FR-Fruit ridges, FP- Fruit pubescence, SP-Shoot Pubescence,FQ-Fruit quality score, ILr – internodal length scoring, LC – Leaf colour, NBR- Number of branches per plant, YVM- Co-efficient of infection of yellow vein mosaic virus(%), PM- Co-efficient of infection of powdery mildew(%),

NB: For details of descriptor code refers to section 3.5.1

Table. 3
Characterization data for cross Sel2 x AC 5 for various qualitative characters

Sel 2 x AC 5	YVM	GH	FC	FR	FQ	ILr	FP	SP	PeC	LC	NBR
R1T1	0	1	4	2	8	2	1	1	2	1	2
R1T2	0	2	2	2	6	1	1	1	2	3	3
R1T3	0	1	4	2	9	2	1	1	2	2	2
R1T4	0	1	4	2	9	2	1	1	2	2	2
R1T5	0	1	4	2	9	2	1	1	2	2	1
R1T6	0	1	2	2	7	2	1	1	2	3	2
R2T1	0	1	4	2	8	2	1	1	2	1	0
R2T2	0	2	2	2	6	2	1	1	2	3	2
R2T3	0	1	4	2	9	1	1	1	2	2	1
R2T4	0	1	4	2	9	1	1	1	2	2	2
R2T5	0	1	4	2	9	2	1	1	2	2	2
R2T6	0	1	2	2	7	1	1	1	2	3	1
R3T1	0	1	4	2	8	2	1	1	2	1	1
R3T2	0	2	2	2	6	2	1	1	2	3	2
R3T3	0	1	4	2	9	2	1	1	2	2	2
R3T4	0	1	4	2	9	2	1	1	2	2	1
R3T5	0	1	4	2	9	2	1	1	2	2	1
R3T6	0	1	2	2	7	2	1	1	2	3	1
R4T1	0	1	4	2	8	2	1	1	2	1	0
R4T2	0	2	2	2	6	2	1	1	2	3	0
R4T3	0	1	4	2	9	1	1	1	2	2	2
R4T4	0	1	4	2	9	2	1	1	2	2	0
R4T5	0	1	4	2	9	1	1	1	2	2	2
R4T6	0	1	2	2	7	1	1	1	2	3	2

Table. 4

Characterization data for cross KL9X Salkeerthy for various qualitative characters

KL9 x Salkeerthy	YVM	GH	FC	FR	FQ	ILr	FP	SP	PeC	LC	NBR
R1T7	3	1	1	2	8	2	1	1	2	1	0
R1T8	0	1	4	3	7	2	1	1	3	2	2
R1T9	1	1	3	3	9	2	1	1	1	2	2
R1T10	2	1	3,4,7	3	8	2	1	1	1,2,3	2	2
R1T11	0	1	4	3	6	2	2	2	1	1	2
R1T12	1	1	4	3	7	2	1	1	2	3	2
R2T7	3	1	1	2	8	2	1	1	2	1	2
R2T8	0	1	4	3	7	2	1	1	3	2	2
R2T9	1	1	3	3	9	1	1	1	1	2	3
R2T10	2	1	3,4,7	3	8	1	1	1	1,2,3	2	2
R2T11	0	1	4	3	6	1	2	2	1	1	2
R2T12	1	1	4	3	7	1	1	1	2	3	0
R3T7	3	1	1	2	8	1	1	1	2	1	0
R3T8	0	1	4	2	7	1	1	1	3	2	3
R3T9	1	1	3	3	9	1	1	1	1	2	2
R3T10	2	1	3,4,7	3	8	1	1	1	1,2	1	2
R3T11	0	1	4	3	6	2	2	2	1	2	2
R3T12	1	1	4	3	7	1	1	1	2	3	3
R4T7	3	1	1	2	8	1	1	1	2	1	2
R4T8	0	1	4	3	7	1	1	1	3	2	2
R4T9	1	1	3	3	9	2	1	1	1	2	2
R4T10	2	1	5,4	3	8	1	1	1	1,2	2	3
R4T11	0	1	4	3	6	1	2	2	1	1	2
R4T12	1	1	4	3	7	1	1	1	2	3	2

Appendix II

Table. 5 Genotypic correlation coefficients among 15 qualitative traits in F1 generation

	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FY	FL
Pht	1.000**									
Dff	0.112	1.000**								
L.no.	0.640*	0.359	1.000**							
IN	0.516	0.245	0.915**	1.000**						
IL	0.559	-0.180	0.330	0.152	1.000**					
FN	0.426	0.514	0.421	0.324	0.211	1.000**				
Nr	-0.294	-0.334	-0.464	-0.394	-0.179	-0.184	1.000**			
FW	-0.313	0.866**	0.008	0.439	0.780**	-0.797**	-0.288	1.000**		
FY	-0.296	0.068	-0.180	-0.219	-0.430	-0.215	-0.097	-0.336	1.000**	
FL	0.020	-0.170	0.058	0.350	-0.280	-0.144	0.098	0.824**	-0.105	1.000**

Table. 6. Phenotypic correlation coefficients among 15 qualitative traits in F1 generation

	Pht	Dff	L.no.	IN	IL	FN	Nr	FW	FY	FL
Pht	1.000 **									
Dff	0.103	1.000**								
L.no.	0.552	0.270	1.000**							
IN	0.394	0.184	0.797	1.000**						
IL	0.466	-0.069	0.214	0.053	1.000**					
FN	0.304	0.327	0.373	0.254	0.113	1.000**				
Nr	-0.281	-0.304	-0.433	-0.343	-0.158	-0.155	1.000**			
FW	-0.082	0.044	-0.030	-0.018	0.007	-0.028	-0.128	1.000**		
FY	-0.280	0.065	-0.173	-0.198	-0.377	-0.179	-0.097	-0.029	1.000**	
FL	-0.001	-0.192	0.055	0.291	-0.267	-0.046	0.092	0.169	-0.108	1.000**

Abbreviation ;Dff-Days to first flowering, , Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW- fruit weight (g), FL-Fruit length (cm), FY-Fruit yield (g)/ plant, * $P<0.05$ and ** $P<0.01$

Table. 7 Genotypic Correlation Matrix -GMA

	Pht	Dff	L.no.	IN	IL	FN	SI	FI	Flp	FG	FW	FL
Pht	1 **											
Dff	-.891**	1 **										
L.no.	.755 **	-.592	1 **									
IN	.876	-.636	.456	1 **								
IL	.044 **	-.925 **	.577	.283	1 **							
FN	-.130	.194	-.805 **	-.323	.009	1 **						
SI	-.114**	.683	-.102**	-.993	-.937 **	.538	1 **					
FI	-.614	.560	.263	-.670	-.992	-.324 *	.608	1 **				
Flp	-.675	.085 **	.224	-.639	-.865	-.408	.392	.453	1 **			
FG	.293	-.687	-.160	.190	.577	.551	-.374	-.184	.278	1 **		
FW	.996 **	-.834 **	.529	.151	.989 **	-.896 *	.706	-.896 *	-.670	.688 *	1 **	
FL	.484	-.588	-.638	.441	.642	.984 **	.258	-.099	-.980	.628	.635	1 **

Table. 8. Phenotypic correlation Matrix –GMA

	Pht	Dff	L.no.	IN	IL	FN	SI	FI	Flp	FG	FW	FL
Pht	1 *											
Dff	-.857*	1 *										
L.no.	.496	-.330	1 *									
IN	.519*	-.510*	.273	1 *								
IL	.761*	-.714*	.297	.781*	1 *							
FN	-.103	.162	-.468	-8.87	-5.07	1 *						
SI	-.392	.306	-.570*	-.286	.280	.106	1 *					
FI	-.223	.223	.449	9.51*	-.169	-.529*	-.130	1 *				
Flp	-.427	.550*	-.177	-.150	-.310	3.58	-.118	6.87	1 *			
FG	.257	-.128	-.166	.142	.377	.274	.110	-.301	-.184	1 *		
FW	.744*	-.665*	.267	.771*	.986*	-.00	-.246	-.169	-.302	.509*	1 *	
FL	.171	-.281	-.253	.306	.305	.440	1.83	-.243	.80	.193	.299	1 *

Dff-Days to first flowering, Pht-Plant height (cm), LNo-Number of leaves/plant, IN-Number of internode on main stem, IL-Internode length, FN-Fruit number / plant, FW-Average fruit weight (g), FL-Fruit length (cm), FG-Fruit girth (mm), FY-Fruit yield (g)/ plant, MFY- Marketable fruit yeield (g), Nr – No. of ridges per fruit, SI – Shoot infestation (%), FI – Fruit infestation (%) Flp – flowering period (days) * P<0.05 and ** P<0.01

Appendix III

Table. 9
Array Variances and Covariances for combining ability Analysis

Characters	vr	wr	wre	wrei	wr+vr	yr	a
Plant height	599.23	254.74	233.49	385.01	853.97	139.00	-43.37
	270.27	20.66	81.50	258.57	290.93	104.25	
	264.60	31.77	78.88	255.84	296.37	120.50	
	207.38	39.39	52.44	226.50	246.77	140.50	
	189.31	143.86	44.09	216.40	333.17	114.50	
Days to first flowering	23.71	11.79	18.32	39.39	35.50	34.50	-1.63
	5.77	9.91	3.22	19.43	15.67	29.00	
	28.05	20.71	21.97	42.84	48.76	42.00	
	41.39	30.12	33.19	52.04	71.51	39.50	
	66.76	58.71	54.53	66.09	125.46	50.50	
Number of leaves	4.45	0.87	0.64	5.55	5.32	15.00	-3.31
	2.67	-1.21	-0.94	4.30	1.46	12.50	
	10.38	5.16	5.91	8.48	15.54	17.50	
	9.68	6.33	5.29	8.19	16.01	19.00	
	10.69	5.96	6.19	8.60	16.65	18.00	
Number of internodes	2.77	-0.27	-0.07	3.75	2.50	14.00	-2.29
	3.14	-1.89	0.23	3.99	1.25	13.50	
	13.15	7.94	8.24	8.17	21.08	19.00	
	5.53	3.52	2.14	5.30	9.04	17.00	
	2.86	1.25	0.00	3.81	4.11	15.50	
length of inernode	0.91	-0.31	0.32	2.11	0.60	10.05	-0.81
	3.26	2.67	3.22	4.00	5.93	9.80	
	2.05	2.72	1.72	3.17	4.77	6.10	
	2.06	1.79	1.74	3.18	3.85	12.25	

	1.62	1.32	1.19	2.82	2.93	9.95	
no. of ridges	0.55	0.28	0.32	0.81	0.83	5.00	-0.06
	0.73	0.34	0.44	0.93	1.07	7.00	
	0.31	0.28	0.15	0.61	0.59	5.00	
	0.37	0.16	0.19	0.66	0.53	5.00	
	1.57	1.06	1.02	1.37	2.63	7.00	
fruit length	4.81	4.99	1.85	12.71	9.81	14.50	-2.39
	0.81	-2.39	-1.68	5.21	-1.58	16.85	
	45.62	37.80	37.83	39.14	83.42	28.75	
	7.52	9.26	4.24	15.89	16.78	17.50	
	6.87	-3.75	3.67	15.19	3.12	15.40	
fruit no.	0.35	0.13	0.00	1.29	0.47	6.00	-0.29
	0.85	0.44	0.42	2.01	1.29	6.50	
	1.42	1.04	0.89	2.60	2.46	7.50	
	1.62	0.74	1.06	2.77	2.36	8.50	
	6.60	5.24	5.20	5.60	11.84	11.50	
fruit weight	1921190.14	10056.07	4308.93	10262.63	1931246.21	21.00	-1884.7
	11.62	9.64	-1884.7	25.24	21.25	16.98	
	1914183.80	-728.04	4286.34	10243.90	1913455.76	35.00	
	549690.83	-1195.85	-112.61	5489.50	548494.98	18.00	
	548937.31	-1658.91	-115.04	5485.73	547278.40	19.17	
fruit yield	986.48	616.32	494.02	2218.63	1602.80	151.50	-241.26
	4637.95	3738.22	3215.67	4810.66	8376.17	243.00	
	2339.47	149.32	1502.48	3416.65	2488.79	181.50	
	129.78	-232.27	-144.53	804.73	-102.49	75.50	
	795.01	1147.36	351.30	1991.71	1942.37	80.50	

a - The point of interception of the regression lines with Wr Ordinate (a)

GENETIC ANALYSIS OF SEGREGATING GENERATIONS FOR YIELD ATTRIBUTES AND RESISTANCE TO FRUIT AND SHOOT BORER (*Earias vittella* Fab.) IN BHINDI (*Abelmoschus* spp.)

By

DIVYA BALAKRISHNAN

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the
requirement for the degree of

Master of Science in Agriculture

Faculty of Agriculture
Kerala Agricultural University, Thrissur

Department of Plant Breeding and Genetics

COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR - 680 656
KERALA, INDIA

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ABSTRACT

The research study entitled "Genetic analysis for yield attributes and resistance to shoot and fruit borer (*Earias Vittella* Fab.) in Bhindi (*Abelmoschus* spp.)" was undertaken during the period 2006-2008 at Department of plant Breeding and Genetics, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur. The main objectives of this project were to study the nature of gene action governing fruit and shoot borer resistance and yield attributes and to attempt for transfer of shoot and fruit borer resistance to genotypes with desirable yield attributes.

Six diverse okra genotypes *viz*, Arka Anamika, KL9, Salkeerthy, Sel 2, Susthira and AC5 were crossed in a 6 x 6 complete diallel pattern. Thirty crosses were made out of which 24 F_1s were fertile and six interspecific crosses were sterile. Fifteen selected F_2s were evaluated for yield attributes and resistance to fruit and shoot borer.

High genetic variability, heritability and genetic gain were observed in fruit weight and plant height. Both F_1 and F_2 of the cross Arka Anamika x Salkeerthy recorded the higher fruit yield than others. Arka Anamika was found to be a good general combiner for fruit number, fruit weight and fruit length. KL9 showed high gca for days to first flowering, internodal number and fruit weight.

Fruit yield was positively associated with number of fruits, number of internodes, fruit weight and fruit length. Shoot and fruit borer infestation recorded negative association with plant height, flowering period, fruit number, fruit yield and internodal length. Overdominance was observed for most of the yield contributing traits.

Generation mean analysis for six generations from two crosses *viz.* Sel 2 x AC 5 and KL 9 x Salkeerthy were carried out and gene action for yield attributes and resistance to fruit and shoot were studied. Duplicate non allelic interactions were

observed for most of the traits studied. Complementary epistasis govern the inheritance of fruit borer resistance in the cross Sel 2 x AC 5. Digenic non-allelic interaction model was found inadequate to explain shoot borer infestation.

Biochemical analysis indicated the presence of higher levels of phenol and tannin content in fruits and shoots of resistant genotypes. The F_1 of the cross Sel 2 x AC 5 was identified as the best hybrid for both marketable fruit yield and resistance to fruit and shoot borer and it also showed field resistance to Yellow Vein Mosaic Virus.