INDUCTION OF GENETIC RECOMBINATIONS IN INTERSPECIFIC CROSSES OF *ABELMOSCHUS*

BY

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DECLARATION

I hereby declare that this thesis entitled **"INDUCTION OF GENETIC RECOMBINATIONS IN INTERSPECIFIC CROSSES OF ABELMOSCHUS"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society

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INTRODUCTION

INTRODUCTION

Okra (*Abelmoschus esculentus* (L) Moench) commonly known as "Bhindi" is one of the major vegetable crops of India This crop is extensively grown throughout the country during the spring-summer (March-June) and rainy (July-September) seasons for its green tender fruits Bhindi belongs to the genus *Abelmoschus* established by Medikus in 1787 The ease with which it can be cultivated and its adaptability to a wide range of growing conditions makes Okra popular among the vegetable growers Bhindi has been reported to have an average nutritive value (ANV) of 3 21 which is higher than tomato, egg plant and most cucurbits except bittergourd (Grubben, 1977) Bhindi has a vast potential as one of the foreign exchange earner crops and accounts for about 60 per cent of the export of fresh vegetables excluding potato, onion and garlic (Sharma and Arora, 1993) Although an array of high yielding varieties are available in bhindi, the Yellow Vein Mosaic Disease (YVMD) is the most important constraint which stands in the way of augmenting production and productivity of the crop This dreadful disease affects the crop in all its stages of growth and causes considerable reduction in the yield of green fruits The extent of damage varies from 45 to 100 per cent, if the crop is not protected within 20 days after germination (Sastry and Singh, 1974) Being a virus disease transmitted by the whitefly (*Bemisia tabaci* Gen) a possible method of control is the use of insecticides to destroy the vector Since bhindi fruits are continuously harvested every second or third day from the time of fruit formation, application of insecticides for the control of this vector will lead to the problem of acute pesticide toxicity besides contributing to environmental hazards Hence the development of resistant varieties assumes paramount importance

Intervarietal breeding programmes were found to be of little value in this respect Fortunately some of the wild species of *Abelmoschus* are known to possess genes for resistance to this dreadful disease The presently recommended varieties like Pusa Sawani, Punjab Padmini and Pusa Makhmali although had tolerance to the disease at the time of release, it appears at present that the tolerance exhibited by these varieties is breaking down Moreover, long light green fruits fetch premium price than the dark green medium fruits of the varieties released in other States Several high yielding local cultivars producing long fruits are under cultivation in Kerala However these varieties are highly susceptible to this disease Hence the situation warranted the need for transferring disease resistance genes from wild species to the local widely cultivated varieties

Several related species of bhindi like *A tuberculatus*, *A manihot* var *pungens*, *A crinitus* etc are found to exhibit high degree of resistance (Nariani and Seth 1958) However, they could not be made use of in resistance breeding with *A esculentus* owing to sterility barriers There are several reports on the resistance of *A manihot* to yellow vein mosaic disease and the transference of this resistance to the improved varieties (Arumugam *et al* 1975) *A tetraphyllus* a related wild species of Okra has also been found as a donor parent (Ugale *et al* 1976) The crosses were found successful, but F_1 plants expressed sterility of varying degrees According to Nerkar and Jambhale (1985), only three wild species viz *A tetraphyllus* *A manihot* and *A manihot* ssp *manihot* (*A caillei*) could be used as sustainable donors of resistant genes into susceptible adapted varieties

A preponderance of low yielding resistant plants resembling the wild relatives was reported by earlier workers (Mathews 1986) who attempted interspecific crosses in bhindi This may be due to the presence of tight linkage existing between low yield and yellow vein mosaic disease resistance Therefore the breakage of this linkage has become necessary for inducing desirable recombinations in the F_1 populations Several earlier workers had reported the use of irradiation for breaking undesirable linkages in wide crosses of *Abelmoschus* (Nirmala Devi, 1982 and Cheriyan, 1986) The influence of the genotypes of the parents on interspecific crosses has been clearly demonstrated in several cases (Pittarelli and Stavely, 1975) Therefore, it would be convenient to make crosses using diverse genotypes in an attempt to identify parents more effective in achieving interspecific fertilization and recombination Hence, a comprehensive breeding programme was planned in the present study with the objective of induction of recombinations of the economic attributes of *Abelmoschus esculentus* and the yellow vein mosaic disease resistance of the wild species of *Abelmoschus* The generated recombinants are expected to go a long way in augmenting the production potential of bhindi

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Abelmoschus Medikus is a genus of herbs, shrubs and trees in Malvaceae family native to tropical Africa and Asia About eight species are found in India of which the fruits of *A esculentus* (L) Moench constitutes the much relished vegetable, the Bhindi or Okra *A moschatus* Medikus yields the musk scented seeds used in perfumery and medicine and *A manihot* (L) Medikus is the source of fibre Before initiating an interspecific breeding programme a brief knowledge of the taxonomy and species relations of the genus is imperative

2.1 Taxonomy of Abelmoschus

The Genus *Abelmoschus* was established by the German Botanist Medikus (1787) on the basis of the nature of dehiscent capsule, but in this respect *Abelmoschus* does not really differ from *Hibiscus* Therefore Candolle (1824) treated *Abelmoschus* as a section within *Hibiscus* All *Abelmoschus* species have therefore synonyms in *Hibiscus*

Based on the caducity of the calyx, Schumann (1890) re-established *Abelmoschus* as a separate genus

Later, Hochreutiner (1924) identified the adnation of the calyx to the petals and the staminal column as a specific characteristic of this genus He also distinguished 14 species and several varieties in *A manihot* and *A moschatus*

Borssum Waalkes (1966) divided the genus *Abelmoschus* into two groups of which the first one included three species which have cultivated forms (*A esculentus*, *A manihot* and *A moschatus*) and the second group with three species occurring only in wild form (*A crinitus*, *A angulosus* and *A ficulneus*) Bates (1968) suggested some additional modifications like inclusion of *A tuberculatus* and the grouping of all subspecies and varieties of *A manihot*

The genus became little more complex by the discovery (Chevalier, 1940) of an African cultivated species which was rediscovered by Siemonsma (1982) and described as *A caillei* (Stevels, 1988)

Based on the available cytogenetical evidence, International Okra Workshop 1990 adopted a classification in which nine species were included in the genus *Abelmoschus* (Table 1) This classification included a new cultivated species *A caillei* which was wrongly identified earlier as *A manihot* ssp *manihot*

Table 1 Classification of genus Abelmoschus

Classification developed by BORSSUM WAALKES (1966)	Classification adopted by International Okra Workshop (1990)	Chromosome number (2n)
A moschatus Medikus	A moschatus Medikus	72
subsp moschatus var moschatus	subsp moschatus var moschatus	
subsp moschatus var betulifolius (Mast) Hochr	subsp moschatus var betulifolius (Mast) Hochr	
subsp biakensis (Hochr) Borss	subsp biakensis (Hochr) Borss	
subsp tuberosus (Span) Borss	subsp tuberosus (Span) Borss	
A manihot (L) Medikus	(2) A manihot (L) Medikus	60 68
subsp manihot		
subsp tetraphyllus (Roxb ex Hornem) Borss var tetraphyllus	(3) A tetraphyllus (Roxb ex Hornem) R Graham var tetraphyllus	130 138
subsp tetraphyllus var pungens (Roxb) Hochr	var pungens (Roxb) Hochr	
A esculentus (L) Moench (including A tuberculatus Pal & Singh)	(4) A esculentus (L) Moench	72 108 144
	(5) A tuberculatus Pal & Singh	58
A ficulneus (L) W & A ex Wight	(6) A ficulneus (L) W & A ex Wight	72
A crinitus Wall	(7) A crinitus Wall	?
A angulosus Wall ex W & A	(8) A angulosus Wall ex W & A	56
	(9) A caillei (A Chev) Stevels	185 199

2 2 Origin of A esculentus

A esculentus originated in tropical Africa has now been widely spread throughout the tropics There are several theories on the origin of *A esculentus* which consider India (Masters, 1875), Ethiopia (Candolle, 1883), West Africa (Chevalier, 1940) and Tropical Asia (Grubben 1977) According to Joshi and Hardas (1956) bhindi is believed to be polyphyletic in origin They also postulated that *A esculentus* (2n= 130) arose through hybridization between one species with n - 29 and another with n - 36 followed by doubling of the chromosomes They also confirmed the presence of the genome of *A tuberculatus* in *A esculentus*

2.3. Cytogenetic structure of *Abelmoschus*

Before attempting interspecific hybridization, the knowledge about the scale of variation in chromosome numbers of the cultivated as well as wild species is important The different chromosome numbers reported for the various species in the genus *Abelmoschus* is summarised in Table 1

The lowest number reported was 2n = 56 for *A angulosus* (Ford, 1938) The highest number reported was close to 200 for *A manihot* var *caillei* (Singh and

Bhatnagar, 1975 and Siemonsma, 1982) The chromosome number reported for *A esculentus* varied greatly from 2n = 66 to 144 However, the most frequently observed chromosome number was 2n = 130 Datta and Naug (1968) suggested that the numbers 2n = 72, 108, 120, 132 and 144 were an indication of a regular series of polyploids with x = 12

2.4 Reproductive biology

Abelmoschus species are predominantly annual and owing to their floral morphology and absence of a self incompatibility system, they are generally regenerated through selfing However, various rates of cross pollination have been reported by Purewal and Randhawa (1947) (4 to 19 0%) Venkitaramani (1953) (4 to 31 7%) Joshi and Hardas (1956) (20%) Mitidieri and Vencovsky (1974) (42 2%) and Martin (1983) (63%)

Aken'Ova and Fatokun (1984) reported maximum of 0 34 per cent outcrossing at a distance up to 6 3 m in April and 3 8 per cent in September indicating seasonal differences Engels and Chandel (1990) reported that depending on the species or variety, season and location, varying degrees of outcrossing upto 60%, occurs in okra Cross pollination occurs mainly due to entomophily and protogyny

Hamon and Koechlin (1991 a) studied the reproductive biology of okra in detail Using Cruden's index (Cruden, 1977) they studied Okra reproductive allocations and reported a facultative autogamy mode Self fertilization kinetics expressed by the setting rate displayed an increase between 7 00 and 16 00 hr

Hamon and Koechlin (1991 b) also reported higher log P/O value (where P and O were pollen and ovule production respectively) for *A moschatus* (2 17) and *A manihot* (2 19) indicating facultative autogamy However, average value of 2 00 for *A esculentus* and 2 05 for *A caillei* suggested more autogamy for these species

2 5 Interspecific hybridization in Bhindi

An effective interspecific hybridization programme is an important means for introgressing desirable genes of the wild species into the cultivated species Interspecific hybridization seems to be a major cause of large variation observed in the cultivated species Interspecific hybridization has been carried out in this genus as early as 1930 s

Teshima (1933) reported a successful cross between *A esculentus* and *A manihot* Later Chizaki (1934) Skovsted

(1935), Ustinova (1937,1949) and Singh *et al* (1938) also reported the success of the same cross

In 1952, Pal *et al* attempted to transfer the true resistance of *A manihot* var *pungens* and symptomless type resistance of *A tuberculatus* to cultivated bhindi variety, Pusa Makhmali In the case of crosses with *A tuberculatus*, the F_1 hybrids were completely sterile and no viable seeds were obtained even from backcrosses They succeeded in overcoming seed sterility through the production of amphidiploids from F_1 hybrids, but were not free from yellow vein mosaic disease Similarly the *A pungens* x *A esculentus* hybrids also exhibited very high degree of sterility The F_1 hybrids were vigorous but mostly sterile as most of the meiotic chromosomes remained as univalents Shrivelled or empty seeds were obtained in a cross between *A ficulneus* x *A esculentus* also

Joshi and Hardas (1956) reported heterotic hybrids between *A esculentus* and *A tuberculatus* They obtained a fertile plant from a colchicine treated sterile F_1 hybrid from this cross Stebbins (1958) reported that in interspecific hybrids male gametes are more easily affected by the genomic disturbances than the female gametes Kuwada (1961) reported that the hybrid between *A esculentus* and *A manihot* was particularly sterile In 1966, he found that the crosses between *A esculentus* and *A tuberculatus* were successful in both the directions, but the hybrids were completely sterile According to Pawan Kumar (1966), pod formation without fertilization might be due to some kind of stimulation after pollination Gadwal *et al* (1968) observed that in the genus *Abelmoschus*, the hybrid embryo failed to grow in cross combinations of *A esculentus* x *A moschatus* *A esculentus* x *A ficulneus* *A tuberculatus* x *A moschatus* and *A ficulneus* x *A moschatus*, but through *in vitro* culture of embryos, it was possible to obtain viable hybrids in those species combinations Later, Kuwada (1974) reported that the hybridization between *A tuberculatus* and *A manihot* was successful only when *A tuberculatus* was the female parent, but the hybrid was completely sterile

Singh et al (1975) reported that the hybrids of an accession from Ghana, which was identified as being immune to yellow vein mosaic, with Indian okra were only partially fertile while those between this accession and *A tetraphyllus* were completely sterile

Hossain and Chattopadhyay (1976) observed high degree of sterility in hybrids from a cross between *A esculentus* and *A ficulneus* These hybrids produced many fruits without seeds, or with only rudimentary seeds and resembled their wild parent in several morphological characters Nair and Kuriachan (1976) reported a spontaneous hybrid between *A tuberculatus* and *A esculentus* which was highly pollen sterile and totally seed sterile in which selfing, open pollination and back crossing produced only fruits with empty seeds

The hybrids of *A esculentus* (2n = 72) x *A tetraphyllus* (2n = 130) studied by Ugale *et al* (1976) showed hybrid vigour One of its genomes manifested a good homology with *A esculentus* and behaved like an amphidiploid Arumugam and Muthukrishnan (1978) reported that F_1 s of crosses involving two wild forms of *A manihot* and two susceptible cultivars of *A esculentus* namely Pusa Sawani and CO1 were resistant to yellow vein mosaic virus They also obtained good recombinants from the F_2 and F_3 generations Mamidwar *et al* (1979) observed reciprocal differences in crosses between *A esculentus* and wild forms of *A manihot* and *A tetraphyllus* The fruitset was highest when *A esculentus* was used as the female parent The hybrids produced seedless fruits or fruits with shrivelled seeds Meshram and Dhapke (1981) reported that the hybrid between *A esculentus* and *A tetraphyllus* was spreading in habit and dwarf in stature and highly male sterile

Dhillon and Sharma (1982) reported yellow vein mosaic resistance in the hybrids from crosses between two susceptible cultivars and *A manihot* Martin (1982) studied the interspecific crosses between an unnamed West African species of *Abelmoschus* and *A esculentus* He found that the hybrids were completely sterile, but a few produced germinable seeds Backcrosses were more fertile with almost complete fertility in the BC_2

Siemonsma (1982) reported that there were two very distinct types of Okra, Soudanien and Guineen and he suggested that one type might have derived from the other through interspecific hybridization According to him, the Guineen type was an amphidiploid of *A esculentus* (2n = 130-140) and *A manihot* (2n – 60-68) Jambhale and Nerkar (1983) obtained some plants resistant to yellow vein mosaic virus from backcrosses of *A esculentus* x *A manihot* Seed fertility in these varied between 58 and 88 per cent According to Hamon and Charrier (1983), the species which differ most from other *Abelmoschus* species is *A moschatus*

In an interspecific breeding programme between *A esculentus* and *A manihot*, Sujatha (1983) observed high degree of pollen fertility (33 4 to 64 5 per cent) in the hybrids but there was hardly any seed set The seeds if at all formed were shrivelled and very small in size Pillai (1984) obtained hybrids with complete resistance to yellow vein mosaic disease by crossing *A manihot* with four susceptible cultivars of *A esculentus* viz AE87, Pusa Sawani, CO1 and Kilichundan But none of them outyielded the highest yielding parent

Nerkar and Jambhale (1985) crossed *A tetraphyllus* (2n – 138), *A manihot* (2n = 66) and *A manihot* ssp *manihot* (2n – 194) with *A esculentus* var Pusa Sawani They produced amphidiploid of the interspecific hybrids through colchicine treatment They developed nine resistant lines with good agronomic characters and fruit quality However most of the F_1 plants exhibited partial to complete sterility

Cheriyan (1986) found that *A manihot* and *A manihot* ssp *tetraphyllus* were cross compatible with *A esculentus* But the F_1 plants did not bear normal seeds and the pollen fertility of the hybrids was much lower than the parents No reciprocal difference in the crossability index was observed

Hamon and Yapo (1986) reported that the crosses between the two subspecies of *A manihot* viz *A manihot* ssp *manihot* and *A manihot* ssp *tetraphyllus* did not produce any plant even if the barriers were not as complete as seen with *A moschatus* species

Hemaprabha (1986) reported the prevalence of various degrees and levels of endoploidy in endosperm and an intimate relationship between the endosperm and embryo such that normal development of the endosperm is essential for the proper development of the embryo to form fertile seeds in interspecific hybrids

Madhusoodanan and Nazeer (1986) also reported sterility in the interspecific hybrids of *Abelmoschus* due to abnormal meiosis as a result of difference in ploidy levels

Mathews (1986) observed preponderance of low yielding YVM resistant plants similar to the wild parents among the F_2 populations of crosses between *A manihot* and *A esculentus*

Prabha (1986) found that the interspecific crosses between the two species mentioned above were cross compatible with absence of total hybrid sterility The hybrids also inherited yellow vein mosaic disease resistance However, she opined that viable seed recovery was very much low in hybrids presumably because of cytogenetic disturbances arising out of chromosomal differentiation that has taken place during speciation

Pushparajan (1986) reported the reproductive isolation of *A moschatus* from all other species of the genus *Abelmoschus*

Suresh Babu (1987) reported that crossability index values were higher when *A tetraphyllus* was used as the female parent

Tekale *et al* (1987) classified eight hybrid lines derived from crosses between *A esculentus* and *A manihot* into four groups based on their morphology and yield They identified five lines with high yield and resistance

Krishnamurthy (1988) reported that the endosperm exercises a hormonal control on the growth and differentiation of embryo

Bhargava (1989) found that embryo deterioration in ovules resulting from crosses between *A manihot* and *A esculentus* started five days after pollination He also observed that cell divisions at this stage were random and within six days embryos had formed an undifferentiated cell mass surrounded by multiple layers of endothelium

Johri (1989) opined that there was compatibility relationship between the endosperm, embryo and integuments

Kondaiah *et al* (1990) made reciprocal crosses between *A manihot* ssp *manihot* and (1) *A tetraphyllus*, (2) induced amphidiploid of *A esculentus* x *A tetraphyllus* and (3) induced amphidiploid of *A esculentus* x *A manihot* The study revealed that *A manihot* ssp *manihot* (hexaploid) contained two genomes from *A tetraphyllus* and a third from *A manihot*

In a study of pollen grain formation and pollen tube growth following interspecific pollination, Swamy and Khanna (1991) reported that failure of seed formation may be due to the slowness of pollen tube growth, abnormal pollen tube or collapse of fertilised ovules or sparsity of pollen grains

2 6. Yellow Vein Mosaic Disease (YVMD) Resistance

Yellow vein mosaic disease is the most serious disease of bhindi This viral disease infects this crop at all stages and severely reduces growth and yield It occurs throughout India wherever Bhindi is grown especially during the rainy season The symptoms appear as clearing of veinlets and veins) followed by chlorosis In advanced stage of infection, the leaves become smaller in size, yellow in colour, the fruits become malformed, fibrous and yellow and the plants become dwarfed

This disease was first reported in Bombay as early as 1924 by Kulkarni Later, the viral nature of the disease was established by Uppal *et al* (1940) and they gave it, its present name "Yellow Vein Mosaic" The disease is spread by *Bemisia tabaci* Gen (Capoor and Varma, 1950 and Varma, 1952) The virus can perpetuate for several weeks in hosts Khan (1983) suspected 0 35 per cent seed transmission under certain circumstances and studied the mechanism of spread of this disease under field conditions He established the seasonal nature of the incidence of this disease and the significance of the primary infection with respect to its subsequent spread

2 6 1 Nature of damage

The loss in yield due to the virus ranged from 50 to 90 per cent depending on stage of crop growth at which infection occurs (Sastry and Singh, 1974) If the plants were affected in early stages of growth, there was total loss so far as yield and quality were concerned If the plants were infected within 35 days of germination, their growth was retarded, a few leaves and fruits were formed, causing a loss of 50 per cent Plants infected on 50 and 65 days after germination, suffered a loss of 80 and 60 per cent respectively Chelliah *et al* (1975) also reported that the infection by the virus in 30 days old crop resulted in 88 per cent loss in yield Sinha and Chakrabarti (1976) confirmed that the disease had an adverse effect on plant height, number of branches, number and size of fruits and seed yield Atiri and Ibidapo (1989) reported that Bhindi mosaic virus and Bhindi leaf curl virus had a synergistic effect in mixed infections

2 6 2 Sources of resistance

An essential pre-requisite of breeding for disease resistance is the availability of a suitable source of resistance Varietal resistance to yellow vein mosaic in *A esculentus* is rare Attempts to locate resistance source of yellow vein mosaic were made by many scientists

Pal *et al* (1952) reported that *Abelmoschus tuberculatus*, closely related to *A esculentus*, was resistant to yellow vein mosaic virus and immune to the attack of fruit borer and their hybrids were seedless or with empty seeds Jha and Mishra (1955) tested 14 varieties of bhindi from different sources against YVM virus, but none of them possessed any resistance Varma and Mukherjee (1955) screened 43 varieties of bhindi in West Bengal and reported that pink types appeared to be resistant

According to Nariani and Seth (1958), *A manihot* var *pungens*, *A crinitus*, *H vitifolius* and *H panduriformis* were immune to YVM virus From 267 indigenous collections, Premnath (1970) reported IHR 15-1 and IHR 20-1 to be resistant to YVMD Sandhu *et al* (1974) reported that resistance to YVM virus was confined to wild species, viz *A manihot*, *A crinitus*, *A moschatus* and *A pungens* However, IC-1542, Selection-1, Section 2-2 and *A tuberculatus* were found to be tolerant to this virus

Arumugam *et al* (1975) reported that accessions of *Abelmoschus manihot*, one each from Africa and Japan, were highly resistant to YVMD and the crosses made between *A esculentus* and *A manihot* yielded viable F_1 seeds But there was 40 per cent sterility in the F_2 generation Of the nine bhindi selections screened for resistance to YVMD by Rao and Bidari (1976), 15-1-74 and 31-2-7 were found to be completely resistant

An accession of bhindi (EC-31830) from Ghana, identified as *A manihot* ssp *manihot* was reported to be immune to YVM virus (Sandhu, *et al* 1974) However, Singh and Thakur (1979) later reported that this accession to be symptomless carrier type Its chromosome complement was reported as 2n - 194 (Singh and Bhatnagar, 1975)

Arumugam and Muthukrishnan (1978) screened 181 cultures of bhindi from different sources under controlled and field conditions, but none of them was found to be resistant to YVM virus Also, all the 46 strains of *A esculentus* assessed by Chauhan *et al* (1981) proved susceptible

Atiri (1983) found some cultivars resistant to YVM virus as well as high yielding Chelliah and Sreenivasan (1983) reported that *A manihot* ssp *tetraphyllus* and *A manihot* were resistant to YVM virus A high degree of the symptomless type of resistance was also identified in *A* *esculentus* var MC-31830 from Ghana (Sharma and Sharma, 1984)

It was concluded by Nerkar and Jambhale (1985) that only wild species, viz *A tetraphyllus*, *A manihot* and *A manihot* ssp *manihot* could be used as suitable donors of resistance to improve susceptible adapted varieties They also reported that under field conditions of natural infection four resistant lines derived from the backcross of *A esculentus* x *A manihot* showed only 4 09 - 19 37 per cent virus infection

Khan and Mukhopadhyay (1986) screened five varieties of *A esculentus* under field conditions Selection 1-1 showed the lowest incidence of virus (24 36%) and gave the highest yield (40 36 q/ha) Salehuzzaman (1987) screened about 300 accessions from 29 countries, but none of them was found to be resistant to YVM virus

2 6 3 Genetics of YVM resistance

For the first time, Singh *et al* (1962) reported from the analysis of segregation data of F_2 and test crosses that the field resistance to yellow vein mosaic virus in the intervarietal crosses of Bhindi (IC 1542 x Pusa Makhmali, IC 1542 x Sel-9 and IC 1542 x Sel-2) was controlled by two recessive genes The field resistant donor line (IC 1542) was assigned the symbol yv_1/yv_1 yv_2/yv_2 and the susceptible parents, Yv_1/Yv_1, Yv_2/Yv_2 From the segregation data of F_2 of BC_1 generation of *A esculentus* var Pusa Sawani x *A manihot* ssp *manihot* grown under natural epiphytotic conditions, Thakur (1976) found that resistance was conditioned by complementary dominant genes

Arumugam and Muthukrishnan (1980) reported that resistance to this virus was conditioned by a single dominant gene, designated as Y The heritability of resistance ranged from 69 to 95 per cent Jambhale and Nerkar (1981) studied the crosses of *A esculentus* variety Pusa Sawani with *A manihot* (2n - 66) and *A manihot* ssp *manihot* (2n= 194) under natural epiphytotic conditions They reported the involvement of a single dominant gene in conferring resistance in each species Dhillon and Sharma (1982), from interspecific crosses of *A esculentus* and *A manihot*, reported dominance of resistance to YVM Virus in *A manihot*

Sharma and Dhillon (1983) from the segregation of backcrosses of *A esculentus* and *A manihot* found that YVM virus was controlled by two dominant complementary genes with additive effects It was observed that some of the plants in *A manihot* ssp *manihot*, F_1s and transgressive segregants were not completely resistant and the symptoms of yellow vein mosaic appeared either on the top or in the new shoot growth quite late in the season especially when the temperature started falling This suggests that the genes responsible for yellow vein mosaic resistance were sensitive to environmental changes Therefore, the possibility that the resistance to YVM virus in *A manihot* ssp *manihot* was conditioned by polygenes cannot be ruled out Pillai (1984) suggested that resistance to yellow vein mosaic was controlled by dominant nuclear gene(s) Later, Mathews (1986) also reported the involvement of a single dominant gene in conferring resistance to this disease

According to Sadashiva (1988) resistance to YVMD in advanced generation lines of Okra was controlled by two pairs of genes Resistance was important only when at least one pair of genes in homozygous dominant condition Intermediate expression was seen when both the genes were in a heterozygous condition Veeraragavatham (1989) reported preponderance of additive gene action for yellow vein mosaic incidence He also noticed inter allelic interaction of complementary nature for yellow vein mosaic resistance measured in terms of virus index in the F_2 generation

Vashisht (1990) carried out a detailed genetic study on reaction to yellow vein mosaic virus disease in Okra According to him the major dominant gene along with minor genes, which acted as modifiers was involved in the inheritance of resistance to this virus The additive gene effects were more important for virus characteristics than the dominance

In view of the above contradictory reports, the genetics of resistance to yellow vein mosaic virus remains unravelled

2 6 4 Achievements

Several varieties resistant to yellow vein mosaic disease like Pusa Sawani, Selection-2 and L-63 (Reghunathan, 1980) had been evolved through intervarietal breeding programme However, these varieties lost resistance to this disease very soon Hence attempts had been made to evolve resistant varieties through interspecific breeding programmes

An yellow vein mosaic resistant variety, Punjab Padmini had been evolved as a result of interspecific hybridization between *A esculentus* and *A manihot* ssp *manihot* in 1982 at Punjab Agricultural University, Ludhiana (Sharma, 1982) The segregation generation was advanced to F_8 with selection practised so as to evolve this variety

Parbhani Kranthi, a YVMD resistant variety was released for commercial cultivation by the Maharashtra State Seed Committee in 1985 It was also derived from the backcross of *A manihot* to the okra variety, Pusa Sawani (Jambhale and Nerkar, 1986) Peter *et al* (1988) identified

Selection-2, an yellow vein mosaic resistant variety for release

In addition, several selections from IIHR, Bangalore like Selection-4, Selection-7, Selection-9, Selection-10 and Selection-12 possessed YVMD resistance and were derived from a wild species *Abelmoschus manihot* var *tetraphyllus* (Marckose and Peter, 1990)

Recently two varieties namely Arka Anamika and Arka Abhay resistant to this disease were evolved at IIHR through interspecific hybridization using *Abelmoschus manihot* sub sp *tetraphyllus* These varieties have been recommended for release at National level (Arka Anamika) and State level (Arka Abhay) cultivation (Anonymous, 1991)

2 7 Irradiation and Recombination

The effect of irradiation in inducing recombination through the breakage of undesirable linkages has been reported earlier by several workers Radiation treatment during early prophase was known to enhance crossing over in *Triticum* (Singh *et al* 1964) Increased variability in F_2 M_2 for quantitative characters was reported in rice (Jalilmiah and Yamaguchi, 1965) Similarly Vig (1973) also reported the use of radiation as well as several other chemicals to increase somatic recombination to increase variability in the F_2

Konzak (1981) reported that the recovery of recombinants without associated undesirable traits may require only screening of a very large segregation population from one or more crosses or sometimes intensive selection and reselection over several generations from specific crosses

Mutation studies were very limited in bhindi compared to other important vegetable crops Kuwada (1970) reported induction of variability in bhindi through induced mutations One bushy mutant was selected by Nandpuri *et al* (1971) through gamma irradiation of seeds Thandapani et *al* (1978) released a mutant variety for yield, MDU - 2 produced by treating seeds of Pusa Sawani with Diethyl Sulfoxide

Nirmala Devi (1982) induced variability in wild species of *Abelmoschus manihot* using 10, 15 and 20 Kr gamma radiation Vigour due to irradiation for plant height, internodal length and length of leaves was significant irrespective of doses of radiation Maximum variability was observed for fruit yield per plant

Abraham and Bhatia (1984) reported that the highest M_2 mutation rates occurred with 60-80 Kr gamma rays Among 25 viable mutants obtained, 14 had altered leaf traits The thick fruit mutant showed superiority over Pusa Sawani for yield

Abraham (1985) studied the genetic status in relation to radio sensitivity, mutation frequency and spectrum in bhindi She also isolated a mutant having the characteristics of *A tetraphyllus* showing resistance to yellow vein mosaic disease from the M_2 generation of irradiated *A esculentus* varieties She observed that hybrids were more sensitive to mutation compared to varietal seeds Abraham (1985) reported that all Bhindi mutants were monogenic recessives

Jambhale and Nerkar (1985) isolated chlorina and variegated plants from the progenies of *A esculentus* seeds that had been subjected to 40 Kr gamma radiation Krishna (1985) attempted a study to assess the efficiency of gamma rays to create variations in bhindi In M_1 generation, germination percentage and plant height declined with increase in dose of gamma rays Number of branches, leaves and flower buds also showed progressive reduction with increase in dose of the mutagen Lower doses increased the stigmatic lobes in flowers Higher doses of gamma rays decreased the size of fruits and yield M_1 plants exhibited several abnormalities like lobbed leaves with serrated margins, dwarf plants, dichotomy of petioles, branches and stem, double fruits and weak stemmed plants In the M_2 eventhough there was increase in variability there was no significant change in the means of quantitative characters like plant height Chlorophyll variation in M_2 was observed at low frequency

In a study on radiation induced variability in interspecific hybrids involving *A esculentus* and *A manihot*, Cheriyan (1986) reported considerable variability in the irradiated F_1 hybrids Dominant characters like branched habit, pubescence and pigmentation of vegetative parts got changed with irradiation It also enhanced the pollen fertility of interspecific hybrids She also suggested that higher doses (above 25 Kr) should be used to create wider variability in interspecific hybrids

Jeevanandam *et al* (1986) reported a marked reduction in germination, survival, plant height on the 15th day and at maturity The reduction was found to be maximum at 60 Kr Regina (1986) reported higher variability in bhindi created though gamma irradiation in M_4 generation and irradiated hybrids showed maximum positive variability

2 8 Variability, heritability and genetic advance

Trivedi and Prakash (1969) observed greater variability in the yield contributing fruit characters, length and thickness of fruits, and greater heritability value for thickness High heritability estimates were observed for plant height, days to flower, yield per plant, seeds per pod and thousand seed weight (Padda *et al* , 1970)

Rao (1972) reported high genotypic coefficients of variation coupled with high estimates of heritability and genetic advance for yield and its components Ngah and Graham (1973) observed that among the major yield components, fruit length had the highest heritability of 84 per cent and the fruit weight had the lowest being 48 per cent Majumdar *et al* (1974) observed high magnitude of genotypic coefficient of variation for several plant characters like yield per plant, number of fruits per plant and weight of fruits per plant

Fruit diameter followed by fruit length , number of flowers, fruit yield and number of fruits per plant exhibited high values of phenotypic coefficient of variation as reported by Singh *et al* (1974) High values of heritability and genetic advance were recorded for fruit diameter and length Lal *et al* (1975) reported high phenotypic and genotypic variability for all characters studied except for yield per plant

Studies conducted by Rao and Kulkarni (1977) revealed that the estimates of heritability and expected genetic advance were highest for number of fruits per plant Rao *et al* (1977) reported good amount of genetic variability for all the quantitative characters in the population studied by them They also observed high heritability for days to flowering, plant height, number of pods and yield High heritability estimates for all the economic characters except height in the F_2 of a half diallel cross involving six varieties were recorded by Rao and Sathyavathi (1977)

Kaul *et al* (1979) observed considerable genetic variation for yellow vein mosaic virus infection, pod yield per plant and number of pods per plant in bhindi Mahajan and Sharma (1979) observed high heritability estimates for number of fruits, fruit length and fruit diameter Mishra and Chhonkar (1979) reported high heritability, genetic advance and genotypic coefficient of variation for number of branches per plant, seeds per pod, pod length and plant height

Singh and Singh (1979) recorded that days to flower, number of fruits per plant and fruit bearing branches were found to be important contributors to genetic variability

Murthy and Bavaji (1980) observed appreciable amount of variability in respect of fruit length, number of fruits and fruit yield per plant Plant height, days to flowering, fruit length and yield displayed high heritability Yield displayed high estimate of genetic advance also

Parthap *et al* (1980) reported high heritability in the narrow sense for all the characters except yield per plant, plant height and number of fruits per plant They also found that fruit length contributed maximum to genetic divergence in Bhindi Rao (1980) reported high heritability in the narrow sense and genetic advance for days to flowering, plant height and number of fruits per plant

Singh *et al* (1980)studied 43 genetic stocks of okra comprising 13 parents and 30 hybrids They observed a wide range of variability for most of the characters studied Rao and Ramu (1981) suggested the phenotypic selection for number of pods and yield to be promising Thaker *et al* (1981) also observed wide range of phenotypic variability for most of the plant characters studied The heritability values were moderate for plant height fruits per plant and fruit length whereas the parameters were low for leaf area, fruit weight and yield

Cheda and Fatokun (1982) conducted numerical analysis of variation pattern in okra The results revealed considerable genetic diversity within the species The accessions were divided into ten groups of three major economic types Palaniveluchamy *et al* (1982) reported that plant height had the highest estimates of heritability and genetic advance among the yield components High values of heritability and genetic advance for fruits per plant, plant height and fruit length were recorded by Vashista *et al*

(1982) Girenko and Pugachev (1983) studied the morphological characters of about 300 bhindi varieties from 32 countries Based on this study, thirteen groups were identified and the clustering was done accordingly

In the line x taster study, Palaniveluchamy *et al* (1983) reported significant variability in six yield related characters Variability within the crosses was found to be moderate to low High values for heritability and genetic advance were also recorded Soubanbabu and Sharma (1983) also reported significant variability for most of the characters studied

Balachandran (1984) reported high phenotypic and environmental coefficients of variation for fruit yield and number of fruits per plant indicating greater influence of environment on these characters Plant yield displayed low heritability and genetic advance Alex (1986) reported high heritability for plant height, days to flowering and fruiting phase Elmaksoud *et al* (1986) recorded high broad and narrow sense heritability values for earliness of flowering, number of fruits per plant and fruit weight

In an interspecific breeding programme, Mathews (1986) recorded high phenotypic and genotypic coefficient of variation for weight of fruits per plant, number of leaves per plant and height of plant

Studies on variability (Balakrishnan and

Balakrishnan, 1988) revealed high phenotypic and genotypic variances for yield per plant and plant height Number of fruits per plant and yield per plant exhibited high phenotypic and genotypic coefficients of variation, heritability and genetic advance Hence they suggested that number of fruits per plant and fruit weight should be taken as the most reliable indices for improving yield in bhindi

Based on discriminant function and D^2 analysis, Kumar and Sheela (1988) grouped different genotypes into five clusters and then the genotypes were arranged in the order of their phenotypic performance Ariyo (1990) evaluated eighteen accessions of okra of diverse background through the techniques of coefficient of racial likeliness and principal coordinate analysis The variation patterns among the accessions were classified by using the techniques of metroglyph analysis and single linkage cluster analysis The study revealed considerable divergence among the accessions and they suggested that the genetic divergence might not be a function of eco-geographical background

2 9. Correlation Studies

A number of studies were on record with regard to correlation of the yield and its components in bhindi

Kohle and Chavan (1967) reported that yield of okra was directly correlated with the length and thickness of the fruit and number of fruits per plant In a study of correlation in bhindi, Martha mary (1969) recorded that yield per plant was directly correlated with height of plant, fruit length, fruit girth and number of fruits Padda *et al* (1970) found positive correlation of plant height with mosaic infection, yield per plant and seeds per pod Mosaic infection was also found to be positively correlated with days to flower

Significant positive correlation between yield and fruit weight and total number of nodes per plant was reported by Thamburaj and Kamalanathan (1973) Majumdar *et al* (1974) reported that days to flowering was negatively correlated with yield per plant Singh *et al* (1974) found that the marketable fruit yield per plant was positively correlated with number of flowers, fruits, branches per plant, fruits on branches and fruit weight

In a study of correlation in 20 varieties of bhindi, Rao and Ramu (1975) reported that yield per plant was significantly correlated with pod and node number and plant height Roy and Chhonkar (1976) from their study on total and partial correlation coefficients concluded that fruit number per plant and branch number per plant were the most important yield contributing characters Rao *et al* (1977) opined that number of fruit per plant, branches per plant, plant height and fruit length were the important yield components in Bhindi Kawthalkar and Kunte (1978) reported that plant height was more useful for the prediction of yield than the number of leaves per plant

In a study of correlation and path coefficient analysis by Korla and Rastogi (1978), yield was found to be correlated with number of fruits per plant and days to flowering Rao and Kulkarni (1978) observed a highly significant positive correlation between plant height and number of pods per plant Singh and Singh (1978a) reported that yield was positively correlated with fruit number per plant, branches per plant, fruit length and fruit weight

Ajimol *et al* (1979) observed that fruit yield was positively correlated with fruit number and length of pods Number of days to flowering made the greatest direct contribution to yield, followed by number of nodes and fruit number

Arumugam and Muthukrishnan (1979) studied the association of yellow vein mosaic with economic characters in okra in the F_3 F_4 and backcross generations of crosses between *H esculentus* varieties (CO1 and Pusa Sawani) and an African and Japanese form of *H manihot* They found that there was significant association between disease reaction and plant height, number branches, days to flowering, fruit length and girth number of seeds per fruit and number of fruits per plant indicating the scope for effective selection for resistance Kaul *et al* (1979) reported that primary branches per plant followed by pod yield per plant had the greatest direct effect on seed yield Mahajan and Sharma (1979) observed that yield had a positively significant association with plant height, number of fruits per plant and fruit length According to Parthap *et al* (1979), the main characters contributing to yield viz stem diameter, number of flowers per plant, pods per plant and plant height should be given major emphasis in bhindi selection programmes to increase the yield

In a study of correlation analysis, Elangovan *et al* (1980) reported that number of fruits per plant, fruit length, fruit width and number of branches could be considered as the primary yield determining components for exercising selection in bhindi

Murthy and Bavaji (1980) observed that fruit number per plant and number of days to flowering had the greatest direct effect on yield Arumugam and Muthukrishnan (1981) reported that fruit yield was highly correlated with number, length and seed content of fruit and to a lower degree with plant height and days to flowering Vashista *et al* (1982) concluded that yield in bhindi depended primarily on number of fruits, plant height and fruit length Balachandran (1984) observed that number of fruits per plant, earliness in flowering, flowering duration and length of fruit were the important contributing characters of yield In a study of F_2 generation of interspecific hybrids of *Abelmoschus*, Mathews (1986) reported that number of fruits per plant, number of flowers per plant, height of plant and earliness in flowering were the major yield contributing characters in all the three generations studied Sheela *et al* (1988a) observed that stem girth had maximum positive direct effect on yield followed by pods per plant

Ariyo (1992) unveiled that pods per plant and pod weight were the major components of pod yield He suggested that in breeding for high yield, both reproductive and vegetative characters should be considered Sivagamasundhari *et al* (1992) reported that number of pods per plant, pod weight, pod girth, pod length and internodal length should be considered together as primary yield determining components in Okra

2 10. Combining ability and gene action

In a line x tester analysis involving two females and seven males, Rao (1977) observed that the parental *per se* performance was a good indicator of the general combining ability (gca) of the parents Kulkarni *et al* (1978) reported additive x additive interaction with epistatic action in the inheritance of days to flower, plant height and fruits per plant In a line x tester study Sharma and Mahajan (1978) reported non-additive gene action for all the agronomic traits studied including days to first flowering, plant height and yield per plant

In another line x tester study involving twenty five females and five males, Singh and Singh (1978 b) observed the predominant role of non-additive gene action for days to flower, plant height, first fruiting node, number of branches per plant, fruit length, number of fruits per plant and yield per plant

In a study of 7 x 7 diallel cross, Parthap *et al* (1981) reported that first fruiting node and days to fifty per cent flowering were under the control of additive gene action whereas for number of fruits and yield both additive and non-additive gene action were involved

In a five parent half diallel cross of diverse bhindi cultivars Poshiya and Shukla (1986) reported highly significant specific combining ability (sca) effect for fruit yield per plant They also observed significant general combining ability (gca) and sca effects for days to fifty percent flowering, fruit length, number of fruits per plant and nodes on main stem

In a ten parent diallel cross (without reciprocals) Vijay and Manohar (1986) studied combining ability for eleven economic traits in Bhindi The component of variation due to gca was larger than that of sca for all the characters studied They observed the predominant role of additive gene action for all the characters except pod weight, pod thickness and first fruiting node

In an inheritance study of an intervarietal cross of bhindi, Randhawa (1989) reported partial to complete dominance for most of the economic characters except for yield per plant which displayed overdominance Hence he suggested that selections for high yielding varieties should be made in early generations In a seven parent diallel study, Veeraragavatham (1989) also indicated preponderance of non-additive gene action for yield of fruits per plant However, Vashisht (1990) found that the additive gene effects were more important than the dominance gene effects for number of fruits per plant, total yield per plant and marketable yield per plant which could be exploited for the improvement of important characters in okra

2 11 Heterosis

Bhindi being an often cross pollinated crop, the scope for heterosis breeding is immense Further many workers have supported non-additive gene action for yield which also augments the proposition for heterosis breeding

Singh *et al* (1938) observed hybrid vigour in interspecific F_1 plants of bhindi The F_1 s showed increased height, branching and number of fruits Vijayaraghavan and Warrier (1946) reported heterosis for various characters in intervarietal hybrids of Okra Pal *et al* (1952) observed strong heterosis in growth and fruiting of interspecific hybrids in this crop

Joshi and Hardas (1956) reported heterosis in interspecific hybrids between *A esculentus* x *A tuberculatus* In a study of six varieties and their F_1 hybrids, Joshi *et al*, (1958) recorded heterosis with respect to plant height, fruit size, number of branches per plant and number and weight of fruits per plant Kuwada (1966) reported heterotic hybrids between *A esculentus* and *A tuberculatus* Mathews (1966) reported that the vigour for earliness exhibited in the F_1 generation of two inter varietal crosses persisted in the F_2 and F_3 generations Akram *et al* (1973) in a study of 20 crosses reported that the F_1 s had better looking fruits, which were also softer and more tender in nature

Lal and Srivastava (1973) observed positive heterosis with respect to plant height, number of branches per plant, fruit length, fruit thickness, number of fruits per plant and fruit yield Rao and Giriraj (1974) reported that ten out of fifteen hybrids studied gave higher yields of fruit than the control, Pusa Sawani, mainly due to many pods per plant and seeds per fruit

Lal *et al* (1975) reported positive heterosis for plant height, days to flower, internodal length, fruit thickness, number of fruits per plant and yield per plant In a study of 24 hybrids from crosses involving 15 parents, Singh *et al* (1975) observed significant heterosis for plant height, number of branches per plant, first fruiting node, fruit length, fruit width, number of fruits per plant and yield per plant Rao and Ramu (1975) reported positive heterosis for pod length and number of ridges on the pod

Ugale *et al.* (1976) reported hybrid vigour in interspecific hybrids from a cross between *A esculentus* x *A tetraphyllus* Kulkarni and Virupakshappa (1977) observed significant heterosis over better parent for earliness, plant height and fruit number per plant Rao and Kulkarni (1977) in a study of fourteen hybrids from crosses involving two lines and seven testers found that the hybrids were taller, maturing earlier and producing more fruits

Singh and Singh (1978 b) also reported substantial heterosis for days to flowering, plant height, first fruiting node, number of branches, internodal distance, fruit length, number of fruits per plant and yield per plant Parthap and Dhankar (1980) reported heterosis for fruit yield and fruit number per plant, fruit number per branch and fruit length Elangovan *et al* (1981) reported heterosis over the mid parental and better parental values for plant height, number of branches, first fruiting node earliness, fruit length, fruit width, fruit number fruit yield and hundred seed weight Parthap *et al* (1981) and Thaker *et al* (1982) also observed heterosis for fruit yield in bhindi

Balachandran (1984) observed desirable heterosis for the major yield contributing characters namely number of fruits per plant and length and weight of fruits

Changan and Shukla (1986) observed that hybrids showing high heterosis in the F_1 generation also showed high inbreeding depression for the various characters High heterosis for yield was reported by Poshiya and Shukla (1986) Elmaksoud *et al* (1986) also reported heterosis for plant height, pod weight and pod length and they justified the commercial utilization of hybrid vigour in okra Heterosis for fruit yield and number of fruits/plant was also reported by Radhika (1988) Sheela *et al* (1988b) also observed significant heterosis for number of fruits per plant and yield per plant In the cross Punjab Padmini x Parbhani Kranthi, Shukla and Gautam (1990) reported heterobeltiosis for yield and its components

Suresh Babu and Dutta (1990) reported 23 82 and 20 03 per cent heterosis with respect to plant height and fruits per plant in interspecific hybrids (*A esculentus* x *A tetraphyllus*) of Bhindi Sivagamasundhari *et al* (1992) also reported high relative heterosis (24 57 per cent) and hetero-beltiosis (12 52 per cent) for fruit yield in Bhindi

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1. MATERIALS

3 1.1 Preliminary Evaluation

The genetic material consisted of fiftysix accessions of *Abelmoschus esculentus* (L) Moench and eight wild types of *Abelmoschus* species collected from different parts of South India The sources of these types are presented in Table 2

3 1.2. Choice of parents for hybridization

The parents comprised of three high yielding *A esculentus* types (Aanakkompan, Eanivenda and AE 1) and two yellow vein mosaic resistant wild species (*A caillei* and *A tetraphyllus* var *tetraphyllus*) selected from the preliminary evaluation programme

3.1.3. Evaluation of F_1 and F_1M_1 generations

The study involved five parents, one standard cultivar, six F_1's, six reciprocals, six irradiated F_1's and six irradiated reciprocals as detailed in Table 3

Table 2 Source of Types

Accession No	Type	Original source
Cultivated Types		
1	Co 11	Coimbatore
2	Pusa Sawani	College of Agri , Vellayani
3	Sevendhari	-do-
4	AE - 1 (Kiran)	-do-
5	Local - 1	Arayoor
6	Local 2	Kalliyoor
7	Local - 3	Karinkal
8	Local - 4 (Aanakkompan)	Vellayani
9	Local - 5	Kayamkulam
10	Local - 6	Adoor
11	Local - 7	Karamana
12	Local - 8 (Eanivenda)	Palapoore
13	Local - 9	Thirupuram
14	Local - 10	Moovattupuzha
15	Local - 11	Kottukal
16	Local - 12	Thiruvalla
17	Local - 13	Perumkadavila
18	Local - 14 (Kilichundan)	Kakkamoola
19	Local - 15	Pilicode
20	Local - 16	Chenkal
21	Local - 17	Pathanamthitta
22	Selection - 2	College of Hort , Vellanikkara
23	Punjab Padmini	do

(Contd)

Table 2 (Contd .)

Accession No	Type	Original source
24	BO-2	College of Hort , Vellanikkara
25	Aroh-1	do
26	Punjab-7	do
27	Selection-1-1	do
28	Selection-4	do
29	TCR-7	NBPGR, Vellanikkara
30	TCR-10	do
31	TCR-17	do
32	TCR-25	do
33	TCR-27	do
34	TCR-36	do
35	TCR-37	do
36	TCR-80	do
37	TCR-128	do
38	TCR-208	do
39	TCR-232	do
40	TCR-291	do
41	TCR-321	do
42	TCR-366	do
43	TCR-373	do
44	TCR-377	do
45	TCR-382	do
46	TCR-386	do
47	TCR-391	do

(Contd)

Table 2 (Contd)

Accession No	Type	Original source
48	TCR-409	NBPGR, Vellanikkara
49	TCR-422	do
50	TCR-423	do
51	TCR-438	do
52	TCR-462	do
53	TCR-695	do
54	TCR-761	do
55	Selection-10	IIHR, Bangalore
56	Parbhanikranthi	Marathawada Krishi Vinjan Peedh
Wild relatives		
57	*Abelmoschus moschatus*	College of Hort Vellanikkara
58	*A tetraphyllus* var *tetraphyllus*	do
59	*A caillei* (*A manihot* sub sp *manihot*)	do
60	Local (wild) - 1	Thiruvananthapuram
61	Local (wild) - 2	Karinkal
62	Local (wild) - 3	Neyyattinkara
63	Local (wild) - 4	Mannuthy
64	Local (wild) - 5	Elanthoor

Table 3 Details of selected parents and hybrids

Sl No	Parents/hybrids	Code No
1	Aanakkompan	L_1
2	Eanivenda	L_2
3	AE 1 (Kiran)	L_3
4	Punjab Padmini	SP
5	*Abelmoschus caillei*	T_1
6	*Abelmoschus tetraphyllus*	T_2
7	Aanakkompan x *A caillei*	L_1xT_1
8	*A caillei* x Aanakkompan	T_1xL_1
9	Aanakkompan x *A tetraphyllus*	L_1xT_2
10	*A tetraphyllus* x Aanakkompan	T_2xL_1
11	Eanivenda x *A caillei*	L_2xT_1
12	*A caillei* x Eanivenda	T_1xL_2
13	Eanivenda x *A tetraphyllus*	L_2xT_2
14	*A tetraphyllus* x Eanivenda	T_2xL_2
15	AE 1 x *A caillei*	L_3xT_1
16	*A caillei* x AE 1	T_1xL_3
17	AE 1 x *A tetraphyllus*	L_3xT_2
18	*A tetraphyllus* x AE 1	T_2xL_3
19	Aanakkompan x *A caillei* (Irradiated)	L_1xT_1-I
20	*A caillei* x Aanakkompan (")	T_1xL_1-I
21	Aanakkompan x *A tetraphyllus* (")	L_1xT_2-I
22	*A tetraphyllus* x Aanakkompan (")	T_2xL_1-I

(Contd)

(Table 3 contd)

Sl No	Parents/hybrids		Code
23	Eanivenda x *A caillei*	(")	L_2xT_1-I
24	*A caillei* x Eanivenda	(")	T_1xL_2-I
25	Eanivenda x *A tetraphyllus*	(")	L_2xT_2-I
26	*A tetraphyllus* x Eanivenda	(")	T_2xL_2-I
27	AE 1 x *A caillei*	(")	L_3xT_1-I
28	*A caillei* x AE 1	(")	T_1xL_3-I
29	AE 1 x *A tetraphyllus*	(")	L_3xT_2-I
30	*A tetraphyllus* x AE 1	(")	T_2xL_3-I

3 1 4 Evaluation of F_2 and F_2M_2 generations

The genetic material consisted of five parents, one standard cultivar, 12 F_2 and 12 F_2M_2 populations derived from the hybrids listed in Table 2

3 2 METHODS

3 2 1 Experimental procedure

3.2 1 1 Preliminary Evaluation

Fiftysix accessions of *A esculentus* (L) Moench collected from different parts of South India were evaluated in a trial replicated twice during May-August 1990 at the Department of Plant Breeding, College of Agriculture, Vellayani The data were statistically analysed and genetic parameters were estimated The accessions were categorised based on the IBPGR descriptor list given below

DESCRIPTORS

1 Growth habit	1 Erect 2 Medium 3 Procumbent
2 Branching habit	1 Branched 2 Unbranched

3	Stem pubescence	1 Glabrous 2 Slight 3 Conspicuous
4	Stem colour	1 Green 2 Green with red patches 3 Purple
5	Leaf shape	See Fig 1
6	Leaf lobing	Number of lobes above the sixth node
7	Lamina margin	1 Deepfid 2 Narrowlyfid 3 Serrated
8	Leaf tip	1 Acute 2 Obtuse
9	Position of fruit on main stem	1 Erect 2 Horizontal 3 Pendulous
10	Fruit colour	1 Yellowish green 2 Green 3 Dark green 4 Green with red patches 5 Dark red 6 Others
11	Fruit shape	See Fig 2
12	Number of ridges per fruit	1 None 2 From 5 to 7 3 From 8 to 10 4 More than 10
13	Fruit pubescence	1 Downy 2 Slightly rough 3 Prickly

In addition, all the important biometric observations were also recorded to categorise these accessions

Eight accessions of wild relatives of bhindi were evaluated in a trial replicated twice to study their resistance to yellow vein mosaic disease Grafting trial was also conducted to confirm the results Diseased shoots collected

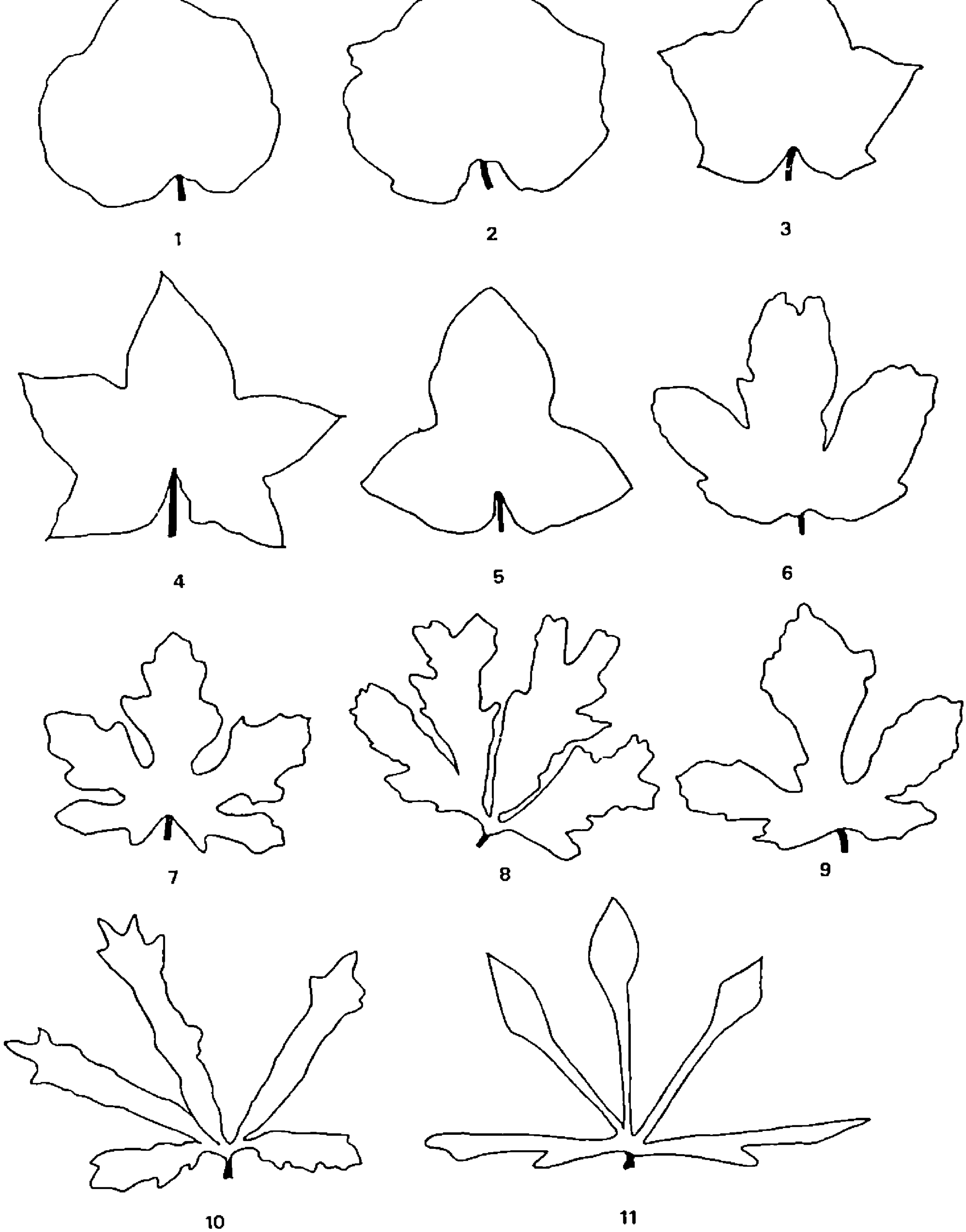


Figure 1 Leaf Shape

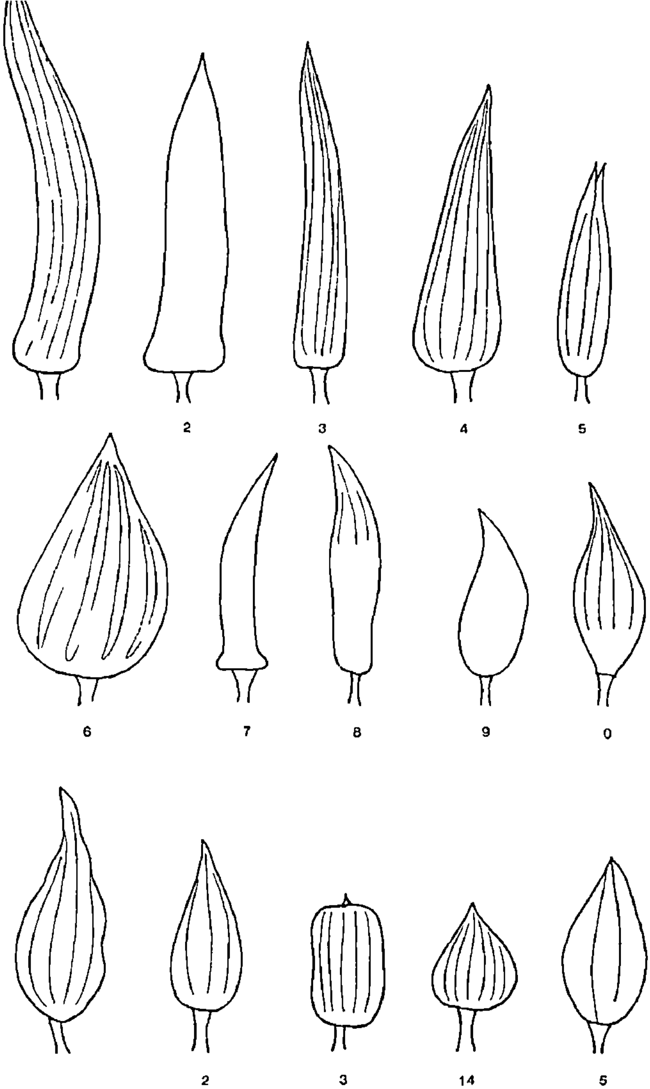


Figure 2 Fruit Shape

from yellow vein mosaic affected plants were grafted on to the field resistant plants by wedge grafting (Nariani and Seth, 1958)

3 2 1 2 Choice of parents and hybridization

The five selected parents were raised in a crossing plot during Aug-Sept 1990 to Dec-Jan 1991 and produced twelve hybrids including reciprocals

The technique of crossing suggested by Giriraj and Rao (1973) was followed The mature flower buds which would open the next day morning were selected in the previous evening A shallow circular cut was made around the fused calyx at about one cm from its base Calyx cups along with corolla were removed as a hood exposing the stigma and the staminal tube The staminal tube was cut open lengthwise without injuring the ovary or style and removed carefully In *A tetraphyllus* the staminal tube was very thin compared to other species Hence scraping of the stamens was practised in this species

The calyx cone which was removed earlier was used for protecting the emasculated flower As an additional protection, a butter paper cover was also provided Mature flower buds of the pollen parents were protected by butter paper covers on the previous day of flowering Pollination was done on the next day morning between 8 and 11 am by rubbing the stigma of the emasculated flowers with the staminal column taken from the pollen parent The pollinated flowers were again protected and labelled The mature dry fruits were collected on 30 to 40 days after pollination and seeds extracted after sun drying the fruits for three days

Phased planting was practised for synchronisation of flowering of *A esculentus* and its wild species

3.2.1.3 Pilot study to standardise irradiation dose

One hundred and fifty seeds were exposed to 10, 20,30,40,50,60 and 70 K rad gamma rays at a dose rate of 0 162 MR/hr The irradiation was done at the Radio Tracer Laboratory, Kerala Agricultural University, Vellanikkara, Thrissur

3.2 1 4 Evaluation of F_1 and F_1M_1 generations

The crossed seeds were partitioned into two groups One group was subjected to gamma irradiation (60 Kr) at the Radio Tracer Laboratory, Vellanikkara The F_1 and F_1M_1 generations were evaluated in a randomised complete block design with 30 treatments (Table 3) from January to

May 1991 along with their parents and the standard cultivar Punjab Padmini In addition to important economic attributes yellow vein mosaic incidence, pollen and seed sterility were also studied

3 2 1 5 Evaluation of F_2 and F_2M_2 generations

Three fruits from each of the plants in the F_1 and F_1M_1 generations were collected and bulked treatment wise All the fruits were collected from the treatments showing high seed sterility Random samples of seeds from each treatment were carried forward to F_2

The evaluation was conducted in three complete randomised blocks during May to Aug 1991 Unsprayed field condition provided favourable environment for natural incidence of yellow vein mosaic disease A single row of the highly susceptible variety Kilichundan, was grown around each replication as a border row to counter the border effect and to enhance the disease incidence All the agronomic practices except insecticidal sprays were followed as per the Package of Practices Recommendations of the Kerala Agricultural University (Anon 1989)

Promising recombinants were selected based on economic attributes and resistance to yellow vein mosaic virus Grafting technique was also practised on the selected plants to confirm disease resistance

3 2 1 6 Details of characters and estimations

The following observations were taken on the randomly selected plants for each of the parents and hybrids In F_2 population all the available plants were used for recording observations

1 Germination

The germinability of the seeds in each treatment was observed both under laboratory and field conditions In the laboratory, the number of seeds germinated in petridishes provided with moist blotting paper (20/dish) was counted every day for a period of eight days In the field, the number of seeds germinated was counted every day for 15 days

2 Plant height

Primary shoot of ten plants from base (soil level) to the top was measured in cm at full grown stage and mean worked out

3 Girth of stem

Girth of the main stem of ten plants at the ground level was measured in cm and the mean value was obtained

4 Number of leaves per plant

Total number of leaves from base to the tip of the plant including the branches was counted after the final harvest Dropped leaves were estimated by counting their nodes

5 Mean leaf area

Two leaves were collected from each of the fourth and eighth nodes of the observational plants Leaf area was ascertained with leaf area meter in sq cm

6 Length of petiole

Mean length of the petiole of two leaves collected from each the fourth and eighth nodes of the observational plants was recorded in cm

7 Days to flowering

Number of days taken from sowing to the opening of the first flower in each plant was recorded

8 First fruiting node

The node in which the first fruit set was noted and recorded

9 Number of branches per plant

Total number of primary branches was counted after the final harvest and recorded

10 Number of flowers per plant

The total number of flowers produced by each observational plant was recorded

11 Number of fruits per plant

The total number of fruits produced by each plant was counted at every harvest and recorded

12. Number of fruits on branches

The total number of fruits produced on branches of the observational plants was counted and averaged

13 Weight of fruits per plant

The fruits produced by each observational plant at each harvest were weighed and the total yield per plant calculated after the final harvest and expressed in grams

14. Length of fruit

The length of three marketable fruits was measured from each plant in cm at the time of harvest and averaged

15 Girth of fruit

The fruits used for recording length were used for measuring girth also Maximum girth of the fruit was measured in centimetres

16. Single fruit weight

Weight of single fruit was calculated by dividing fruit weight by number of fruits harvested

17. **Pollen fertility**

Pollen fertility of parents and F_1 plants was estimated using acetocarmine test Observations from ten randomly selected plants were recorded for each parent/hybrid The pollen fertility was measured as

$$\text{Percentage of viable pollen} = \frac{\text{No of viable pollen}}{\text{Total no of pollens under observation}} \times 100$$

18. **Crossability index**

Crossability index was calculated following Rao (1979)

$$\text{Crossability index} = \frac{\text{Crossing efficiency of the cross}}{\text{Selfing efficiency of female parent}} \times 100$$

19 **Number of seeds per fruit**

A random sample of three fruits from each plant was taken from the third, sixth and nineth harvest, seeds extracted, counted and averaged

20 Number of ridges per fruit

Fruits were collected from the third, sixth and nineth harvest of the observational plants and number of ridges was counted

21 Incidence of yellow vein mosaic disease

For the purpose of quantitative analysis, the disease intensity was scored using the rating scale developed by Arumugam *et al* (1975) (Table 4)

Table 4 Yellow vein mosaic disease rating scale

	Symptoms	Grade	Rating scale
i	No visible symptoms characteristic of the disease	Highly resistant	1
ii	Very mild symptoms, basal half of the primary veins green, mild yellowing of anterior half of primary veins, secondary veins and veinlets Infection is also seen late in the season under field conditions	Resistant	2
iii	Veins and veinlets turn completely yellow (Plate 1)	Moderately resistant	3
iv	Pronounced yellowing of veins and veinlets 50% of the leaf lamina turned yellow, fruits exhibit slight yellowing	Susceptible	4
v	Petiole, veins veinlets and inter-veinal area turn yellow in colour Leaves start drying from margin Fruits turn yellow in colour	Highly susceptible	5

The disease rating for each treatment in a replication was calculated as follows

$$\text{Mean disease rating} = \frac{\text{Sum of disease scores of plants observed}}{\text{Number of plants}}$$

22 Scoring of fruit and shoot borer infestation

a Percentage of shoot infestation

The number of shoot infested plants in a plot was counted and expressed in percentage

b Percentage of fruit infestation

The total number of fruits damaged by fruit and shoot borer in a treatment was counted and expressed in percentage

23 Scoring for other pests and diseases

a Leaf spot incidence

The total number of infested plants in a treatment was counted, averaged and expressed in percentage

b Leaf webber incidence

The total number of plants damaged in a treatment as a result of leaf webber attack was counted and expressed in percentage

3 2 2 Statistical analysis

The data collected from the preliminary evaluation trial were recorded separately for all the main items of study Selection of parents was made based on this trial The genetic parameters viz genotypic, phenotypic and environmental coefficients of variation, correlations, selection indices, and genetic divergence were computed In the evaluation of F_1 and F_1M_1 generations, the line x tester analysis, combining ability and heterosis estimates were worked out The data collected from the F_2 and F_2M_2 generations were subjected to analysis of covariance A brief account of these methods were given in the following sections

3 2 2 1 Evaluation of germplasm

Analysis of variance and covariance was applied to estimate the phenotypic, genotypic and environmental components of variance and covariance The estimates of coefficients of variation, correlation coefficients, heritability coefficient and genetic advance were computed from the formulae given below

Phenotypic, genotypic and environmental components of variance and genetic parameters

These components of variances were estimated by equating the expected value of mean squares (MS) to the respective variance components

1 **Phenotypic variance.** $V_{(p)} - V_{(G)} + V_{(E)}$

Where $V_{(G)}$ - Genotypic variance

$V_{(E)}$ = Environmental variance estimated as mean square due to error

2 **Genotypic variance**

$$V_{(G)} = \frac{\text{Mean square (Treatment) - Mean square (Error)}}{\text{Number of replications}}$$

These genetic parameters were worked out as per Jain (1982)

The Phenotypic, genotypic and environmental coefficients of variations were worked out for each character by making use of the estimates of $V_{(P)}$, $V_{(G)}$ and $V_{(E)}$ defined above

Phenotypic Coefficient of variation (PCV %)

$$= \frac{\sqrt{V_{(p)}}}{\text{Mean}} \times 100$$

Genotypic Coefficient of variation (GCV %)

$$= \frac{\sqrt{V_{(G)}}}{\text{Mean}} \times 100$$

Environmental Coefficient of variation (ECV %)

$$= \frac{\sqrt{V_{(E)}}}{\text{Mean}} \times 100$$

where mean indicated the mean of a character taken over all the varieties

Heritability (in broad sense)

It is defined as the ratio of the genotypic variance to the phenotypic variance and was estimated for each character as

$$\text{Heritability } (h^2) = \frac{V_{(G)}}{V_{(P)}} \quad \text{or}$$

$$= \frac{V_{(G)}}{V_{(P)}} \times 100, \text{ (in percentage)}$$

Genetic advance

The expected genetic improvement by selection was given by the genetic advance (G A) which was worked out as

$$G\ A\ -\ k\ h^2\ \sqrt{V_{(P)}}$$

where k' is the standardised selection differential, which is equal to 2 06 in the case of 5% selection in large samples

Phenotypic, genotypic and environmental correlations

These correlations were computed by completing the analysis of covariance tables between each pair of observations The phenotypic correlation coefficient between two characters x & y was estimated as $r_p\ (x,y)$

$$r_p\ (x,y)\ -\ \frac{Cov_p\ (x,y)}{\sqrt{V_{(p)}x}\ \ x\ \sqrt{V_{(p)}y}}$$

where $Cov_p(x\ y)$ denoted the phenotypic covariance between characters x and y This was obtained by equating the respective expected values of Mean sum of products $V_{(p)}x$ and $V_{(p)}y$ denote the estimated phenotypic variances for x and y respectively

The genotypic correlation coefficient $r_g(x,\ y)$ and environmental correlation coefficient $r_e(x,\ y)$ were also computed from the analysis of covariance tables The above formula was used in this case also with the phenotypic covariance and variances replaced by the genotypic or environmental covariances and variances

The significance of the correlation coefficients was tested with reference to the critical value or r at (n-2) degrees of freedom where n is the number of pairs of observations used (Snedecor & Cochran, 1980)

Path coefficient Analysis

Path analysis is applied to identify relatively important component characters (which are the independent variables) of a dependent variable on the basis of their direct and indirect effects and helps the plant breeder to lay emphasis on component characters during selection The solution of the matrix equation

$$\underset{\sim}{A}\underline{B} = \underline{C}$$

where $\underset{\sim}{A}$ is the genotypic intercorrelation matrix with respect to independent variables, $\underline{B}$ is the column vector of path coefficients and $\underline{C}$ is the column vector of genotypic correlation coefficients between the dependent and independent variables Vector $\underline{B}$ provides estimates of path coefficients which means the direct effect of the independent variable on the dependent variable, and also the indirect effect of each independent variable on dependent variable through other variables Residual variation which could arise from unknown and uncontrollable factors was also estimated using vector *B* (Dabholkar, 1992)

Selection Index

Selection index proposed by Smith (1936) based on discriminant function of the observable characters was used to select the genotypes for crop improvement The phenotype was expressed as

$I - b_1x_1 + b_2x_2 + \quad + b_nx_n$ when n characters were involved and the genetic worth H, of a plant is defined as $H = a_1G_1 + a_2G_2 + \quad + a_nG_n$ where G_1, G_2 G_n represent the genotypic value of the characters and a_1, a_2, a_n denote the weights to be assigned to each character The 'b' coefficients are determined such that the correlation between H and I is maximum, so that maximum gain can be expected in the selection of the phenotype This will lead to the solution of the system of matrix equations given by $\underset{\sim}{P}\underline{b} - \underset{\sim}{G}\underline{a}$ where $\underset{\sim}{P}$ and $\underline{G}$ are the phenotypic and genotypic variance covariance matrix respectively, $\underline{b}$ is the column vector of b coefficients and $\underline{a}$ the column vector of assigned weights which are taken as unity in the present case without distinguishing the relative importance of each of the component characters Selection indices were calculated for all the genotypes and those with the highest values were considered for further breeding programme The expected genetic advance through this method was also estimated

Cluster analysis

The multivariate analysis using Mahalanobis D^2 (Mahalanobis, 1928) statistics was used to group the genotypes Based on the biometric measurements, the genotypes were arranged into a number of clusters such that the genotypes within a cluster showed less divergence and the genotypes between clusters showed large divergence The extent of divergence was measured by the statistical distance, D^2 (or $d = \sqrt{D^2}$), between two genotypes For 'n' genotypes and observations on 'p' characters, the distance between the first and second genotypes was worked out as

$$D^2 = \sum_{ij} W_{ij} \, (\bar{X}_i^1 - \bar{X}_i^2) \, (\bar{X}_j^1 - \bar{X}_j^2)$$

where $\bar{X}_i$ and $\bar{X}_i$ were the mean values of the i^{th} character for the first and the second genotypes respectively Similarly, $\bar{X}_j$ and $\bar{X}_j$ were the mean values of the j^{th} character, $ij = 1, 2, \quad , p$ and W_{ij} were the elements of the inverse of the estimated variance covariance matrix

For each pair these D^2 values were computed and then the pairs of genotypes were ranked based on the magnitude of the relative distance, D^2 Two clones with smallest distance were considered as belonging to a cluster Torcher's method (Rao, 1952) was used for the formation of the clusters of accessions The inter and the intra cluster distances also were tabulated and the cluster diagram was drawn

3 2 2 2 Evaluation of F_1 and F_1 M_1 generations

The data pertaining to various characters were analyzed following the line x tester model as given in Singh and Choudhary (1985) The cultivated accessions were taken as the lines and the wild relatives as the testers The data for each character were analyzed by separating into various components among the lines, testers and the hybrids through the analysis of variance technique (Table 5) Significant differences among the crosses and the reciprocals in both the non irradiated and the irradiated situations were tested The line x tester analysis was carried out for those characters in which the genotypic differences for crosses were significant The general and specific combining ability effects (gca and sca) were estimated for the characters

Table 5 ANOVA FOR F_1 and F_1M_1 generations

Source	df	MS
Replication	r-1	
Treatments	v-1	
Parents	l + t-1	
lines	l-1	
testers	t-1	
Standard parent Vs rest	1	
Hybrids	2 l t-1	
Irradiated hybrids	2 l t-1	
Parents Vs Hybrids	1	
Parents Vs Irradiated hybrids	1	
Crosses		
lines	l-1	M_l
testers	t-1	M_t
lines x testers	(l-1)(t-1)	M_{lxt}
Reciprocals		
lines	l-1	
testers	t-1	
lines x testers	(l-1) (t-1)	
Irradiated crosses		
lines	l-1	M_l
testers	t-1	M_t
lines x testers	(l-1) (t-1)	M_{lxt}
Irradiated reciprocals		
lines	l-1	
testers	t-1	
lines x testers	(l-1) (t-1)	
Error	(r-1) (v-1)	M_e

where r – number of replications (3),
v = number of treatments (30)
l = number of lines (3) and
t = number of testers (2)

excluding the reciprocals

In Table 5, the test for significance for lines and testers coming under each of the irradiated and non irradiated crosses/reciprocals were made against the mean squares due to the corresponding lines x testers, while the significance of lines x testers was tested against the mean squares for error

The genetic components were estimated as

$$\text{Cov H S (lines)} = \frac{M_l - M_{lxt}}{rxt}$$

$$\text{Cov H S (testers)} = \frac{M_t - M_{lxt}}{rxl}$$

$$\sigma^2 \underline{gca} = \text{Cov H S (average)}$$

$$= \frac{1}{2(2\,lt-l-t)} \left[\frac{(l-1)\,M_l + (t-1)\,M_t}{l + t - 2} - M_{lxt} \right]$$

$$\sigma^2 \underline{sca} = \frac{M_{lxt} - M_e}{r}$$

when $F = 0$, $\sigma^2 D = 4\ \sigma^2 \underline{sca}$ and $F = 1$, $\sigma^2 D = \sigma^2 \underline{sca}$

where F is the inbreeding coefficient

The estimates of the gca effects for the lines and testers and the sca effects of the combinations were estimated as follows

1 Mean $= \frac{X}{ltr}$

2 gca effects of lines $g_i = \frac{X_i}{tr} - \frac{X}{ltr}$

3 gca effects of testers, $g_j - \frac{X_j}{lr} - \frac{X}{ltr}$

4 Sca effects in combinations

$$S_{ij} - \frac{X_{ij}}{r} - \frac{X_i}{tr} - \frac{X_{.j}}{lr} + \frac{X}{ltr}$$

Where, X – total of all hybrid combinations

$X_{i.}$ – total of i^{th} line over 't' testers and 'r' replications

X_j = total of j^{th} tester over 'l' lines and 'r' replications

X_{ij} = total of the hybrid between i^{th} line and j^{th} tester over 'r' replication

The standard error pertaining to gca effects of lines and testers and sca effects in different combinations were calculated as given below

$$SE\ (g_i)\ \text{lines} = \sqrt{\frac{Me}{rt}}$$

$$S\ E\ (g_j)\ \text{testers} = \sqrt{\frac{Me}{rl}}$$

$$S\ E\ (S_{ij})\ \text{in combinations} - \sqrt{\frac{Me}{r}}$$

Proportional contribution of lines, testers and line x tester to total variance

$$\text{Contribution of lines} = \frac{SSl}{SSc} \times 100$$

$$\text{Contribution of testers} = \frac{SSt}{SSc} \times 100$$

$$\text{Contribution of } (l \times t) = \frac{SS\,(lxt) \times 100}{SS\,(\text{Crosses})}$$

where SSl = Sum of squares due to lines

SSt = Sum of squares due to testers

SS (lxt) = Sum of squares due to line x tester

SSc = total SS of the interaction table

Heterosis

The three types of heterosis namely relative heterosis, heterobeltiosis and standard heterosis were estimated using the relation

$$H = \frac{\overline{X}\,F_1 - \overline{X}\,P}{\overline{X}p} \times 100$$

where $\overline{X}F_1$ = mean value of F_1

and XP – mean value of mid parent or better parent as the case may be

For testing the significance of the difference between the mean value of the F_1 and those of the midparent and better parent, the critical difference values were calculated as follows

1 CD I (For testing the significance over mid parental value)

$$\text{CD (at 5\% level)} = t_e\ (0\ 05) \sqrt{\frac{3\ MSe}{2r}}$$

$$\text{CD (at 1\% level)} = t_e\ (0\ 01) \sqrt{\frac{3\ MSe}{2r}}$$

2 CD II (For testing the significance over better parent or over standard cultivar)

$$\text{CD (at 5\% level)} = t_e\ (0\ 05) \sqrt{\frac{2\ MSe}{r}}$$

$$\text{CD (at 1\% level)} = t_e\ (0\ 01) \sqrt{\frac{2\ MSe}{r}}$$

where MSe is the mean square for error, r, the number of replications $t_e(0\ 05)$ and $t_e(0\ 01)$ are the critical values of 't' corresponding to error degrees of freedom at 0 05 and 0 01 levels respectively

RESULTS

The data collected from the different experiments were tabulated and subjected to statistical analysis wherever required The results obtained are interpreted and presented below

4 1 Evaluation of Bhindi germplasm

The analysis of variance of the different characters studied showed that the genotypes differed significantly for all the characters except stem girth, yellow vein mosaic disease incidence and leaf webber attack The abstract of ANOVA is presented in table 6

4.1 1 Genetic divergence

The data were subjected to D^2 analysis to cluster the accessions

The D^2 values varied from 0 00 to 525897 displaying high divergence among the accessions On the basis of relative magnitude of D^2 values, the accessions were grouped into four clusters (Table 7) Among the four clusters, cluster I was the largest having 30 accessions followed by cluster III with 14 accessions The cluster II and $\bar{X}P$ – mean value of mid parent or better parent as the case may be

For testing the significance of the difference between the mean value of the F_1 and those of the midparent and better parent, the critical difference values were calculated as follows

1 CD I (For testing the significance over mid parental value)

$$CD \text{ (at 5\% level)} = t_e \text{ (0 05)} \sqrt{\frac{3 \text{ MSe}}{2r}}$$

$$CD \text{ (at 1\% level)} - t_e \text{ (0 01)} \sqrt{\frac{3 \text{ MSe}}{2r}}$$

2 CD II (For testing the significance over better parent or over standard cultivar)

$$CD \text{ (at 5\% level)} = t_e \text{ (0 05)} \sqrt{\frac{2 \text{ MSe}}{r}}$$

$$CD \text{ (at 1\% level)} = t_e \text{ (0 01)} \sqrt{\frac{2 \text{ MSe}}{r}}$$

where MSe is the mean square for error, r, the number of replications t_e(0 05) and t_e(0 01) are the critical values of 't' corresponding to error degrees of freedom at 0 05 and 0 01 levels respectively

3 2 2 3 Evaluation of F_2 and F_2 M_2 generations

The F_2 and F_2 M_2 progenies were raised in a replicated trial along with their parents and the standard cultivar, Punjab Padmini Since the genotypic variation was very large within the crosses, the observations were recorded from all the observational plants of the F_2's and F_2 M_2's The variation in these generations were studied by computing the range coefficient of variation and the per cent change over the standard parent The plants were classified into different classes for each character to identify the proportion of heterogeneity

The analysis of covariance was resorted to taking the unequal stands as covariate The treatment means were adjusted by using the regression equation given below

$$\text{Adj}\ (\bar{Y}j) = \text{Unadj}\ (\bar{Y}j) - b\ (\bar{X}j - \bar{X})$$

where Adj ($\bar{Y}j$) and Unadj ($\bar{Y}j$) were the adjusted and the unadjusted treatment means respectively of the j^{th} treatment $\bar{X}j$ was the mean number of observational plants of the j^{th} treatment $\bar{X}$ was the average number of observational plants over all treatments and b the regression coefficient The critical differences for comparing the treatment means also were computed accordingly

RESULTS

Table 6 ANOVA for Twentyone Characters in Bhindi - Experiment I

Sl No	Source	df	Height of Plant	Girth of stem	No of leaves/plant	Leaf area	Days to flowering	First Fruiting node
1	Replication	1	945 25	0 91	0 18	825 00**	84 02**	0 02
2	Treatments	55	2040 20**	2 26	20 32**	30912 75**	42 63**	2 61**
3	Error	55	278 85	1 29	10 63	83 33	3 95	0 16
		C D	33 48	2 28	6 54	10 30	3 99	0 80

* Significant at 5% level
** Significant at 1% level

(contd)

Table 6. (contd)

Sl No	Source No	df	No of branches per plant	No of flowers per plant	No of fruits per plant	No of fruits on branches	Fruit length	Fruit girth	Single fruit weight
1	Replication	1	0 01	10 80	1 77	0 07	0 55	0 62	25 38
2	Treatments	55	87 71**	21 39**	31 30**	3 16**	11 69**	0 51**	64 43**
3	Error	55	11 95	9 43	5 98	0 67	1 48	0 15	14 20
		C D	0 94	6 16	4 90	1 64	2 44	7 56	7 56

(contd)

* Significant at 5% level

** Significant at 1% level

Table 6 (contd)

Sl No	Source	df	Weight of fruits per plant	No of ridges per fruit	No of seeds per fruit	YVMD scoring	% of shoot infestation by *E vit ella*	% of fruit infestation by *E vit ella*	Leaf spot incidence	% of leaf webber incidence
1	Replication	1	13884 50**	0 01	567 00*	0 15	3 30*	2 62*	12 30*	41 22
2	Treatments	55	11697 45**	4 94**	846 03**	1 30	2 07**	0 79*	8 50**	7 24
3	Error	55	668 69	0 01	90 02	0 84	0 60	0 47	1 97	4 68
		C D	51 5	0 23	19 02	1 84	1 55	1 37	2 81	4 28

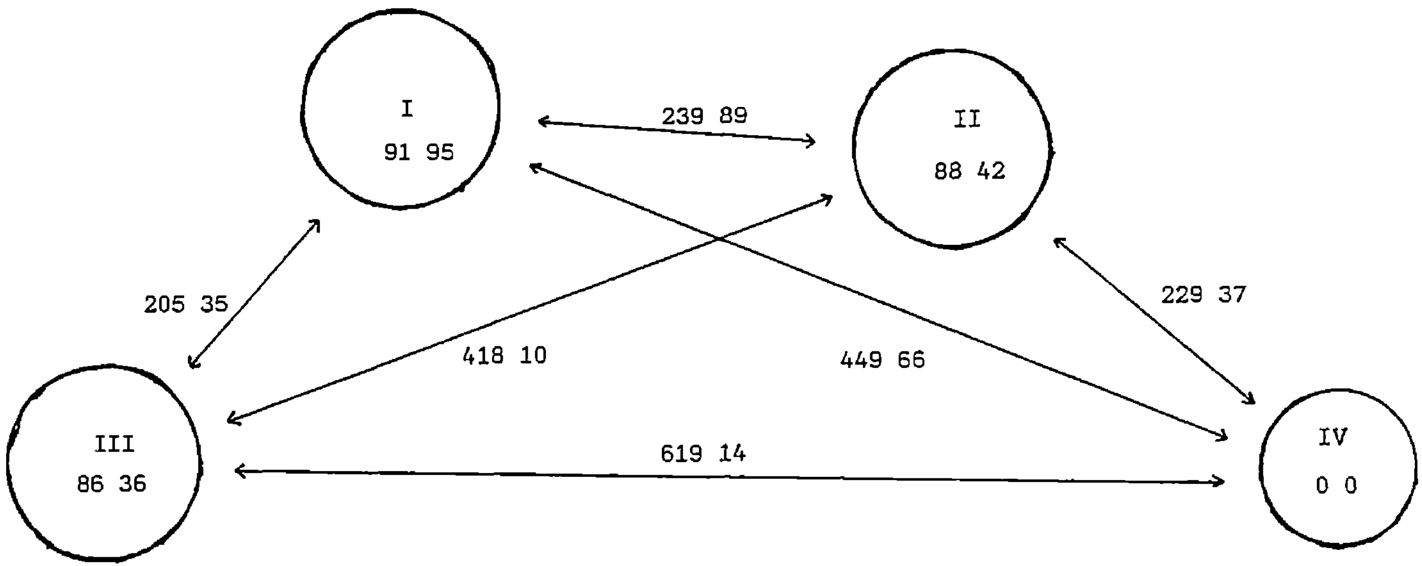
* Significant at 5% level

** Significant at 1% level

Table 7 Composition of clusters

Cluster No	No of types	Accession Number and type
I	30	1 (CO1) 3 (Sevendhari) 4 (Kiran) 5 (LO 1)
		6 (LO 2) 7 (LO 3) 9 (LO 5) 10 (LO 6) 18 (LO 14) 21(LO 17)
		23 (Punjab Padmini) 24 (BO 2) 25 (Aroh 1)
		26 (Punjab 7) 32 (TCR 25) 35 (TCR 37) 36 (TCR 80)
		37 (TCR 128) 38 (TCR 208) 39 (TCR 232)
		42 (TCR 366) 43 (TCR 373) 44 (TCR 377)
		45 (TCR 382) 48 (TCR 409) 49 (TCR 422)
		53 (TCR 695) 54 (TCR 761) 55 (Selection 10)
		56 (Parbhani Kranthi)
II	11	8 (Aanakkompan) 11 (LO 7) 13 (LO 9)
		19 (LO 15) 20 (LO 16) 29 (TCR 7) 30 (TCR 10)
		31 (TCR 17) 41 (TCR 321) 46 (TCR 386) 52 (TCR 462)
III	14	2 (Pusa Sawani) 14 (LO 10) 15 (LO-11) 16 (LO 12)
		17 (LO 13) 22 (Selection 2) 27 (Selection 1 1) 28 (Selection 4) 33 (TCR 27) 34 (TCR 36) 40 (TCR 291) 47 (TCR 391)
		50 (TCR 423) 51 (TCR 438)
IV	1	12 (Eanivenda)

Fig 3 Cluster diagram



Intra and inter cluster distances(D-values) among the 56 accessions grouped in four clusters

Table 8 Intra(Diagonal) and inter cluster average of D^2 and D values (parenthesis)

luster	I	II	III	IV
I	8454 68 (91 95)	57547 27 (239 89)	42167 73 (205 35)	202191 97 (449 66)
II		7818 58 (88 42)	174809 92 (418 03)	52612 00 (229 37)
III			7459 00 (86 36)	38339 71 (619 14)
IV				0 00 (0 00)

and IV contained eleven and one accession respectively

The intracluster distance ranged from 0 00 to 91 95 (Table 8) The maximum value was recorded with respect to cluster I, being the largest cluster, while cluster IV had an intercluster value of zero, since it contained only one accession As regards intercluster distance, the highest genetic distance (D = 619 14) was observed between the clusters III and IV

The minimum intercluster distance (205 35) was recorded between the clusters I and III

The cluster means (Table 9) between the most divergent clusters, cluster III and IV varied widely in respect of plant height, stem girth, number of leaves per plant, leaf area, days to flowering, number of flowers per plant, number of fruits per plant, number of branches and fruit yield per plant The highest mean value for fruit weight per plant was recorded in cluster IV (305 00) whereas the lowest value in cluster III (190 25) Maximum values were recorded in cluster IV for all the characters except number of days to flowering, length, girth and weight of fruit first fruiting node, number of seeds per fruit and number of ridges per fruit Cluster I recorded maximum value for length and girth of fruit However, maximum mean value for single fruit weight (19 55) was recorded in the cluster II The diagram showing the genetic distances among

Table 9 Cluster means for Seventeen Characters in Bhindi

Sl No	Characters	Clusters I	II	III	IV
1	Height of plant (cm)	117 93	116 45	102 45	165 90
2	Girth of stem (cm)	6 88	7 28	6 81	7 60
3	No of leaves/plant	22 22	22 58	19 68	26 90
4	Leaf Area (cm^2)	303 57	437 21	155 61	652 17
5	Days to flowering	41 93	45 55	47 86	39 00
6	First fruiting node	6 11	6 43	5 66	5 20
7	No of branches/plant	1 11	1 00	0 49	1 75
8	No of flowers/plant	16 72	17 23	13 99	26 70
9	No of fruits/plant	13 69	12 87	11 25	24 05
10	No of fruits on branches	1 32	0 80	0 33	3 45
11	Fruit length (cm)	17 50	15 44	16 37	14 13
12	Fruit girth (cm)	6 44	6 41	6 31	6 32
13	Single fruit weight(gm)	19 25	19 55	17 79	17 22
14	Weight of fruits (gm)	257 41	236 02	190 25	305 00
15	No of seeds/fruit	83 35	79 57	87 41	44 00
16	No of ridges/fruit	5 47	7 35	5 64	7 00
17	YVMD scoring	2 31	2 40	2 23	3 00

different clusters is presented in Figure 3 The accessions were also characterized based on morphological and biometrical characters following the IBPGR descriptors (Appendix I and II)

Majority of the accessions showed erect growth habit (83 93%) as given in Table 10 The branching and nonbranching types were seen in almost equal frequencies in the germplasm Majority of the accessions (57 14%) had slight stem pubescence Fifty two per cent of the accessions had green stem colour whereas fortythree per cent had green colour with red patches at nodal region Majority of the accessions had five lobed narrow leaves with narrowlyfid margin Acute leaf tip was common among the accessions than the obtuse tip About 94 64 per cent of the accessions produced fruits in an erect position and were mostly green in colour while few accessions (8 93%) produced green fruits with red patches, whereas 16 07 per cent of the accessions produced dark green fruits Biometrical characterisation of the accessions (Table 11) revealed that majority of the accessions were tall having height more than 125 cm However, few accessions (16 07%) having height less than 75 cm were also present in the germplasm Most of the accessions had stem girth ranging between 6 1-7cm More than fifty per cent of the accessions had 20-25 leaves per plant and narrow leaves (< 300 sq cm) Majority of the

Table 10 Variation in bhindi germplasm for morphological characters

Sl No	Descriptor	No of access ions	% of acces ions under each class
1	<u>Growth habit</u>		
	1 Erect	47	83 93
	2 Medium	9	16 07
	3 Procumbent	Nil	0 00
2	<u>Branching habit</u>		
	1 Branched	29	51 79
	2 Unbranched	27	48 21
3	<u>Stem pubescence</u>		
	1 Glabrous	23	41 07
	2 Slight	32	57 14
	3 Conspicuous	1	1 79
4	<u>Stem colour</u>		
	1 Green	29	51 79
	2 Green with red patches	24	42 86
	3 Purple	3	5 36
5	<u>Leaf shape</u>		
	1 (Fig 1)	1	1 79
	2	1	1 79
	3	4	7 14
	4	8	14 29
	5	Nil	0 00
	6	2	3 37
	7	2	3 57
	8	Nil	0 00
	9	28	50 00
	10	10	17 86
6	<u>Leaf lobing</u>		
	1 4 lobes	2	3 37
	2 5 lobes	54	96 43
7	<u>Lamina margin</u>		
	1 Deep Fid	7	12 50
	2 Narrowly Fid	25	44 64
	3 Serrated	24	42 86

Sl No	Descriptor	No of access ions	% of accessions under each class
8	<u>Leaf tip</u>		
	1 Acute	38	67 86
	2 Obtuse	18	32 14
9	<u>Position of Fruit on main stem</u>		
	1 Erect	53	94 64
	2 Horizontal	3	5 36
	3 Pendulous	Nil	0 00
10	<u>Fruit Colour</u>		
	1 Yellowish-green	13	23 21
	2 Green	26	46 43
	3 Dark green	9	16 07
	4 Green with red patches	5	8 93
	5 Dark red	Nil	0 00
	6 Others	3	5 6
11	<u>Fruit shape (Fig 2)</u>		
	1	9	16 07
	2	11	19 64
	3	31	55 36
	4	4	7 14
	5	Nil	0 00
	6	Nil	0 00
	7	1	1 79
12	<u>No of ridges/ plant</u>		
	1 None	1	1 79
	2 From 5 to 7	39	69 54
	3 From 8 to 10	16	28 57
	4 More than 10	0	0 00
13	<u>Fruit pubescence</u>		
	1 Downy	25	44 54
	2 slightly rough	28	50 00
	3 Prickly	3	5 36

Table 11 Variability in bhindi germplasm for biometrical characters

Sl No	Characters	No of accessions	% of accessions under each class
1	Height of plant (cm)		
	<75	9	16 07
	75 100	13	23 21
	101 125	10	17 86
	126-150	19	33 93
	>150	5	8 93
2	Girth of stem (cm)		
	<6	6	10 71
	6 1-7 0	26	46 43
	7 1-8 0	20	35 71
	>8	4	7 14
3	No of leaves per plant		
	<15	Nil	0 00
	15 20	18	32 14
	2 0-25	31	55 36
	>25	7	12 50
4	Leaf Area (cm^2)		
	<200	14	25 00
	20 1 300	18	32 14
	301 400	13	23 21
	401-500	7	12 50
	>500	4	7 14
5	Days to flower		
	<40	12	21 43
	41 50	37	66 07
	51 60	7	12 50
	>60	Nil	0 00
6	First fruiting node		
	<5	6	10 71
	5-6	22	39 29
	6 7	14	25 00
	7-8	10	17 86
	>8	4	7 14
7	Fruit length (cm)		
	<13	1	1 79
	13 17	33	58 33
	17 20	16	28 57
	>20	6	10 71
8	Fruit girth (cm)		
	<5	Nil	0 00
	5 6	13	23 21
	6 7	34	60 71
	7 8	9	16 01
	>8	Nil	0 00
9	Single fruit weight (g)		
	<15	16	28 57
	15 20	19	33 93
	20-25	13	23 21
	25 30	7	12 50
	>30	1	1 79
10	No of fruits per plant		
	<10	14	25 00
	10 15	12	39 28
	15 20	17	30 36
	>20	3	5 36
11	Weight of fruit per plant (g)		
	<200	13	23 21
	200-300	34	60 72
	300-400	5	8 93
	>400	4	7 14
12	No of branches per plant		
	<1	40	71 43
	1-2	13	23 21
	>2	3	5 36
13	No of fruits on branches		
	<1	38	67 86
	1-2	10	17 86
	>2	8	14 29

accessions started flowering between 41 and 50 days However twelve accessions commenced flowering even before forty days Most of the accessions developed fruiting on or between 5th and 7th node whereas in few accessions fruiting began only above the eighth node

More than sixty per cent of the accessions in the germplasm produced fruits with medium length (13-17 cm) Few accessions with very lengthy fruits (>20 cm) were also available in the germplasm Nearly sixtyone per cent of the accessions produced medium sized fruits with fruit girth ranging between 6 and 7 cm Single fruit weight varied widely among the accessions Only one accession produced fruit with a mean weight more than 30 g Majority of the accessions produced 10-15 fruits per plant However, three accessions produced more than twenty fruits per plant While fifteen per cent of the accessions were found to be high yielders producing more than 300 g per plant, four accessions had fruit weight more than 400 g/plant

4 1 2 Selection of Superior accessions

Selection indices were worked out to identify superior accessions for hybridisation work based on discriminant function analysis The index values constructed for all the accessions were arranged in the order of merit (Table 12)

Table 12 Selection Index values in descending order

Sl No	Index value	Acc No	Sl No	Index value	Acc No
1	2525 682	12	29	1413 121	7
2	2092 899	8	30	1400 142	9
3	1917 666	4	31	1373 834	18
4	1847 023	38	32	1335 487	20
5	1839 509	30	33	1319 368	31
6	1838 154	32	34	1311 717	13
7	1770 653	40	35	1300 233	48
8	1745 132	14	36	1280 159	43
9	1731 834	17	37	1271 102	42
10	1726 280	29	38	1249 863	53
11	1720 122	41	39	1207 883	50
12	1677 411	19	40	1195 773	44
13	1656 557	21	41	1192 947	11
14	1643 114	34	42	1168 500	51
15	1615 806	2	43	1156 035	46
16	1607 285	22	44	1140 366	15
17	1582 152	1	45	1085 583	38
18	1577 666	36	46	1081 231	5
19	1567 726	10	47	1077 718	45
20	1532 882	16	48	1048 998	54
21	1469 058	37	49	998 647	26
22	1469 058	37	50	994 962	3
23	1468 033	35	51	858 852	25
24	1462 758	6	52	830 087	56
25	1454 262	23	53	817 579	55
26	1431 754	47	54	740 851	24
27	1415 166	52	55	667 606	27
28	1415 157	49	56	512 034	28

Plate 1 Yellow Vein Mosaic disease symptom

Plate 2 Aanakkompan (L_1)

Plate 1.

Plate 2.

The index values ranged from 2525 68 to 512 03 Accession 12 recorded the maximum score (2525 68) followed by the accession 8 (2092 90) and the accession 4 (1917 67) These lines were selected as parents for hybridization programme

The single genotype included in cluster IV was accession 12, the top ranking accession The accessions with second and third ranks were in cluster II and cluster I respectively Most of the remaining top ranking accessions were included in cluster II The selected accessions were given in Plates 2 to 4

4 1 3 Variability studies

Different variability parameters were computed and presented in Table 13 High phenotypic and genotypic coefficient of variation (PCV and GCV) were observed for plant height, leaf area, number of fruits per plant, weight of fruits per plant, single fruit weight, number of branches per plant and number of fruits on branches Highest PCV (68 54) and GCV (55 24)) values were recorded for number of fruits on branches closely followed by number of branches and leaf area Yellow vein mosaic disease (YVMD) scoring recorded high PCV (44 97) whereas the GCV was found to be low (20 67) The lowest PCV and GCV values were recorded for

Table 14 Estimates of phenotypic (P) and genotyp c (G) corre ation coefficients between yie d and y e d contributing characters in bhindi

		No of leaves per plant	Leaf area	No of days to flower ng	No of flowers per plant	No of fruits per plant	Length of fru t	G rth of fru t	S ngle fruit wt	F rst fru t ing node	No of branches per plant	No of fru ts on b anches	No of ridges pe fru t	YVMD or ng	Wt of fru t per plant
He ght of plant	P	0 4428	0 32 8	0 1567	0 5526	0 5282	0 2174	0 0411	0 2055	0 1814	0 0766	0 1425	0 0736	0 2606	).2435
	G	0 4694**	0 3573	0 1791	0 6619	0 5754	0 3265	0 8748	0 1949	0 2056	0 0426	0 1766	0 0814	0 5278	0 2468
No of leaves per plant	P		0 3495**	0 0960	0 7310	0 6303**	0 0769	0 0987	0 1409	0 3863	0 4492	0 4330	0 1414	0 1047	) 4006
	G		0 6002**	0 2076	0 7765**	0 7683	0 2550	0 6344**	0 1272	0 6243	0 4929**	0 6581	0 2786	0 1272	0 6871**
Leaf area	P			0 2224	0 4089	0 3660	0 1719	0 0249	0 0252	0 2332	0 2155	0 2894	0 2434	0 0436	0 3544
	G			0 24[illegible]	0 651[illegible]	0 4382	0 1990	0 7126	0 0407	0 2439	0 2372	0 3584	0 2514	0 1024	0 3716
No of days to flowe r ng	P				0 2987	0 3106	0 0126	0 0160	0 1639	0 3546	0 2318	0 0680	0 1857	0 3731	0 1221
	G				0 4991	0 4066	0 0192	0 4119	0 3135	0 4385	0 2749	0 0435	0 2146	0 6543	0 0875
No of flowers per plant	P					0 9027	0 0349	0 1086	0 3303	0 1316	0 2927	0 4608	0 0659	0 0899	1 4659**
	G					1 0461	0 0223	0 6410	0 1532	0 2018	0 2473	0 7120	0 1326	0 0744	0 7595**
No of fru ts per plant	P						0 0640	0 0716	0 4309	0 0894	0 2132	0 4615	0 1431	0 1364	4889
	G						0 0923	0 8 87**	0 2869	0 0999	0 1397	0 6215	0 1806	0 0176	5882
Fru t length	P							0 0031	0 2342	0 0766	0 0598	0 0398	0 2649	0 1965	0 1912
	G							0 8513	0 3535	0 0568	0 0568	0 0815	0 0319	0 5902	0 284
Fru t g rth	P								0 0670	0 0181	0 1023	0 0609	0 0167	0 1115	0 0034
	G								0 4639**	0 5629	0 1852	0 8473	0 3029	2 7620	0 4723**
S ngle fruit weight	P									0 1782	0 0941	0 0505	0 0653	0 1945	0 5135**
	G									0 2290	0 2566	0 0564	0 0915	0 4949	0 5723
First fr u t ng node	P										0 5621**	0 2123	0 1313	0 0090	0 2030
	G										0 6291**	0 3997	0 1285	0 1127	0 2144
No of branches per plant	P											0 4710	0 3376	0 2787	0 3014
	G											0 4171	0 4116	0 5786	0 3413
No of fruits on branches	P												0 2031	0 1735	0 4005
	G												0 2662	0 3872	0 4534**
No of r dges per plant	P													0 0869	0 0938
	G													0 1555	0 0990
YVMD scor ng	P														0 0500
	G														0 0401

* S gn f cant at 5% level ** S gn f cant at 1% level

Table 13 Mean Coefficient of variation heritability and genetic advance in bhindi (Experiment I)

Sl No	Characters	Mean	PCV	GCV	h^2 %	GA 5%
1	Height of plant(cm)	114 62	29 71	25 89	75 95	53 28
2	No of leaves/plant	21 74	18 10	10 12	31 31	2 54
3	Leaf area (cm^2)	307 27	40 52	40 41	99 46	255 07
4	Days to flowering	45 51	10 60	9 66	83 02	8 25
5	First fruiting node	12 17	9 71	9 13	88 44	2 15
6	No of branches/plant	1 89	50 36	43 92	76 01	1 49
7	No of flowers/plant	16 06	24 44	15 23	38 87	3 14
8	No of fruits/plant	13 28	32 51	26 79	67 91	6 04
9	No of fruits on branches	2 02	68 54	55 24	64 94	1 85
10	Fruit length (cm)	16 75	15 32	13 49	77 51	4 10
11	Fruit girth (cm)	6 40	8 99	6 68	55 35	0 66
12	Single fruit weight (gm)	18 89	33 19	26 53	63 88	8 25
13	Weight of fruits/ Plant (gm)	239 21	32 87	31 04	89 19	144 47
14	No of ridges/fruit	5 88	26 77	26 69	99 46	3 23
15	YVMD scoring	2 30	44 97	20 67	21 13	0 45
16	No of seeds/fruit	82 86	26 11	23 46	80 77	35 99

plant and plant height Leaf area recorded the highest values for heritability (99 46) and genetic advance (255 07) closely followed by weight of fruits per plant High heritability (80 77) coupled with moderate genetic advance (35 99) was recorded for number of seeds per fruit Number of days to flowering number of fruits per plant fruit length single fruit weight first fruiting node, number of branches number of fruits on branches and number of ridges per fruit recorded high heritability whereas genetic advance was found to be very low for these characters YVMD scoring recorded the lowest values for both the heritability and genetic advance

4 1 4 Correlations

Data on correlations (Table 14) revealed in general that genotypic correlations were higher than the phenotypic correlations for most of the characters in this experiment The phenotypic correlations were however slightly higher than the genotypic correlations in respect of number of branches per plant with number of fruits per plant and number of fruits on branches

Among different characters studied pod yield was positively and significantly associated with number of leaves per plant, leaf area, number of flowers per plant, number of fruits per plant, fruit girth, single fruit weight, number of branches and number of fruits on branches Among these yield components, number of leaves per plant had significant positive association with plant height, leaf area number of flowers and fruits per plant, first fruiting node , number of branches and fruits on branches Leaf area was also found to be closely associated with all these characters except first fruiting node and number of branches per plant

Significant negative associations of days to flowering with number of flowers per plant and number of fruits per plant were recorded However, significant positive correlation was observed with single fruit weight and first fruiting node Significant positive association was also noticed between number of flowers per plant and number of fruits per plant, fruit girth and number of fruits on branches Similar type of association was also observed for number of fruits per plant

Among the fruit characters, fruit length was found to be positively and significantly associated with fruit girth and single fruit weight whereas fruit girth was found to be positively and significantly

Plate 4.

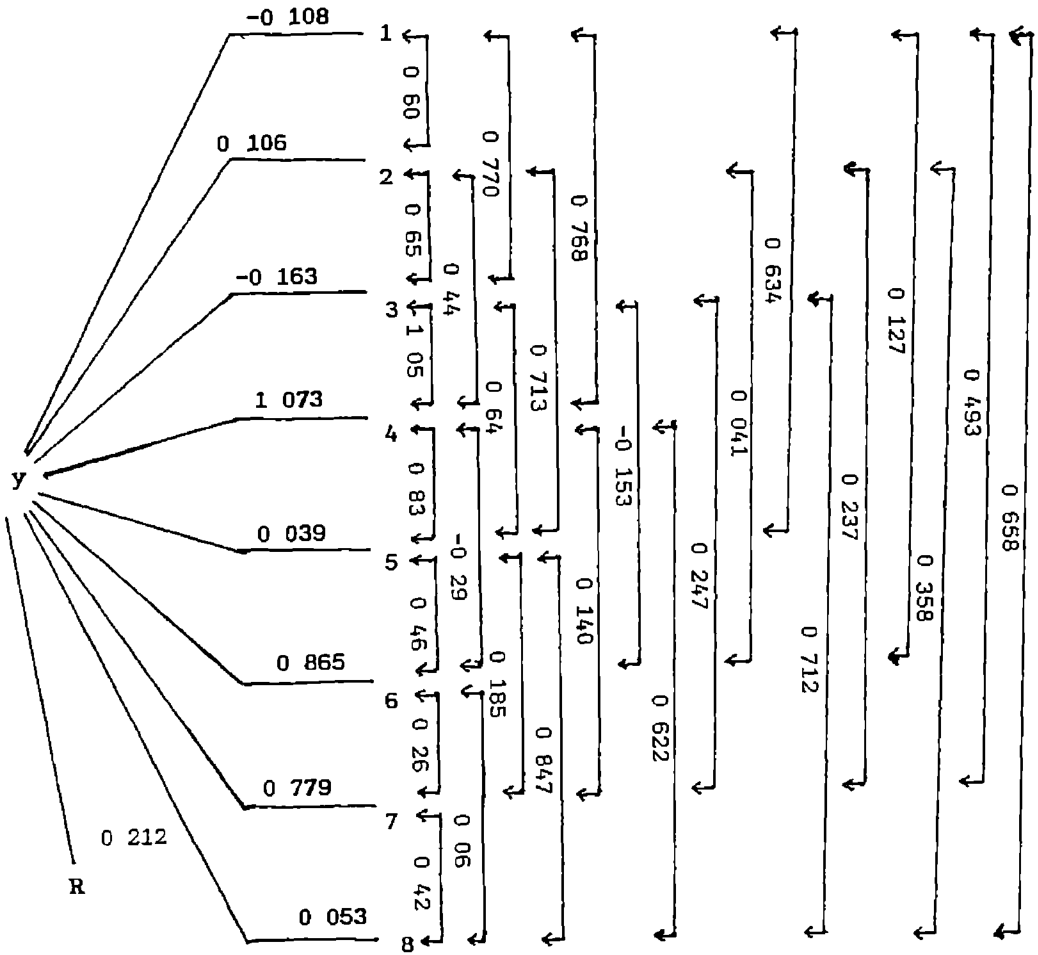
correlated with all other traits except days to flowering and number of branches per plant Single fruit weight, one of the major yield component had only negative association with fruit girth, whereas it recorded significant positive correlation with length of fruit Number of branches per plant and number of fruits on branches had significant positive association with each other and also with first fruiting node

Yellow vein mosaic incidence was found to be significantly and negatively associated with plant height and fruit girth However, the correlations of days to flowering, fruit length, single fruit weight and number of branches per plant with yellow vein mosaic incidence were found to be positively significant

4 1 5 Path coefficient Analysis

The Path analysis in Bhindi has brought out the direct influence of component traits on yield as presented in Table 15 and Figure 4 Number of fruits per plant recorded the maximum direct effect (1 0729) on yield followed by single fruit weight (0 8645) Number of flowers per plant and number of leaves per plant had negative direct influence on yield, but of low magnitude However, these characters influenced yield mainly through their indirect

Fig 4 Path diagram of direct effects and inter-relationship of yield contributing characters on pod yield



Characters

1 Leaves per plant

2 Leaf area

3 Flowers per plant

4 Fruits per plant

5 Girth of fruit

6 Single fruit weight

7 Number of branches

8 Fruits on braanches

Y Pod yield

R Residual

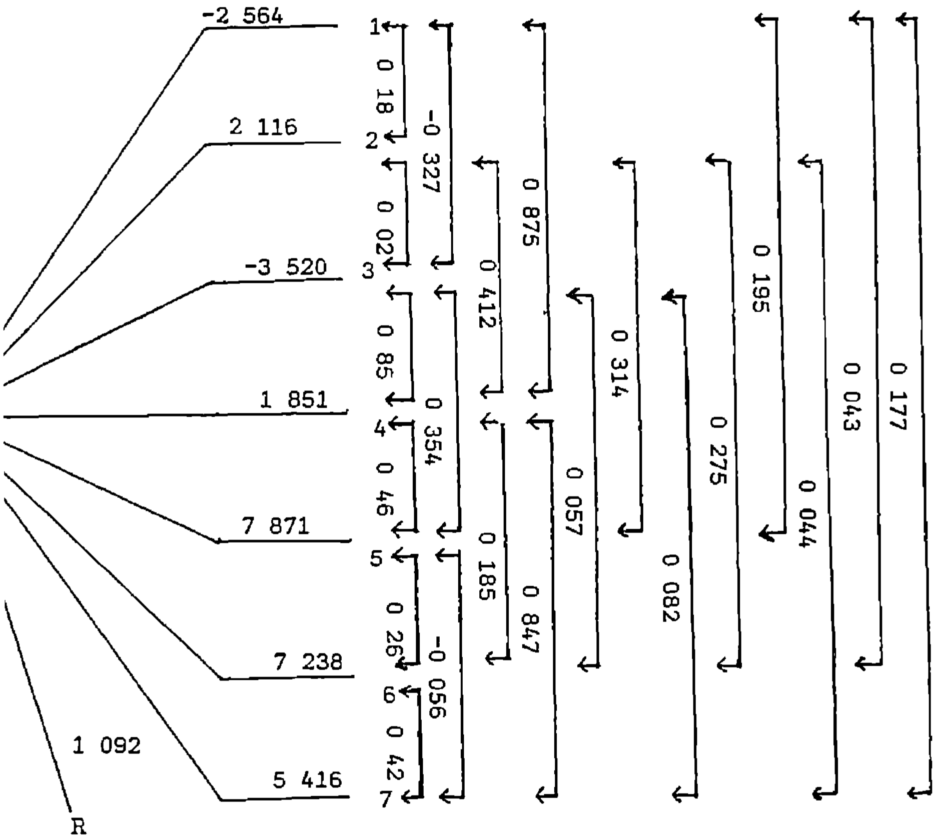
Table 15. Estimates of direct and indirect effects of yield contributing characters on pod yield

Characters	No of leaves/ plant (x_1)	Leaf area (x_2)	No of flowers/ plant (x_3)	No of fruits/ plant (x_4)	Fruit girth (x_5)	Single fruit weight (x_6)	No of branches per plant (x_7)	No of fruits on branches (x_8)	Observed genotypic correlation with yield
No of leaves per plant(x_1)	**-0 1084**	0 0097	0 7268	0 8243	-0 0250	0 1100	0 0383	0 0351	0 6871**
Leaf Area (x_2)	-0 0651	**0 0162**	0 1064	0 4702	0 0280	0 0352	0 0185	-0 0191	0 3776*
No of flowers per plant(x_3)	0 0842	0 0106	**-0 1633**	1 1323	0 0252	-0 1324	0 0192	-0 0379	0 7595**
No of fruits per plant(x_4)	0 0833	0 0071	0 1708	**1 0729**	0 0326	0 2480	0 0109	-0 0331	0 5882**
Fruit girth(x_5)	0 0688	0 0116	0 1047	0 8891	**0.0393**	-0 4010	0 0144	-0 0452	0 4723**
Single fruit weight (x_6)	-0 0138	0 0007	0 0250	-0 3078	-0 0183	**0 8645**	0 0200	0 0030	0 5723**
Number of branches per plant(x_7)	0 0534	0 0038	-0 0404	0 1499	0 0073	0 2218	**0.0778**	-0 0254	0 3413*
Number of fruits on branches(x_8)	-0 0713	0 0058	0 1163	0 6668	0 033	-0 0488	0 0371	**0 0533**	0 4534**

Residual effect - 0 2115

Bold face figures indicates direct effects

Fig 5 Path diagram of direct effects and inter-relationships of yield contributing characters on YVMD Incidence



<u>Characters</u>

1 Plant height

2 Days to flowering

3 Length of fruit

4 Girth of fruit

5 Weight of single fruit

6 Number of branches

7 Number of fruits on branches

Y YVMD incidednce

R Residual

Table 16 Estimates of direct and indirect effects of yield components on Yellow Vein Mosiac incidence in Bhindi

Characters	Height of plant (x_1)	Days to flowering (x_2)	Fruit length (x_3)	Fruit girth (x_4)	Single fruit weight (x_5)	Number of branches/plant (x_6)	Number of fruits on branches (x_7)	Observed Genotypic correlation with YVMD
Height of plant (x_1)	**-2.5635**	-0 3790	1 1494	1 6189	-1 6183	0 3083	0 9564	-0 5278**
Days to flowering (x_2)	0 4591	**2.1162**	0 0676	-0 7623	-3 4516	1 9896	0 2356	0 6543**
Fruit length (x_3)	0 8370	-0 0406	**-3.5203**	1 5754	0 4471	0 5899	0 1706	0 5902**
Fruit girth (x_4)	-2 2426	-0 8717	-2 9968	**1.8506**	-4 4307	1 3404	4 5888	-2 7620**
Single fruit weight (x_5)	-0 5271	0 9280	0 2000	1 0417	**-7.8713**	4 5589	2 1647	0 4949**
Number of branches per plant (x_6)	-0 1092	0 5818	-0 2869	0 3427	-4 9581	**7.2375**	-2 2291	0 5786**
Number of fruits on branches (x_7)	-0 4527	0 0921	-0 1109	1 5680	-3 1462	-2 9789	**5.4158**	0 3872*

Residual effect = 1 0919

Bold face figures indicate direct effects indirect effects through the other characters resulting in positive association with YVMD incidence Number of branches recorded opposite trend with a very high positive direct effect and negative indirect effects

The direct and indirect effects of various characters revealed that the single fruit weight and number of branches per plant had the maximum negative and positive influence on YVMD incidence respectively Branching types were found to be more susceptible than the shybranching accessions

4.1 6 Evaluation of wild relatives

The eight accessions of wild relatives of Bhindi were also evaluated separately in a randomised block design with three replications The data were statistically analysed and the ANOVA presented in Table 17 Significant varietal differences were noticed for all the characters except number of ridges per plant

The wild accessions were crossed with *A esculentus* (var Kilichundan) to study their compatibility No fruitset was obtained between *A moschatus* and *A esculentus* indicating strong genetic barrier between these two species All other accessions were found to be compatible with *A esculentus* Moreover, natural crossing

Table 17 ANOVA for thirteen characters in wild relatives of Bhindi

Sl No	Source	df	Height of plant	Girth of stem	No of leaves/ plant	Leaf area	Days to flowering	No of flowers per plant
1	Replication	2	34 52	0 19	0 51	706 00	1 68	4 95
2	Treatments	7	1753 19**	3 49**	154 30**	108332 50**	50 35**	188 54**
3	Error	14	44 07	0 38	11 98	535 00	3 44	8 58

Sl No	Source	df	No of fruits/ plant	Fruit length	Fruit girth	Single fruit weight	First fruiting node	No of branches per plant	No of ridges/ fruit
1	Replication	2	0 81	0 001	0 003	27 72	0 00	0 02	30 25
2	Treatments	7	101 04**	27 82**	12 13**	222 28**	2 29**	7 84**	7 86
3	Error	14	7 46	0 46	0 03	12 45	0 00	0 07	30 25

* Significant at 5% level
**Significant at 1% level

was also observed between *A esculentus*, *A caillei* and *A tetraphyllus*

Results of the screening trial revealed that all the wild accessions were resistant to yellow vein mosaic disease under field conditions except *A moschatus* Out of the forty plants inoculated by grafting graft union was established in fourteen plants with thirty five percent success Graft union failed to establish in the case of *A tetraphyllus* due to the slender nature of its stem

Based on compatibility, resistance and other desirable attributes two accessions viz accession No 58 (*A tetraphyllus*) and accession No 59 (*A caillei*) were selected as the donor parents (Plates 5 and 6)

4 2 1 Production of hybrids

The selected cultivated bhindi varieties were crossed with wild accessions for the production of hybrid seeds including reciprocals Detailed study on intervarietal difference in compatibility was undertaken (Table 18 and 19)

Various ranges of fruitset were obtained in the crosses of *A esculentus* with *A caillei* and *A tetraphyllus* Crosses of three accessions of *A esculentus* with the wild relatives showed that the percentage of

FIG. 6 COMPATIBILITY IN THE GENUS ABELMOSCHUS

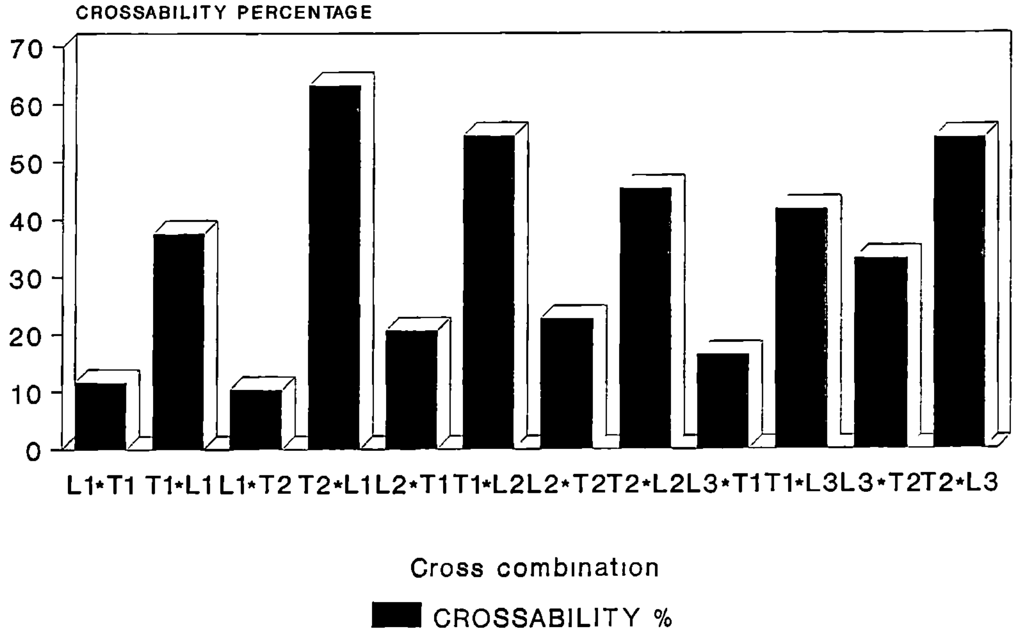


Table 18 Results of interspecific hybridization in the genus Abelmoschus

	Cross combination	Total no of crosses	No of fruits	% of fruitset	Length of fruit(cm)		No of seeds/fruit	
					Cross	female parent open pollinated	Cross	female parent open pollinated
1	Aanankkompan x A caillei	32 00	12 00	31 58	22 00	23 00	22 00	23 00
2	A caillei x Aanakkompan	20 00	16 00	80 00	15 00	16 00	43 00	42 00
3	Aanankkompan x A tetraphyllus	36 00	16 00	44 44	21 00	23 00	39 00	48 00
4	A tetraphyllus x Aanakkompan	43 00	34 00	79 07	9 00	8 00	17 00	20 00
5	Eanivenda x A caillei	22 00	18 00	81 81	22 00	22 00	41 00	44 00
6	A caillei x Eanivenda	20 00	15 00	75 00	17 00	16 00	38 00	42 00
7	Eanivenda x A tetraphyllus	45 00	36 00	80 00	21 00	22 00	43 00	44 00
8	A tetraphyllus x Eanivenda	53 00	34 00	34 15	8 00	8 00	18 00	20 00
9	AE 1 x A caillei	25 00	20 00	80 00	18 00	18 00	39 00	40 00
10	A caillei x AE 1	20 00	17 00	35 00	16 00	16 00	38 00	42 00
11	AE 1 x A tetraphyllus	23 00	23 00	100 00	17 00	18 00	40 00	40 00
12	A tetraphyllus x AE 1	54 00	41 00	75 93	8 00	8 00	16 00	20 00

Table 19 Compatibility in the genus Abelmoschus

Sl No	Parents/Crosses	% of fruitset	No of seeds/ fruit	% of germi nation	Cross ability index (%)
1	Aanakkompan	64 34	48 00	84 44	
2	Eanivenda	72 67	44 00	77 78	
3	AE 1	88 96	40 00	76 66	
4	Abelmoschus caillei	70 65	42 00	67 78	
5	Abelmoschus tetraphyllus	73 99	20 00	36 67	
6	Aanakkompan x A caillei	31 58	35 00	27 63	11 71
7	A caillei x Aanakkompan	80 00	43 00	22 00	37 63
8	Aanakkompan x A tetraphyllus	44 44	39 00	15 65	10 40
9	A tetraphyllus x Aanakkompan	79 07	17 00	25 56	63 32
10	Eanivenda x A caillei	81 81	41 00	15 33	20 68
11	A caillei x Eanivenda	75 00	38 00	38 44	54 47
12	Eanivenda x A tetraphyllus	80 00	43 00	16 44	22 74
13	A tetraphyllus x Eanivenda	64 15	18 00	21 33	45 39
14	AE 1 x A caillei	80 00	39 00	14 39	16 46
15	A caillei x AE 1	85 00	38 00	26 00	41 76
16	AE 1 x A tetraphyllus	100 00	40 00	22 61	33 15
17	A tetraphyllus x AE 1	75 93	16 00	24 22	54 22

Plate 5 *Abelmoschus caillei* (*A manihot* ssp *manihot*) (T_1)

Plate 6 *Abelmoschus tetraphyllus* (T_2)

Plate 6.

fruitset differed widely among the crosses The percentage of fruitset was almost double in the reciprocal crosses as compared to the direct crosses No difference was noticed in fruit length of the open pollinated fruits The number of seeds per fruit was the highest (43) for *A caillei* x Aanakkompan and Eanivenda x *A tetraphyllus* The percentage of seed germination was less in crossed seeds than in parents, with the lowest value (14 39%) recorded for AE_1 x *A caillei* The crossability index values ranged from 10 40 (Aanakkompan x *A tetraphyllus*) to 63 32 (*A tetraphyllus* x Aanakkompan (Table 19) In all the combinations, the crossability index values were found to be higher in reciprocal crosses involving wild maternal parent than in the corresponding crosses in which *A esculentus* accessions were used as female parent (Figure 6) This was particularly true in the case of Aanakkompan where physical barriers may also be involved in preventing fertilization

4 2 2 Standarisation of irradiation dose

A pilot study was undertaken to find the effect of various doses of gamma rays in inducing recombinants The results were given in Table 20 and 21 The results indicated a marked reduction in germination, survival and plant height on the 15th day and at maturity (Figure 7) The reduction in

FIG.7 Effect of gamma rays on traits in M1 generation of Bhindi

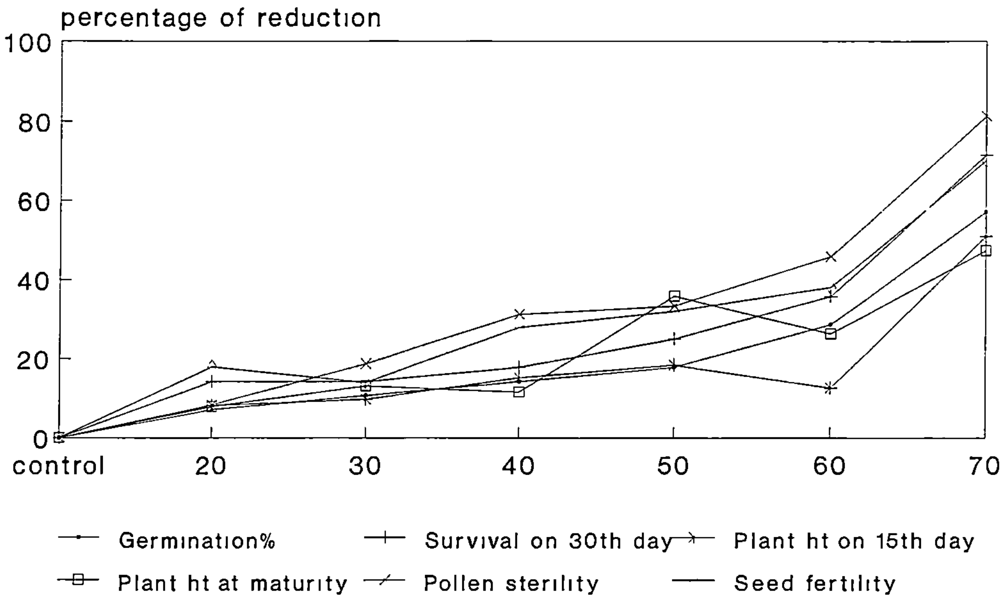


Table 20 Effect of gamma rays on different traits in M_1 generation of bhindi

Dose of gamma rays	Percentage of reduction on					
	Germination (%)	Survival on 30th days (%)	Plant height on 15th day	Plant height at maturity	Pollen fertility	Seed fertility
Control	-	-	-	-	-	
20 Kr	7 14	14 28	8 20	7 89	8 33	18 00
30 Kr	10 72	14 28	9 73	13 16	18 75	14 00
40 Kr	14 28	17 85	15 21	11 58	31 28	28 00
50 Kr	17 85	25 00	18 40	35 53	33 83	32 00
60 Kr	28 57	33 71	12 60	26 32	45 83	38 00
70 Kr	57 14	71 42	50 91	47 37	81 23	70 00

Table 21 Correlation and regression Coefficients for reduction of different M_1 parameters with doses of gamma rays of bhindi

	Parameters	Correlation coefficient	Regression coefficient
1	Germination	0 890	0 877
2	Survival on 30th day	0 869	1 020
3	Plant height on 15th day	0 750	0 640
4	Plant height at maturity	0 890	0 750
5	Pollen fertility	0 940	1 280
6	Seed fertility	0 900	0 960

pollen and seed fertility increased gradually upto 60 Kr followed by a drastic reduction at 70 Kr treatment The rate of reduction was found to be maximum for pollen fertility (1 28) and minimum for plant height on 15th day (0 64) Based on this study, 60 Kr dose was selected for inducing recombinants in the interspecific hybrids

4 3 Evaluation of F_1 and F_1M_1 generations

The analysis of variance revealed significant differences for all the characters among the entries evaluated (Table 22) Combining ability analysis was done for two sets of treatments namely crosses and their irradiated counterparts (Table 23 and Table 24) The mean performance of the parents and the hybrids pertaining to different characters was given in Table 25 and Plates 10-12 The three estimates of heterosis namely relative heterosis, hetero-beltiosis and standard heterosis were also computed and presented in Tables 26 35

Percentage of germination

Wild relatives differed significantly in germination whereas significant differences were not observed among the cultivated parents Significant

Table 22 Analysis of variance for F_1 and F_1M_1 generations

Source	Degrees of freedom	Mean squares: Percentage of germination	Plant height	Girth of stem	No of leaves per plant	Leaf area
Replication	2	6 64**	713 86**	1 08**	75 23**	565 75
TREATMENTS	29	8 29**	2823 76**	7 33**	198 54**	74738 0**
Parents	4	4 65**	2064 03**	10 69**	75 26**	69244 4**
lines	2	0 16	3451 36**	2 35**	51 39**	18358 0**
testers	1	7 09**	600 01	31 74**	1 13	237765 2**
SP vs rest	1	1 11	769 72	0 53	107 58**	5413 4*
Hybrids	11	1 41*	4488 12**	3 46**	306 33**	107335 1**
Irr hybrids	11	2 52**	592 62**	6 75**	52 02**	55093 5**
Hybrids vs Irr hybrids	1	0 92	15520 30**	46 24**	1389 52**	79800 0**
Parents vs hybrids	1	130 01**	31 00	0 20	0 34	286 4
Parents vs Irr hybrids	1	113 83**	8099 90**	32 12**	781 34	39895 7**
CROSSES						
lines	2	0 64	3017 90	1 16	135 54	67957 1
testers	1	0 01	702 00	19 59	167 81	346386 6
lines x testers	2	1 90*	8424 40**	1 49**	697 37**	47082 7**
RECIPROCALS						
lines	2	0 29	1339 80	1 25	132 54	4694 7
testers	1	1 17	1969 40	11 57*	66 93	577103 2*
lines x testers	2	1 70	6950 70**	0 30	329 18**	8538 5**
IRR CROSSES						
l nes	2	33 62	1 43	0 07	19 88	41382 9
testers	1	0 29	399 03	25 99	85 02	310598 1*
lines x testers	2	5 60**	522 70	3 54**	51 86	13369 8**
IRR RECIPROCALS						
lines	2	2 87	15090 70*	0 68	39 88	30799 7
testers	1	1 88	5 75	35 62	1 73	37160 8
lines x testers	2	0 57	61 48	2 07**	39 14	2157 2**
ERROR	58	0 58	225 84	0 14	16 44	1285 3

(Contd)

Table 22 (Contd)

Source	Degrees of freedom	Length of petiole	Days to flowering	First fruiting node	Branches per plant	Flowers per plant	Fruits per plant
		Mean squares					
Replication	2	2 16	3 19	1 24*	2 57**	29 34*	12 07
TREATMENTS	29	124 68**	198 31**	9 43**	18 95**	51 02**	54 20**
Parents	4	94 25**	178 83**	32 96**	23 84**	38 04**	29 21*
lines	2	3 37*	82 62**	0 76	5 92**	3 56	2 75
testers	1	266 67**	121 50**	4 34**	51 63**	68 68**	104 17**
SP vs rest	1	2 95	347 31**	5 58**	9 15**	13 46	3 72
Hybrids	11	139 11**	88 38**	4 96**	0 67**	60 89**	52 08**
Irr hybrids	11	151 67**	119 72**	14 91**	25 08**	23 86**	15 87
Hybrids vs Irr hybrids	1	5 61**	88 00**	3 51**	8 61**	320 05**	578 57**
Parents vs hybrids	1	9 10**	975 71**	11 39**	10 31**	1 30	1 07
Parents vs Irr hybrids	1	23 37**	1476 97**	23 16**	29 83**	220 87**	379 48**
CROSSES							
lines	2	52 64	76 42	0 03	3 41	38 04	46 46*
testers	1	793 21**	101 39	31 13*	39 16**	86 59	84 11*
lines x testers	2	3 28*	219 14**	0 95	8 91**	90 94**	1 83
RECIPROCALS							
lines	2	44 00	4 45	1 93	10 69	59 23	122 63
testers	1	494 87**	211 97	9 81	16 94	149 13	48 71
lines x testers	2	4 68**	25 02**	2 52*	6 98*	23 71	11 63
IRR CROSSES							
lines	2	87 88	39 69	1 26	6 59	35 05	19 86
testers	1	551 45**	3 46	48 61*	96 74**	9 12	10 86
lines x testers	2	20 51	132 84**	2 54	18 97**	255 14**	16 88
IRR RECIPROCALS							
lines	2	3 77	72 83	5 04	0 51	18 18	17 78
testers	1	856 98	474 94	77 75	109 52**	34 45	38 81
lines x testers	2	12 11*	125 85**	9 87**	8 74**	35 71*	7 84
ERROR	58	0 91	2 92	0 37	0 49	7 83	8 75

(Contd)

Table 22 (Contd)

Source	Degrees of freedom	Mean squares: No of fruits on branches	Length of fruit	Girth of fruit	Single fruit weight	Weight of fruits/ plant
Replication	2	4 59**	2 13	0 63**	8 09**	2126 13**
TREATMENTS	29	10 95**	89 39**	8 82**	165 21**	24987 1**
Parents	4	32 47**	177 28**	10 99**	282 57**	3074 1**
lines	2	9 27**	13 02**	0 22	70 22**	3722 3**
testers	1	75 62**	194 94**	38 00**	530 16**	33750 0**
SP vs rest	1	17 69**	0 03	0 29	20 26**	3074 1**
Hybrids	11	9 71**	58 15**	9 49**	81 51**	3434 2**
Irr hybrids	11	2 15*	513 48**	9 41**	94 66**	4855 9**
Hybrids vs Irr hybrids	1	18 10**	24 73**	3 60**	8 41**	7060 7**
Parents vs hybrids	1	14 39**	398 28**	3 52**	1276 52**	286946 1**
Parents vs Irr hybrids	1	49 78**	565 09**	11 10*	1440 36**	360144 0**
CROSSES						
lines	2	5 79	34 98	3 57	1 62	11653 5
testers	1	19 41	248 87	31 05	459 96*	49404 8
lines x testers	2	5 08*	34 87*	5 00**	5 89**	4709 6*
RECIPROCALS						
lines	2	1 44	33 17	3 84	1 58	10643 0**
testers	1	39 69	133 84**	39 87**	414 72**	21283 0**
lines x testers	2	11 51**	13 72*	4 26**	0 71	58 6
IRR CROSSES						
lines	2	1 92	12 97	1 49	0 12	301 2
testers	1	6 48	214 25*	23 32	421 08**	17420 9**
lines x testers	2	2 90	7 29**	1 53*	1 11	434 5
IRR RECIPROCALS						
lines	2	1 53	6 69	2 74	10 38	14121 8
testers	1	2 21	273 78**	43 62	511 35	2244 0
lines x testers	2	0 60	8 64**	5 68	38 83**	1647 6
ERROR	58	1 04	0 98	0 09	1 04	617 7

(Contd)

Table 22 (Contd)

Source	Degrees of freedom	Mean squares					
		No of seeds per fruit	No of via ble seeds/ fruit	No of ridges/ fruit	YVMD incidence	% of infestation by E vitella Shoot	% of infestation by E vitella Fruit
Replication	2	3 55	0 53	0 04	0 01	2 93**	4 99**
TREATMENTS	29	2578 40**	2531 40**	5 64**	0 59**	5 72**	3 56**
Parents	4	1982 90**	1871 90**	8 10**	1 20**	5 37**	3 81**
lines	2	844 43**	871 69**	9 00**	0 05**	1 10**	0 28**
testers	1	4715 20**	4482 70**	13 50**	0 33**	19 28**	0 13
Sp vs rest	1	68 64**	108 90**	8 09**	0 22**	2 21**	7 71**
Hybrids	11	15 77	3 67	5 83	0 03	4 35**	1 07**
Irr hybrids	11	7 56	0 63	5 12**	0 06**	0 96	2 89**
Hybrids vs Irr hybrids	1	56 18**	5 01	1 98**	0 07**	15 39**	10 69**
Parents vs hybrids	1	46373 00**	46421 80	1 58**	7 68**	37 40**	4 57**
Parents vs Irr hybrids	1	48882 00**	47164 70	5 27**	6 59**	82 89**	21 59**
CROSSES							
lines	2	5 22	0 38	4 03	0 00	4 45	0 81
testers	1	5 85	6 37	14 89	0 00	7 84*	5 99
lines x testers	2	6 78	0 34	5 49	0 00	0 30	0 37
RECIPROCALS							
lines	2	1 79	3 01	1 80	0 05*	2 98	0 40
testers	1	13 21	17 58	22 92	0 02	23 10*	1 46
lines x testers	2	55 67**	3 38	1 68**	0 05**	0 27	0 56
IRR CROSSES							
lines	2	5 45	0 08	1 74	0 01	22 96	0 11
testers	1	3 08	3 30	22 18	0 10	8 41	9 90
lines x testers	2	0 08	0 05	1 74**	0 10**	13 82**	2 02**
IRR RECIPROCALS							
l nes	2	9 90	0 09	1 58	0 05	1 33	0 27
testers	1	20 74	2 01	21 06	0 14	1 69	15 79
lines x testers	2	31 55	0 58	1 58**	0 04**	0 60	1 41**
ERROR	58	7 12	7 08	0 03	0 01	0 29	0 36

* Significant at 5% level ** S gnificant at 1% level Irr Irradiated

Table 23(a) General combining ability effects of lines and testers non irradiated crosses

Sl No	Character	Testers		Lines		
		T_1	T_2	L_1	L_2	L_3
1	Percentage of germination	0 01	0 01	0 10	0 11	0 01
2	Plant height	2 08	2 08	3 80	4 81	8 61
3	Stem girth	0 35**	0 01**	0 08	0 09	0 17
4	No of leaves per plant	1 02	1 02	1 56	0 05	1 62
5	Leaf area	46 24**	46 24**	21 30	19 65	40 95**
6	Petiole length	2 21**	2 21**	0 32	0 79*	1 11**
7	Days to flowering	0 79	0 79	1 17	1 21	0 04
8	First fruiting node	0 44*	0 44*	0 02	0 01	0 01
9	No of branches per plant	0 49*	0 49*	0 28	0 07	0 21
10	No of flowers per plant	0 73	0 73	0 02	0 83	0 85
11	No of fruits per plant	0 72	0 72	0 77	0 26	1 03
12	No of fruits on branches	0 35	+0 35	0 33	0 0006	0 33
13	Fruit length	1 24**	2 24**	0 55	0 37	0 92*
14	Fruit girth	0 44**	0 44**	0 23*	0 04	0 27*
15	Single fruit weight	1 69**	1 69**	0 16	0 18	0 02
16	Pod yield per plant	17 47**	17 47**	15 14	0 96	14 18
17	No of seeds per fruit	0 19	0 19	0 35	0 20	0 15
18	No of viable seeds per furit	0 20	0 20	0 08	0 09	0 01
19	No of ridges per fruit	0 33	0 33	0 15	0 17	0 32
20	YVMD incidence	0 0039	0 0039	0 0039	0 0039	0 0078
21	Percentage of fruit infestation by *E vitella*	0 24	0 24	0 74	0 26	0 38
22	Percentage of shoot infestation by *E vitella*	0 25	0 25	0 06	0 03	0 03

* Significant at 5% level

** Significant at 1% level

Table 23(b) General combining ability effects of lines and testers in irradiated crosses

Sl No	Character	Testers		Lines		
		T_1	T_2	L_1	L_2	L_3
1	Percentage of germination	0 04	0 04	0 10	0 19	0 29
2	Plant height	1 57	1 57	0 18	0 14	0 04
3	Stem girth	+0 40**	0 40**	0 04	0 01	0 03
4	No of leaves per plant	0 72	0 72	0 22	0 47	0 69
5	Leaf area	43 79**	43 79**	20 14	11 42	31 57**
6	Petiole length	1 85**	1 85**	1 45**	0 49	1 11**
7	Days to flowering	0 15	0 15	0 94	0 20	0 74
8	First fruiting node	0 55**	0 55**	0 17	0 10	0 07
9	No of branches per plant	0 77**	0 77**	0 30	0 08	0 38
10	No of flowers per plant	0 24	0 24	0 89	0 68	0 21
11	No of fruits per plant	0 26	0 26	0 70	0 31	0 39
12	No of fruits on branches	0 20	0 20	0 20	0 03	0 17
13	Fruit length	1 25**	1 15**	0 47	0 51	0 04
14	Fruit girth	0 38**	0 38**	0 08	0 19	0 11
15	Single fruit weight	1 61**	1 61**	0 02	0 06	0 04
16	Pod yield per plant	10 37	10 37	2 69	1 76	0 93
17	No of seeds per fruit	0 14	0 14	0 26	0 37	0 11
18	No of viable seeds per furit	0 14	0 14	0 01	0 03	0 04
19	No of ridges per fruit	0 37	0 37	0 07	0 13	0 20
20	YVMD incidence	0 0394	0 0394	0 0022	0 0356	0 0378
21	Percentage of fruit infestation by *E vitella*	0 22	0 22	0 31	0 05	0 26
22	Percentage of shoot infestation by *E vitella*	0 19	0 19	0 13	0 01	0 12

* Significant at 5% level

** Significant at 1% level

Table 24 Specific combining ability effect of interspecific crosses in Bhindi

No of crosses	% of germination	Plant height (cm)	Stem girth (cm)	No of leaves/ plant	Leaf area (cm²)	Petiole length (cm)	No of branches/plant	Days to flowering	First fruiting node	No of flowers/ plant	No of fruits/ plant	No of fruits on branches	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)	Weight of fruits /plant (g)	No of seeds/ fruit	No of viable seeds /fruit	No of ridges/ fruit	YVMD incidence	% of fruit borer infestation shoot	fruit
$L_1 \times T_1$	0 20	13 79	-0 01	3 97	24 64	0 15	0 47	2 30**	0 10	1 46	0 66	0 35	0 47	0 09	0 04	8 37	0 28	0 09	0 15	0 004	0 09	0 10
$L_2 \times T_1$	0 04	3 24	0 12	0 94	8 09	0 13	0 29	0 83	0 05	1 02	0 94	0 16	0 46	0 25	0 35	1 70	0 12	0 05	0 17	0 004	0 03	0 04
$L_3 \times T_1$	0 16	10 55	0 11	3 03	32 73	0 28	0 18	1 47	0 15	0 44	0 34	0 19	0 93	0 34*	0 31	10 08	0 40	0 04	0 32	0 008	0 06	0 06
$L_1 \times T_2$	0 20	13 79	0 01	3 97	24 64	0 15	0 47	2 30**	0 10	1 46	0 66	0 35	0 47	0 09	0 04	8 37	0 28	0 09	0 15	0 004	0 09	0 10
$L_2 \times T_2$	0 04	3 29	0 12	0 94	8 09	0 13	0 29	0 83	0 05	1 02	0 94	0 16	0 46	0 25	0 35	1 70	0 12	0 05	0 17	0 004	0 03	0 14
$L_3 \times T_2$	0 16	10 55	0 11	3 03	32 73	0 28	0 18	1 47	0 15	0 44	0 34	0 19	0 93	0 34*	0 31	10 08	0 40	0 04	0 32	0 008	0 06	0 06
$L_1 \times T_1I$	0 04	0 26	0 26	1 07	18 00	0 71	0 61	1 52	0 08	0 70	0 62	0 27	0 12	0 13	0 04	3 24	0 04	0 01	0 07	0 006	0 57	0 12
$L_2 \times T_1I$	0 30	0 25	0 25	0 22	2 16	0 36	0 04	0 10	0 25	0 33	0 45	0 12	0 30	0 17	0 16	1 20	0 05	0 03	0 13	0 039	0 28	0 10
$L_3 \times T_1I$	0 34	0 01	0 01	0 85	20 16	0 37	0 57	1 62	0 17	0 36	0 17	0 15	0 42	0 20	0 12	2 04	0 01	0 04	0 20	0 045	0 29	0 22
$L_1 \times T_2I$	0 04	0 20	0 26	0 07	18 00	0 71	0 61	1 52	0 01	0 70	0 62	0 27	0 12	0 13	0 04	3 24	0 04	0 01	0 07	0 006	0 57	0 12
$L_2 \times T_2I$	0 30	0 25	0 25	0 22	2 16	0 36	0 04	0 10	0 25	0 33	0 45	0 12	0 30	0 07	0 16	1 20	0 05	0 03	0 17	0 039	0 28	0 10
$L_3 \times T_2I$	0 34	0 01	0 01	0 85	20 16	0 35	0 57	1 62	0 17	0 36	0 17	0 15	0 42	0 20	0 12	2 04	0 01	0 04	0 20	0 045	0 29	0 22
$SE(S_{ij})$	0 44	8 68	0 22	2 34	20 70	0 55	0 40	0 99	0 35	1 62	1 71	0 59	0 57	0 17	0 59	14 35	1 54	9 54	0 10	0 058	0 35	0 49
$SE(S_{j} S_{k})$	0 62	12 27	0 31	3 31	29 27	0 78	0 57	1 47	0 50	2 28	2 42	0 83	0 81	0 24	0 83	20 29	2 18	2 17	0 14	0 082	0 31	0 44

able 25 Mean performance of the parents and hybrids in F_1 and F_1M_1 generations

of osses	% of germination	Plant height (cm)	Stem girth (cm)	No of leaves/plant	Leaf area (cm²)	Petiole length (cm)	Days to flowering	First fruiting node	No of branches/plant	No of flowers/plant	No of fruits/plant	No of fruits on branches	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)	Total fruit weight (g)	No of ridges/fruit	No of seeds/fruit	No of viable seeds/fruit	YVMD incidence	% of festation by E vitella Shoot	% of festation by E vitella Fruit
	84 44	63 27	7 40	21 57	322 53	20 13	49 83	5 40	1 93	15 40	11 70	4 00	22 87	6 87	29 73	340 33	8 00	91 53	88 00	5 00	23 00	36 07
	77 78	130 53	8 17	29 37	166 27	18 83	52 53	6 30	2 90	16 30	13 57	4 60	20 77	6 43	22 10	301 67	8 00	84 17	80 67	4 57	20 00	30 00
	76 67	104 50	6 40	23 07	251 00	18 03	42 40	5 47	0 13	14 13	13 00	1 30	18 70	6 77	20 77	270 00	5 00	59 50	55 50	3 83	26 67	23 32
	78 87	76 10	6 33	21 07	303 67	17 90	40 83	4 80	0 93	14 80	12 10	1 90	16 23	6 40	16 83	203 33	5 00	75 40	73 83	3 80	33 33	20 00
	67 78	94 97	8 30	32 50	472 00	20 20	63 67	6 30	1 70	16 50	10 00	2 90	14 83	7 83	22 30	215 00	8 00	85 83	83 33	1 00	8 33	13 33
	36 67	74 97	3 70	31 63	73 87	6 87	54 67	8 00	7 57	23 27	18 33	10 00	3 46	2 80	3 50	65 00	5 00	29 77	28 67	1 83	6 67	53 33
x T_1	27 63	168 53	7 43	53 33	534 60	24 90	53 70	5 40	4 97	18 47	15 23	2 33	17 60	7 77	13 40	210 00	7 87	4 13	1 87	1 00	10 00	13 33
x L_1	22 00	133 23	7 77	36 73	513 47	23 13	64 53	6 17	2 70	14 07	7 80	1 73	15 57	7 70	13 03	106 33	8 00	4 37	0 60	1 00	13 33	8 33
x T_2	15 65	73 30	5 43	23 40	109 33	10 70	62 73	8 63	5 13	14 10	15 93	6 53	7 33	4 63	3 53	55 00	5 00	4 67	0 13	1 00	6 67	30 00
x L_1	25 56	55 50	6 53	23 63	82 00	11 17	60 27	8 60	4 53	15 37	10 43	3 83	8 17	4 87	3 33	35 00	5 00	5 73	0 30	1 50	6 67	28 33
x T_1	15 33	120 50	7 83	34 13	480 00	26 23	70 20	5 67	1 67	13 47	9 07	2 90	17 00	7 67	15 60	141 67	8 00	? 93	0 93	1 00	16 67	8 33
x L_2	38 44	84 73	7 00	26 73	398 17	20 00	64 43	6 07	2 13	12 87	8 03	3 33	11 07	7 83	13 23	110 00	7 77	2 90	2 90	1 00	10 00	6 67
x T_2	16 44	127 43	5 00	33 67	154 00	12 17	60 50	8 60	6 33	24 00	19 03	4 00	6 83	3 53	3 40	26 67	5 00	2 50	6 67	1 00	6 67	16 67
L_2	21 33	45 17	5 53	15 03	117 00	11 47	59 67	8 07	1 97	19 90	14 53	4 07	4 10	3 10	3 00	23 33	5 00	5 13	0 47	1 00	11 67	20 00
T_1	14 34	58 27	7 90	22 83	175 73	19 30	68 40	6 27	1 57	10 20	9 03	2 00	8 97	4 97	13 03	66 67	5 10	4 63	1 30	1 00	20 00	5 00
L_3	26 00	56 97	7 57	20 10	424 86	17 40	69 47	8 16	2 63	16 33	17 43	0 50	9 03	5 37	13 47	68 33	6 00	9 20	3 27	1 00	16 67	1 67
T_2	22 61	109 10	6 47	34 90	94 67	7 73	54 83	8 00	5 60	17 20	11 33	2 93	7 10	4 37	4 77	22 33	5 00	1 10	0 33	1 07	8 33	11 67
L_3	24 22	111 50	5 47	33 33	63 67	6 43	57 90	8 33	6 77	25 27	18 17	6 57	7 07	4 00	4 60	20 00	5 00	0 47	6 67	1 30	10 00	16 67

(Contd)

Table 25 (Contd)

No of crosses	% of germination	Plant height (cm)	Stem girth (cm)	No of leaves/plant	Leaf area (cm)	Petiole length (cm)	Days to flowering	First fruiting node	No of branches/plant	No of flowers/plant	No of fruits/plant
$L_1 \times T_1 I$	27 55	85 53	7 20	27 50	478 03	26 77	61 37	5 80	3 23	12 63	6 67
$T_1 \times L_1 I$	15 33	53 13	7 33	20 17	208 93	22 00	62 23	6 50	3 10	11 10	7 20
$L_1 \times T_2 I$	27 50	54 57	3 23	16 73	107 33	11 43	73 33	8 60	4 20	18 23	11 97
$T_2 \times L_1 I$	23 56	39 33	3 20	14 23	71 00	11 40	65 33	8 07	5 33	11 13	11 57
$L_2 \times T_1 I$	40 00	70 63	5 53	22 87	404 37	17 83	62 17	5 67	1 93	11 00	6 87
$T_1 \times L_2 I$	32 22	68 03	6 34	20 67	276 80	23 90	74 97	5 53	1 33	10 13	4 03
$L_2 \times T_2 I$	24 22	71 37	4 63	19 83	128 67	8 83	63 67	10 43	6 80	10 43	5 70
$T_2 \times L_2 I$	31 89	89 17	3 93	25 03	96 67	7 87	61 97	12 33	8 20	18 53	8 17
$L_3 \times T_1 I$	8 00	69 73	6 17	24 43	208 43	16 37	65 53	6 77	1 73	12 53	5 80
$T_1 \times L_3 I$	16 22	64 70	5 56	20 47	233 33	22 50	71 63	5 20	1 47	11 63	6 70
$L_3 \times T_2 I$	27 11	71 70	3 83	25 20	66 67	7 40	56 90	9 00	9 80	11 77	6 33
$T_2 \times L_3 I$	27 06	53 47	3 70	15 27	68 77	7 83	53 87	9 40	7 17	11 50	7 00
C D 5%	9 13	17 01	0 42	4 56	40 57	1 08	1 93	0 69	0 79	3 17	3 35

No of crosses	No of fruits on branches	Fruit length (cm)	Fruit girth (cm)	Single fruit weight (g)	Total fruit weight (g)	No of ridges/fruit	No of seeds/fruit	No of viable seeds/fruit	YVMD incidence	% of festation by E vitella Shoot	% of festation by E vitella Fruit
$L_1 \times T_1 I$	1 77	10 80	6 50	12 23	98 33	7 63	2 87	0 87	1 00	8 33	10 00
$T_1 \times L_1 I$	2 80	14 10	8 20	16 03	131 00	7 43	6 17	1 17	1 33	6 67	6 67
$L_1 \times T_2 I$	4 57	3 20	3 47	2 80	10 67	5 00	2 27	0 07	1 27	5 00	11 67
$T_2 \times L_1 I$	2 80	4 83	3 60	3 60	15 00	5 00	1 40	0 33	1 40	3 33	6 67
$L_2 \times T_1 I$	2 23	14 27	5 50	13 03	71 67	8 00	1 27	0 77	1 00	10 00	6 67
$T_1 \times L_2 I$	1 30	12 63	5 97	11 87	71 67	8 03	2 43	0 93	1 00	13 33	6 67
$L_2 \times T_2 I$	2 73	5 00	2 83	2 40	16 67	5 00	0 20	0 07	1 47	5 00	8 33
$T_2 \times L_2 I$	2 53	7 60	5 07	2 20	20 00	5 00	0 07	0 03	1 00	1 67	10 00
$L_3 \times T_1 I$	1 90	10 53	5 63	11 93	71 67	6 00	2 50	1 17	1 03	18 33	3 33
$T_1 \times L_3 I$	1 50	12 60	6 50	14 57	91 67	6 03	2 50	0 33	1 00	16 67	1 67
$L_3 \times T_2 I$	2 20	6 10	4 50	2 97	21 67	5 00	1 70	0 10	1 00	1 67	5 00
$T_2 \times L_3 I$	2 37	3 50	2 67	2 97	21 67	5 00	3 20	0 37	1 17	1 67	6 67
C D 5%	1 15	1 12	0 33	1 15	28 13	0 18	3 02	3 01	0 28	4 99	5 09

Plate 7 The fruits of the parents and the hybrids of the cross Aanakkompan x A *caillei*

Plate 8 The fruits of the parents and the hybrids of the cross Aanakkompan x A *tetraphyllus*

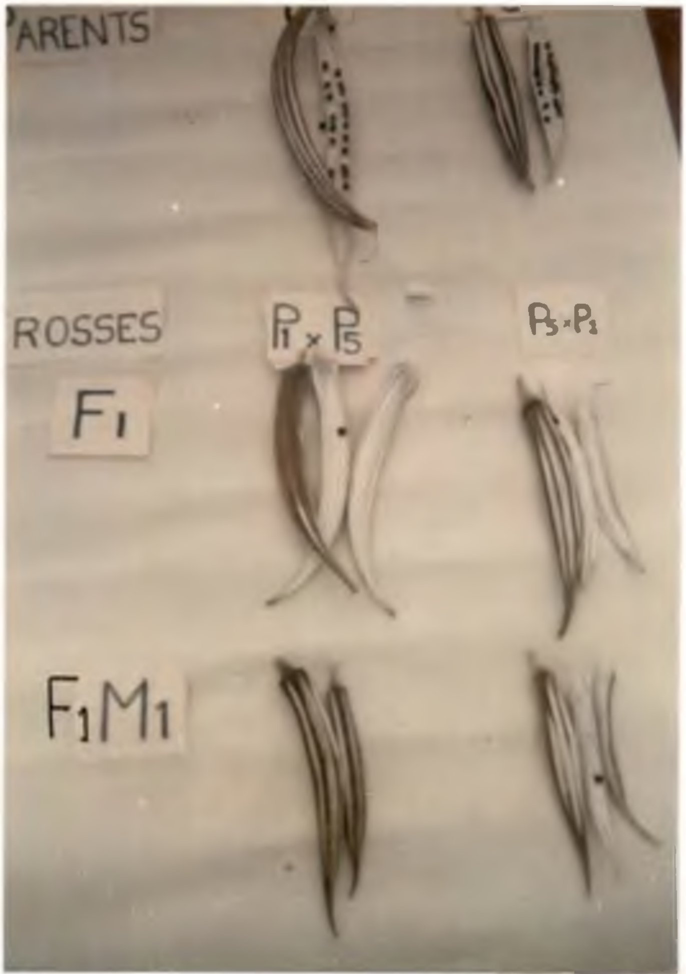
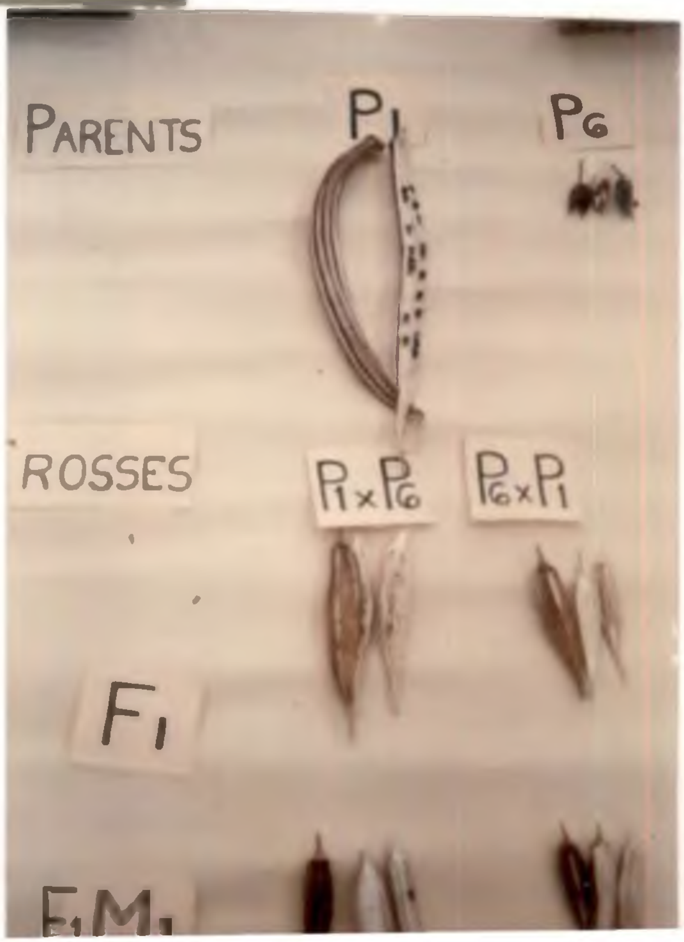

PARENTS
ROSSES
$P_1 \times P_5$
$P_5 \times P_1$
F_1
F_1M_1

Plate 8


PARENTS
P_1
P_6
ROSSES
$P_1 \times P_6$
$P_6 \times P_1$
F_1

differences in germination among the hybrids as well as the irradiated hybrids were also recorded The variance due to parents *vs* hybrids was found to be significant among the non irradiated as well as the irradiated hybrids No reciprocal difference in percentage of germination was observed Further the variance due to hybrids *vs* irradiated hybrids was also non-significant The general as well as specific combining ability (gca and sca) effects were also found to be nonsignificant

Plant height

The performance showed that the hybrids L_1 x T_1 and T_2 x L_1 expressed the highest (168 53) and the lowest (39 33) mean values respectively for this trait

The cultivated varieties differed significantly in height whereas significant difference was not noticed among the wild relatives The comparisons hybrids *vs* irradiated hybrids and parents *vs* irradiated hybrids were highly significant while the difference between parents and hybrids was found to be insignificant

Four hybrids exhibited significant positive relative heterosis of which L_1 x T_1 recorded the maximum (113 01) and T_2 x L_2 the minimum (-56 04) (Table 26) Majority of the hybrids registered significant negative

Table 26 e e a h e e en e p e Eh n

	Plant he ght			G rth of stem		
Hybr ds	RH	HB	SH	RH	HB	H
L xT1	1 0**	46**	2 46**	5 5	10 48**	8**
T xL	68 00**	40 29**	5 0 **	1 02	6 39	22 5**
L xT2	6 05	2 23	3 68	2 6	26 62**	4 22**
T2xL	9 0	25 9	2 0	66**	1 6**	3 6
L2xT	6 8	68	58 4**	4 92	5 66	2 0**
T1xL2	24 85*	35 09**	34	4 99**	5 66**	10 9
L2xT2	24 02*	2 8	6 45**	15 5**	38 80**	2 0 **
T2x 2	56 04**	65 40**	40 64*	6 82	32 *	2 64
L3xT	4 58**	44 24**	2 43	48*	4 82	24 8 *
T xL3	42 8 *	45 48**	25 4	2 99	8 80*	9 59**
L3xT2	2 58	4 40	43 36**	28 2**	1 09	2 2
T xL	4 6*	6 0	46 52**	8 32*	4 5 **	9**
L1xT I	8 0	9 94	12 39	8 28	13 25**	4**
T x I	2 6 *	44 06**	0 8	6 62	69**	5 80 *
L xT2I	2 05	2 2	8 29	4 80**	56 5**	48 9 **
T2xL I	4 0**	4 54**	48 2**	42 34**	56 6**	50 55**
L xT1I	36**	45 89**	9	32 85**	33 3 **	2 64*
T x 2I	9 66**	4 88**	0 66	22 6 **	2 25**	0 6
L2xT2I	0 54**	45 32**	6 22	43 8**	43 33**	26 86**
T2x 2I	22	3 69**	1	33 8**	5 90**	92**
xT	0 06**	3 2 **	8	16 05**	25 66**	2 5
T xL	5 **	38 09**	4 98	24 22**	32 89**	59*
L3xT2I	20 10	31 9**	5 8	24 16**	40 6**	60 9**
T2xL3I	86**	51 65**	29 08	26 **	42 9**	4 2 **
CD 5%	25	24 54	24 54	0 5	0 6	0 6

* S gn f ant at 5% level ** S gn f cant at 1% level

RH Re at e hete os s HB Hete o be t os s and SH Standa d hete os s relative heterosis Eight hybrids recorded significant standard heterosis of which two exhibited negative trend

Both the gca as well as sca effects were found to be insignificant for this character Among the lines L_3 recorded negative gca whereas among the testers T_2 was found to be a negative combiner with respect to this tra t The hybrid L_1 x T_1 recorded the maximum (13 79) sca effect for this trait

Girth of stem

This trait also recorded similar trend as the plant height Significant differences were noticed among the parents hybrids and the irradiated hybrids with regard to this character Parents were not significantly different from the hybrids for this trait also but differed significantly from the irradiated hybrids

All the irradiated hybrids displayed relative heterosis and heterobeltiosis in the negative direction for this character (Table 26) Four normal hybrids recorded significant positive relative heterosis for this attribute with maximum heterosis (28 12) for L_3 x T_2 None of the hybrids recorded positive heterosis in comparison with their better parents However nine hybrids registered significant positive standard heterosis of which the normal hybrid L_3 x T_1 had the maximum value (24 80)

Significant gca effects were shown by the wild relatives for this trait However there was no significant difference in gca among the lines T_1 was identified as the better combiner for this character All the hybrids recorded insignificant sca effects of which L_2 x T_1 and L_1 x T_1^I registered the maximum values among the crosses and the irradiated crosses respectively

Leaves per plant

Significant difference was observed both among the hybrids and the irradiated hybrids for this trait The differences between parents hybrids and the irradiated hybrids were not significant Significant line x tester interaction was found in the crosses and the reciprocals whereas it was absent in the irradiated counterparts

The hybrid L_1 x T_1 displayed the maximum heterosis in all the three types of comparisons (Table 27) Among the non irradiated hybrids six hybrids recorded positive standard heterosis whereas none of the irradiated hybrids recorded significant positive heterosis for this trait in any of the comparisons

Both the gca as well as sca variances were found to be insignificant However L_1 x T_1 recorded the maximum sca effect (3 97) for this trait

Plate 9 Seeds of the interspecific hybrids

Plate 10 A high yielding resistant F_1M_1 plant of the cross L_1 x T_1 I

Plate 9.

Plate 10.

Leaf area

Significant difference was noticed among the lines testers hybrids and the irradiated hybrids for this character No significant difference was observed between the parents and the hybrids for this character Moreover interaction between lines and testers was found to be significant both in the irradiated and non-irradiated crosses and their reciprocals

Nine hybrids recorded positive relative heterosis whereas fifteen hybrids registered the same in the negative direction (Table 27) All the hybrids recorded significant standard heterosis of which eight were of positive nature

Significant gca effects were shown by the parents L_3 T_1 and T_2 of which T_1 recorded positive value However the sca effects were found to be insignificant for this trait also

Length of petiole

Significant differences were observed among lines testers hybrids and the irradiated hybrids for this character Majority of the hybrids displayed significant heterosis for this trait (Table 28) L_1 x T_1 I recorded the

Table 27 Pe centage of hetero s n d ffe ent nte spec f c c os es of Bh nd

	Numbe of leaves pe plant			Leaf area		
Hyb ds	RH	HB	SH	RH	HB	SH
L xT	9 26**	64 09**	15 1**	34 5 **	13 26*	6 05**
T xL	8	3 02	4 2**	29 8**	8 89	9 2 **
L xT_2	0	26 02*	11 06	44 84**	66 10**	64 00**
T_2x	1	25 29*	12 5	58 6 **	4 58**	3 00**
L xT	0 3	5 02	6 98**	50 4 **	69	8 **
T xL_2	9	1 5	6 86	24 **	15 64*	2 *
L_2xT_2	10 39	6 45	59 80**	28 26	38	49 29**
T_2xL_2	**	52 48**	28 6	2 60	29 63	6 4 *
L xT_1	8	29 **	8 35	5 9**	62 **	42 **
T_1xL_3	2 66**	38 15**	4 60	1 5 *	9 99	9 9 **
L_3xT_2	2 6 *	0 34	65 64**	41 2	62 28**	68 8 **
T_2x	2 8 *	5 38	58 9**	60 80**	4 6 **	9 **
L xT_1I	2	5 39	30 52	20 33**	28	5 42**
T xL I	2 9*	3 94**	4 2	4 4 **	55 4**	2 *
xT_2	**	4 **	20 60	45 85**	66 **	64 66 *
T_2xL I	46 0**	55 0 **	32 46*	64 18**	77 99**	6 62**
L_2xT_1I	26 0 **	29 6 **	8 54	26 **	4 3	6 *
T xL_2I	8**	36 40**	1 90	13 27	4 **	8 8 *
L_2xT_2	4 98**	3 31**	5 89	6	22 61	5 6 **
T_2xL_2	9 *	20 8 *	18 80	19 49*	4 86*	68 **
L_3xT	2 0	24 8 *	5 95	42 4**	55 84**	3 6**
T xL_3	26 *	3 02**	2 85	35 46**	50 5 **	2 6**
L_3xT_2I	86	20 33	19 60	58 96**	73 44**	8 05**
T xL I	44 **	5 2**	2 3	5 66**	2 60**	*
CD 5%		6 62	6 62	50 0	58 55	58 55

* S gn f ant at 5% level ** S gn f cant at % le e

RH Re at ve hete os s HB Hete o belt osis and SH Standard heteros s maximum positive heterosis for this character in all the three types of comparisons

Significant gca effects were exhibited by the lines and testers for this trait However the sca effect was found to be insignificant for all the combinations

Days to flowering

Significant difference was noticed between and among the parents hybrids and the irradiated hybrids implying the wide array of variation for this character Moreover the interaction effect of the lines and testers were also found to be significant in all the combinations

All the hybrids displayed significant relative heterosis of which only one hybrid showed desirable negative heterosis for this attribute (Table 28) Majority of the hybrids registered significant positive heterobeltiosis indicating that the hybrids were late in flowering when compared to the better parent (Figure 8) Standard heterosis exhibited by all the hybrids was also found to be significantly positive in nature

The gca values of both the lines as well as the testers were found to be insignificant However significant sca effects were exhibited by the hybrids $L_1 \times T_1$ and $L_1 \times T_2$ for this trait

FIG.8 HETEROSIS % _ DAYS TO FLOWERING

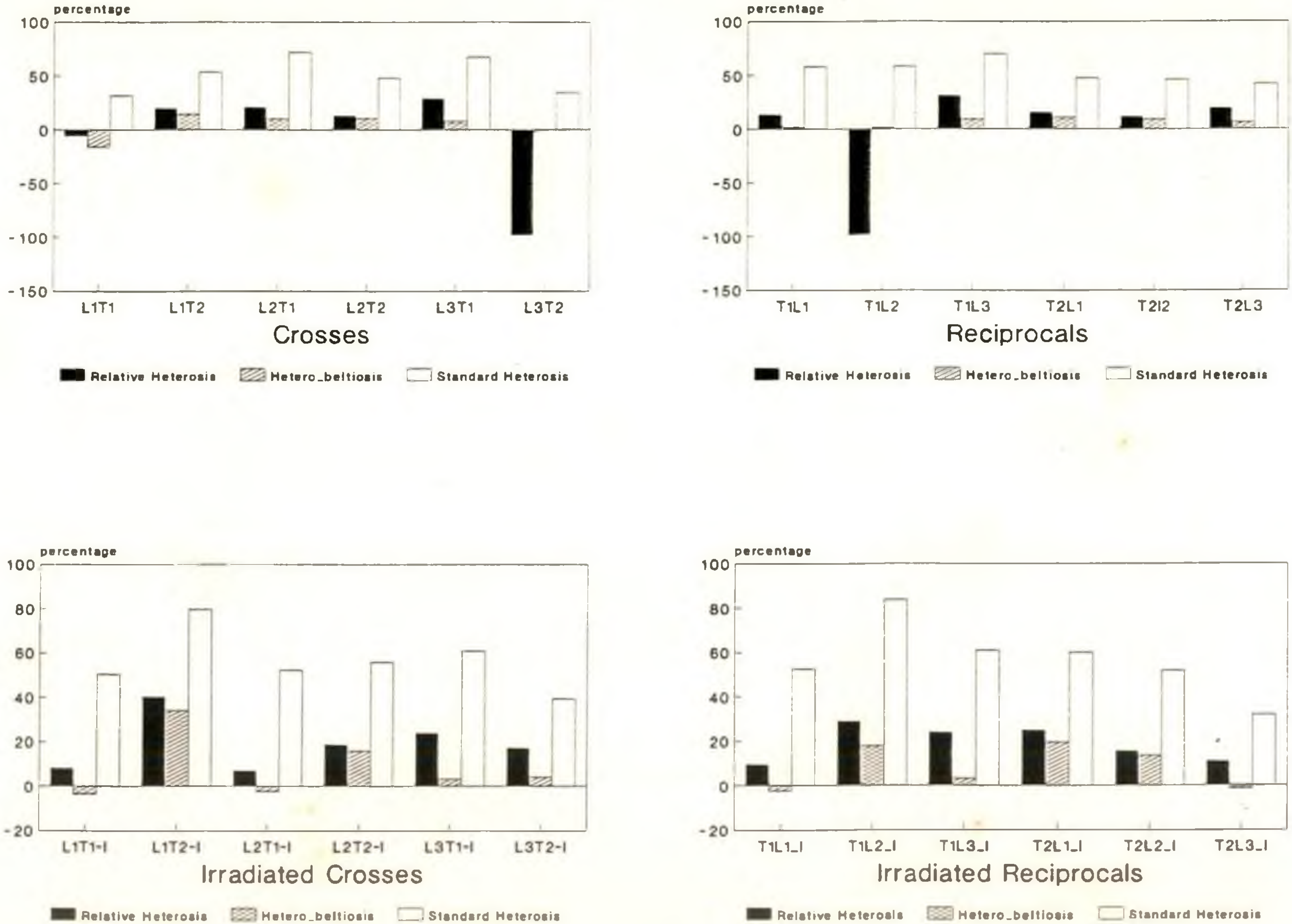


Table 28 e tage of hete o s d e ent e s f c os es o Bn d

	Length of pet o e			Days to Flower ng		
Hybr ds	RH	HB	SH	RH	HB	SH
$L\ xT_1$	23 48**	23 2 **	39 1**	5 38*	15 66**	3 52**
T_1xL_1	4 0**	14 50**	29 22**	13 1**	1 35	58 05**
L_1xT_2	20 4**	46 85**	40 22**	20 06**	14 74**	53 64**
T_2xL_1	1 26**	44 51**	3 60**	15 35**	10 24**	4 61**
L_2xT_1	34 4 **	29 85**	46 54**	20 83**	10 26**	1 93**
T_1xL_2	2 49	0 99	3**	10 89	1 19	5 80**
L_2xT_2	5 29	35 38**	32 0 **	12 8 **	10 66**	48 8**
T_2xL_2	10 4*	39 10**	35 92**	33**	9 15**	46 14**
L_3xT_1	0 94	4 46	82	28 97**	7 43*	6 52**
T_1xL_3	9 00*	13 86**	2 79	30 99**	9 11**	70 4**
L_3xT_2	3 91**	57 13**	56 82**	2.97	0 29	34 29**
T_2xL_3	48 35**	64 4**	64 08**	19 30**	5 9	4 8 **
$L\ xT_1I$	32 5**	32 52**	49 55**	8 14*	3 61	50 **
T_1xL_1	9 10*	8 91*	22 19**	9 66**	2 26	52 4 **
L_1xT_2I	15 3**	43 22**	36 15**	40 35**	34 3**	9 60**
T_2xL_1I	15 56**	43 37**	36 31**	25 03**	19 50**	60 00**
L_2xT_1I	9 15*	12 23**	0 95	7 01**	2 36	52 2 **
T_1xL_2I	2 4 **	18 32**	33 52**	29 04**	17 75**	8 62**
L_2xT_2I	31 28**	53 11**	50 67**	18 9**	15 91**	55 94**
T_2xL_2I	58 8 **	58 20**	56 03**	15 62**	13 35**	5 8**
L_3xT_1I	14 36**	18 96**	8 55	23 94**	3 24	60 99**
T_1xL_3I	1 71**	11 39**	25 70**	35 06**	12 50**	5 44**
L_3xT_2I	40 56**	58 66**	58 66**	17 24**	4 08	39 36**
T_2xL_3I	3 91**	56 82**	56 82**	10 79**	1 46	3 94**
CD 5%	35	56	1 56	2 42	2 9	2 9

* S gn f cant at 5% level ** S gn f cant at 1% level

RH Re at ve heteros s HB Hetero belt os s and SH Standard heteros s

First fruiting node

Significant differences were observed among the wild parents whereas the cultivated varieties did not differ significantly for this character Pairwise comparison also showed significant difference among parents hybrids and irradiated hybrids for this trait Interactions of the lines and testers were found to be significant both in irradiated as well as nonirradiated reciprocals whereas it was absent in direct cross s

Eighty per cent of the hybrids displayed positive undesirable heterosis for this trait (Table 29) However only five hybrids displayed significant positive hetero beltiosis for this character

The testers showed significant gca effect for this trait of which T_1 was found to be the best negative combiner for this trait The sca effects of all the hybrids were found to be insignificant

Number of branches per plant

The difference between parents hybrids as well as irradiated hybrids were significant for this tra t Significant interaction effects between lines and testers were noticed in all the sets of hybrids

Table 29 e t e of he e d ffe e t pec B

	First fru t ng node			Branches per p an		
Hybr ds	RH	HB	H	RH	HB	H
L xT	69	14 29	12 0	83**	157 5 **	4 4 4 **
T xL	5 4	2 06	28 54**	48 6	39 90	90 *
L_1xT_2	28 8 **	88	9 9**	8 00	32 23**	45 09**
T_2xL_1	28 6**	50	9 **	4 63	40 6**	8 0**
L_2xT_1	00	0 00	8 3	2 9	42 4	9
$T xL_2$	65	3 65	26 46*	9	26 55	0
L_2xT_2	20 28**	50	9 **	20 92	6 8	580 65**
T_2xL_2	8 **	0 88	68 **	62 **	98**	0
L xT	6 4	0 48	0 63**	7 0**	65	68 82
$T xL_3$	8 83**	29 68**	0 21**	187 50**	54 1	82 80**
$L xT_2$	8 8**	0 00	66 6 **	4 45*	26 02*	502 50**
T_2xL	2 68**	4	4**	84**	0 5	62 96 *
L xT I	0 86	94	20 83*	7 96	67 36*	24 **
T x I		3 18	42**	0 80	60 62*	33 0**
$L xT_2I$	28 6**	50	9 **	11 8	44 52**	6 **
T_2xL_1	20 45**	0 88	68 3**	2 21	29 59**	473 9 *
L xT I	10 00	10 00	18	6 09	33 45	10
$T x _2I$	2 22	2 22	5	42	54 4	4
L_2xT_2	45 8 **	30 38**	29**	29 89*	0 7	8**
T_2xL_2I	05**	52 58**	54 9**	56 84**	8 32	8 2**
$L_3xT I$	5 04**	46	41 04**	89 0	1 6	86
$T x _3$	64	1 46	8 33	60 66	13 53	58 06
L_3xT_2I	34 6 **	13 38**	88 96**	154 55**	29 00**	9 6**
$T_2xL I$	9 5 **	1 50**	95 83**	86 23**	5 28	670 00**
CD 5%	0 86	0 99	0 99	1 44	1 67	6

* S gn f cant at 5% eve ** S gn f cant at 1% level

RH Re at ve heteros s HB Hetero belt osis and SH Standard heteros s

The gca as well as the sca effects were found to be significant for this trait Among the Lines L_2 recorded maximum gca (0 83) whereas the maximum sca effect was recorded by the hybrid L_1 x T_1 for this trait

Number of fruits per plant

No significant difference was observed among the lines whereas the testers differed significantly with respect to this important yield component The differences among the irradiated hybrids were found to be insignificant However differences between parents *vs* irradiated hybrids as well as hybrids *vs* irradiated hybrids were found to be significant Insignificant line x tester interaction was observed in al the combinations for this trait

The ean values for this yield component ranged from 4 03 (T_1 x L_2I) to 19 03 (L_2xT_2) The irradiated hybrids displayed negative heterosis for this character in all the three comparisons *viz* (Figure 9) relat ve heterosis hetero beltiosis and standard heterosis (Table 30) The hybrid L_2 x T_2 displayed maximum standard heteros s (57 27) for this trait Among the hybrids of *A caille* (T_1) T_1 x L_3 recorded the maximum heterosis (44 05) comparison to the standard cultivar Punjab Padmini

The gca as well as sca effects were found to be

Maximum relative heterosis as well as hetero beltiosis were exhibited by the hybrid L_1 x T_1 for this trait (Table 29) All the hybrids registered significant positive standard heterosis of which L_3 x T_2I recorded the maximum value (953 76)

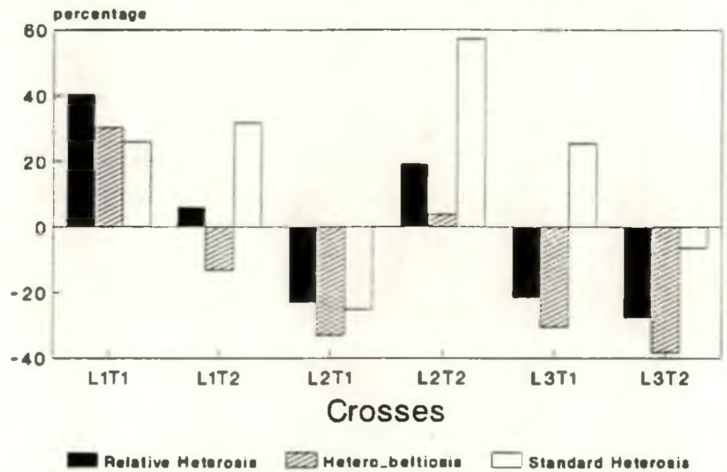
The testers registered significant gca effects for this character However the sca effects were found to be insignificant for all the combinations

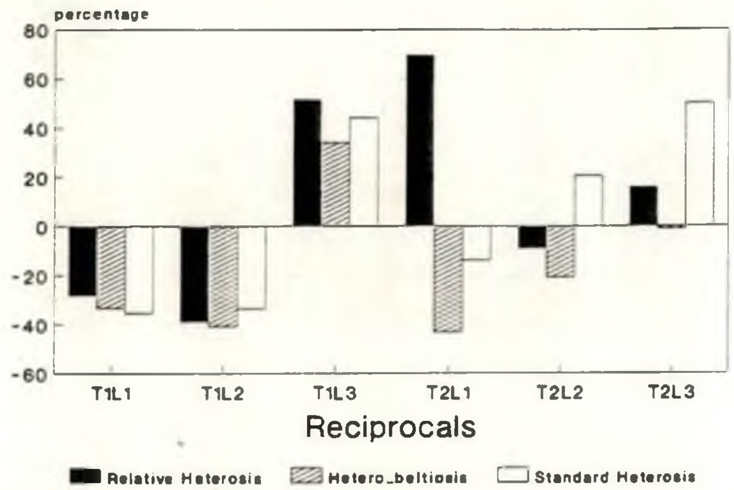
Number of flowers per plant

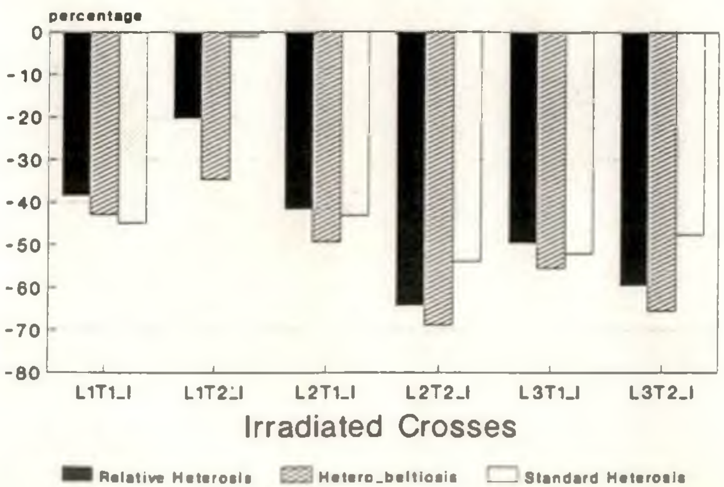
The cultivated parents did not differ significantly whereas the wild relatives showed significant difference for this trait Significant difference was also exhibited by the hybrids as well as irradiated hybrids for this character No significant difference was observed between the parents and hybrids for this trait The interaction effects of the parents were found to be significant in all the combinations except reciprocal crosses

Only one hybrid T_2 x L_3 recorded significant positive relative heterosis whereas none of the hybrids displayed significant positive hetero beltiosis for this character (Table 30) However L_2 x T_2 T_2 x L_2 and T_2 x L_3 displayed significant positive desirable heterosis of which maximum value (70 74) was recorded for T_2 x L_3

FIG.9 HETEROSIS % _ NO.OF FRUITS/PLANT







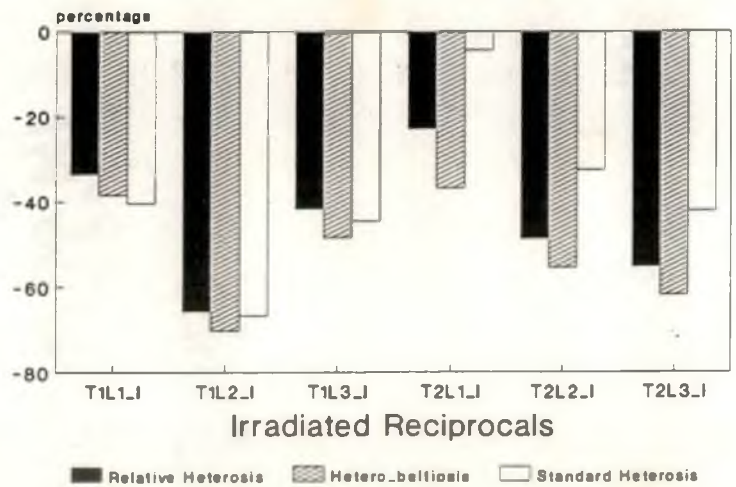


Table 30 Pe ce age o heteros s n d e ent n e spec f c c osses o Bn d

Hybr ds	F owe s per p ant			Fru ts per plant		
	RH	HB	SH	RH	HB	SH
L xT$_1$	5 80	11 94	24 80	40 3 *	30 17	25 8
T xL$_1$	11 9	14 73	4 93	28 11	33 33	35 54
L xT$_2$	2 08*	39 41**	4 3	6 09	13 09	3 65
T$_2$xL	20 5	33 95**	3 85	30 46*	43 10**	3 80
L$_2$xT	8	18 36	8 99	23 04	33 16	25 04
T$_1$xL$_2$	2 52	22 00	04	31 86	40 83*	64
L$_2$xT$_2$	0*	3 4	62 6**	0 31	3 82	5 **
T$_2$xL$_2$	0 58	14 48	34 46*	8 90	20 3	20 68
L$_3$xT$_1$	3 40**	38 18**	3 08*	21 48	30 54	25
T$_1$xL$_3$	6 63	1 03	10 4	51 57**	34 08	44 05*
L$_3$xT$_2$	8 02	26 04*	6 22	27 67*	38 19**	6 6
T$_2$xL$_3$	5 3**	8 60	0 4**	15 99	0 87	50 *
L xT$_1$I	20 5	76 6 **	14 60	38 53*	42 99*	44 88*
T xL$_1$I	0 4 *	32 3*	25 00	33 64	38 46	40 50*
L$_1$xT$_2$I	5 2	21 66*	23 8	20 28	34 0*	0
T$_2$xL$_1$I	42 44**	52 1 **	24 80	22 94	36 88**	4 38
L$_2$xT$_1$	32 9 **	33 33	25 68	4 1*	49 3 **	4 22*
T$_1$xL$_2$I	38 2 **	38 61**	31 55*	65 80**	0 30**	66 69**
L$_2$xT$_2$I	4 28**	55 18**	29 53	64 26**	68 90**	5 89**
T$_2$xL$_2$I	6 34	20 3 *	25 20	48 7**	55 43**	32 48
L$_3$xT$_1$I	18 9	24 06	15 34	49 57**	55 39**	52 0 *
T xL$_3$I	24 06	29 52*	21 42	41 4*	48 46**	44 6 *
L$_3$xT$_2$I	3 06**	49 42**	20 47	59 59**	65 47**	47 69*
T$_2$xL$_3$I	38 50**	50 58**	22 30	55 31**	6 8 **	42 9*
CD 5%	3 96	4 57	4 5	4 18	4 83	4 83

* S gn f cant at 5% level ** S gn f cant at 1% level

RH Relat ve heteros s HB Hetero beltios s and SH Standard heteros s insignificant Among the lines L_1 was the best general combiner for this yield component Among the hybrids L_2 x T_2 L_1 x T_1 and L_3 x T_1 recorded positive sca effect as evident from the heterosis estimates Among the irradiated hybrids L_1 x T_2 followed by L_2 x T_1 were found to be the best crosses with respect to this character

Fruits on branches

Significant differences were recorded among parents crosses and irradiated crosses indicating wide array of variation present in the population for this character Significant line x tester interaction was observed among the crosses as well as the reciprocal crosses Majority of the hybrids displayed negative relative heterosis as well as hetero beltiosis for this trait (Table 31) However only five hybrids displayed negative heterosis in comparison to the standard cultivar Punjab Padmini The gca as well as sca effects were found to be insignificant for this trait also Among the lines L_1 was found to be the best general combiner for this trait

Length of fruit

Significant differences were noticed among the parents hybrids and the irradiated hybrids for th s

FIG.10 HETEROSIS % _ LENGTH OF FRUIT

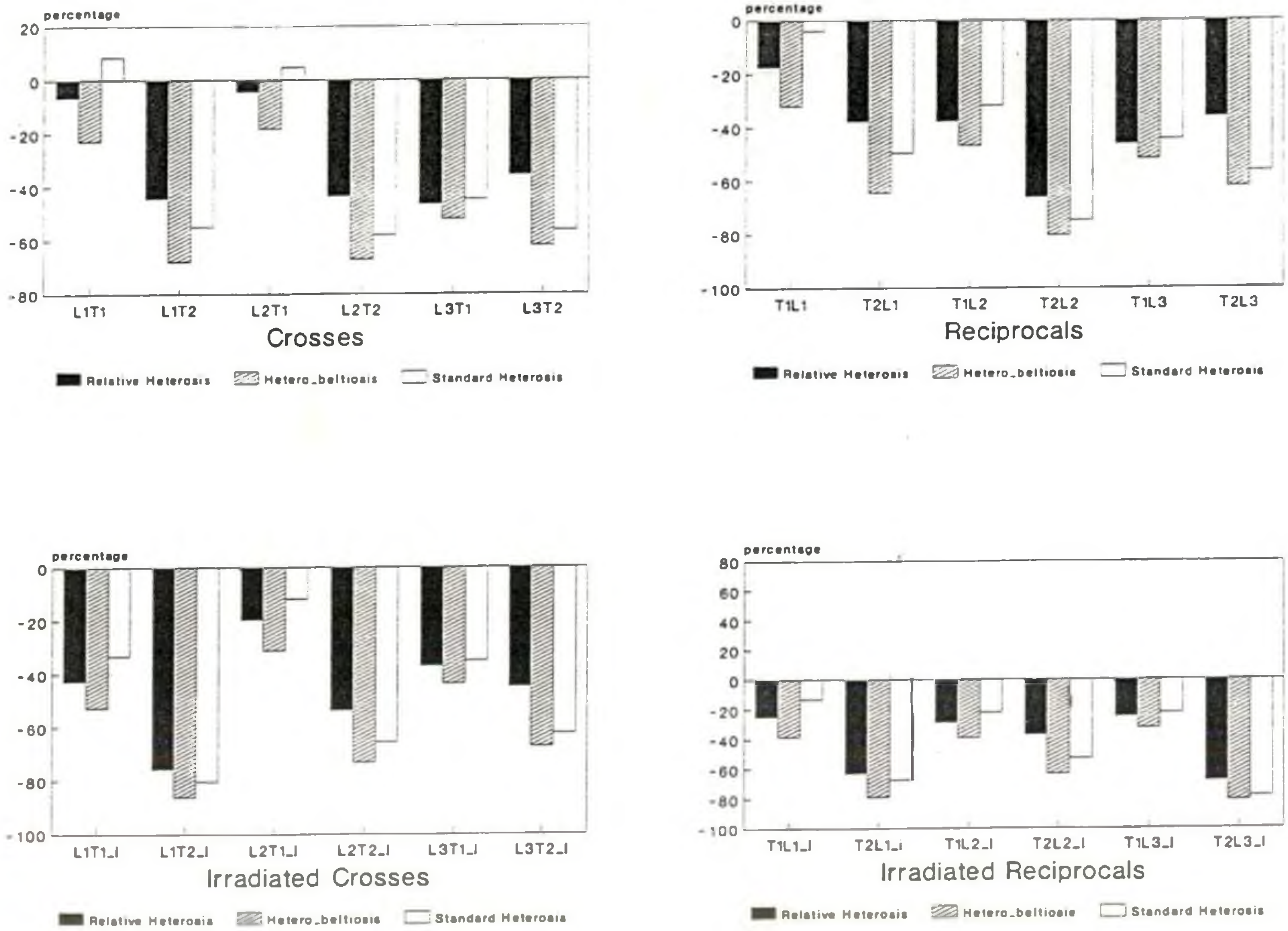


Table 31 Fe n ag o hete s e e t e pe f ro ses of Bh d

	Number of fru ts on branches			Length of fru t		
Hybr ds	RH	HB	SH	RH	HB	SH
L xT	3 33	42 50*	2 05	6 63	23 04**	8 44
T_1xL_1	49 80*	56 5**	8 95	40**	31 92**	4 0
$L xT_2$	6 1	34 0**	243 68**	44 26**	67 95**	54 84**
T_2xL	45 9**	6 0**	10 58*	3 87**	64 28**	49 66**
L_2xT_1	2 6 *	36 96*	52 6	4 49	9 **	4 14
$T xL_2$	20	2 6	5 26	3 8 **	46 0**	9**
L_2xT_2	45 2 **	60 00**	1 0 53*	43 55**	67 2**	5 92**
T_2xL_2	44 25**	59 30**	14 8**	66 **	80 26**	4 4**
L_3xT_1	4 6	3 0	5 30	46 50**	52 13**	44 **
T_1xL_3	6 9*	82 76**	3 68*	46 4**	51 7 **	44 36**
L_3xT_2	48 4**	70 70**	54 21	35 83**	62 03**	56 25**
T_2xL_3	6 28	34 30**	24 9**	36 0**	62 19**	56 44**
$L xT_1 I$	48 0*	55 5**	6 84	42 1**	52 78**	33 46**
$T_1xL I$	8 84	30 00	4	25 20**	38 35**	2*
$L xT_2I$	34 **	54 30**	40 53**	5 6 **	86 0 **	80 28**
T_2xL	60 00**	72 00**	4 37	63 2 **	8 88**	0 24**
L_2xT	40 5 *	51 52**	3	9 8 **	3 30**	2 08*
T_1xL_2I	65 **	71 4**	3 53	29 04**	39 9**	22 8**
L_2xT_2I	62 60**	72 0**	43 10	53 2**	73 04**	65 50**
T_2xL_2	65 34**	74 0**	33 16	3 9**	63 14**	5 **
L_3xT	9 52	34 47	0 00	9**	43 69**	5 2**
T_1xL_3I	28	48 28	21 05	24 84**	32 62**	22 3 **
L_3xT_2I	6 06**	78 00**	5 74	44 87**	67 38**	62 42**
T_2xL_3	58 05**	76 30**	24 74	68 3 **	81 28**	8 4 **
CD 5%	1 44	1 67	67	1 40	1 62	62

* S gn f cant at 5% level ** S gn f cant at 1% level

RH Relat ve heteros s HB Hetero beltios s and SH Standard heteros s character Significant interaction among the cultivated varieties and the wild relatives was also noticed in all the combinations Lines did not have any differential effect in any of the hybrids However testers have significant effect in all the combinations except the direct crosses

All the hybrids recorded negative estimates of hetero beltiosis for this trait (Table 31) Only two hybrids L_1 x T_1 and L_2 x T_1 recorded positive heterosis over standard parent (Figure 10) Both the testers showed highly significant gca effect whereas only one line L_3 showed significant but negative gca effect for this character The sca effects were found to be insignificant for all the combinations

Girth of fruit

The differences among parents crosses and their irradiated reciprocals were found to be significant for this trait also The line x tester interaction was found to be significant in all the combinations for this character

Four hybrids exhibited significant positive heterosis whereas thirteen hybrids manifested significant negative heterosis in comparison to the mid parental value (Table 32) Majority of the hybrids displayed negative heterobeltiosis for this character However desirable

Table 32 e taqe ete s e en pe s e Bh j

Hyb ds	G rth of fru t RH	HB	SH	S ngle fru t we ght RH	HB	SH
L_1xT_1	5 1	0 7	21 41	48 49**	54 93**	20 38**
$T xL_1$	4 6	66	20 30	49 9 **	56 10**	22 58**
L_1xT_2	4 24	32 61**	2 66*	48 66**	71 31**	49 32**
T_2xL	0 2	29 11**	2 9 **	9 96**	88 80**	80 2 **
L_2xT	5*	2 04	9 84	29 3**	30 04**	
$T xL_2$	9 8 *	0 00	22 34	40 4 **	40 6 **	21 39**
L_2xT_2	5 **	45 0**	44 84**	73 44**	84 62**	9 80**
T_2xL_2	2 8 **	51 9**	5 56**	76 56**	86 43**	82 1 **
L_3xT_1	0 00**	36 53**	22 34	39 49**	41 5 **	22 58**
T_1xL_3	24 **	31 42**	6 09	3 45**	39 60**	9 96**
L_3xT_2	4 69	31 40*	2*	60 69**	03**	55**
T_2xL_3	12 6*	37 2 **	3 50**	62 09**	7 85**	2 6 **
L xT I	56	16 99	56**	52 99**	58 86**	2 2 **
T xL I	6	4 3	28 *	38 38**	46 08**	4
$L xT_2I$	28 2 **	49 49**	4 8**	83 5**	90 50**	83 6**
T_2xL_1I	25 54**	47 60**	43 45**	80 4**	89 24**	80 99**
L_2xT_1I	22 86**	29 6**	4 06	4 31**	41 5 **	22 58**
T_1xL_2I	16 26**	23 75**	6 2	46 53**	46 7 **	29 4 **
L_2xT_2I	38 68**	55 99**	5 8**	8 25**	89 4**	85 4**
T_2xL_2I	9 86	21 15	20 8	82 81**	90 05**	86 93**
$L_3xT I$	46 9**	28 10**	2 0	44 60**	46 50**	29 11**
$T xL_3I$	60 60**	6 99	56	32 34*	34 66**	43**
L_3xT_2I	1 85	29 36*	29 69*	75 53**	85 70**	82 35**
T_2xL_3I	41 **	58 08**	8 28**	75 5 **	85 70**	82 35**
CD 5%	40	62	62	1 44	6	6

* S gn f cant at 5% level ** S gn f cant at 1% leve

RH Relat e heteros s HB Hetero belt os s and SH Standard heteros s positive standard heterosis was manifested by seven hybrids of which T_1 x L_1I (Plate 10) recorded the maximum value (28 13)

All the parents except L_2 showed significant general combining ability for this trait However significant sca effects were exhibited by only two hybrids L_3 x T_1 and L_3 x T_2

Single fruit weight

Both the block effects and the genotypic differences were found to be significant for this character The differences among parents lines testers crosses and the interactions among them were also significant Significant influence of the wild parents was observed in all the combinations except the irradiated reciprocals

All the hybrids displayed significantly negative relative heterosis hetero beltiosis as well as standard heterosis for this trait (Table 32) Testers recorded significant gca effect for this character However the gca effects of lines as well as the sca effects of the hybrids were found to be nsignificant Among the hybrids L_2 x T_1 exhibited the maximum positive specific combining ability for this character

Weight of fruits per plant

Highly significant differences were observed among parents hybrids and the irradiated hybrids indicating the prevalence of wide array of variation present in the population for fruit yield per plant The mean squares due to line x tester interaction was found to be significant only among the crosses

All the hybrids manifested highly significant negative heterosis in comparison with the mid parental as well as the better parental value (Table 33) Only one hybrid L_1 x T_1 exhibited positive heterosis over the standard parent Punjab Padmini (Figure 11)

The testers showed significant gca effects for this trait also However the gca of the lines as well as the sca of the hybrids were found to be insignificant

Number of seeds per fruit

Significant difference was observed among the lines and testers with respect to this attribute However the differences among crosses as well as irradiated crosses were insignificant for this character The difference between the irradiated and nonirradiated hybrids were found to be significant whereas it was insignificant for number of viable seeds per fruit

FIG 11 HETEROSIS%_ WEIGHT OF FRUITS/PLANT

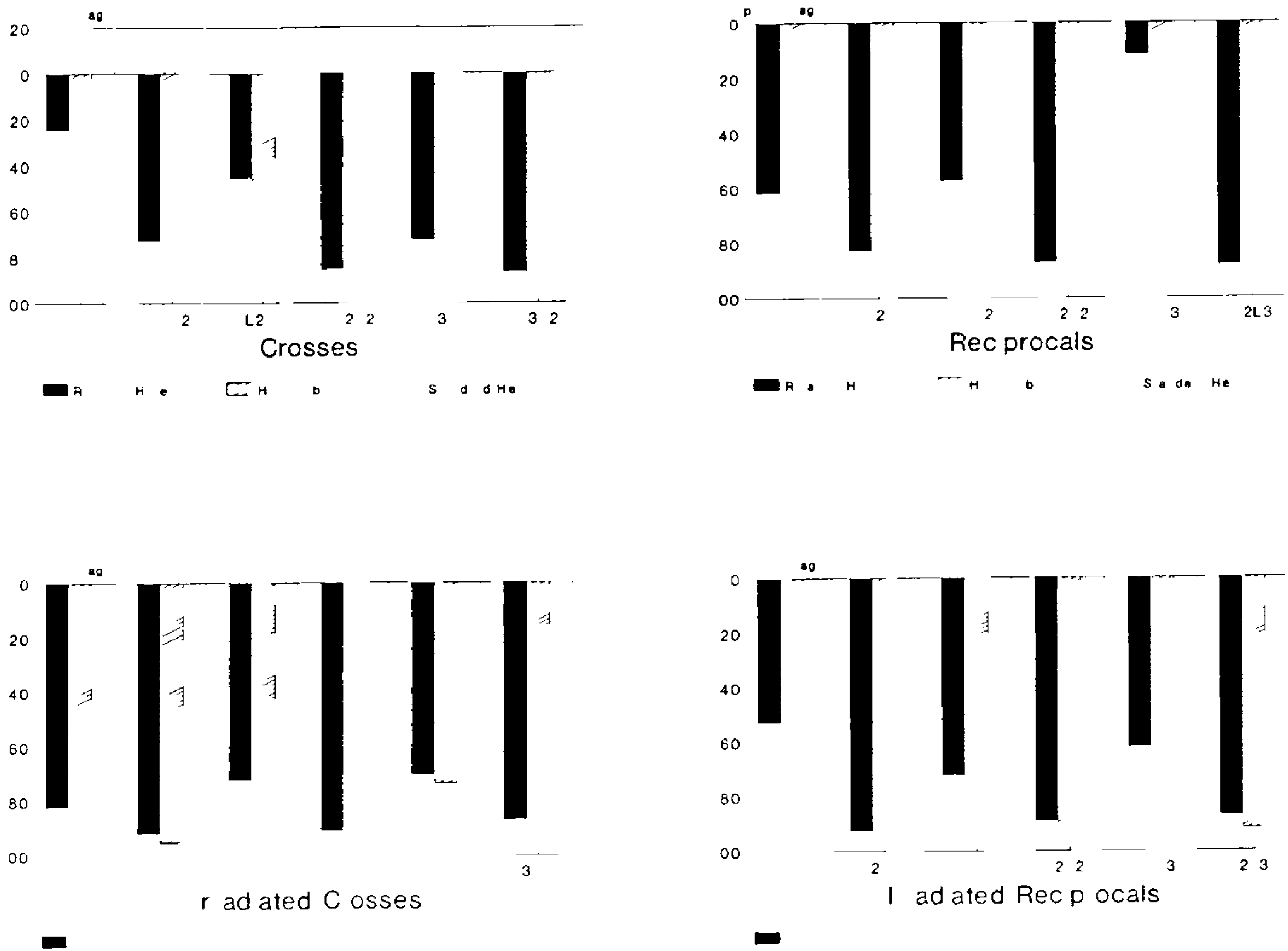


Table 33 e s e es B

Hybr ds	We ght of fru ts per plant RH	HB	SH	Number of seeds per fru t RH	HB	SH
L_1xT_1	24 37**	38 30**	3 28	95 34**	95 49**	95 42**
T_1xL_1	6 **	68 76**	47 71**	95 07**	95 23**	94 20**
L_1xT_2	2 86**	83 84**	72 95**	92 30**	94 90**	93 81**
T_2xL_1	82 3**	89 2**	82 79**	90 55**	93 74**	92 40**
L_2xT_1	45 6**	86 19**	79 51**	96 55**	96 50**	96 1**
$T xL_2$	5 42**	63 54**	45 90**	96 55**	96 62**	96 5**
L_2xT_2	85 45**	91 16**	86 88**	95 88**	97 03**	96 88**
T_2xL_2	8 2 **	92 2 **	88 53**	9 54**	93 9 **	93 20**
L_3xT_1	2 5 **	75 31**	6 21**	93 63**	94 61**	93 86**
T_1xL_3	1 82**	74 69**	66 39**	8 34**	89 28**	8 80**
L_3xT_2	86 6 **	9 3**	89 02**	9 54**	81 51**	98 54**
T_2xL_3	88 06**	92 59**	90 6**	98 95**	99 21**	99 8**
L xT I	82 5**	71 **	51 64**	96 6**	96 86**	96 9**
T_1xL_1 I	52 82**	61 51**	5 57**	93 04**	93 26**	9 82**
L xT_2I	91 77**	95 10**	91 80**	96 26**	97 52**	96 99**
T_2xL_1 I	92 60**	95 59**	92 62**	97 69**	98 4 **	98 14**
L_2xT_1 I	2 26**	76 24**	64 5**	98 51**	98 52**	98 32**
T_1xL_2I	2 26**	76 24**	64 75**	9 14**	97 1 **	96 8**
L_2xT_2I	90 9 **	94 4 **	9 80**	99 6 **	99 6**	99 3**
T_2xL_2I	89 09**	93 3 **	90 16**	99 88**	99 92**	99 91**
L_3xT_1 I	0 45**	73 46**	6 75**	96 56**	97 09**	96 68**
L_1xT_3I	62 20**	66 05**	4 92**	96 56**	97 09**	96 68**
L_3xT_2I	8 06**	91 9 **	89 34**	96 19**	58 4**	9 68**
T_2xL_3I	8 06**	9 9 **	89 34**	92 83**	96 3 **	9 4**
CD 5%	35 5	23 29	23 29	3 77	4 36	4 36

* S gn f cant at 5% level ** S gn f cant at 1% level

RH Re at ve heteros s HB Hetero belt os s and SH Standard heteros s

Table 34 a o hete e en e f osses of bh n

Hybr ds	No of v able seed per fru t			No of r dges per fru t		
	RH	HB	SH	RH	HB	SH
L_1xT_1	9 82**	97 82**	97 47**	1 63	1 63	5 40**
T_1xL	99 30**	99 32**	99 19**	0 00	0 00	60 00**
L_1xT_2	99 78**	99 85**	99 82**	23 08**	37 50**	0 00
T_2xL_1	99 49**	99 66**	99 59**	23 08**	37 50**	0 00
L_2xT_1	98 87**	98 88**	98 4**	0 00	0 00	60 00**
T_1xL_2	96 46**	96 52**	96 07**	2 88	2 88	55 40**
L_2xT_2	99 8 **	99 90**	99 91**	23 08**	37 50**	0 00
T_2xL_2	99 4**	99 42**	99 36**	23 08**	37 50**	0 00
L_3xT_1	98 13**	98 44**	98 24**	21 54**	36 50**	2 00
T_1xL_3	95 29**	96 08**	95 57**	7 69**	2 50	20 00**
L_3xT_2	99 22**	98 50**	99 55**	0 00	0 00	0 00
T_2xL_3	99 83**	99 8 **	99 91**	0 00	0 00	0 00
L_1xT_1I	98 98**	99 0 **	98 82**	4 63*	4 63*	52 60**
$T xL_1I$	98 63**	98 67**	98 42**	7 13**	7 13**	48 60**
$L xT_2I$	99 88**	99 92**	99 91**	23 08**	37 50**	0 00
T_2xL_1I	99 95**	99 97**	99 96**	23 08**	37 50**	0 00
L_2xT_1I	99 06**	99 36**	98 96**	0 00	0 00	60 00**
$T xL_2I$	98 8 **	98 88**	98 91**	0 38	0 38	60 60**
L_2xT_2I	99 87**	99 91**	99 96**	23 08**	37 50**	0 00
T_2xL_2I	99 95**	99 96**	98 42**	23 08**	37 50**	0 00
L_3xT_1I	98 31**	98 60**	99 55**	7 69**	25 00**	20 00**
T_1xL_3I	99 52**	99 60**	99 86**	7 23**	24 63**	20 60**
L_3xT_2I	99 6**	99 82**	99 86**	0 00	0 00	0 00
T_2xL_3I	99 12**	99 33**	99 50**	0 00	0 00	0 00
CD 5%	3 6	4 35	4 35	0 24	0 28	0 28

* S gnif cant at 5% level   ** Sign f cant at 1% level

RH Relat ve heteros s HB Hetero be t os s and SH Standard heteros s

Both the total number of seeds per fruit as well as viable seeds/fruit displayed highly significant negative heterosis (Table 33) in all the three types of comparisons indicating very high sterility of these hybrids (Plates 7 to 9)

Number of ridges per fruits

Significant genotypic differences were observed for this character among the lines as well as testers The comparisons like parents *vs* hybrids parents *vs* irradiated hybrids and hybrids *vs* irradiated hybrids were found to be significant Significant line X tester interaction was recorded in both the irradiated as well as non irradiated crosses Both the gca as well as sca effects were found to be insignificant for this trait

YVMD incidence

The cultivated varieties recorded high incidence of this disease with mean disease score ranging from 5 00 (L_1) to 3 83 (L_3) T_1 was found to be completely free from disease with a score of 1 Majority of the hybrids also recorded score 1 revealing the dominant nature of resistance (YVMD) Among the hybrids T_2 x L_1 recorded the maximum score (1 50) for this disease

FIG.12 HETEROSIS % _ YVMD INCIDENCE

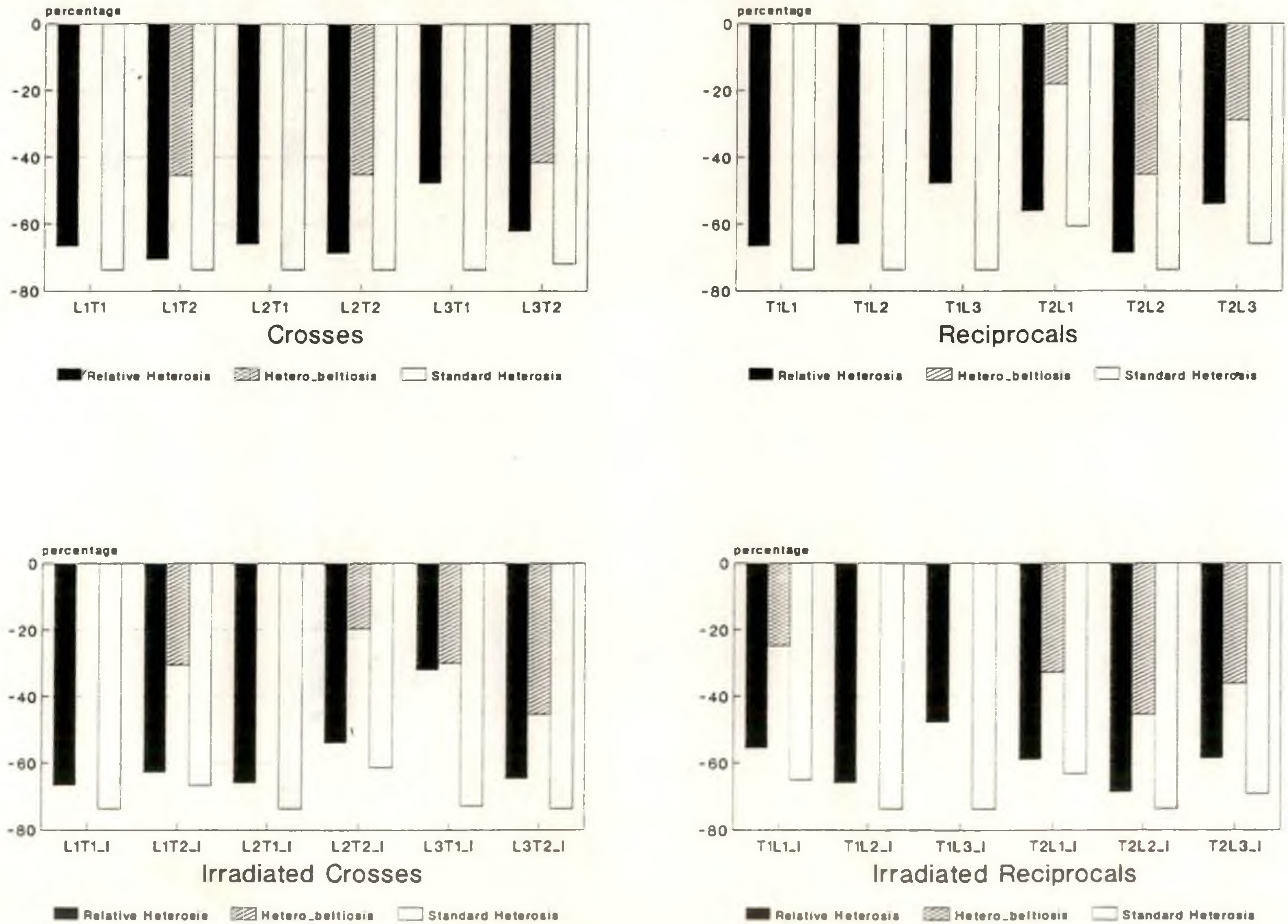


Table 35 Pe entage of hete os s d ffe ent nte pe f c crosses o Bh d

	YVMD nc dence			% of nfestat on by E <u>v te la</u>		
Hybr ds	RH	HB	SH	RH	HB	SH
L xT	66 6 **	0 00	68**	36 83**	20 05**	0 00**
T_1xL_1	66 6 **	0 00	3 68**	15 79**	60 02**	60 01**
L_1xT_2	0 2**	45 36**	3 68**	55 53**	0 00	9 99**
T_2xL	6 08**	18 03**	60 53**	55 53**	0 00	9 99**
L_2xT_1	65 9 **	0 00	3 68**	1 68*	100 12**	49 98**
$T xL_2$	65 93**	0 00	3 68**	29 40**	20 05**	0 00**
L_2xT_2	68 5**	45 06**	3 68**	49 38**	0 00	9 99**
T_2xL_2	68 5**	45 06**	73 68**	12 49**	74 96**	64 99**
L_3xT_1	59 8**	0 00	73 68**	14 29**	140 10**	39 99**
T_1xL_3	58 8**	0 00	3 68**	4 74	100 02**	49 98**
L_3xT_2	62 19**	41 53**	71 84**	50 03**	24 89**	5 0 **
T_2xL_3	54 06**	28 96**	65 80**	40 01**	49 99**	0 00**
L_1xT_1I	66 6 **	0 00	73 68**	47 38**	0 00	5 0 **
T_1xL_1I	55 6 **	33 81**	65 00**	55 53**	19 33**	79 99**
L_1xT_2I	62 8 **	30 60**	66 58**	66 67**	25 04**	85 09**
T_2xL_1I	59 00**	32 79**	63 16**	7 80**	50 0 **	90 0 **
L_2xT_1I	65 93**	0 00	73 68**	29 40**	20 05**	0 00**
$T xL_2I$	65 93**	0 00	73 68**	5 89*	60 02**	60 01**
L_2xT_2I	54 06**	19 6 *	6 32**	62 50**	25 04**	85 00**
T_2xL_2I	68 5**	45 6**	73 68**	87 48**	74 96**	94 99**
L_3xT_1I	57 **	3	72 89**	4 74	120 05**	45 00**
T_1xL_3I	58 8**	0 00	73 68**	4 74	100 12**	45 98**
L_3xT_2I	64 66**	45 36**	73 68**	89 98**	74 96**	94 99**
T_2xL_3	58 66**	36 0 **	69 21**	85 98**	4 96**	94 99**
CD 5%	0 2	0 14	0 14	0 64	0 74	0 4

* S gn f cant at 5% level ** S gn f cant at 1% level

RH Re at ve heteros s HB Hetero-belt os s and SH Standard heteros s

The line X tester analysis also showed significant difference among the parental as well as hybrid populations for YVMD incidence The interaction effects of the cultivated and wild parents were found to be significant in all the hybrids except non irradiated crosses

The general and specific combining abilities were found to be very small and insignificant for this trait However T_1 was found to be the better combiner for resistance to this disease than the wild parent T_2 Among the hybrids L_3 x T_1 L_3 x T_2I L_2 x T_1I and L_1 x T_1I were found to be the better combinations for exploiting resistance (Table 35 and Figure 12)

Percentage of fruit and shoot borer infestation

The parents recorded comparatively higher percentage of shoot as well as fruit infestation by this pest than the hybrids Among the parents L_1 and T_2 recorded the maximum percentage of shoot (23 33) and fruit (53 33) infestation respectively The parent T_1 was found to be comparatively resistant with low percentage of shoot (8 33) as well as fruit (13 33) infestation Majority of the hybrids recorded very low mean values indicating the possibility of exploiting resistance to this pest

Significant difference was observed among the

i at 1 A profusely bran h ll res tant F_1 plant
of the cross T_2 x 2

t 2 A esistant plant of the cross I_1 x L_1
surroui ded by disea ed plants

Plate 12.

parents as well as hybrids for this trait All the hybrids displayed negative heterosis for this character (Table 35) The combining ability estimates were found to be very low and insignificant

Pollen fertility

The acetocarmine test of pollen fertility of parents and interspecific hybrids is presented in Table 36 The pollen fertility in the parental species *A tetraphyllus* was found to be very high (96 49 per cent) *A caillei* also recorded 91 55 per cent pollen fertility Among the three selected accessions of *A esculentus*, AE1 recorded the maximum fertility (95 53 per cent)

Among the hybrids, direct crosses had higher pollen fertility than the reciprocals Pollen fertility was also found to be lesser in the irradiated hybrids in comparison to their non-irradiated counterparts Pollen fertility ranged from 14 56 per cent (T_1 x L_3) to 28 72 per cent (L_1 x T_2) in the case of crosses whereas it ranged from 10 17 per cent (T_2 x L_1) to 16 76 per cent (L_2 x T_2 I) for non-irradiated hybrids The pollen fertility was found to be very low in the irradiated hybrids particularly when *A tetraphyllus* was used as the maternal parent

Table 36 Pollen fertility in parents and interspecific hybrids

Sl No	Parents/hybrids	Mean Pollen fertility (%)	Standard error
1	L_1	93 28	2 80
2	L_2	92 45	3 78
3	L_3	95 53	2 33
4	SP	94 75	2 27
5	T_1	91 55	3 13
6	T_2	96 49	2 09
7	L_1xT_1	17 93	3 34
8	T_1xL_1	14 99	3 60
9	L_1xT_2	28 72	5 04
10	T_2xL_1	18 25	5 09
11	L_2xT_1	17 52	4 63
12	T_1xL_2	16 82	3 61
13	L_2xT_2	25 73	3 94
14	T_2xL_2	23 60	6 88
15	L_3xT_1	15 14	3 49
16	T_1xL_3	14 56	3 48
17	L_3xT_2	22 03	3 50
18	T_2xL_3	19 10	3 29
19	L_1xT_1I	15 06	5 38
20	T_1xL_1I	13 63	3 65
21	L_1xT_2I	12 31	3 68
22	T_2xL_1I	10 17	1 76
23	L_2xT_1I	15 20	4 24
24	T_2xL_2I	15 27	5 83
25	L_2xT_2I	16 76	3 19
26	T_2xL_2I	11 94	2 47
27	L_3xT_1I	15 07	5 48
28	T_1xL_3I	14 61	3 97
29	L_3xT_2I	14 90	3 95
30	T_2xL_3I	10 85	4 73

4.3 1 Genetic components of variance

The magnitude of gca and sca variance and the variance ratios (GCA/SCA) for all the 22 traits were computed and the data presented in Table 37 The genetic components of variance were also estimated and presented in Table 38

The variance ratio was found to be less than unity for all the traits except petiole length, first fruiting node and single fruit weight Among the yield components, single fruit weight recorded maximum GCA/SCA ratio of 4 36 Additive genetic variance (F 0 = 28 29, F 1 = 14 14) was found to be greater than dominance genetic variance (F 0 = 1 62, F 1 = 6 47), where F denotes the inbreeding coefficient

The variance ratio for fruit length was only 0 30 Dominance genetic variance (F 0 = 45 19, F 1 = 11 30) was found to be greater than the additive genetic variance (F 0 – 13 60, F 1 – 6 80) The fruit girth also recorded the same results with a variance ratio of 0 23 The dominance genetic variance (F 0 = 6 55, F 1 – 1 64) was greater than the additive variance (F 0 – 1 47, F 1 = 0 74) for this trait Weight of fruits per plant recorded variance ratio of 0 68 The dominance genetic variance (F 0 = 5455 85, F 1 = 1363 96) was found to be greater than the additive genetic

Table 37 Magnitude of GCA variance and SCA variance

Sl No	Character	GCA	SCA	Ratio of GCA/SCA variance
1	Percentage of germination	-0 07 (0 15)	1 76 (1 67)	N E (N E)
2	Plant height (cm)	-282 07 (-18 51)	1276 89 (98 45)	N E (N E)
3	Girth of stem (cm)	0 28 (0 25)	0 45 (3 49)	0 62 (0 07)
4	Leaves per plant	-26 24 (-0 49)	226 98 (11 81)	N E (N E)
5	Leaf area (cm^2)	5413 54 (5607 22)	15265 78 (14028 15)	0 35 (1 39)
6	Length of Petiole (cm)	14 11 (10 57)	0 79 (0 53)	17 86 (1 62)
7	Days to flowering	-6 40 (-5 01)	72 07 (43 31)	N E (N E)
8	First fruiting node	0 45 (0 69)	0 19 (0 72)	2 37 (0 96)
9	No of branches per plant	0 31 (0 84)	2 81 (6 16)	0 11 (0 14)
10	No of flowers per plant	-1 75 (-10 89)	27 70 (82 44)	N E (N E)
11	No of fruits per plant	2 72 (0 001)	-2 31 (2 71)	N E (N E)
12	No of fruits on branches	0 25 (0 03)	1 35 (0 62)	0 19 (0 05)
13	Length of fruit (cm)	3 40 (3 47)	11 30 (3 10)	0 30 (1 65)

(Contd)

Table 37 (Contd)

Sl No	Character	GCA	SCA	Ratio of GCA/SCA variance
14	Girth of fruit (cm)	0 37 (0 34)	1 64 (1 92)	0 23 (0 18)
15	Single fruit weight (g)	7 07 (6 63)	1 62 (0 02)	4 36 (331 50)
16	Weight of fruits per plant (g)	929 89 (265 39)	1363 96 (-61 07)	0 68 (N E)
17	No of seeds per fruit	-0 06 (0 22)	-0 11 (-2 35)	0 55 (N E)
18	No of viable seeds per fruit	-0 06 (0 22)	-0 10 (-0 33)	0 60 (N E)
19	No of ridges per fruit	0 10 (0 22)	1 82 (0 57)	N E (0 56)
20	YVMD incidence	0 00 (-0 003)	-0 003 (0 03)	0 00 (N E)
21	Percentage of fruit infestation by *E vitella*	0 10 (0 05)	0 003 (0 55)	33 33 (0 109)
22	Percentage of shoot infestation by *E vitella*	0 25 (0 20)	0 003 (4 510)	33 33 (0 004)

(Values in parenthesis denote the estimates of irradiated hybrids)

N E Not estimable values

Table 38 Estimates of additive and dominance variances

Characters	A		D	
	F – 0	F – 1	F – 0	F = 1
1 Percentage of germination	-0 28	-0 14	1 76	0 44
	(-0 60)	(-0 30)	(6 69)	(3 35)
2 Plant height (cm)	1128 28	-564 14	4867 56	1516 89
	(-74 05)	(-37 02)	(395 81)	(98 95)
3 Stem girth (cm)	1 94	0 56	1 80	0 45
	(1 00)	(0 50)	(13 36)	(3 49)
4 No of leaves/plant	-104 96	-52 48	907 91	226 98
	(-1 96)	(-0 98)	(47 23)	(21 91)
5 Leaf area (cm^2)	21654 14	10827 07	61063 12	15265 78
	(22428 86)	(11214 43)	(16112 60)	(4028 15)
6 Length of petiole (cm)	56 42	28 21	3 16	0 79
	(42 27)	(21 13)	(26 12)	(6 53)
7 No of days to flowering	-25 60	-12 80	288 29	72 07
	(-20 04)	(10 02)	(173 23)	(43 31)
8 First fruiting node	1 80	0 90	0 77	0 19
	(2 76)	(1 38)	(2 89)	(0 72)
9 No of branches/plant	1 24	0 62	11 23	2 81
	(3 37)	(1 68)	(24 64)	(6 16)
10 No of flowers/plant	-6 99	-3 50	110 81	27 70
	(43 57)	(-27 78)	(324 75)	(82 44)
11 No of fruits/plant	10 89	5 45	-9 23	-2 31
	(-0 004)	(-0 002)	(10 84)	(2 71)
12 No of fruits on branches	1 00	0 50	5 40	1 350
	(0 12)	(0 00)	(2 48)	(0 620)
13 Fruit length (cm)	13 60	6 80	45 19	11 30
	(13 86)	(6 93)	(8 44)	(2 10)

(Contd)

(Contd)

Characters	A		D	
	F = 0	F - 1	F - 0	F = 1
14 Fruit girth (cm)	1 47 (1 38)	0 74 (0 69)	6 55 (1 92)	1 64 (0 48)
15 Single fruit weight (g)	28 29 (26 54)	14 14 (13 27)	1 62 (0 09)	6 47 (0 02)
16 Weight of fruits per plant (g)	3719 55 (1016 56)	1859 78 (530 78)	5455 85 (-244 27)	1363 96 (61 07)
17 No of ridges per fruit	0 41 (1 30)	0 21 (0 65)	7 28 (2 28)	1 82 (0 57)
18 No of seeds per fruit	-0 26 (0 87)	-0 13 (0 44)	-0 44 (-9 39)	-0 11 (-2 35)
19 No of viable seeds/ fruit	-0 26 (0 87)	-0 13 (0 44)	-0 40 (-9 32)	-0 10 (-2 23)
20 Score of YVMD incidence	1 00 (0 82)	0 50 (0 41)	0.01 (81 04)	0 003 (4 51)
21 Percentage of infestation by *E vitella*	0 40 (0 26)	0 20 (0 13)	0 01 (2 21)	0 003 (0 55)

A - Additive variance D - Dominance variance

F - Inbreeding coefficient

(Values in parenthesis denote the estimates of the irradiated hybrids) variance (F 0 – 3719 55 F 1 = 1859 78)

4 3 2 Proportional contribution of lines, testers and line x tester to total variance

The results are presented in Table 39 and Figure 13 Of the total variance of percentage of germination, line x tester contributed maximum (74 74 per cent) to the total variance whereas testers contributed maximum (60 09 per cent) to the total variance of leaf area

In the case of days to flowering also the line x tester contributed maximum (63 29 per cent) With regard to the first fruiting node, testers contributed 94 52 per cent, whereas line x tester and lines contributed only 5 71 per cent and 0 71 per cent respectively to the total variance Branches per plant also recorded the same results with maximum contribution by testers (61 37 per cent) to the total variance followed by interaction effect (21 91 per cent)

Of the total variance of flowers per plant, line x tester contributed maximum (76 06 per cent) to the total variance With regard to number of fruits per plant, lines contributed 37 06 per cent, testers 33 55 per cent and line x tester 29 39 per cent to the total variance Fruits on branches also recorded the same results with maximum

CH1 - GERMINATION

CH2 - PLANT HEIGHT

CH3 - GIRTH OF STEM

CH4 - NO.OF LEAVES / PLANT

CH5 - MEAN LEAF AREA

CH6 - LENGHT OF PETIOLE

CH7 - DAYS TO FLOWERING

CH8 - FIRST FRUITING NODE

CH9 - NO OF BRANCHES / PLANT

CH10- NO OF FLOWERS / PLANT

CH11- NO OF FRUITS / PLANT

CH12- NO OF FRUIS ON BRANCHES

CH13- WEIGHT OF FRUITS / PLANT

CH14- LENGHT OF FRUIT

CH15- GIRTH OF FRUIT

CH16- SINGLE FRUIT WEIGHT

CH17- NO OF RIDGES / FRUIT

CH18- NO OF SEEDS / FRUIT

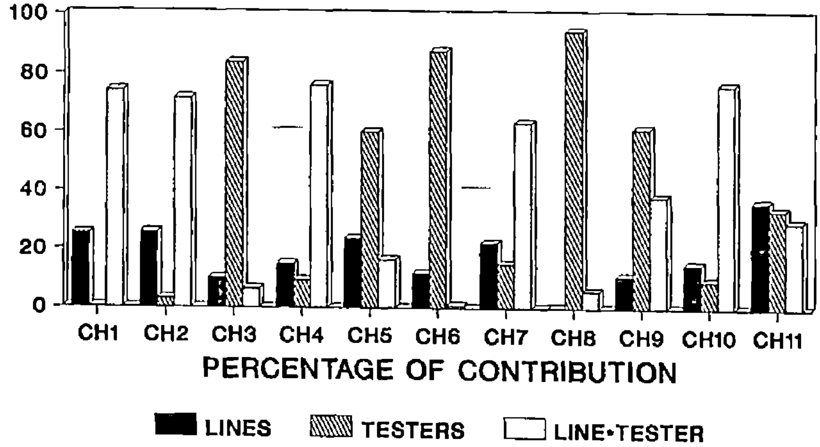
CH19- NO OF VIABLE SEEDS / FRUIT

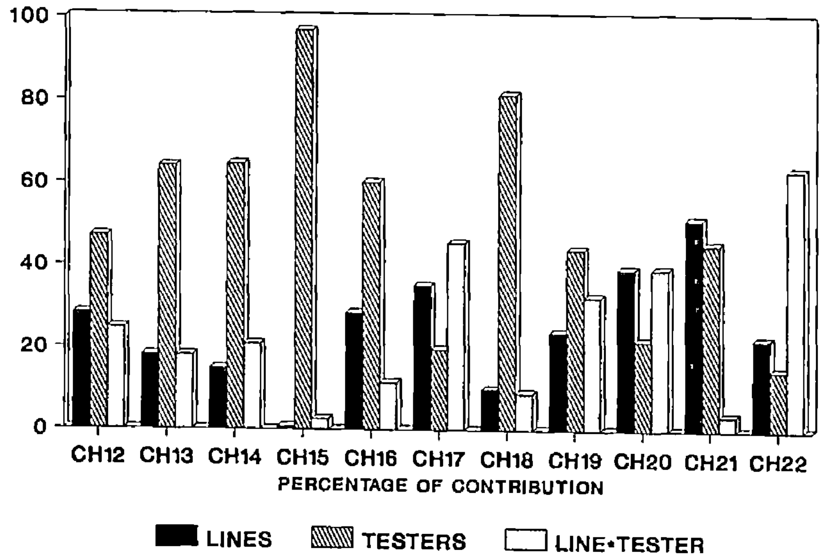
CH20- YVMD INCIDENCE

CH21- % OF FRUIT INFESTATION - *E vitella*

CH22- % OF SHOOT INFESTATION - *E vitella*

Fig 13 Proportional Contribution of lines, testers and lines x testers to total variance





contribution by line x tester (47 15 per cent)

Testers contributed maximum to the total variance of fruit length (64 05 per cent), fruit girth (64 45 per cent) and single fruit weight (96.94 per cent) Line x tester contributed 17 95 per cent and 20 75 per cent to the total variance of length and girth of fruit respectively Lines contributed 18 per cent to the total variance of fruit length

With regard to weight of fruits per plant, testers contributed maximum (60 15 per cent) to the total variance Testers contributed maximum to the total variance of viable seeds per fruit (81 39 per cent) and ridges per fruit (43 90 per cent)

Out of the total variance for YVMD incidence, contribution by line x tester was 39 13 per cent, of lines 39 13 per cent and testers 21 74 per cent As regards to fruit borer incidence, testers contributed maximum to the total variance of fruit (45 24 per cent) infestation

4 4 Evaluation of F_2 and F_2 M_2 generations

The results are presented in tables 40 to 56 for different characters Since the variation in number of plants was very large within the crosses, analysis of covariance was carried out taking the unequal stands of the

Table 40 Analysis of covariance table for F_2 and $F_2 M_2$ generations

Source	Degrees of freedom	Mean squares																
		Plant height	Stem girth	No of branches/ plant	First fruiting node	Days to flowering	Leaves per plant	Leaf area	No of flowers per plant	No of fruits/ plant	Fruit length	Fruit girth	Single fruit/ weight	Wt of fruits/ plant	No of ridges/ fruit	No of seeds/ fruit	YVMD inci dence	% of fruit borer attack
Replications	2	31 25	0 13	0 48	0 18	0 16	10 44	437 10	1 71	1 38	1 16	0 16	2 52	312 12	0 15	3 55	0 02	17 61
Treatments	29	1636 49**	4 30**	12 01**	8 31**	95 82**	244 34**	74888 19**	82 31**	73 46**	76 94**	2 94**	91 38**	16351**	4 41**	1634 90	2 35**	77 10
Regression	1	59 76	0 49	0 35	2 02	1 56	11 74	321 49	12 51	0 03	0 61	0 02	0 29	152 00	0 00	0 12	0 07	13 81
Error	57	64 28	0 13	0 80	1 03	10 25	15 24	457 89	7 59	2 32	0 97	0 43	2 63	781 60	0 04	9 52	0 06	27 91
C D at 5%		14 22	0 63	1 59	1 80	5 68	6 92	37 94	4 89	2 70	1 39	0 76	2 87	49 60	0 37	5 47	0 45	8 92
C D at 1%		18 89	0 84	2 11	2 39	7 54	9 18	50 41	6 49	3 59	2 32	1 01	3 82	74 52	0 49	7 27	0 59	12 36
Coefficient of variation (%)		9 93	5 54	20 96	13 50	5 39	10 39	8 70	19 40	16 21	8 20	10 73	14 71	31 22	3 37	18 03	16 18	30 21

** Significant at 1% level

Plate 13 A hιgh yιeldιng resιstant plant - T_1 x I_1

Plate 14 A hιgh yιeldιng resιstant plant - T_1 x L_1I

Plate 14.

plants as covariate The analysis of covariance (Table 40) revealed that the genotypes differed significantly for all the characters except percentage of fruit borer incidence

Germination

Among the hybrids there was general reduction in germination in the F_2 and F_2M_2 generation (Table 41) as compared to the F_1 and F_1M_1 generations Germination percentage ranged from 8 00 per cent (L_3 x T_1I) to 40 00 percentage (L_2 x T_2I) among the hybrids in the first generation whereas it ranged from 6 46 per cent T_1 x L_1I) to 24 63 per cent (L_1xT_1) in the second generation

Plant height

The results are presented in Table 42 The hybrids L_2x T_1 (110 50 cm) and T_1 x L_2I (84 93 cm) recorded maximum mean plant height among the F_2's and F_2M_2's respectively The mean height of F_2M_2's was found to be significantly lesser than the corresponding F_2's

Variation was minimum in L_1 (1 92 per cent) The wild relatives recorded more variation than the cultivated accessions The variation for this trait among F_2 progenies ranged from 15 08 (L_3 x T_2) to 35 82 (L_1 x T_1) per cent

Table 41 Germination percentage in segregation generations of interspecific hybrids

hybrids	Germination percentage of seeds	
	F_1 and F_1M_1 generation	F_2 and F_2M_2 generation
L_1	84 44	76 11
L_2	72 78	77 78
L_3	76 66	66 66
SP	78 89	78 89
T_1	67 78	61 11
T_2	36 67	26 67
L_1xT_1	27 63	24 63
T_1xL_1	22 00	15 65
L_1xT_2	15 65	8 00
T_2xL_1	25 56	18 50
L_2xT_1	15 33	12 52
T_1xL_2	38 44	23 56
L_2xT_2	16 44	14 39
T_2xL_2	21 33	12 61
L_3xT_1	14 39	10 00
T_1xL_3	26 00	24 22
L_3xT_2	22 61	8 00
T_2xL_3	24 22	17 11
L_1xT_1I	27 55	16 22
T_1xL_1I	15 33	6 46
L_1xT_2I	27 50	12 60
T_2xL_1I	23 56	15 33
L_2xT_1I	40 00	16 44

Table 41 (contd)

hybrids	Germination percentage of seeds	
	F_1 and F_1M_1 generation	F_2 and F_2M_2 generation
T_1xL_2I	32 22	18 44
L_2xT_2I	24 22	11 33
T_2xL_2I	31 89	20 00
L_3xT_1I	8 00	12 22
T_1xL_3I	16 22	16 00
L_3xT_2I	16 89	12 22
T_2xL_3I	27 00	11 89

FIG. 14 PROPORTION OF RECOMBINANTS - PLANT HEIGHT

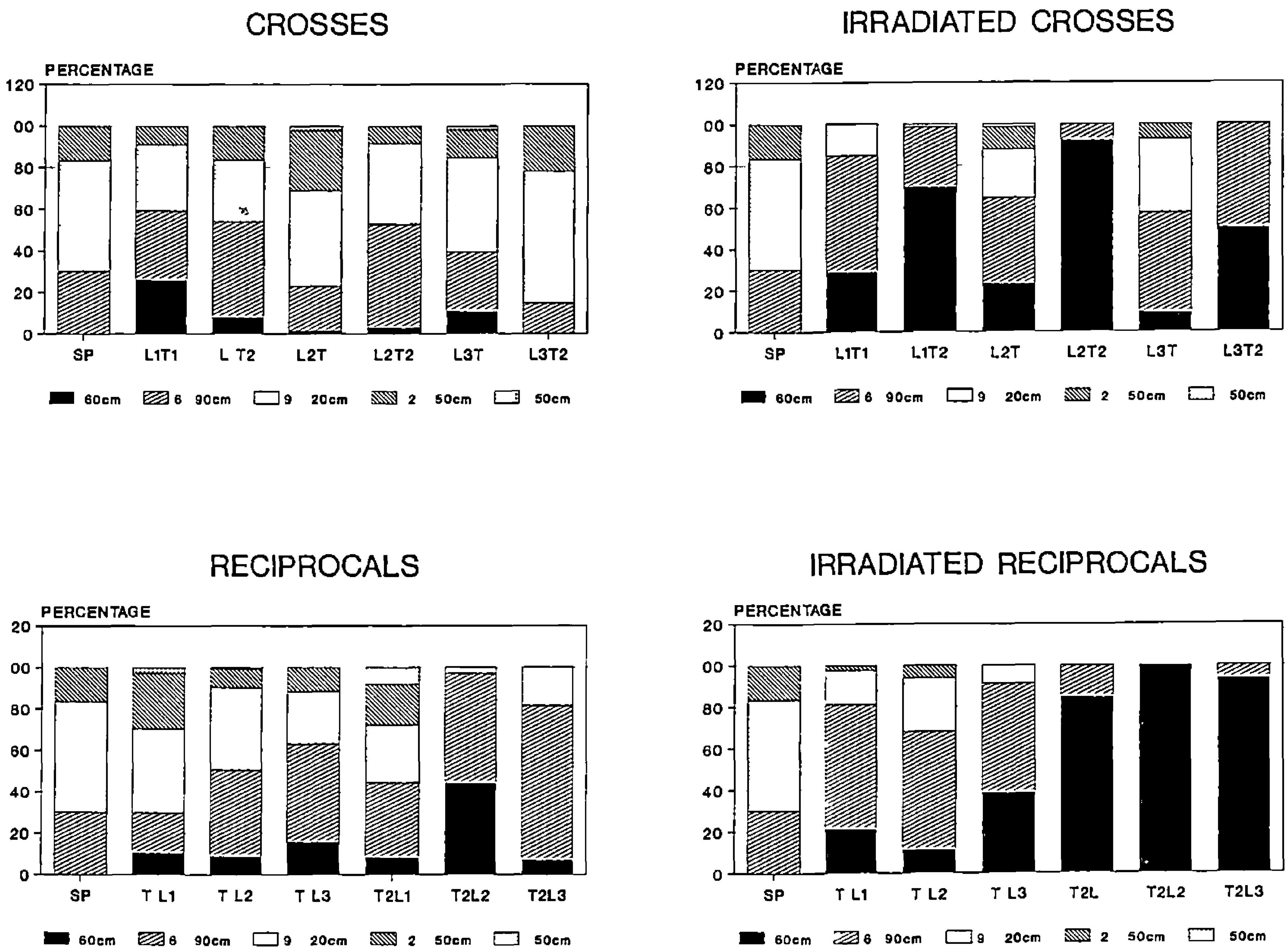


Table 42 Variations for plant height in F_2 and F_2M_2 generations

Treatment	Adjusted Mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis)					Per cent Increase over standard parent
			<60	61 90	91 120	121 150	>150	
L_1	73 18	78 0 85 5 (1 92)	Nil	30 (100 0)	Nil	Nil	Nil	
L_2	128 80	112 0 165 0 (11 17)	Nil	Nil	6 (20 0)	21 (70 0)	3 (10 0)	
L_3	109 15	92 0-135 0 (10 30)	Nil	Nil	23 (76 7)	7 (23 3)	Nil	
Sp	98 95	68 0-137 0 (24 08)	Nil	9 (30 0)	16 (53 3)	5 (16 7)	Nil	
T_1	71 08	32 0-116 0 (33 20)	8 (28 7)	14 (46 6)	8 (26 7)	Nil	Nil	
T_2	105 15	78 0 122 0 (13 41)	Nil	4 (13 3)	19 (63 4)	7 (23 4)	Nil	
L_1xT_1	82 90	25 0 145 0 (35 82)	23 (26 1)	29 (33 0)	28 (31 8)	8 (9 1)	Nil	16 22**
T_1xL_1	100 40	40 0 154 0 (30 78)	7 (10 5)	13 (19 4)	27 (40 3)	18 (26 8)	2 (3 0)	1 47
L_1xT_2	91 03	52 0 144 0 (25 35)	3 (8 1)	17 (45 9)	11 (39 7)	6 (16 3)	Nil	8 00
T_2xL_1	99 23	52 50 165 0 (30 50)	3 (8 3)	13 (36 1)	10 (27 8)	7 (19 4)	3 (8 4)	0 28
L_2xT_1	110 51	55 0-168 00 (21 78)	1 (1 2)	19 (21 8)	40 (46 0)	25 (28 7)	2 (2 3)	11 68
T_1xL_2	100 58	32 0 13 0 (23 79)	10 (8 8)	47 (41 6)	45 (39 8)	10 (8 9)	1 (0 9)	1 65
L_2xT_2	91 42	54 50-12 0 (19 04	1 (2 8)	18 (50 0)	14 (38.9)	3 (8 3)	Nil	7 61
T_2xL_2	63 71	32 0 0 ((28	15 (44 1)	18 (52 8)	1 (2 9)	Nil	Nil	35 61**

(contd)

Treatment	Adjusted Mean (cm)	Range (Coefficient of variation in parenthesis)	Number of Plants under each class (percentage in parenthesis) <60	61 90	91 120	121 150	>150	Per cent Increase over standard parent
L_3xT_1	99 75	26 0 150 0 (26 47)	12 (10 7)	32 (28 6)	51 (45 5)	15 (13 4)	2 (1 8)	0 81
T_1xL_3	85 61	28 0 142 0 (32 07)	15 (15 8)	45 (47 3)	24 (25 3)	11 (11 6)	Nil	13 48
L_3xT_2	104 31	67 0 128 0 (15 08)	Nil	6 (14 6)	26 (63 4)	9 (22 0)	Nil	5 42
T_2xL_3	77 61	36 0 108 00 (18 25)	3 (7 0)	32 (74 4)	8 (18 6)	Nil	Nil	21 57**
L_1xT_1I	71 71	23 0 110 0 (30 77)	19 (28 8)	37 (56 1)	10 (15 2)	Nil	Nil	28 07**
T_1xL_1I	77 01	28 0 120 0 (26 08)	17 (21 2)	48 (60 0)	13 (16 3)	2 (2 5)	Nil	22 17**
L_1xT_2I	47 50	22 0 84 0 (29 42)	46 (69 70	19 (28 8)	1 (10 5)	Nil	Nil	52 00**
T_2xL_1I	41 93	20 0 70 00 (30 61)	50 (84 7)	9 (15 3)	Nil	Nil	Nil	57 63**
L_2xT_1I	84 12	28 0 160 0 (34 76)	15 (23 1)	27 (41 5)	15 (23 1)	7 (10 8)	1 (1 5)	14 99*
T_1xL_2I	84 93	35 0 140 0 (26 31)	9 (11 1)	46 (56 8)	21 (25 9)	5 (6 2)	Nil	14 17
L_2xT_2I	36 45	22 0 55 0 (35 00)	24 (92 3)	2 (7 7)	Nil	Nil	Nil	63 16**
T_2xL_2I	37 47	30 0 52 0 (16 71)	26 (100 00)	Nil	Nil	Nil	Nil	62 13**
L_3xT_1I	87 25	48 0 133 0 (22 20)	5 (8 9)	27 (48 2)	20 (35 7)	4 (7 2)	Nil	11 82**
$T_{1xL3}I$	66 82	38 0 108 0 (25 08)	2 (38 6)	30 (52 6)	5 (8 8)	Nil	Nil	32 47**
L_3xT_2I	53 04	22 0 72 0 (25 23)	17 (50 0)	17 (50 00)	Nil	Nil	Nil	46 40**
T_2xL_3I	41 73	23 0 70 0 (29 37)	43 (93 5)	3 (6 5)	Nil	Nil	Nil	57 83**

CD(0 05) 14 22

$L_3 \times T_2I$ recorded maximum variation for this character (35 00 per cent) among the F_2M_2's

Majority of the plants of the F_2's and F_2M_2's came under the height group of 61-90 cm closely followed by the group 91-120 cm (Figure 14) Few tall plants with height greater than 150 cm were also obtained among the F_2's However, dwarf plants with height less than 60 cm were also obtained particularly in the crosses $T_2 \times L_2$ Majority of the plants of the F_2M_2's were dwarf types coming under this group (< 60 cms)

Girth of stem

The results are presented in Table 43 The crosses $L_2 \times T_1$ and $T_2 \times L_3I$ registered maximum (7 75 cm) and minimum (4 11 cm) stem girth respectively The mean stem girth of the crosses involving the wild parent *A tetraphyllus* (T_2) was found to be generally less

Among the parents, L_1 and T_2 recorded less variation for this trait The variation among the F_2's ranged from 7 56 ($L_2 \times T_1$) to 98 77 per cent ($L_2 \times T_2$) whereas in F_2M_2's it ranged from 7 53 ($T_1 \times L_3I$) to 20 63 ($L_3 \times T_2I$) per cent The variation for this trait was found to be comparatively lesser in the irradiated crosses than in the non-irradiated counterparts Moreover the crosses of T_2

Plate 15 A high yielding resistant plant L_2 x T_1I

Plate 16 A high yielding resistant plant I_1 x L_2I

Table 42 Variations for plant height in F_2 and F_2M_2 generations

Treatment	Adjusted Mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <60	61 90	91 120	121 150	>150	Per cent Increase over standard parent
L_1	73 18	78 0 85 5 (1 92)	Nil	30 (100 0)	Nil	Nil	Nil	
L_2	128 80	112 0 165 0 (11 17)	Nil	Nil	6 (20 0)	21 (70 0)	3 (10 0)	
L_3	109 15	92 0 135 0 (10 30)	Nil	Nil	23 (6 7)	7 (23 3)	Nil	
Sp	98 95	68 0 137 0 (24 08)	Nil	9 (30 0)	16 (53 3)	5 (16 7)	Nil	
T_1	71 08	32 0 116 0 (33 20)	8 (28 7)	14 (46 6)	8 (26 7)	Nil	Nil	
T_2	105 15	78 0 122 0 (13 41)	Nil	4 (13 3)	19 (63 4)	7 (23 4)	Nil	
L_1xT_1	82 90	25 0 145 0 (35 82)	23 (26 1)	29 (33 0)	28 (31 8)	8 (9 1)	Nil	16 22**
T_1xL_1	100 40	40 0 154 0 (30 78)	7 (10 5)	13 (19 4)	27 (40 3)	18 (26 8)	2 (3 0)	1 47
L_1xT_2	91 03	52 0 144 0 (25 35)	3 (8 1)	17 (45 9)	11 (39 7)	6 (16 3)	Nil	8 00
T_2xL_1	99 23	52 50 165 0 (30 50)	3 (8 3)	13 (36 1)	10 (27 8)	7 (19 4)	3 (8 4)	0 28
L_2xT_1	110 51	55 0 168 00 (21 78)	1 (1 2)	19 (21 8)	40 (46 0)	25 (28 7)	2 (2 3)	11 68
T_1xL_2	100 58	32 0 132 0 (23 79)	10 (8 8)	47 (41 6)	45 (39 8)	10 (8 9)	1 (0 9)	1 65
L_2xT_2	91 42	54 50 132 0 (19 04)	1 (2 8)	18 (50 0)	14 (38.9)	3 (8 3)	Nil	7 61
T_2xL_2	63 71	32 0 98 0 ((28 98)	15 (44 1)	18 (52 8)	1 (2 9)	Nil	Nil	35 61**

(contd)

Plate 15.

Plate 16.

Table 43 Variations for girth of stem in F_2 and F_2M_2 generations

Treatment	Adjusted Mean (cm)	Range (coefficient of variation in parenthesis)	No of plants under each class (percentage in parenthesis) <4	4 6	6-8 (cm)	>8	Per cent increase over standard parent
L_1	7 32	7 0 8 5 (5 88)	Nil	Nil	22 (73 3)	8 (26 7)	
L_2	7 6	7 2-8 6 (12 89)	Nil	Nil	22 (73 3)	8 (26 7)	-
L_3	7 20	6 5-7 5 (12 89)	NIl	Nil	27 (90 0)	3 (10 0)	-
SP	7 22	7 0 7 8 (18 05)	Nil	Nil	30 (100 00)	Nil	
T_1	7 65	5 8 9 0 (12 29)	Nil	3 (10 0)	25 (83 3)	2 (6 7)	-
T_2	3 31	3 2-4 2 (3 07)	25 (83 3)	5 (16 7)	Nil	Nil	-
L_1xT_1	7 37	4 1 9 1 (17 62)	Nil	45 (51 1)	33 (37 5)	10 (11 4)	2 08
T_1xL_1	7 52	4 5 9 3 (16 53)	1 (1 5)	6 (9 0)	35 (52 2)	25 (37 3)	4 16
L_1xT_2	4 35	3 0 5 8 (17 94)	16 (43 2)	21 (56 8)	Nil	Nil	39 75**
T_2xL_1	4 58	3 1 8 2 (31 49)	7 (19 4)	26 (72 2)	3 (8 3)	Nil	-36 59**
L_2xT_1	7 75	6 2 8 5 (7 56)	Nil	Nil	65 (74 7)	22 (25 3)	7 34

(contd 2)

Table 43 (contd)

Treat-ment	Adju-sted mean (cm)	Range (Coeffi cient of variation in paren-thesis)	Number of plants under each class (percentage in parenthesis) <4	4-6 (cm)	6-8	>8	Percent increase over standard parent
T_1xL_2	7 54	4 1-8 9 (22 52)	Nil	10 (8 9)	74 (65 5)	29 (25 6)	4 43
L_2xT_2	5 56	4 2-8 0 (98 77)	Nil	18 (50 0)	17 (47 2)	1 (2 8)	-22 99**
T_2xL_2	4 80	3 5 6 2 (13 59)	2	28 (82 4)	4 (11 8)	Nil	-33 52
L_3xT_1	6 56	4 2 8 4 (13 59)	Nil	28 (25 0)	80 (71 4)	4 (3 6)	-9 14*
T_1xL_3	7 47	5 4-8 3 (8 47)	Nil	4 (4 2)	85 (89 5)	6 (6 3)	3 46
L_3xT_2	5 97	5 2-7 1 (8 43)	Nil	14 (34 2)	27 (65 8)	Nil	-17 31**
T_2xL_3	4 90	4 1 6 9 (15 46)	Nil	32 (74 4)	11 (25 6)	Nil	-32 13**
L_1xT_1I	7 40	5 2-8 7 (10 66)	Nil	8 (12 1)	48 (72 7)	10 (15 1)	2 49
T_1xL_1I	7 53	5 4-8 5 (9 38)	Nil	2 (2 5)	58 (72 5)	20 (25 0)	4 29
L_1xT_2I	5 41	3 9-6 4 (10 49)	2 (3 0)	57 (86 14)	7 (10 6)	Nil	25 01**
T_2xL_1I	4 96	3 5 6 5 (13 59)	2 (3 4)	56 (94 9)	1 (1 7)	Nil	-31 30**
L_2xT_1I	7 27	4 8-8 4 (14 17)	Nil	11 (16 9)	30 (46 2)	24 (36 9)	0 69
T_1xL_2I	7 41	3 0 8 5 (9 67)	1 (1 2)	6 (7 4)	57 (70 4)	17 (21 0)	2 63

(contd)

Table 43 (contd .)

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <4	4-6 (cm)	6-8	>8	Percent increase over standard parent
L_2xT_2I	5 29	4 3-7 0 (11 70)	Nil	21 (80 8)	5 (19 2)	Nil	-26.73**
T_2xL_2I	4 46	3 8-5 5 (8 19)	1 (3 9)	25 (96 2)	Nil	Nil	-38 23**
L_3xT_1I	6 91	5 2-8 2 (10 29)	Nil	7 (12 50)	45 (80 4)	4 (7 1)	-4 29
T_1xL_3I	7 32	6 1-8 5 (7 53)	Nil	Nil	51 (89 5)	6 (10 5)	1 39
L_3xT_2I	4 62	3 0-6 2 (20 63)	9 (26 5)	20 (58 8)	5 (14 7)	Nil	-36 01**
T_2xL_3I	4 11	3 2-5 4 (15 63)	15 (22 6)	31 (67 4)	Nil	Nil	-43 07**

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* Significant at 5% level
** Significant at 1% level

recorded more variation than those of T_1

Majority of the plants belonged to the category of 6 1-8 cm among the F_2's whereas most of the plants belonged to the category of 4-6 cm in F_2M_2's

Number of leaves per plant

The results are presented in Table 44 There was significant difference among the parents, F_2's and F_2M_2's for this trait The F_2's and F_2M_2's had significantly higher number of leaves than their parents The segregating population of the wild parent T_2, registered more number of leaves compared to other combinations L_1 x T_1I (43 60) and L_3 x T_2 (57 01) recorded maximum number of leaves respectively among the crosses involving T_1 and T_2

Maximum variation for this trait was recorded by the cross T_1 x L_1 (43 21 per cent) followed by L_1 x T_1 (41 02 per cent) Fifteen crosses registered marked superiority in comparison with the standard cultivar, 'Punjab Padmini' for this trait

The frequency distribution showed that majority of the plants of the parents except T_2 belonged to the category of 20-40 Among the crosses of T_1, majority of the plants of the F_2M_2's had higher number of leaves than the F_2's Both the F_2's and F_2M_2's of the T_2 had higher number of leaves ab e a p p 2 2 2

Treatment	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <20	20 40	40 60	60 80	>80	Per cent Increase over standard parent
L_1	24 66	20 29 (12 9)	Nil	30 (100 0)	Nil	Nil	Nil	
L_2	27 89	22 42 (17 30)	Nil	29 (96 7)	1 (3 3)	Nil	Nil	
L_3	37 12	32 48 (9 87)	Nil	20 (75 0)	10 (25 0)	Nil	Nil	
SP	33 86	26 46 (25 50)	Nil	24 (80 10)	6 (20 0)	Nil	Nil	
T_1	29 19	22 42 (17 72)	Nil	29 (96 7)	1 (3 3)	Nil	Nil	
T_2	57 76	40 85 (5 13)	Nil	4 (13 3)	16 (53 3)	10 (33 3)	Nil	
L_1xT_1	33 12	10 68 (41 02)	13 (14 8)	49 (55 7)	22 (25 0)	4 (4 6)	Nil	2 19
T_1xL_1	31 98	12 62 (43 21)	14 (20 9)	38 (56 7)	10 (14 9)	5 (7 5)	Nil	5 55
L_1xT_2	42 25	24 82 (19 55)	Nil	15 (40 5)	15 (40 5)	6 (16 2)	1 (2 8)	24 78*
T_2xL_1	47 98	46 72 (31 25)	Nil	Nil	22 (61 1)	14 (38 9)	Nil	41 70**
L_2xT_1	25 11	16 36 (19 66)	8 (2)	79 (90 8)	Nil	Nil	Nil	25 84*
T_1xL_2	27 03	16 38 (24 36)	15 (13 3)	98 (86 7)	Nil	Nil	Nil	20 17
L_2xT_2	44 25	24 62 (27 16)	Nil	13 (36 1)	22 (61 1)	1 (2 8)	Nil	30 69**
T_2xL_2	41 15	25 65 (30 52)	Nil	13 (38 2)	16 (47 1)	5 (14 7)	Nil	21 53*
L_3xT_1	25 31	12 38 (21 76)	87 (77 7)	25 (22 3)	Nil	Nil	Nil	25 25*
T_1xL_3	29 99	15 52 (27 53)	12 (12 6)	72 (75 8)	11 (11 58)	Nil	Nil	11 43
L_3xT_2	57 01	28 85 (23 56)	Nil	4 (9 8)	21 (51 2)	11 (26 8)	5 (12 2)	68 37**
T_2xL_3	54 46	29 104 (33 33)	Nil	1 (2 4)	21 (48 8)	16 (37 2)	5 (11 6)	60 84**

(contd)

Table 44 (contd)

Treatment	Adjusted Mean	Range (coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <20	20 40	40 60	60 80	>80	Per cent Increase over standard parent
L_1xT_1I	43 60	26 64 (24 36)	Nil	24 (36 4)	38 (57 6)	4 (6 0)	Nil	28 77**
T_1xL_1I	40 80	23 60 (18 91)	Nil	39 (48 8)	40 (50 0)	1 (1 3)	Nil	20 50*
L_1xT_2I	46 12	24 75 (36 46)	Nil	11 (16 7)	41 (62 1)	13 (19 7)	1 (1e 5)	36 21**
T_2xL_1I	38 57	22 62 (24 99)	Nil	35 (59 3)	23 (39 0)	1 (1 7)	Nil	13 91
L_2xT_1I	30 50	12 56 (33 85)	11 (16 9)	44 (67 7)	10 (15 4)	Nil	Nil	9 92
T_1xL_2I	38 20	18 62 (20 96)	1 (1 2)	68 (84 0)	11 (13 6)	1 (1 2)	Nil	12 82
L_2xT_2I	45 73	24 65 (25 54)	Nil	1 (3 9)	24 (92 2)	1 (3 9)	Nil	35 06**
T_2xL_2I	30 79	45 56 (22 65)	Nil	Nil	26 (100 0)	Nil	Nil	9 07
L_3xT_1I	32 30	4 68 (18 75)	Nil	Nil	49 (87 5)	7 (42 5)	Nil	4 61
T_1xL_3I	25 97	15 45 (36 32)	7 (12 3)	48 (84 2)	2 (3 5)	Nil	Nil	23 30
L_3xT_2I	36 52	26 80 (30 72)	Nil	25 (73 5)	8 (23 5)	Nil	1 (4 2)	7 86
T_2xL_3I	48 42	26 85 (31 79)	Nil	12 (26 1)	21 (45 7)	11 (23 9)	2 (4 4)	43 00**

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than that of T_1 Among segregation generations, L_3 x T_1 registered maximum proportion (77 7 per cent) of plants with less than 20 leaves per plant

Leaf area

The results are presented in Table 45 Among the parents L_1 (466 07) and T_2 (92 60) recorded the maximum and minimum leaf area respectively Majority of the crosses of T_2 parent had narrow leaves similar to wild parent

All the combinations displayed wide array of variation for this character Maximum variation (46 85 per cent) was recorded by T_1 x L_1 whereas T_1 x L_3 registered minimum (12 45) coefficient of variation for this trait All the combinations registered negative heterosis for this character Majority of the plants in most of the crosses belonged to the category of 300-500 sq cm particularly when T_1 was used as one of the parents

Days to flowering

The results are presented in Table 46 The parents and hybrids showed significant difference for this trait All the parents except T_1 showed earliness in flowering and were on par But T_1 recorded a significantly higher value

Table 45 Variation for leaf area in F_2 and F_2M_2 generations

Treatments	Adjusted Mean (cm^2)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <100 cm^2	100 300 cm^2	300 500 cm^2	>500 cm^2	Per cent increase over standard parent
L_1	466 07	365 625 (13 81)	Nil	Nil	21 (70 0)	9 (30 0)	
L2	435 97	385 525 (8 99)	Nil	Nil	26 (86 7)	4 (13 3)	
L_3	364 27	300 425 (10 58)	Nil	Nil	30 (100 00)	Nil	
SP	441 70	368 520 (1 56)	Nil	Nil	27 (90 0)	3 (10 0)	
T_1	424 53	360 593 (13 37)	Nil	Nil	26 (86 7)	4 (13 3)	
T_2	92 60	45 120 ((8 28)	22 (73 3)	8 (26 7)	Nil	Nil	
L_1xT_1	287 23	85 610 (40 35)	2 (2 3)	39 (44 3)	43 (48 9)	4 (4 5)	34 97**
T_1xL_1	288 72	75 545 (46 85)	2 (3 0)	32 (47 8)	30 (44 8)	3 (4 4)	34 63**
L_1xT_2	75 27	45 125 (26 96)	34 (91 9)	3 (8 1)	Nil	Nil	82 96**
T_2xL_1	70 73	35 85 (19 01)	36 (100 0)	Nil	Nil	Nil	83 99**
L_2xT_1	364 18	275 525 (15 27)	Nil	4 (4 6)	81 (93 1)	2	17 55**
T_1xL_2	337 28	85 525 (32 37)	2 (1 8)	32 (28 3)	73 (64 6)	6 (5 3)	23 64**
L_2xT_2	73 60	35 120 (26 81)	33 (91 7)	3 (8 3)	Nil	Nil	83 34**
T_2xL_2	49 52	38 84 (25 38)	34 (100 0)	Nil	Nil	Nil	88 79**

(contd)

Table 45 (contd)

Treatments	Adjusted Mean cm^2	Range (Coefficient of variation in parenthesis)	Number of Plants under each class(percentage in parenthesis) <100	100-300 cm^2	300 500	>500	Per cent increase over standard parent
L_3xT_1	285 20	108 460 (33 13)	2 (1 8)	61 (54 5)	49 (43 8)	Nil	35 43**
T_1xL_3	395 67	312 545 (12 45)	Nil	3 (3 2)	90 (4 7)	2 (2 1)	-10 42**
L_3xT_2	60 88	44 88 (21 05)	41 (100 0)	Nil	Nil	Nil	-86 22**
T_2xL_3	59 06	37 64 (24 84)	43 (100 0)	Nil	Nil	Nil	86 63**
L_1xT_1I	433 79	210 610 (14 31)	Nil	3 (4 6)	56 (84 8)	7 (10 6)	1 79
T_1xL_1I	440 07	307 507 (12 46)	Nil	Nil	66	14	0 37
L_1xT_2I	66 50	48 110 (21 76)	62 (93 9)	4 (6 1)	Nil	Nil	84 94**
T_2xL_1I	70 15	38-125 (31 26)	55 (93 2)	4 (6 8)	Nil	Nil	84 12**
L_2xT_1I	387 88	200 510 (20 07)	Nil	8 (12 3)	52 (80 0)	5 (7 7)	12 30**
T_1xL_2I	429 24	280 540 (14 63)	Nil	1 (1 2)	68 84 0)	12 (14 8)	2 83
L_2xT_2I	56 24	42 95 (23 09)	26 (100 0)	Nil	Nil	Nil	-87 27
T_2xL_2I	45 28	25 82 (32 89)	26 (100 00)	Nil	Nil	Nil	89 75
L_3xT_1I	352 57	223 450 (14 81)	Nil	4 (7 1)	52 (92 9)	Nil	20 18
T_1xL_3I	412 60	320 540 (13 66)	Nil	Nil	51 (89 5)	6 (10 5)	6 59
L_3xT_2I	54 56	38 105 (27 66)	33 (97 1)	1 (2 9)	Nil	Nil	-87 65
T_2xL_3I	54 39	32 90 (28 9)	46 (100 0)	Nil	Nil	Nil	-87 60

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for days to flowering (68 85) Majority of the hybrids were late in flowering compared to their cultivated parents The F_2M_2's showed earliness in flowering as compared to their corresponding F_2 population Moreover, the crosses of T_2 registered lesser number of days to flowering than the crosses of T_1 Among the crosses, L_1 x T_1 and L_3 x T_2I recorded the maximum (68 75) and minimum (46 67) values respectively

Less variation was noticed among parents, F_2's and F_2M_2's for this trait L_3 x T_2I recorded maximum variation (23 24 per cent) for this trait followed by L_1 x T_2 (17 56 per cent)

The frequency distribution of this character showed that majority of the plants of the F_2's and F_2M_2's came under the range of 50-60 days (Figure 15) L_1 x T_1 had maximum proportion (64 8 per cent) of plants with late flowering habit (> 70 days) similar to its wild parent T_1

First fruiting node

The results are presented in Table 47 The cultivated varieties were found to fruit at lower nodes as compared to the wild relatives used in this study In general, the plants of the segregating population resembled the wild parents with respect to this character with the

FIG. 15 PROPORTION OF RECOMBINANTS - DAYS TO FLOWERING

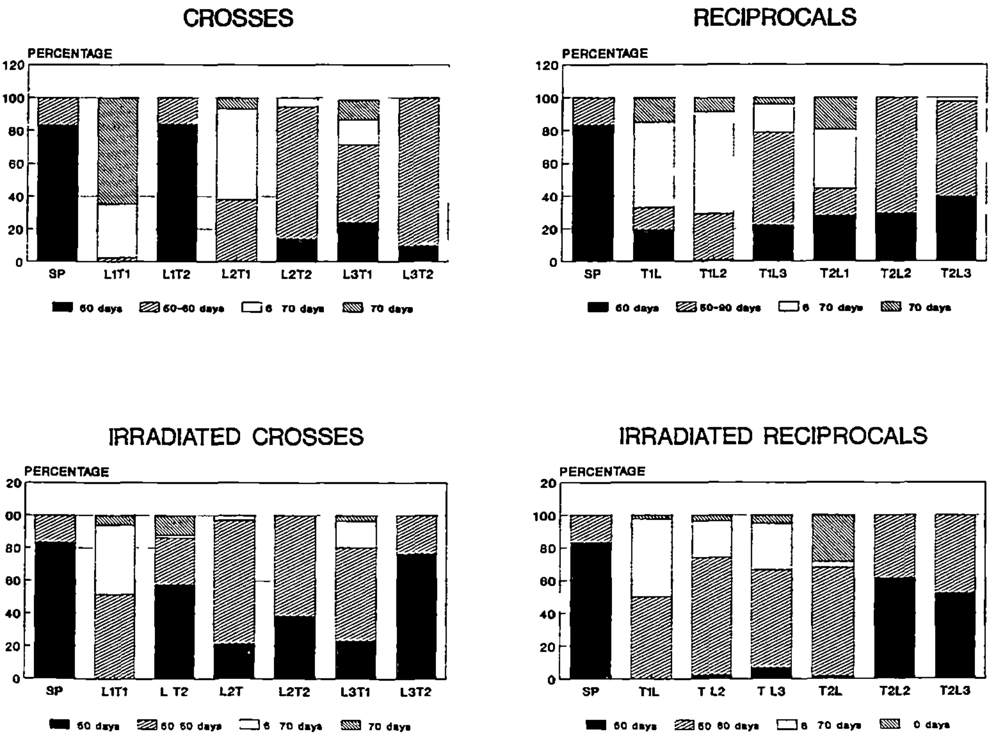

Table 46 Variations for days to flowering in F_2 and F_2M_2 generations

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <50	50 60	61-70	>70	Per cent increase over standard parent
L_1	48 47	47 55 ((5 03)	4 (13 3)	26 (86 7)	Nil	Nil	
L_2	49 28	46 52 (4 84)	17 (56 7)	13 (43 3)	Nil	Nil	
L_3	45 58	43 48 (2 33)	30 (100 0)	Nil	Nil	Nil	
SP	46 72	45 50 (6 28)	25 (83 3)	5 (16 7)	Nil	Nil	
T_1	68 85	64 72 (3 21)	Nil	Nil	14 (46 7)	16 (53 3)	
T_2	44 62	47 55 (7 64)	9 (30 0)	21 (70 0)	Nil	Nil	
L_1xT_1	68 75	58 104 (11 95)	Nil	2 (2 3)	29 (33 0)	57 (64 8)	47 15**
T_1xL_1	67 60	49 92 (12 37)	13 (19 4)	9 (13 4)	35 (52 2)	10 (14 9)	44 69**
L_1xT_2	47 93	44 125 (17 56)	31 (83 8)	6 (16 2)	Nil	Nil	2 59
T_2xL_1	52 50	48 72 (16 52)	10 (27 8)	6 (16 7)	3 (36 1)	7 (19 4)	12 37**
L_2xT_1	61 37	54 74 (8 25)	Nil	33 (37 9)	48 (55 2)	6 (6 9)	31 36**
T_1xL_2	63 22	52 76 (8 61)	1 (0 9)	32 (28 3)	70 (61 9)	10 (8 8)	35 32**
L_2xT_2	53 99	47 62 (6 81)	5 (13 9)	29 (80 6)	2 (5 6)	Nil	15 56**
T_2xL_2	51 25	46-59 (7 44)	10 (29 4)	24 (70 6)	Nil	Nil	9 70
L_3xT_1	56 57	44 88 (15 86)	21 (24 1)	53 (47 3)	17 (15 2)	15 (13 4)	21 08
T_1xL_3	55 06	47 59 (12 89)	21 (22 1)	54 (56 8)	16 (16 8)	4 (4 2)	17 85**

(contd)

(Table 46 (contd)

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <50	50 60	61-70	>70	Per cent increase over standard parent
L_3xT_2	52 67	48 58 (5 21)	4 (9 8)	37 (90 2)	Nil	Nil	12 74**
T_2xL_3	50 01	44 60 (7 10)	17 (39 5)	25 (58 1)	1 (2 4)	Nil	7 04
L_1xT_1I	60 12	52 71 (8 84)	Nil	34 (51 5)	28 (42 4)	4 (6 1)	28 68**
T_1xL_1I	49 66	44 73 (12 86)	Nil	40 (50 0)	38 (47 5)	2 (2 5)	6 29
L_1xT_2I	52 54	43 80 (9 13)	38 (57 6)	19 28 8)	1 (1 5)	8 (12 1)	11 82
T_2xL_1I	53 04	46 62 (7 20)	1 (1 7)	39 (66 1)	2 (3 4)	17 (28 8)	13 53*
L_2xT_1I	56 52	46 60 (7 16)	14 (21 5)	49 (75 4)	2 (3 1)	Nil	20 98*
T_1xL_2I	48 79	48 74 (9 30)	2 (2 5)	58 (71 6)	18 (22 2)	3 (3 7)	4 43
L_2xT_2I	53 97	45 58 (9 35)	10 (38 5)	16 (61 5)	Nil	Nil	15 52*
T_2xL_2I	58 25	45 56 (6 53)	16 (61 5)	10 (38 5)	Nil	Nil	24 68*
L_3xT_1I	53 97	45 70 (12 94)	13 (23 2)	32 (57 1)	9 (16 1)	2 (3 6)	15 52*
T_1xL_3I	58 25	48 74 (11 87)	4 (7 0)	34 (59 6)	16 (28 1)	3 (5 3)	24 68**
L_3xT_2I	46 67	42 52 (23 24)	26 (76 5)	8 (23 5)	Nil	Nil	0 11
T_2xL_3I	50 67	39 55 (8 06)	24 (52 2)	22 (47 8)	Nil	Nil	8 45

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Table 47 Variations for First fruiting node in F_2 and F_2M_2 generations

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) 4 5	6 7	8 9	>9	Per cent increase over standard parent
L_1	5 91	5 0 8 0 (7 22)	6 (26 0)	20 (6 67)	4 (13 3)	Nil	
L_2	5 41	5 0 6 0 (7 85)	8 (26 7)	22 (73 3)	Nil	Nil	
L_3	4 58	4 0 6 0 (15 92)	22 (73 3)	8 (26 7)	Nil	Nil	
SP	6 01	6 0 8 0 (11 06)	Nil	29 (96 7)	1 (3 3)	Nil	
T_1	7 08	5 0 8 0 (6 76)	17 (56 7)	11 (36 7)	2 (6 7)	Nil	
T_2	7 98	7 0 10 0 (9 64)	Nil	8 (26 7)	18 (60 0)	4 (13 3)	
L_1xT_1	7 38	4 0 16 0 (43 72)	23 (26 1)	16 (18 2)	13 (14 8)	36 (40 9)	22 80
T_1xL_1	8 26	5 0 9 0 (5 44)	18 (26 8)	17 (25 4)	13 (19 4)	19 (28 4)	37 44*
L_1xT_2	10 25	8 0 12 0 (13 07)	Nil	Nil	1 (2 7)	36 (97 3)	70 55**
T_2xL_1	9 53	5 0 13 0 (29 17)	4 (11 1)	6 (16 7)	17 (19 4)	19 (52 8)	58 57**
L_2xT_1	6 48	4 0 10 0 (23 64)	31 (35 6)	39 (44 8)	15 (17 2)	2 (2 3)	7 82
T_1xL_2	8 54	5 0 13 0 (22 52)	12 (10 6)	38 (33 6)	39 (34 5)	24 (21 2)	42 10**
L_2xT_2	9 44	4 0-14 0 (28 20)	3 (8 3)	5 (13 9)	8 (22 2)	20 (55 6)	57 07**
T_2xL_2	9 36	5 0 15 0 (29 94)	2 (8 3)	4 (13 9)	10 (22 2)	18 (55 6)	55 74**
L_3xT_1	6 39	4 0 12 0 (28 67)	55 (5 9)	30 (11 8)	14 (29 4)	13 (52 9)	6 32
T_1xL_3	6 52	4 0-12 0 (22 74)	37 (49 1)	22 (26 8)	33 (12 5)	3 (11 6)	8 49

(contd)

Table 47 (contd)

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) 4 5	6 7	8 9	>9	Per cent increase over standard parent
L_3xT_2	11 19	6 0 16 0 (19 74)	Nil	1 (2 5)	1 (2 5)	39 (95 0)	86 16**
T_2xL_3	8 80	6 0 14 0 (27 93)	Nil	16 (37 2)	10 (23 3)	17 (39 5)	46 42**
L_1xT_1I	7 91	5 0 12 0 (25 52)	5 (7 6)	28 (42 4)	18 (27 3)	15 (22 7)	31 61*
T_1xL_1I	7 07	5 0 10 0 (18 57)	10 (12 5)	46 (57 5)	20 (25 0)	4 (5 0)	17 64
L_1xT_2I	8 57	6 0 12 0 (22 66)	Nil	16 (24 2)	31 (47)	19 (28 8)	42 60**
T_2xL_1I	7 47	5 0 14 0 (22 73)	11 (18 7)	32 (54 2)	12 (20 3)	4 (6 8)	24 29
L_2xT_1I	6 06	4 0 9 0 (16 5)	22 (33 8)	38 (38 5)	5 (7 7)	Nil	0 83
T_1xL_2I	6 92	5 0 10 0 (15 70)	5 (6 2)	59 (72 8)	16 (19 8)	1 (1 2)	15 14
L_2xT_2I	10 20	5 0 12 0 (30 09)	2 (7 7)	6 (23 1)	4 (15 4)	14 (53 8)	69 72**
T_2xL_2I	5 18	5 0 8 0 (15 50)	15 (57 7)	9 (34 6)	2 (7 7)	Nil	13 81
L_3xT_1I	5 45	5 0 8 0 (14 00)	40 (71 4)	14 (25 0)	2 (3 6)	Nil	9 32
T_1xL_3I	5 91	5 0 10 0 (19 22)	25 (43 9)	28 (49 1)	3 (5 3)	1 (1 8)	1 66
L_3xT_2I	7 32	5 0 12 0 (25 53)	3 (8 8)	16 (47 1)	8 (23 5)	7 (20 6)	21 80
T_2xL_3I	8 30	4 0 14 0 (26 28)	3 (4 3)	6 (13 0)	27 (58 7)	6 (13 0)	38 10*

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maximum value for $L_3 \times T_2$ (11 19) However few crosses namely $T_2 \times L_2I$, $L_3 \times T_1I$ and $T_1 \times L_3I$ were found to be fruiting below the sixth node

The maximum coefficient of variation was registered by $L_1 \times T_1$ (43 72 per cent) for this trait Significant positive heterosis was manifested by twelve crosses compared to the standard variety 'Punjab Padmini'

Number of branches per plant

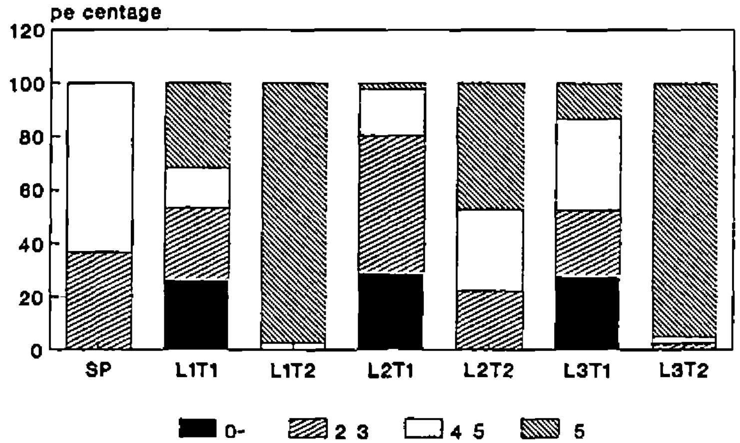
The results are presented in Table 48 The parents, F_2's and F_2M_2's differed significantly with respect to this character

Large variation for number of branches existed in the F_2 as well as in the F_2M_2 populations as F_2s had higher variation than F_2M_2s The crosses $L_3 \times T_2$ and $T_1 \times L_3I$ registered the maximum (8 19) and minimum (2 15) values respectively Among the parents, T_2 recorded maximum coefficient of variation (96 12 per cent) $L_1 \times T_1$ (92 17 per cent) and $L_1 \times T_2I$ (51 44 per cent) registered maximum variation among the F_2's and F_2M_2's respectively

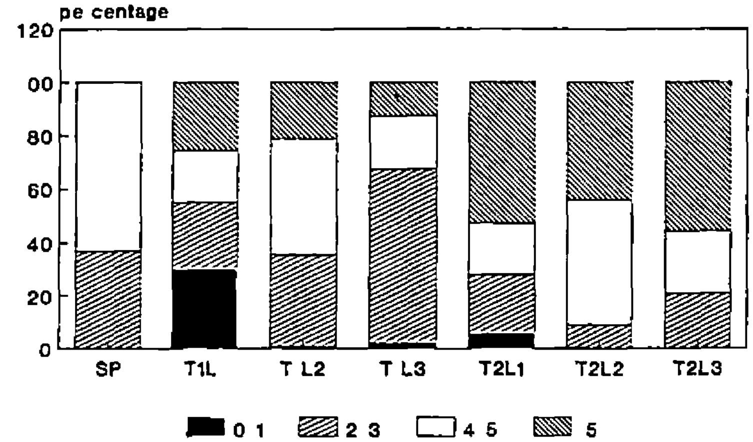
The distribution of plants under different classes showed the preponderance of medium to highly branching plants among F_2 and F_2M_2 populations (Figure 16) Majority

NUMBER OF BRANCHES PER PLANT

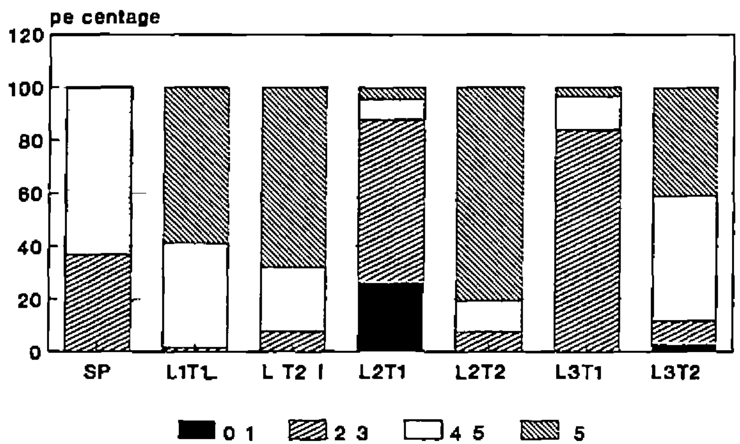
Crosses



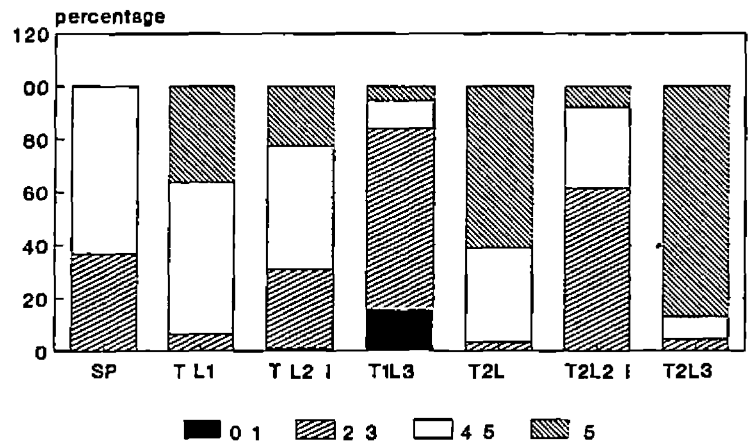
Reciprocals



Irradiated Crosses



Irradiated Reciprocals



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generations

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis)				Per cent increase over standard parent
			0 1	2–3	4 5	>5	
SP	3 40	2 0 5 0 (26 56)	Nil	11 (36 70)	19 (63 30)	Nil	
L_1	0 90	1 0 5 0 (5 83)	25 (83 3)	3 (10 0)	2 (6 7)	Nil	
L_2	2 43	2 0 3 0 (20 74)	Nil	30 (100 0)	Nil	Nil	
L_3	0 77	0 0 2 0 (89 22)	22 (73 3)	8 (26 7)	Nil	Nil	
T_1	1 43	1 0 3 0 (39 88)	15 (50 0)	15 (50 00)	Nil	Nil	
T_2	3 60	6 0 10 0 (96 12)	Nil	Nil	Nil	30 (100 00)	
L_1xT_1	3 53	0 0 12 0 (92 17)	23 (26 1)	24 (27 3)	13 (14 8)	28 (31 8)	3 82
T_1xL_1	3 39	0 0 12 0 (28 31)	20 (29 8)	17 (25 4)	13 (19 4)	17 (25 4)	0 29
L_1xT_2	6 69	4 0 14 0 (42 11)	Nil	Nil	1 (2 7)	36 (7 3)	96 76**
T_2xL_1	6 36	1 0 12 0 (69 38)	2 (5 6)	8 (22 2)	7 (19 4)	19 (52 8)	87 06**
L_2xT_1	2 27	0 0 8 0 (33 54)	25 (28 7)	45 (51 7)	15 (17 3)	2 (2 3)	33 24
T_1xL_2	5 13	1 0 8 0	1	39	49	24	50 88*
L_2xT_2	4 90	2 0 8 0 (44 42)	Nil	8 (22 2)	11 (30 6)	17 (47 2)	44 12
T_2xL_2	5 90	3 0 12 0 (87 63)	Nil	3 (8 8)	16 (47 1)	15 (44 1)	73 53*
L_3xT_1	2 16	0 0 6 0 (41 54)	31 (27 7)	28 (25 0)	38 (33 9)	15 (13 4)	36 47
T_1xL_3	3 59	1 0 8 0 (49 68)	2 (2 1)	62 (65 3)	19 (20 0)	12 (12 6)	5 59
L_3xT_2	8 19	2 0 12 0 (32 31)	Nil	1 (2 4)	1 (2 4)	39 (95 1)	140 88**
T_2xL_3	6 13	2 0 12 0 (27 33)	Nil	9 (20 9)	10 (23 3)	24 (55 8)	80 29**
L_1xT_1I	5 94	2 0 12 0 (35 64)	Nil	1 (1 50)	26 (39 4)	39 (59 1)	74 71**

(contd

Table 48 (contd)

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) 0 1	2 3	4 5	>5	Per cent increase over standard parent
T_1xL_1I	4 86	2 0 9 0 (33 10)	Nil	5 (6 3)	46 (57 5)	29 (36 2)	42 94**
L_1xT_2I	5 98	2 0 10 0 (51 44)	Nil	5 (7 6)	16 (24 2)	45 (68 2)	75 88**
T_2xL_1I	5 83	2 0 12 0 (34 68)	Nil	2 (3 4)	21 (35 6)	36 (61 02)	71 47**
L_2xT_1I	2 49	1 0 6 0 (38 56)	17 (26 2)	40 (61 5)	5 (1 7)	3 (4 60)	26 76**
T_1xL_2I	4 36	1 0 8 0 (34 28)	1 (1 2)	24 (29 6)	38 (46 9)	18 (22 3)	28 24**
L_2xT_2I	7 89	2 0 12 0 (31 43)	Nil	2 (7 7)	3 (11 5)	21 (80 8)	132 06**
T_2xL_2I	3 38	3 0 6 0 (18 57)	Nil	16 (61 5)	8 (30 8)	2 (7 7)	0 59
L_3xT_1I	2 91	2 0 6 0 (31 43)	Nil	47 (83 9)	7 (12 5)	2 (3 6)	14 41
T_1xL_3I	2 15	0 0 6 0 (18 57)	9 (15 8)	39 (68 4)	6 (10 5)	3 (5 3)	36 76
L_3xT_2I	5 13	0 0 12 0 (48 28)	1 (2 9)	3 (8 8)	16 (47 1)	14 (41 2)	50 88**
T_2xL_3I	6 53	2 0 12 0 (35 31)	Nil	2 (4 3)	4 (8 7)	40 (87 0)	92 86**

CD (0 05) 1 59

of the plants of the crosses of T_2 were having more than five branches per plant while only two crosses of T_1 (L_1 x T_1 and L_1 x T_1I) had maximum proportion of plants coming under this category

Number of flowers per plant

The results are presented in Table 49 Significant difference was shown by the progeny for this trait Among the parents, T_2 had significantly higher number of flowers per plant (34 70) The F_2M_2's produced only lesser number of flowers per plant as compared to the parents and F_2's Among the crosses of T_1, T_1 x L_1 recorded the maximum value (18 45) closely followed by T_1 x L_2I (17 61) T_2 x L_2 produced maximum (21 30) number of flowers per plant among the crosses of the T_2 parent

There was wide variation for number of flowers per plant among the plants of the F_2's and F_2M_2's Maximum coefficient of variation (74 88 per cent) was recorded by L_2 x T_2I for this trait Among the parents L_2 showed more variation (33 95 per cent) than the other two parents

Most of the segregants produced flowers in the range 10-15 while all the parents except L_1 and T_2 had maximum proportion of plants distributed in the 15-20 group However, several recombinants with more than 20 flowers per

Table 49 Variations for number of flowers per plant in F_2 and F_2M_2 generations

Treatment	Adjusted mean	Range (Co-efficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <5	5 10	10-15	15-20	>20	Percent increase over standard parent
L_1	13 33	4-22 (32 06)	1 (3 3)	3 (10 0)	19 (6 33)	5 (16 7)	2 (6 7)	
L_2	14 90	6 28 (33 95)	Nil	4 (13 3)	8 (26 7)	14 (46 7)	4 (13 3)	
L_3	15 40	12-22 (14 32)	Nil	Nil	9 (3 0)	17 (56 7)	4 (13 3)	
SP	15 97	12-22 (22 36)	Nil	3 (10 00)	3 (10 0)	19 (63 3)	5 (16 7)	
T_1	13 20	6-22 (33 79)	Nil	4 (13 3)	15 (5 0)	6 (20 0)	5 (16 7)	
T_2	34 70	22-58 (16 42)	Nil	Nil	Nil	Nil	30 (100 00)	
L_{1xT1}	13 51	4-26 (44 27)	8 (9 1)	19 (21 6)	29 (33 00)	26 (29 5)	6 (6 8)	-15 40
T_{1xL1}	18 45	0-40 (45 20)	1 (1 5)	4 (6 4)	19 (28 4)	25 (37 3)	18 (26 3)	15 53
L_{1xT2}	13 6	2-30 (45 29)	2 (5 4)	3 (8 1)	16 (43 2)	5 (13 5)	11 (29 7)	-15 53
T_2xL_1	12 61	2-32 (42 36)	1 (2 8)	4 (11 1)	27 (75 0)	3 (8 3)	1 (2 3)	-21 04
L_2xT_1	15.32	3-24 (26 48)	Nil	7 (8 1)	35 (40 2)	34 (39 1)	11 (12 6)	4 07
T_{1xL2}	15 59	4-28 (41 32)	4 (3 5)	14 (12 4)	48 (47 5)	30 (26 6)	17 (15)	-2 38

(contd)

(Table 49 contd)

Trea-ment	Adju-sted mean	Range (co effi cient of varia-tion in paren thesis)	Number of plants under each class (percentage in parenthesis) <5	5-10	10-15	15-20	>20	Percent increase over stand-ard parent
L_2xT_2	15 44	4-26 (44 18)	1 (2 8)	3 (8 3)	8 (22 2)	13 (36 1)	11 (30 6)	-3 32
T_2xL_2	21 30	6-44 (46 35)	5 (14 9)	10 (29 4)	3 (8 8)	2 (5 9)	14 (41 2)	3 37*
L_3xT_1	15 31	0 32 (38 50	6 (5 4)	5 (4 5)	43 (38 4)	41 (36 6)	17 (15 1)	4 13
T_1xL_3	15 54	3-22 (35 59)	4 (4 3)	10 (10 5)	40 (42 1)	30 (31 6)	11 (11 6)	-2 07
L_3xT_2	12 64	0-22 (36 54)	1 (2 4)	8 (19 5)	16 (39 0)	11 (26 8)	5 (12 2)	-20 85
T_2xL_3	10 87	2-28 (56 50)	3 (7 0)	18 (41 9)	12 (27 9)	5 (11 6)	5 (11 6)	-31 93*
L_1xT_1I	13 62	4-28 (41 19)	1 (1 5)	13 (15 7)	32 (48 4)	10 (15 2)	10 (15 2)	-14 72
$T_{1xL1}I$	15 30	2 34 (51 17)	4 (5 0)	18 (22 5)	26 (32 5)	17 (21 3)	15 (18 7)	-4 20
L_1xT_2I	9 35	1-24 (66 22)	10 (15 2)	21 (31 8)	18 (27 3)	7 (16 6)	10 (15 1)	41 45**
T_2xL_1I	9 89	3 21 (48 95)	6 (10 2)	27 (45 7)	15 (25 4)	9 (15 3)	2 (3 4)	-39 32**
L_2xT_1I	16 56	4-34 (48 61)	4 (6 2)	5 (7 7)	25 (38 4)	16 (24 6)	15 (23 1)	-3 69
T_1xL_2I	17 61	1 36 (47 70)	2 (2 5)	12 (14 8)	25 (30 9)	20 (24 7)	22 (27 1)	10 27
L_2xT_2I	5 16	0-12 (74 88)	12 (46 2)	7 (26 9)	6 (23 1)	1 (3 8)	Nil	67 69*
T_2xL_2I	6 90	3-15 (44 64)	7 (26 4)	11 (42 3)	7 (26 9)	1 (3 9)	Nil	-56 79**

(Table 49 contd)

Treatment	Adjusted Mean	Range (Coefficient of variation in parenthesis	Number of plants under each class					Percent increae over standard parent
			<5	5-10	10-15	15-20	>20	
L_3xT_1I	15 94	3-28 (38 37)	Nil	5 (8 9)	22 (39 3)	16 (28 6)	13 (23 2)	0 19
T_1xL_3I	10.69	16 (29 31)	I (1 8)	17 (29 8)	33 (57 9)	6 (10 5)	Nil	-33 06*
L_3xT_2I	10 57	2-28 (53 38)	4 (11 3)	8 (23 5)	15 (44 1)	2 (5 9)	5 (14 7)	-33 81*
T_2xL_3I	6 84	0-20 (71 49)	15 (32 6)	16 (34 8)	10 (31 7)	3 (6 5)	2 (4 3)	-57 17**

C D(0 05) - 4 89

* Significant at 5% level
** Significant at 1% level

plant were also available Among, the segregants T_1 x L_2I (22) and T_1 x L_1 (18) had maximum number of plants in the >20 group

Number of fruits per plant

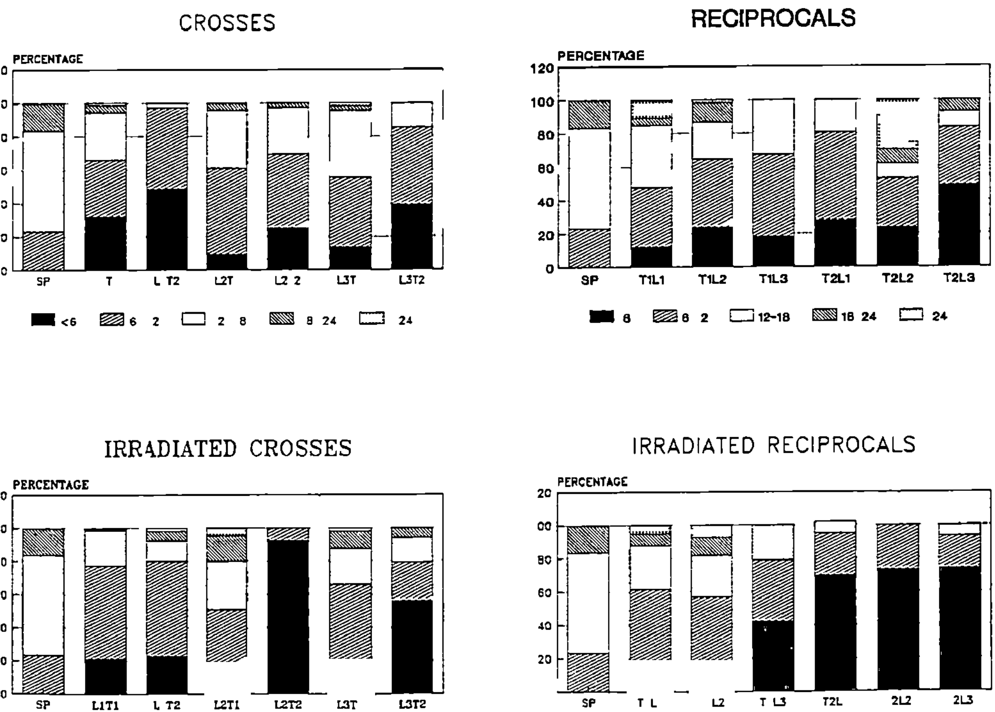
The results are presented in Table 50 The parents, F_2's and F_2M_2's showed significant differences for this trait Among the crosses, T_1 x L_1 and L_2 x T_2I recorded the maximum (13 37) and minimum (4 41) values respectively for this trait Only one cross T_1 x L_1 registered mean value greater than the standard variety, 'Punjab Padmini'

The F_2's and F_2M_2 populations registered very high coefficient of variation compared to their parents The frequency distribution of plants for this trait showed that in majority of the crosses, maximum proportion of plants belonged to the category of 6-12 fruits per plant (Figure 17) The proportion of plants with less than six fruits was higher among F_2's compared to their parents However, few transgressive segregants producing more than 24 fruits were also obtained in the crosses, T_1 x L_1, T_2 x L_2 and T_1 x L_1I

Length of fruit

The results are presented in Table 51 The three cultivated accessions differed significantly with respect to

FIG. 17 PROPORTION OF RECOMBINANTS - NUMBER OF FRUITS PER PLANT



and F_2M_2 generations

Treatment	Adjusted Mean	Range (coefficient of variation in parenthesis)	Number of plants under each class(percentage in parenthesis) <6	6 12	12 18	18 24	>24	Per cent Increase over standard parent
J	c 12	3 14 (33 04)	5 (16 7)	19 (63 3)	6 (20 0)	Nil	Nil	
L_2	11 46	3 24 (44 26)	2 (6 7)	13 (43 3)	13 (43 3)	1 (3 3)	1 (3 3)	
L_3	14 40	8 18 (17 74)	Nil	5 (16 7)	23 (76 7)	2 (6 7)	Nil	
SP	13 36	8 19 (22 16)	Nil	7 (23 3)	18 (60 0)	5 (16 7)	Nil	
T_1	9 23	6 14 (28 16)	Nil	22 (73 3)	8 (26 7)	Nil	Nil	
T_2	30 30	20 50 (23 18)	Nil	Nil	Nil	2 (6 7)	28 (93 3)	
L_1xT_1	12 82	0 26 (58 68)	28 (31 8)	30 (34 1)	25 (28 4)	4 (4 5)	1 (1 14)	4 04
T_1xL_1	13 37	0 29 (50 19)	8 (11 9)	24 (35 8)	25 (37 3)	3 (4 5)	7 (10 4)	0 07
L_1xT_2	5 01	1 12 (61 71)	18 (48 6)	18 (48 6)	1 (2 7)	Nil	Nil	62 50*
T_2xL_1	7 16	1 12 (53 69)	10 (27 8)	19 (52 8)	7 (19 4)	Nil	Nil	46 41**
L_2xT_1	9 51	2 16 (39 75)	8 (2)	45 (51 7)	30 (34 5)	4 (4 6)	Nil	28 82**
T_1xL_2	9 45	0 24 (58 76)	27 (23 9)	46 (40 7)	25 (22 1)	13 (11 5)	2 (1 8)	29 27**
L_2xT_2	9 06	0 18 (5 84)	9 (25 0)	16 (44 4)	10 (27 8)	1 (2 8)	Nil	32 19**
T_2xL_2	6 90	0 36 (64 67)	8 (23 5)	10 (29 4)	3 (8 8)	3 (8 8)	10 (29 4)	48 35**
L_3xT_1	10 40	0 28 (43 07)	15 (13 4)	47 (42 0)	45 (40 2)	3 (2 7)	2 (1 8)	22 16*
T_1xL_3	9 17	4 16 (35 13)	17 (17 9)	47 (49 5)	31 (32 6)	Nil	Nil	31 36**

(contd)

Treatment	Adjusted Mean	Range (Coefficient of variation in parenthesis)	class(percentage in parenthesis) <6	6 12	12 18	18 24	>24	Per cent increase over standard parent
L_3xT_2	6 32	0 12 (47 79)	16 (39 0)	19 (46 3)	6 (14 6)	Nil	Nil	52 69**
T_2xL_3	6 32	2 19 (66 72)	21 (48 8)	15 (34 9)	4 (9 3)	3 (7 0)	Nil	52 69**
L_1xT_1I	8 65	2 16 (42 29)	14 (21 2)	37 (56 1)	14 (21 2)	1 (1 5)	Nil	35 25**
T_1xL_1I	10 56	2 26 (55 70)	14 (12 5)	35 (43 8)	21 (26 3)	6 (7 5)	4 (5 0)	20 96**
L_1xT_2I	6 09	2 23 (60 03)	15 (22 7)	38 (57 4)	8 (12 1)	4 (6 1)	1 (1 5)	54 42**
T_2xL_1I	4 66	1 14 (64 30)	41 (69 5)	15 (25 4)	4 (6 8)	Nil	Nil	65 12**
L_2xT_1I	11 62	2 28 (132 59)	11 (16 9)	22 (33 8)	19 (29 2)	10 (15 4)	3 (4 6)	13 02
T_1xL_2I	11 27	1 28 (57 46)	14 (17 3)	32 (39 5)	20 (24 7)	9 (11 1)	6 (7 4)	15 64
L_2xT_2I	2 68	0 8 (70 33)	24 (92 3)	2 (7 7)	Nil	Nil	Nil	79 94**
T_2xL_2I	4 27	2 8 (36 57)	19 (73 1)	7 (26 9)	Nil	Nil	Nil	68 04
T_1xL_3I	10 25	2 24 (54 34)	11 (19 6)	26 (46 4)	12 (21 4)	6 (10 7)	1 (1 8)	23 28**
T_1xL_3I	7 04	0 13 (44 81)	24 (42 1)	31 (54 4)	12 (21 1)	Nil	Nil	47 31**
L_3xT_2I	7 16	0 18 (70 77)	19 (55 9)	8 (23 5)	5 (14 7)	2 (5 9)	Nil	46 41**
T_2xL_3I	4 41	0 14 (55 72)	34 (73 9)	9 (19 6)	3 (6 5)	Nil	Nil	66 99**

CD (0 05) 2 70

FIG. 18 PROPORTION OF RECOMBINANTS - LENGTH OF FRUIT

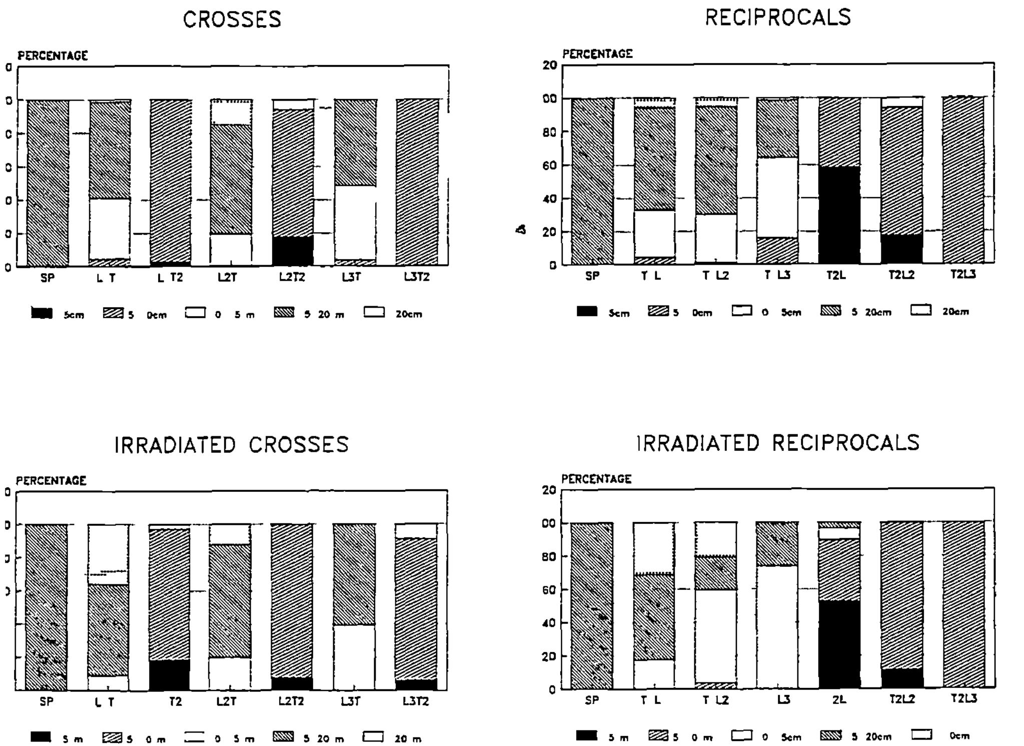


Table 51 Variations for fruit length in F_2 and F_2M_2 generations

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis) <5	5 10	10 15	15 20	>20	Percent increase over standard parent
L_1	21 28	18 0 25 5 (11 09)	Nil	Nil	Nil	3 (10 0)	27 (90 0)	
L_2	18 12	16 0 24 0 (11 26)	Nil	Nil	Nil	21 (70 0)	9 (30 0)	
L_3	18 06	15 5 19 5 (15 74)	Nil	Nil	5 (16 7)	25 (83 3)	Nil	
SP	17 18	15 0 19 0 (8 58)	Nil	Nil	Nil	30 (100 00)	Nil	-
T_1	15 36	13 8 17 5 (3 82)	Nil	Nil	4 (13 3)	26 (86 7)	Nil	
T_2	3 73	3 2 4 2 (4 78)	30 (100 00)	Nil	Nil	Nil	Nil	
L_1xT_1	13 31	8 0 20 0 (17 20)	Nil	4 (4 5)	32 (36 4)	51 (58 0)	1 (1 1)	22 5*
T_1xL_1	15 33	8 5 21 5 (41 89)	Nil	3 (4 5)	19 (28 4)	41 (61 2)	4 (6 0)	10 77*
L_1xT_2	6 64	3 8 8 1 (14 42)	1 (2 7)	36 (7 3)	Nil	Nil	Nil	61 35**
T_2xL_1	5 71	4 1 7 4 (34 11)	21 (58 3)	15 (41 7)	Nil	Nil	Nil	66 76**
L_2xT_1	16 54	12 5 24 0 (15 08)	Nil	Nil	17 (19 5)	50 (57 5)	13 (14 9)	3 73
T_1xL_2	15 24	7 5 24 5 (17 17)	Nil	1 (0 9)	33 (29 2)	73 (64 6)	6 (5 3)	11 29*
L_2xT_2	7 21	6 1 8 1 (6 37)	Nil	36 (100 00)	Nil	Nil	Nil	58 03**
T_2xL_2	4 28	3 5 13 2 (46 86)	6 (17 6)	26 (76 5)	2 (5 9)	Nil	Nil	75 09**

(contd)

Table 51 (contd)

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis) <5	5 10	10 15	15 20	>20	Percent increase over standard parent
L_3xT_1	13 63	8 17 3 (15 82)	Nil	4 (3 6)	50 (44 6)	58 (51 8)	Nil	-20 66**
T_1xL_3	13 22	8 0 20 0 (20 64)	Nil	15 (15 8)	46 (48 4)	33 (34 7)	1 (1 1)	-23 05**
L_3xT_2	6 76	6 0 8 5 (7 21)	Nil	41 (100 00)	Nil	Nil	Nil	60 65**
T_2xL_3	8 26	5 8 7 0 (9 90)	Nil	43 (100 00)	Nil	Nil	Nil	51 92**
L_1xT_1I	18 48	14 5 24 (18 26)	Nil	Nil	6 (9 1)	36 (54 5)	24 (36 4)	7 57
T_1xL_1I	17 8	12 5 28 (32 57)	Nil	Nil	14 (17 5)	41 (51 3)	25 (31 2)	3 61
L_1T_2I	6 87	4 0 10 (19 02)	12 (18 2)	52 (78 8)	2 (3 0)	Nil	Nil	60 61**
T_2xL_1I	5 66	3 0 16 (46 86)	21 (35 6)	22 (37 3)	4 (6 8)	2 (3 4)	Nil	67 05**
L_2xT_1I	16 61	12 0 24 (15 34)	Nil	Nil	13 (20 0)	44 (67 7)	8 (12 3)	-3 32
T_1xL_2I	16 51	12 5 22 (13 53)	Nil	3 (3 7)	45 (55 6)	16 (19 8)	17 (21 0)	3 90
L_2xT_2I	7 37	4 8 8 1 (11 72)	2 (7 7)	24 (92 3)	Nil	Nil	Nil	-57 10**
T_2xL_2I	6 27	4 0 7 8 (14 52)	3 (11 5)	23 (88 5)	Nil	Nil	Nil	63 50**

(contd)

Table 51 (contd)

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis) <5	5 10	10-15	15 20	>20	Percent increase over standard parent
L_3xT_1I	16 94	12 0-18 (7 49)	Nil	Nil	22 (39 3)	34 (60 7)	Nil	-1 40
T_1xL_3I	13 37	12 16 8 (7 54)	Nil	Nil	42 (73 7)	15 (26 3)	Nil	22 18**
L_3xT_2I	8 27	4 5 14 2 (30 42)	2 (5 9)	29 (85 3)	3 (8 8)	Nil	Nil	51 86**
T_2xL_3I	6 17	5 4 8 5 (14 89)	Nil	46 (100 00)	Nil	NIl	Nil	-6409**

C D (0 05) 1 39

* Significant at 5% level
**Significant at 1% level

this yield component L_1 was found superior to L_2 and L_3 with a mean length of 21 28 cm The F_2's were found significantly inferior compared to their cultivated parents Among the parents T_2 recorded the lowest mean value (3 73 cm) for this trait The mean fruit length of the crosses of T_2 was significantly lesser than the corresponding crosses of T_1 However, there was significant increase in the mean length of the crosses compared to the parent, T_2 The crosses T_2 x L_1I (46 86) and L_2 x T_2 (6 37) registered the maximum and minimum coefficient of variations respectively for this character

Most of the plants of the crosses involving T_2 parent belonged to the category of 5-10 cm whereas all other crosses registered the maximum number of plants in the 15-20 cm range Several recombinants with more than 20 cm fruit length were observed particularly in the crosses T_1 x L_1I, L_1 x T_1I and T_1 x L_2I (Figure 18)

Girth of fruit

The results are presented in Table 52 The crosses involving T_2 parent had less mean value for this trait as compared to the crosses of T_1 The coefficient of variation was also generally less for this trait except in the case of L_1 x T_2I (75 86%) Majority of the plants had mean girth of

Table 52 Variations for girth of fruit in F_2 and F_2M_2 generations

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis) <5	5-6	6 7	>7	Percent increase over standard parent
L_1	7 98	6 8 8 5 (4 77)	Nil	Nil	26 (86 7)	4 (13 3)	
L_2	6 26	5 2 7 8 (8 26)	NIl	1 (3 3)	29 (96 7)	Nil	
L_3	5 28	4 8 5 8 (4 19)	Nil	30 (100 00)	Nil	Nil	
SP	6 59	5 5-7 3 (7 00)	Nil	1 (3 3)	29 (96 7)	Nil	
T_1	7 50	7 0 8 2 (5 35)	Nil	Nil	25 (83 3)	5 (16 I)	
T_2	4 20	3 2 4 5 (7 67)	6 (20 0)	24 (80 0)	Nil	Nil	
L_1xT_1	6 64	4 2 9 8 (17 94)	Nil	16 (18 2)	49 (55 7)	23 (26 1)	0 76
T_1xL_1	6 94	4 4 9 1 (17 41)	Nil	12 (17 9)	38 (56 7)	17 (25 4)	5 31
L_1xT_2	5 33	2 5 8 1 (22 26)	5 (13 5)	24 (64 9)	8 (21 6)	Nil	-19 12**
T_2xL_1	5 15	3 1-8 2 (21 09)	Nil	19 (52 8)	14 (38 9)	3 (8 3)	21 85**
L_2xT_1	7 00	5 8 8 2 (9 36)	Nil	Nil	79 (90 8)	8 (9 2)	6 22
T_1xL_2	6 63	4 4 8 5 (15 8)	Nil	29 (25 7)	70 (61 9)	14 (12 4)	0 61
L_2xT_2	5 85	4 2 7 1 (12 01)	NIl	16 (44 4)	20 (55 6)	Nil	11 23
T_2xL_2	4 44	3 5-7 5 (26 53)	3 (8 8)	18 (52 91)	13 (38 10)	Nil	32 63**

(contd)

Table 52 (contd)

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis)				Percent increase over standard parent
			<5	5 6	6-7	>7	
L_3xT_1	6 12	4 2 9 4 (16 61)	Nil	39 (34 8)	69 (61 6)	4 (3 6)	-7 13
T_1xL_3	6 60	4 9 8 1 (10 96)	Nil	14 (14 7)	80 (84 2)	1 (1 1)	-0 15
L_3xT_2	5 65	4 8 6 5 (8 88)	Nil	20 (48 8)	21 (51 2)	Nil	14 26**
T_2xL_3	6 20	4 4 8 5 (11 08)	Nil	20 (46 5)	16 (37 2)	7 (16 3)	-5 92
L_1xT_1I	7 42	5 4 8 5 (7 80)	Nil	1 (1 5)	52 (78 8)	13 (19 7)	12 59
T_1xL_1I	7 23	5 4 8 4 (7 85)	Nil	1 (1 3)	73 (91 2)	6 (7 6)	9 71
L_1xT_2I	5 50	3 5 9 6 (75 86)	13 (19 7)	25 (37 9)	28 (42 4)	Nil	16 54**
T_2xL_1I	4 16	2 5 6 5 (35 10)	21 (35 6)	16 (27 1)	22 (37 3)	Nil	-36 87**
L_2xT_1I	6 80	4 0 8 2 (11 00)	Nil	7 (10 8)	53 (81 5)	5 (7 7)	3 19
T_1xL_2I	6 76	4 2 8 2 (16 62)	Nil	21 (25 9)	48 (59 3)	12 (14 8)	2 58
L_2xT_2I	6 14	4 2 7 8 (16 89)	Nil	12 (46 2)	14 (53 8)	Nil	6 83

(contd 2)

Table 52 (contd)

Treatment	Adjusted mean (cm)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis)				Percent increase over standard parent
			<5	5 6	6-7	>7	
T_2xL_2I	5 40	2 5-6 8 (18 84)	1 (3 9)	7 (26 9)	18 (69 2)	Nil	18 06**
L_3xT_1I	6 34	5 1 7 8 (13 41)	Nil	26 (46 4)	30 (53 6)	Nil	3 79
T_1xL_3I	7 73	4 5 8 0 (11 13)	Nil	8 (14 0)	48 (84 2)	1 (1 8)	17 30**
L_3xT_2I	5 22	3 2 7 0 (21 77)	6 (17 6)	12 (35 3)	16 (47 1)	Nil	-20 79**
T_2xL_3I	4 58	2 4 7 0 (26 48)	9 (19 6)	24 (52 2)	13 (28 2)	Nil	-30 50**

C D (0 05) 0 76

* Significant at 5% level

**Significant at 1% level

fruit between 6 and 7 cm However, few recombinants with more than 8 cm for this trait were also available particularly in crosses, L_1 x T_1 and T_1 x L_1

Single fruit weight

The mean fruit weight of the crosses was significantly lesser than the parents except in the case of L_1 x T_1I and T_1 x L_1 Twentyfive per cent of the crosses recorded high coefficient of variations for this trait (Table 53) Maximum number of plants had mean weight between 10-15 g However, several recombinants having more than 20 g for this trait were also available The crosses T_1 x L_1 and L_1 x T_1I recorded maximum number of recombinants with mean fruit weight greater than 290 gm (Figure 19)

Weight of fruits per plant

The results are presented in Table 54 Among the parents, L_2 recorded the highest yield (228 50 g) whereas among the F_2's T_1 x L_1 recorded the maximum value (227 04 g) for this trait All other F_2's were found inferior compared to other cultivar parents The F_2's of crosses of T_1 (*A caillei*) recorded significantly higher yield in all the combinations as compared to the crosses of T_2, *A tetraphyllus*

FIG. 19 PROPORTION OF RECOMBINANTS - SINGLE FRUIT WEIGHT

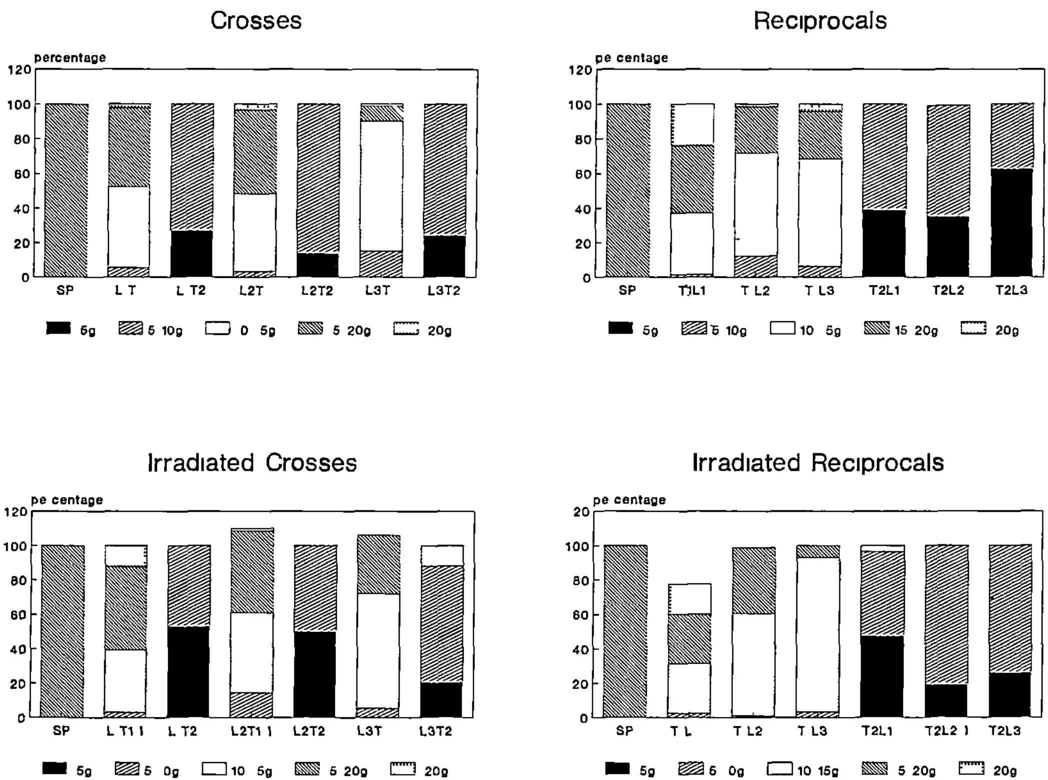


Table 53 Variations for single fruit weight in F_2 and F_2M_2 generations

Treatment	Adjusted mean (g)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis) <5	5 10	10 15	15 20	>20	Percent increase over standard parent
L_1	23 31	20 29 0 (11 85)	Nil	Nil	Nil	Nil	30 (100 00)	
L_2	18 36	16 5 22 5 (10 56)	Nil	Nil	Nil	20 (66 7)	10 (33 3)	
L_3	15 76	13 0 18 0 (8 05)	Nil	Nil	5 (16 7)	25 (83 3)	Nil	
SP	15 49	15 18 5 (8 41)	Nil	Nil	Nil	30 (100 00)	Nil	
T_1	17 59	15 5 20 (6 97)	Nil	Nil	Nil	28 (93 3)	2 (6 7)	
T_2	6 42	4 5 8 (7 94)	18 (60 0)	12 (40 0)	Nil	Nil	Nil	
L_1xT_1	12 90	9 5 22 (31 83)	Nil	5 (5 7)	41 (46 6)	40 (45 4)	2 (2 3)	16 72
T_1xL_1	16 18	8 5 21 5 (38 90)	Nil	1 (1 5)	24 (35 8)	26 (38 8)	16 (23 9)	4 45
L_1xT_2	5 12	4 0 5 5 (9 17)	10 (27 0)	27 (73 0)	Nil	Nil	Nil	66 95**
T_2xL_1	4 89	3 5 5 5 (12 71)	14 (35 9)	22 (61 1)	Nil	Nil	Nil	68 43**
L_2xT_1	14 72	8 5 20 5 (16 84)	Nil	3 (3 4)	39 (44 8)	42 (48 4)	3 (3 4)	4 97
$T_1x L_2$	12 57	7 0 20 (19 21)	Nil	14 (12 4)	67 (59 3)	30 (26 5)	2 (1 8)	18 85*
L_2xT_2	5 65	4 5 7 (52 16)	5 (13 9)	31 (86 1)	Nil	Nil	Nil	63 52**
T_2xL_2	4 20	3 5 7 5 (17 03)	12 (35 3)	22 (64 7)	Nil	Nil	Nil	72 89**

(contd)

Table 53 (contd)

Treatment	Adjusted mean (g)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis)					Percent increase over standard parent
			<5	5-10	10-15	15-20	>20	
L_3xT_1	11 22	6 0-22 (10 17)	Nil	17 (15 2)	84 (75 0)	10 (8 9)	1)(0 9)	-27 57**
T_1xL_3	13 03	8 0-26 (16 54)	Nil	6 (6 3)	59 (62 1)	26 (27 4)	4 (4 2)	-15 88
L_3xT_2	5 20	3 5 6 5 (62 18)	10 (24 4)	31 (75 6)	NIl	Nil	Nil	-66 43**
T_2xL_3	6 48	4 0-6 0 (13 91)	27 (62 8)	16 (37 2)	Nil	Nil	Nil	58 17**
L_1xT_1I	15 7	8 0-24 (19 15)	Nil	2 (3 0)	24 (36 4)	32 (48 5)	8 (12 1)	1 36
T_1xL_1I	14 72	8 0 25 (20 40)	Nil	2 (2 5)	23 (28 8)	23 (28 8)	14 (17 5)	4 97
L_1xT_2I	5 28	3 0-9 0 (77 3)	35 (53 0)	31 (47 0)	Nil	Nil	Nil	-65 91**
T_2xL_1I	4 04	2 5 12 (42 13)	28 (47 5)	29 (49 1)	2 (3 4)	Nil	Nil	73 92**
$L_2 xT_2$	14 64	8 0 23 (21 17)	Nil	3 (4 6)	30 (46 2)	31 (48 7)	1	-5 49
$T_2 xL_2$	14 20	8 0 19 (17 31)	Nil	1 (1 2)	48 (59 3)	31 (38 3)	Nil	8 33
L_2xT_2 I	5 43	3 5-6 8 (15 88)	13 (50 0)	13 (50 0)	Nil	Nil	Nil	64 95**
T_2xL_2I	5 34	3 5-6 5 (17 50)	5 (19 2)	21 (80 8)	Nil	Nil	Nil	-65 53*

(contd)

Table 53 (contd)

Treatment	Adjusted mean (g)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (Percentage in parenthesis) <5	5 10	10-15	15-20	>20	Percent increase over standard parent
L_3xT_1I	13 91	10 0 16 (16 45)	Nil	3 (5 4)	34 (60 7)	19 (33 9)	Nil	-10 20
T_1xL_3I	12 32	8 0 15 (13 54)	Nil	2 (3 5)	51 (89 5)	4 (7 0)	Nil	20 46*
L_3xT_2I	6 09	4 0 14 (48 32)	7 (20 6)	23 (67 6)	4 (11 8)	NIl	Nil	60 68**
T_2xL_3I	4 85	3 5-7 5 (22 00)	12 (26 1)	34 (73 9)	Nil	Nil	Nil	-68 69**

C D (0 05) 2 87

* Significant at 5% level

**Significant at 1% level

FIG. 20 PROPORTION OF RECOMBINANTS - WEIGHT OF FRUITS PER PLANT

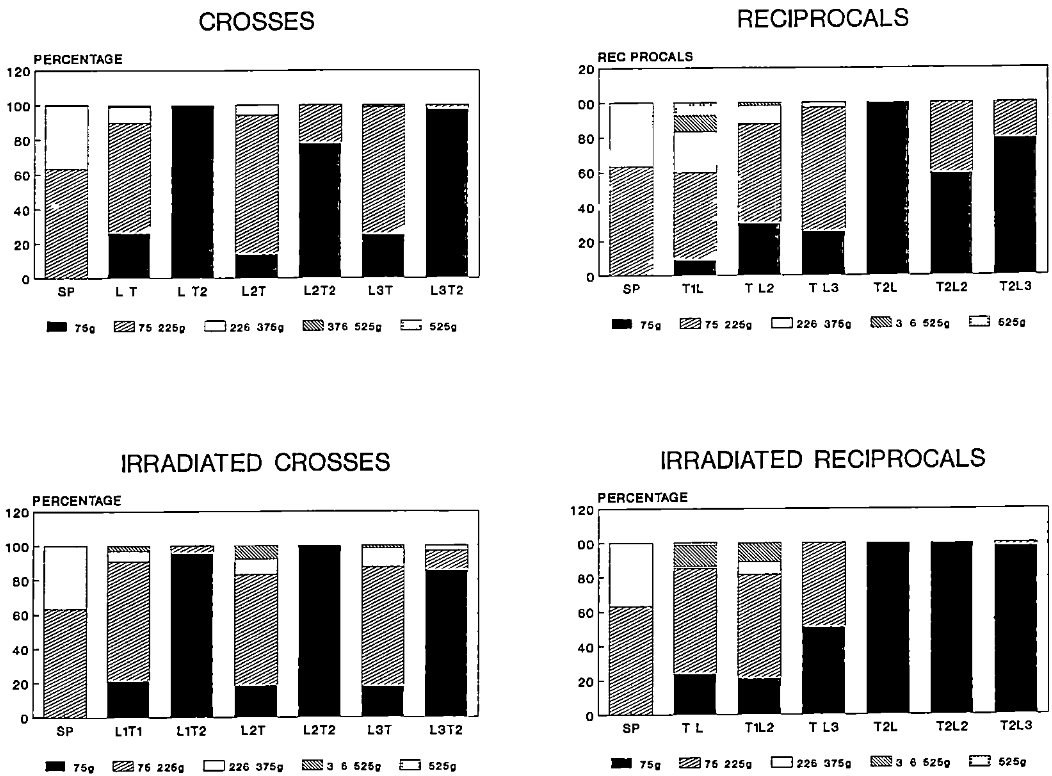


Table 54 Variation for weight of fruits per plant in F_2 and F_2M_2 generations

Treatment	Adjusted Mean (g)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <75	75 225	226 375	376 525	>525	Per cent Increase over standard parent
L_1	132 54	72 396 (70 48)	1 (3 3)	14 (46 7)	14 (46 7)	1 (3 3)	Nil	
L_2	228 50	100 540 (53 99)	2 (6 7)	15 (50 0)	11 (36 7)	1 (3 3)	1 (3 3)	
L_3	223 17	120 310 (21 17)	Nil	13 (43 3)	17 (56 7)	Nil	Nil	
SP	231 40	140-350 (27 60)	Nil	19 (63 3)	11 (36 7)	Nil	Nil	
T_1	162 87	94 250 (29 03)	Nil	26 (86 7)	4 (13 3)	Nil	Nil	
T_2	185 08	100 286 (25 02)	Nil	24 (80 0)	6 (20 0)	Nil	Nil	
$L_1 \times T_1$	115 43	0 416 (76 95)	23 (26 10)	56 (63 6)	8 (9 1)	1 (1 1)	Nil	50 12
$T_1 \times L_1$	227 04	0 672 (68 27)	6 (9 0)	34 (50 6)	16 (23 9)	6 (9 0)	5 (7 5)	1 88
$L_1 \times T_2$	31 76	4 70 (63 11)	37 (100 0)	Nil	Nil	Nil	Nil	86 27
$T_2 \times L_1$	32 89	0-70 (57 65)	36 (100 0)	Nil	Nil	Nil	Nil	85 79
$L_2 \times T_1$	140 97	27 270 (38 06)	12 (13 8)	70 (80 5)	5 (5 7)	Nil	Nil	39 08
$T_1 \times L_2$	130 17	0 440 (72 71)	34 (30 1)	65 (57 5)	12 (10 6)	2 (1 8)	Nil	43 75
$L_2 \times T_2$	44 64	0 99 (65 83)	28 (77 8)	8 (22 2)	Nil	Nil	Nil	80 71
$T_2 \times L_2$	67 32	0 195 (91 48)	20 (58 8)	14 (41 2)	Nil	Nil	Nil	70 91
$L_3 \times T_1$	118 10	0 616 (60 09)	28 (25 0)	83 (74 1)	Nil	Nil	1 (0 9)	48 96
$T_1 \times L_3$	122 79	27 276 (44 68)	24 (25 3)	68 (71 6)	3 (3 2)	Nil	Nil	46 94

(contd)

Table 54 (contd)

Treat m rt	Adjus-ted Mean (g)	Range (coefficient of variati n in paren-thesis)	Number of plants under each class(percentage in parenthesis) <75	75-225	226-375	376-525	>525	Per cent Increase over standard parent
L_3xT_2	33 19	0 84 (80 22)	40 (7 6)	1 (2 4)	Nil	Nil	Nil	85 66
T_2xL_3	46 35	10 136 (59 57)	37 (79 1)	9 (20 9)	Nil	Nil	Nil	-79 97
L_1xT_1I	139 27	30 396 (54 28)	14 (21 2)	46 (69 7)	4 (6 1)	2 (3 0)	Nil	-39 81
T_1xL_1I	169 16	24 572 (80 99)	19 (23 8)	49 (61 3)	1 (1 3)	10 (12 5)	1 (1 3)	26 90
L_{1xT2}^{I}	31 14	8 110 (68 84)	63 (95 5)	3 (4 5)	Nil	Nil	Nil	86 54
T_2xL_1I	18 54	0-60 (86 80)	59 (100 0)	Nil	Nil	Nil	Nil	91 99
L_2xT_1I	177 98	24-480 (63 98)	12 (18 5)	42 (64 6)	6 (9 2)	5 (7 7)	Nil	23 09
T_1xL_2I	165 19	0-504 (74 06)	17 (21 0)	49 (60 5)	6 (7 4)	9 (11 1)	Nil	28 61
L_2xT_2I	13 60	0-40 (78 94)	26 (100 0)	Nil	Nil	Nil	Nil	94 12
T_2xL_2I	22 73	6-48 (43 70)	26 (100 00)	Nil	Nil	Nil	Nil	90 18
L_3xT_1I	121 86	20-384 (80 84)	10 (17 9)	39 (69 6)	6 (10 7)	1 (1 8)	Nil	47 34
T_1xL_3I	85 09	0-196 (55 51)	29 (50 9)	28 (49 1)	Nil	Nil	Nil	63 23
L_3xT_2I	35 10	0 252 (72 28)	29 (85 3)	4 (11 8)	1 (2 9)	Nil	Nil	84 83
T_2xL_3I	21 43	0 78 (73 16)	45 (97 8)	1 (2 2)	Nil	Nil	Nil	90 74

CD(0 05) 49 60

Great variation for weight of fruits per plant was registered by the F_2 population It was as high as 91 48 per cent in F_2 of T_2 x L_2 and 86 80 per cent in F_2 of T_2xL_1I Among the parents, L_1 showed considerable variation for this character (70 48 per cent)

All the plants of the wild relatives had yield less than 375 g per plant All the F_2's showed a negative trend for weight of fruits per plant with majority of the plants being distributed in the category of < 225 g per plant (Figure 20) Majority of the F_2 plants of crosses involving T_2 produced very low yield (< 75 g per plant) Few recombinants with higher yield (> 525 g) were also obtained from the present experiment

Yellow vein mosaic intensity

The results are presented in Table 55 There was significant difference among the treatments for yellow vein mosaic intensity Among the parents, the lowest disease intensity was shown by L_3 which was significantly lesser compared to L_1 and L_2 The parent, L_2 registered the highest mean score of 4 39 The semiwild parent T_1 was completely free from disease with a mean score of one

The F_2 of L_1 x T_1I recorded the maximum, coefficient of variation (61 53 per cent) for this trait

G. 21 PROPORTION OF RECOMBINANTS - YVMD INCIDNENCE

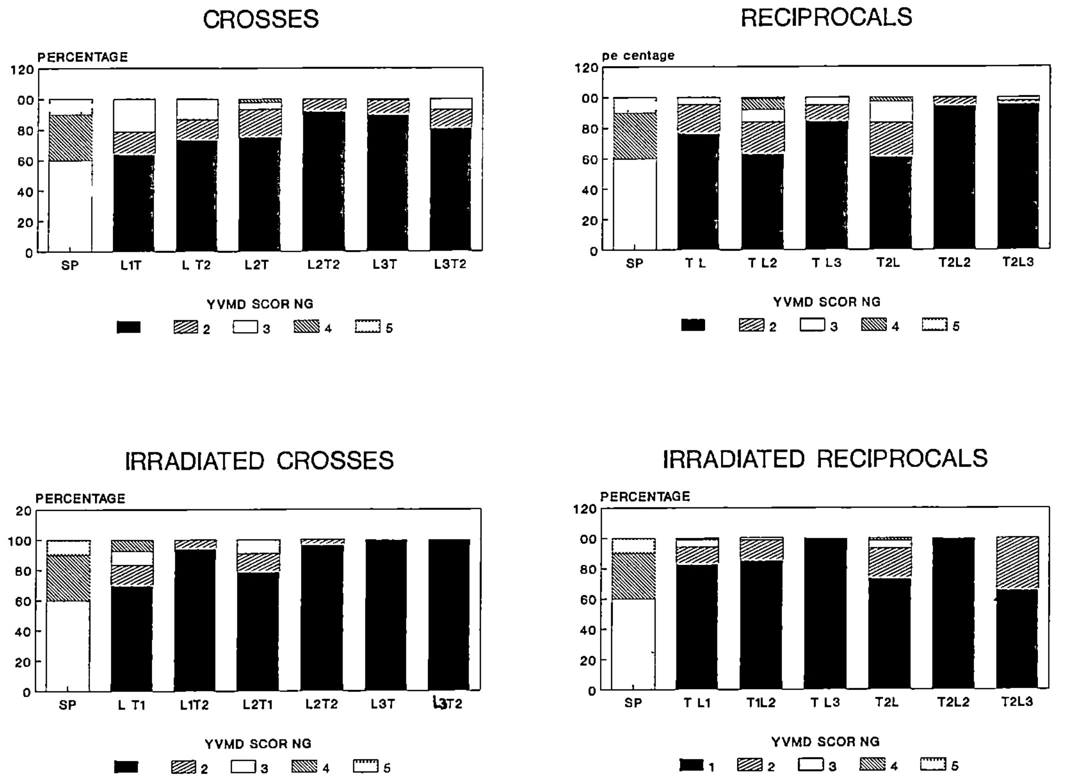


Table 55 Variations for Yellow vein mosaic incidence in F_2 and F_2M_2 generations

Treatments	Adjusted Mean (score)	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) 1	2	3	4	5	Per cent increase over standard parent
L_1	4 24	3 0-5 0 (21 30)	Nil	Nil	9 (3 0)	2 (3 7)	10 (63 3)	
L_2	4 39	3 0-5 0 (17 50)	Nil	Nil	5 (16 7)	9 (30 0)	16 (53 3)	
L_3	2 82	1 0 4 0 (23 70)	1 (3 3)	7 (23 4)	19 (63 3)	3 (10 0)	Nil	
SP	3 52	3 0-5 0 (19 50)	Nil	Nil	18 (60 0)	9 (30 0)	3 (10 0)	
T_1	1 00	1 0 (0)	30 (100 0)	Nil	Nil	Nil	Nil	
T_2	1 19	1 0-2 0 (32 50)	25 (83 3)	5 (16 7)	Nil	Nil	Nil	
L_1xT_1	1 56	1 0-3 0 (51 99)	56 (63 6)	3 (14 8)	19 (21 6)	Nil	Nil	55 68**
T_1xL_1	1 27	1 0 3 0 (42 59)	51 (76 1)	13 (19 4)	3 (4 5)	Nil	Nil	63 92**
L_1xT_2	1 42	1 0-3 0 (51 41)	27 (73 0)	5 (13 5)	5 (13 5)	Nil	Nil	59 66**
T_2xL_1	1 61	1 0-4 0 (52 89)	22 (61 1)	8 (22 2)	5 (13 9)	1 (2 8)	Nil	-54 26**
L_2xT_1	1 32	1 0-4 0 (41 92)	65 (74 1)	16 (18 4)	4 (4 6)	2 (2 3)	Nil	62 50**
T_1xL_2	1 57	1 0 5 0 (59 67)	11 (62 8)	24 (21 8)	9 (8 0)	8 (7 1)	1 (0 9)	-5 40**
L_2xT_2	1 10	1 0-2 0 (25 72)	33 (91 7)	3 (8 3)	Nil	Nil	Nil	68 75**
T_2xL_2	1 01	1 0-2 0 (22 53)	32 (94 1)	2 (5 9)	Nil	Nil	Nil	-71 31**
L_3xT_1	1 09	1 0-2 0 (30 85)	100 (89 3)	11 (9 8)	1 (0 9)	Nil	Nil	69 03**

(contd)

Table 55 (contd)

Treat-ments	Adju-sted Mean (score)	Range (Coeffi-cient of varia-tion in paren-thesis)	Number of plants under each class (percentage in parenthesis) 1	2	3	4	5	Per cent increase over stand-ard parent
T_1xL_3	1 18	1 0-3 0 (43 29)	80 (84 2)	10 (10 5)	5 (5 3)	Nil	Nil	-66 48**
L_3xT_2	1 28	1 0-3 0 (46 67)	33 (80 5)	5 (12 2)	3 (7 3)	Nil	Nil	63 64**
T_2xL_3	1 07	1 0-3 0 (31 86)	41 (95 4)	1 (2 3)	1 (2 3)	Nil	Nil	-69 60**
L_1xT_1I	1 53	1 0-4 0 (61 53)	46 (69 7)	9 (13 6)	6 (9 1)	5 (7 6)	Nil	-56 53**
T_1xL_1I	1 24	1 0-4 0 (48 09)	66 (82 5)	9 (11 3)	4 (5 0)	1 (1 2)	Nil	-64 77**
L_1xT_2I	1 06	1 0-2 0 (22 47)	62 (93 9)	4 (6 1)	Nil	Nil	Nil	-69 89**
T_2xL_1I	1 34	1 0 4 0 (49 14)	43 (72 9)	12 (20 3)	3 (5 1)	1 (1 7)	Nil	61 9 *
L_3xT_1I	1 30	1 0 3 0 (48 88)	51 (72 3)	8 (12 3)	6 (9 3)	Nil	Nil	63 0 **
T_1xL_2I	1 14	1 0-3 0 (34 64)	69 (85 2)	11 (13 6)	1 (1 43)	Nil	Nil	-67 **
L_2xT_2I	1 07	1 0-2 0 (18 68)	25 (96 2)	1 (3 8)	Nil	Nil	Nil	-69 60**
T_2xL_2I	1 02	1 0 (0 0)	26 (100 0)	Nil	Nil	Nil	Nil	-71 02**
L_3xT_1I	1 00	1 0 (0 0)	56 (100 0)	Nil	Nil	Nil	Nil	71 59**
T_1xL_3I	1 0	1 0 (0 0)	57 (100 0)	Nil	Nil	Nil	Nil	-71 59**
L_3xT_2I	1 02	1 0 (0 0)	36 (100 0)	Nil	Nil	Nil	Nil	71 02**
T_2xL_3I	1 37	1 0-2 0 (35 41)	30 (65 2)	16 (34 8)	Nil	Nil	Nil	-61 08**

CD(0 05) 0 45

Majority of the F_2's showed comparatively low coefficient of variation (< 50 per cent) for this trait

The frequency distribution for this character has shown the high susceptibility of L_1 and L_2 to yellow vein mosaic disease (Figure 21) More than 50 per cent of the population of L_1 and L_2 was under the score 5 indicating the maximum expression of symptoms Among the progeny, T_2 x L_2I, L_3 x T_1I, T_1 x L_3I and L_3 x T_2I have shown complete resistance against this disease with a mean score of one Among the F_2's only one plant (T_1 x L_2) belonged to the extreme susceptibility group with a mean score of five All the crosses recorded desirable negative heterosis for this trait as compared to the standard variety 'Punjab Padmini'

Among the crosses, T_1 x L_1I and T_1 x L_2I recorded the maximum number of (11) high yielding (> 350 g/plant) yellow vein mosaic disease resistant recombinants (mean score = 1) followed by T_1 x L_1 (10) and L_2 x T_1I (9) (Table 57 and Plates 13-16)

Fruit borer incidence

The results are presented in Table 56 The treatments differed significantly for fruit borer infestation The semi wild parent T_1 recorded least infestation by this pest (7 42 per cent) whereas T_2 recorded

FIG. 22 PROPORTION OF RECOMBINANTS - FRUIT BORER INCIDENCE

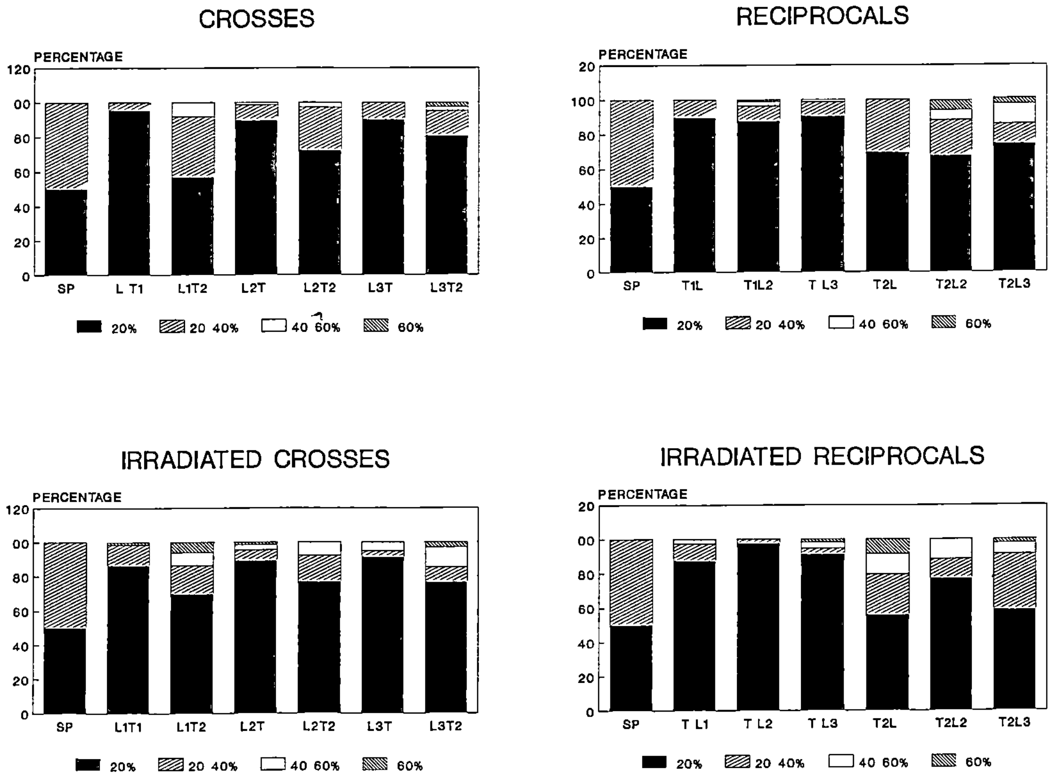


Table 56 Variations for percentage of fruit borer incidence in F_2 and F_2M_2 generations

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) >20	20 40	40-60	>60	Per cent increase over standard parent
L_1	11 68	0 30 (89 06)	18 (60 0)	12 (40 0)	Nil	Nil	
L_2	13 08	0 40 (100 12)	21 (70 0)	8 (26 7)	1 (3 3)	Nil	
L_3	16 75	10 40 (66 50)	21 (70 0)	7 (23 3)	2 (6 7)	Nil	
SP	14 42	0 30 (81 62)	15 (50 0)	15 (50 0)	Nil	Nil	
T_1	7 42	0 30 (127 80)	26 (86 7)	4 (13 3)	Nil	Nil	
T_2	83 08	20 60 (41 38)	Nil	19 (63 3)	9 (30 0)	2 (6 7)	
L_1xT_1	0 83	0 60 (72 22)	83 (95 4)	4 (4 6)	Nil	Nil	92 94
T_1xL_1	4 61	0 30 (4850)	60 (89 6)	7 (10 4)	Nil	Nil	68 03
L_1xT_2	16 71	0 40 (75 91)	21 (56 8)	13 (35 10)	3 (8 8)	Nil	15 88
T_2xL_1	14 73	0-40 (84 07)	25 (69 4)	11 (30 6)	Nil	Nil	2 15
L_2xT_1	2 32	0 40 (231 57)	78 (89 7)	8 (9 2)	1 (1 1)	Nil	83 91
T_1xL_2	2 60	0-60 (203 07)	99 (87 6)	10 (8 8)	3 (2 70)	1 (0 9)	-81 97
L_2xT_2	11 12	0-40 (104 95)	26 (72 2)	9 (25 0)	1 (2 80)	Nil	22 88
T_2xL_2	14 42	0-60 (115 34)	23 (67 6)	7 (20 6)	2 (5 9)	2 (5 4)	0 00
L_3xT_1	2 73	0 30 (144 15)	101 (90 2)	11 (9 8)	Nil	Nil	81 07

(contd)

Table 56 (contd)

Treatments	Adjusted Mean	Range (Coefficient of variation in parenthesis)	Number of plants under each class (percentage in parenthesis) <20	20 -40	40 60	>60	Per cent increase over standard parent
T_1xL_3	3 96	0 40 (141 35)	86 (90 5)	8 (8 4)	1 (1 05)	Nil	72 54
L_3xT_2	10 10	0 60 (136 06)	33 (80 6)	6 (14 6)	1 (2 4)	1 (2 4)	29 96
T_2xL_3	14 76	0 60 (119 07)	32 (74 4)	5 (11 6)	5 (11 6)	1 (3 4)	2 36
L_1xT_1I	6 11	0 60 (184 03)	57 (86 4)	8 (12 1)	Nil	1 (1 5)	57 63
T_1xL_1I	4 48	0 40 (160 68)	70 (87 5)	8 (10 0)	2 (2 5)	Nil	68 93
L_1xT_2I	18 82	0 70 (88 71)	46 (69 7)	11 (16 7)	5 (7 6)	4 (6 0)	30 51
T_2xL_1I	15 35	0 80 (128 09)	33 (55 9)	14 (23 7)	7 (11 9)	5 (8 5)	6 45
L_2xT_1I	5 21	0 60 (203 87)	58 (89 2)	4 (6 2)	2 (3 1)	1 (1 5)	63 87
T_1xL_2I	0 33	0 30 (313 82)	79 (97 5)	2 (2 5)	Nil	Nil	97 71
L_2xT_2I	12 79	0 40 (106 96)	20 (76 9)	4 (15 4)	2 (7 7)	Nil	11 30
T_2xL_2I	11 31	0 50 (146 27)	20 (77 0)	3 (11 5)	3 (11 5)	Nil	21 57
L_3xT_1I	3 48	0 50 (264 89)	51 (91 1)	2 (3 6)	3 (5 3)	Nil	75 87
T_1xL_3I	3 96	0 60 (245 83)	52 (91 2)	2 (3 5)	2 (3 5)	1 (1 8)	72 54
L_3xT_2I	10 45	0 50 (183 75)	26 (76 5)	3 (8 8)	4 (11 8)	1 (2 9)	27 53
T_2xL_3I	16 91	0 60 (147 73)	27 (58 7)	15 (32 6)	3 (6 5)	1 (2 2)	17 27

CD(0 05) 8 92

the maximum infestation (33 08 per cent) Among the cultivated parents, L_3 showed significantly higher infestation (33 08 per cent) as compared to other parents The F_2's and F_2M_2's of T_1 recorded lesser infestation similar to their wild parent A *caillei* (Figure 22)

Isolation of recombinants

On evaluation of the F_2 and F_2M_2 progeny, fifty seven plants (Table 57) recorded significantly higher yield coupled with yellow vein mosaic resistance (score 1) Since a severe outbreak of the disease was noticed during the season, the plants were selected based on field screening The selected plants were also subjected to grafting However in most of the cases grafting failed due to the over thickness and maturity of the root stock

Among the crosses, T_1 x L_1I and T_1 x L_2I recorded the maximum number (11) of recombinants (Figure 23) followed by T_1 x L_1 (10) and L_2 x T_1I (9)

FIG.23 HIGH YIELDING RESISTANT RECOMBINANTS

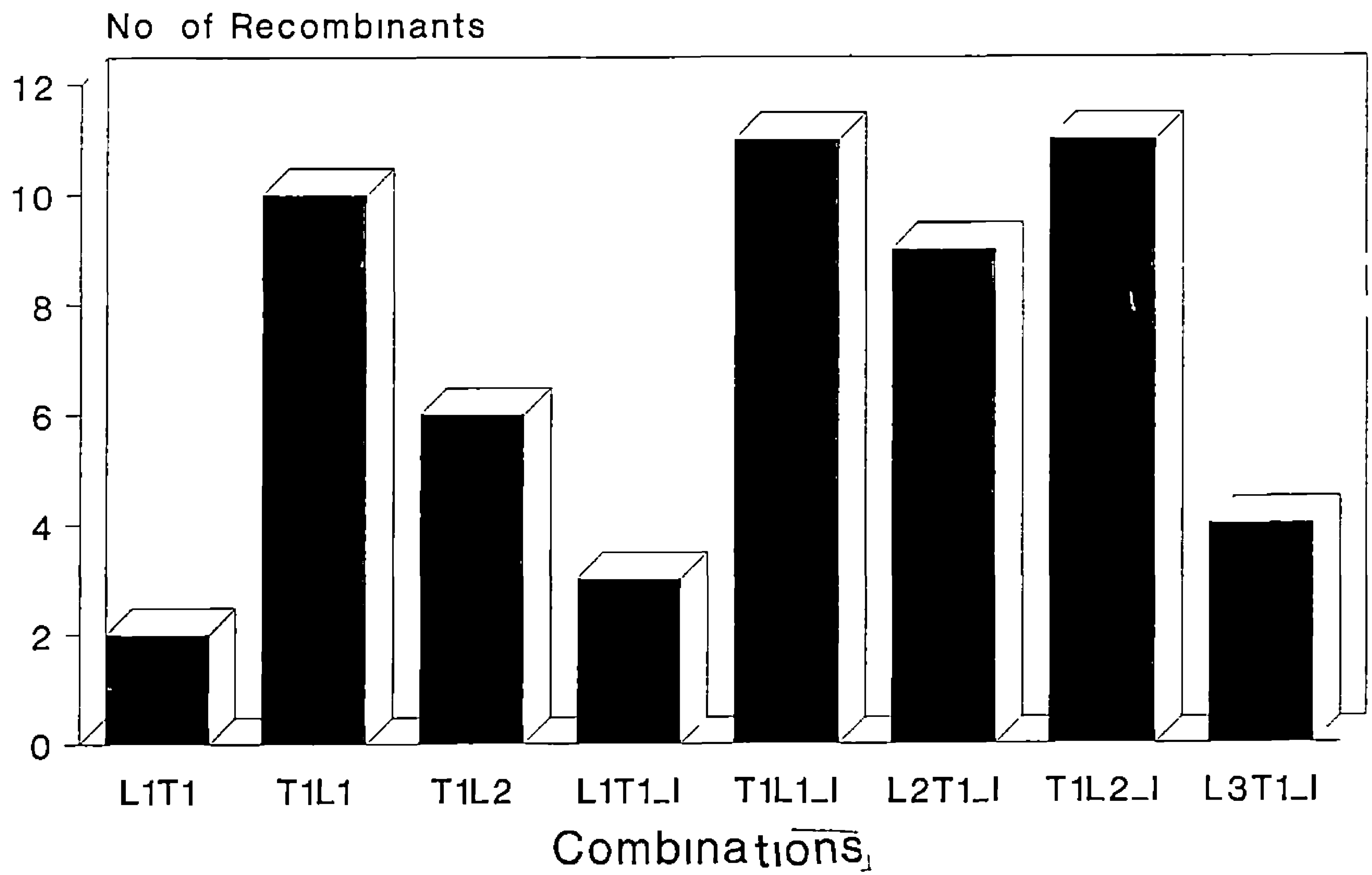


Table 57 High Yielding Resistant Recombinants

Sl No	Combinations	Number of Yellow vein mosaic disease free recombinants having Weight of fruits per plant	
		> 250	> 525 gm
1	L_1xT_1	2	-
2	T_1xL_1	10	5
3	T_1xL_2	6	-
4	L_3xT_1	1	1
5	L_1xT_1I	3	-
6	T_1xL_1I	11	-
7	L_2xT_1I	9	-
8	T_1xL_2I	11	-
9	L_3xT_1I	4	-

DISCUSSION

DISCUSSION

Okra or Lady's finger commonly known as Bhindi in India is one of the most important fruit vegetables, cultivated throughout the tropics and warmer parts of the temperate zone Germplasm collections have been made both from indigenous as well as from exotic sources and are being utilized in the different parts of the country The major emphasis being given to develop high yielding varieties capable of giving more marketable yield of dark green, tender thin, medium long, smooth, 4-5 ridged pods However in Kerala, long light green fruits fetches higher price than the dark green thin fruits Hence location specific breeding for varieties of high yield potential is of paramount importance in this crop The most serious disease affecting the production of Okra is yellow vein mosaic disease which has been reported to cause losses between 50 per cent and 90 per cent Generally intervarietal hybridization has been used for the improvement of cultivated species The wide crosses will increase the available gene pool In addition specific genes for resistance to diseases, insect pests and other edaphic stresses can be transferred from the wild related species Several resistant varieties have been released in different parts of our country utilizing the resistant genes from wild sources However most of these varieties were found to be susceptible under Kerala conditions Hence the present study aimed at producing high yielding resistant genotypes displaying resistance under Kerala conditions

Germplasm collection comprising of 56 genotypes were evaluated and three varieties *viz* Aanakkompan, Eanivenda and AE1 were selected as parents Based on resistance and compatibility, two wild relatives namely *A caillei* (A Chev) Stevels (*A manihot* ssp *manihot*) and *A tetraphyllus* (Roxb ex Hornem) R Graham var *tetraphyllus* (*A manihot* ssp *tetraphyllus*) were selected as donor parents The earlier attempts on interspecific hybridization has shown the preponderance of resistant plants having wild characters in the F_2 generation of these wide crosses (Mathews 1986) Cheriyan (1986) was able to induce variability on the interspecific hybrids of *Abelmoschus* through irradiation Moreover several scientists have reported the use of irradiation for inducing recombinants in wide crosses However, according to Konzak (1981), the recovery of recombinants without associated undesirable traits may require only screening of a very large segregating population from one or more of several crosses In the present study, both approaches have been attempted to isolate recombinants having YVMD resistance

5 1. Evaluation of Bhindi germplasm

In a breeding programme, progenies derived from diverse crosses are expected to show a broad spectrum of genetic variability providing a greater scope for isolating high yielding segregates in the advanced generations Genetic diversity has been analysed in many crops but such studies in Bhindi are very much limited

On the basis of seventeen quantitative characters, the fifty six accessions were grouped into four clusters The same line of study was earlier carried out by Girenko and Pugachev (1982), grouping the three hundred accessions into thirteen basic groups However, in the present study only four clusters were obtained which may be due to the reduced number of accessions available in the germplasm collection

The highest intercluster distance was noted between clusters III and IV There appeared a parallel and similar intra and inter cluster divergence, although, the clusters vary in their constituents Based on the inter cluster distance, the cluster IV was found to be highly divergent from all other clusters The close relationship between the clusters I and III based on inter-cluster distance suggested similarities of natural and human selection operated during the development of these types However, the work on this aspect was meagre in this crop The genetic differences between the clusters were reflected in their cluster means The clusters differed among each other for one or more characters Cluster I recorded highest mean value for yield and most of the economic characters except the fruit traits Its divergence from cluster III was confirmed by the lowest mean value of this cluster for majority of the yield components

Several workers reported that the clustering pattern could be utilised in choosing parents for cross combinations likely to generate the highest possible variability for various economic characters Theoretically the maximum amount of heterosis or recombination will be manifested in cross combinations involving parents belonging to most divergent clusters However, the present study mainly aimed at transferring YVMD resistance from the wild relatives to cultivated elite genotypes rather than the exploitation of heterosis alone Hence, selection indices were also constructed to identify the best genotypes from the available clusters Based on this, three lines were selected for hybridization programme The top ranking accession (Eanivenda) belonged to the cluster IV and the other two accessions *viz* AE1 and Aanakkompan belonged to the clusters I and II respectively No variety was selected from the cluster III, the cluster having the lowest mean value

Cataloguing of the accessions based on IBPGR descriptors had also been attempted so as to identify suitable accessions in future, based on the specific objectives of the breeding programme

5 1.1 Variability, heritability and genetic advance in Bhindi germplasm

Yield components

The variability available in the breeding material is important in the selection of superior plant types The genetic variation of quantitative characters is influenced by environmental factors The total variability can be partitioned into its heritable and non heritable components with the help of genetic parameters like genotypic coefficient of variation, heritability and genetic advance Hence an attempt had been made in the present study to elucidate these parameters in Bhindi germplasm as well as among the interspecific hybrids of Bhindi

Significant varietal differences were observed for all the characters except stem girth, YVMD incidence and leaf webber attack All the plant characters studied in Bhindi by many earlier workers (Singh and Singh, 1978 b Mishra and Chhonkar, 1979, Kaul et *al* , 1979 Murthy and

Bavaji, 1980 and Balachandran, 1984) recorded significant differences among genotypes

Moderate to high phenotypic as well as genotypic coefficient of variations were recorded for most of the economic attributes except number of leaves per plant, days to flowering, fruit length and first fruiting node The high estimates of phenotypic and genotypic coefficient of variation recorded for number of fruits on branches and number of branches per plant in agreement with the observations of Singh and Singh (1979) and Balachandran (1984) Moderate Phenotypic coefficient of variation (PCV) and Genotypic coefficient of variation (GCV) were recorded for yield and its major components like number of fruits per plant and single fruit weight This was also supported by the findings of many earlier workers (Majumdar *et al* , 1974 Kulkarni, 1977 Rao *et al* , 1977 Thaker *et al* , 1981 and Balakrishnan, 1988) The characters namely fruit girth, fruit length, first fruiting node and days to flowering displayed very low GCV supported by the findings of Balachandran (1984) This observation differs from that of Trivedi and Prakash (1969) who obtained greater variability for length and thickness of pods High genetic variability for number of days to flowering was reported by Rao (1972) and for pod length by Mishra and Chhonkar (1979) Parthap *et al* (1980) and Murthy and Bavaji (1980) also highlighted the contribution of length of fruits to total divergence in the population The difference in the observations is attributed to the different populations involved in the studies

Heritable variation may be effectively used with greater degree of accuracy when heritability was studied in conjunction with genetic advance (Majumdar *et al* , 1974) A high genetic gain along with high heritability shows the most effective condition of selection In the present study, high heritability estimates were observed for all the characters except number of leaves per plant and number of flowers per plant This finding was in consonance with the reports of several scientists (Rao, 1972, Kulkarni, 1977, Rao *et al* , 1977 Mishra and Chhonkar, 1979 Vashista *et al* , 1982 and Elmaksoud et *al* , 1986) However, the observation regarding fruit yield was in contrary to the observations of Lal *et al* (1973) and Balachandran (1984)

The low heritability estimates recorded for number of leaves per plant and number of flowers per plant indicated significant environmental influence on this character The genotypic as well as phenotypic coefficients of variation were also comparatively low for these characters High heritability coupled with high genetic advance as percentage of mean were recorded for plant height, leaf area, weight of fruits per plant and number of seeds per fruit confirming the preponderance of additive genes in controlling the expression of these traits This result is in accordance with that of Balakrishnan and Balakrishnan (1988) It therefore appears that selection for these characters should be effected for practical purposes However, the observation regarding total fruit yield was in contrary to the findings of Lal *et al* (1977) and Balachandran (1984) who suggested nonadditive gene action for this trait Low heritability combined with low genetic advance as percentage of mean was observed for number of leaves and flowers per plant This indicated that the scope for improving these characters through selection is very much limited and this may be attributed to the nonadditive gene effects on these traits

High heritability with low genetic advance was recorded for the economic traits including number of fruits per plant, days to flowering, fruit length and single fruit weight Therefore high heritability alone does not result in increased genetic advance This indicated that nonadditive gene action was operative in the inheritance of these characters

The nonadditive gene action recorded for days to flower was in conformity with the findings of Kulkarni *et al* (1978 b) However the present finding was contrary to that of Rao and Sathyavathi (1977) For number of pods also additive gene action was reported by Kulkarni *et al* (1978

b) whereas Parthap (1980) observed non additive gene action for this trait The present study also indicated nonadditive gene action for length and girth of fruit single fruit weight and number of ridges per fruit.

YVMD incidence

Moderate phenotypic coefficient of variation (PCV) was recorded for this trait However, the GCV was found to be less than half of PCV This indicated narrow range of variation for YVMD resistance in Bhindi germplasm This was in disagreement with the findings of Kaul *et al* (1979) The finding supported the need for interspecific breeding programme for generating variability so as to help in screening resistant genotypes The low heritability coupled with very low genetic advance suggested preponderance of nonadditive gene action for this trait Since this disease is a vector transmitted one, environment plays an important role in the spread of inoculum Hence, the intensity of disease symptoms depends greatly on environmental factors Sharma and Dhillon (1983) also reported that the genes responsible for resistance to virus are sensitive to the environmental changes This accounts for the low heritability recorded for this trait during the present investigation

5 1 2 Association studies

Association studies provide reliable information on nature, extent and direction of selection The efficiency of selection mainly depends upon the direction and magnitude of association between yield and its components Correlation studies provide estimates of the degree of the association of yield with its components and also association among the components The estimation of the direct and indirect effects of yield components on yield will help in the simultaneous improvement of many characters in directed crop evolution

The correlation studies among quantitative characters and YVMD resistance unveiled interesting aspects The results on correlation indicated similar trend in genotypic and phenotypic correlations In general genotypic correlations were higher than the phenotypic correlations Fruit yield was found to be significantly correlated with leaves per plant, leaf area, flowers per plant, fruits per plant, fruit girth, single fruit weight, branches per plant and fruits on branches The strong positive correlation of number of fruits per plant on fruit yield was in accordance with the findings of several earlier workers (Kohle and Chauhan, 1967 Roy and Chhonkar, 1976, Mahajan and Sharma, 1979, Elangovan *et al* , 1980, Ariyo, 1992 Vashista *et al* , 1992)

Singh *et al* (1974) and Parathap *et al* (1979) reported significant positive correlation between fruit yield and number of flowers per plant in accordance with the present finding Negative but non-significant correlation was observed between yield and days to flowering in conformity with the findings of Korla and Rastogi (1978) who suggested selection of early flowering types with a large number of fruits for yield improvement in this crop Positive but non-significant correlation existed between fruit yield and plant height in contrary to the findings of Vashista (1982)

Length and girth of fruit were reported to be important in selection programmes by many workers In the present study significant positive correlation of fruit girth and single fruit weight with yield was observed whereas length of fruit recorded positive but non significant correlation with yield However many scientists have earlier identified fruit length as one of the traits having strong positive association with yield (Mahajan and Sharma, 1979)

Path analysis also identified number of fruits per plant as the trait having maximum positive direct effect on yield, followed by single fruit weight Number of flowers per plant recorded the maximum negative direct effect on yield

Breeding for disease resistance requires information on the association of resistance with other economic characters The correlation of fruit length with YVMD incidence was found to be positive and significant But the direct effect of fruit length on YVMD incidence was negative Therefore the positive association of fruit length on YVMD incidence may be resulting from its indirect influence through the other traits Number of branches per plant recorded the maximum positive effect indicating that non branching types were more resistant as compared to the highly branching genotypes The present finding was in agreement with the reports of Arumugam and Muthukrishnan (1979)

Mathews (1986) also reported significant positive association of YVMD intensity with number of branches per plant and length of fruits However negative association was reported by Mathews (1986) between YVMD incidence and days to flowering in disagreement with the present finding Direct selection of early flowering plants having large number of fruits can be practiced for improving the yield

Significant negative association of YVMD incidence was observed with fruit girth and plant height The direct effects of plant height on YVMD incidence were also found to be negative Therefore selection of tall plants will be useful for isolating resistant lines Days to flowering had positive correlation and direct effect indicating that late varieties were more susceptible to this disease than the early accessions Padda *et al* (1970) reported positive correlation of YVMD incidence with plant height and days to flowering

Interrelations between characters gives an idea about the effect of selection for one character on the improvement of other traits The present study identified number of leaves per plant, leaf area, number of flowers per plant, number of fruits per plant, girth of fruit, single fruit weight and number of branches per plant as the major yield components in Bhindi The study also suggested the selection of tall shybranching, early flowering types with increased fruit weight for improving YVMD resistance in Bhindi

5 1.3 Irradiation dose

Recombination is a key process in the creation of genetic variation The recombination of linked genes is brought about by crossing over Undesirable linkage is one of the major hindrances in transferring useful genes from wild to cultivated species Genes are inherited in blocks which cannot be separated by hybridization Thus, the available potential for recombination is not fully realised in hybridization programmes It is therefore desirable to increase recombination, particularly to break gene blocks in which there is negligible crossing over Further release of genetic variability and independent assortment of linked loci can be expected if recombination in the F_1 can be enhanced

The effects of several doses of gamma ray irradiation were studied so as to identify the optimum dose for inducing recombinations in interspecific hybrids

The results indicated gradual reduction in germination survival on 30th day, plant height on 15th day, plant height at maturity, pollen fertility and seed fertility up to 50 Kr, then followed by a sharp reduction The 70 Kr dose was found to be lethal leading to more than 50% reduction for these traits This was in accordance with the findings of Abraham and Bhatia (1984) and Jeevanandam *et al* (1986) However, Nirmaladevi (1982) and Cheriyan (1986) reported that even low doses of gamma irradiation (16-25 Kr) induced variability for qualitative and quantitative characters of interspecific hybrids However, the preponderance of wild types was also observed by them suggesting that higher doses of gamma ray irradiation need to be employed in inducing recombinants having the characters of cultivated types coupled with the resistance of wild relatives Hence based on the present study, the dose close to the lethal dose, 60 Kr, was selected as the optimum dose for inducing breaks in closely linked genes so as to release the variability present in the interspecific hybrids for effecting selection of resistance types

5 2 Interspecific crossing behaviour

A esculentus, *A moschatus*, *A caillei* and *A tetraphyllus* ssp *tetraphyllus* were crossed in all the possible combinations No fruit set was obtained between *A moschatus* and the cultivated varieties indicating strong genetic barrier between these two species However Gadwal et al (1968) obtained viable hybrids of this species with *A esculentus*, *A ficulneus* and *A tuberculatus* through embryoculture technique Pushaparajan (1986) also reported that *A moschatus* is reproductively isolated from other species in conformity with the present finding According to Hamon and Charriar (1983) also, the species which differ most from other *Abelmoschus* species is *A moschatus*

In the present study, spontaneous hybrids were obtained in two species combinations Natural crossing between *A caillei* and *A tetraphyllus* ssp *tetraphyllus* was frequent The natural hybrids were very highly vigorous having almost double height than the parents These hybrids resembled the female parent *A caillei* in morphological characters However, dark pinkish colour of the *A tetraphyllus* was also present Floral characters were similar to the female parent whereas the spiny five ridged fruits resembled the male parent, *A tetraphyllus* ssp *tetraphyllus* The hybrids were found to be completely sterile producing unfilled seeds However, seed coat was found to be well developed Spontaneous hybrids were also obtained in the combination *A tetraphyllus* x *A caillei* The hybrids were also highly vigorous but resembled the female parent in most of the characters However, hybrids were not completely sterile as compared to the direct crosses Abraham (1985) isolated a mutant having the characteristics of *A tetraphyllus* from the M_2 progenies of *A esculentus* varieties Moreover, in the present study, natural crossing was observed between *A tetraphyllus* ssp *tetraphyllus* and the two cultivated species, *A caillei* and *A esculentus* This point towards the possibility of *A tetraphyllus* ssp *A tetraphyllus* as one of the common progenitors of these two cultivated species This finding was in conformity with the reports of Ugale *et al* (1976) that one genome is common between *A esculentus* and *A tetraphyllus* Sterility in these natural hybrids may be due to the extreme morphological as well as genomic differentiation of these species in the course of evolution and artificial selection for cultivation The fruit characters of *A tetraphyllus* ssp *tetraphyllus* were inherited in the hybrids showing its strong dominant nature The natural hybrids exhibited vegetative luxuriance and resembled the female parent in leaf and stem characters, like colour, spiny nature, number of leaf lobes etc This implies strong maternal influence on these characters Ariyo (1993) reported that the crosses between the two sub species of *A manihot* did not produce any plant even if the barriers were not as complete as seen with *A moschatus* species However, with regard to the inheritance of characters their finding was in agreement with the present finding that many characters of *A tetraphyllus* var *tetraphyllus* were expressed in the progeny like violet colour of the stem, heavy branching at the base, pubescence, shape and number of ridges of the fruits, thin diameter of the main stem and the branches and deeplobing nature of the leaves, especially when *A tetraphyllus* ssp *tetraphyllus* was used as the female parent Natural hybridization between *A tuberculatus* as one of the progenitors of Bhindi and *A esculentus* have been reported earlier by several scientists (Nair and Kuriachen, 1976) The present study points towards the involvement of *A tetraphyllus* ssp *tetraphyllus* contributing to the second genome of the cultivated species of *A esculentus*

Compatibility

The intervarietal difference in hybridization behaviour was observed in the present study One of the accessions of *A esculentus* Aanakkompan showed significant difference in fruitset when used as female parent in crosses with both the wild relatives In all the combinations the percentage of fruitset was almost double in the reciprocals than the direct crosses Contrary to this, the other two accessions of *A esculentus* recorded higher fruitset in the direct crosses than the reciprocals This may be due to some physical barrier present in Aanakkompan preventing fertilization The very tender nature of the peduncle of this accession may be one of the reasons for this low fruit set as compared to other accessions Hamon and Koechlin (1991 b) also reported intervarietal diversity in the number of ovules which must be fertilised to ensure fruit setting Aanakkompan, the top ranking accession used in the present study had eight to nine carpels Lack of pollen availability to fertilize minimum number of carpels to ensure fruitset may be one of the reasons for the low percentage of fruitset in this accession Swamy and Khanna (1991) also supported this view that the sparcity of pollen grains resulted in flower drop in the interspecific crosses Among the three accessions of *A esculentus* excessive flower drop was noticed in the case of Aanakkompan having more number of carpels than the other accessions Compatibility as measured by the crossability index was found to be higher in the reciprocal crosses as compared to the direct crosses Moreover, crossability index values were higher when *A tetraphyllus* was used as the female parent in agreement with the findings of Suresh Babu (1987) Cheriyan (1986) reported that no reciprocal difference in compatibility existed between these two species and *A esculentus* contrary to the present finding However, the reciprocal difference in compatibility obtained in the present study was in conformity with the observations of Mamidwar *et al* (1979) The reciprocal difference in compatibility of the crosses involving *A esculentus* and *A caillei* can be attributed to the higher ploidy status of *A caillei* as compared to *A esculentus*

5 3 Evaluation of F_1 and F_1M_1 generations

Combining ability is useful to assess the ability of the parents to produce superior hybrids in combination and at the same time to elucidate the nature of gene action involved In the present study line x tester analysis was used to study the general and specific combining ability (gca and sca) effects in the non-irradiated as well as irradiated hybrids excluding reciprocals The line x tester model helps in understanding the interaction between the lines (high yielding accessions of *A esculentus*) and testers (YVMD resistant wild relatives) The general combining ability of the parents and the nature of gene action involved for each character was assessed

In the line x tester analysis, the variances due to the lines were significant for most of the traits except number of fruits per plant, number of leaves per plant, first fruiting node, number of flowers per plant, fruit girth and percentage of germination But the variance due to testers was non-significant only for plant height and number of leaves per plant However, the variances due to parents *vs* hybrids were highly significant for most of the characters The variances due to parents *vs* hybrids were found to be insignificant for a few characters including plant height, stem girth, number of leaves, leaf area number of flowers and fruits per plant The non-significant variance recorded for number of flowers per plant and for number of fruits per plant may be due to the high sterility of these interspecific hybrids However the variances due to parents *vs* irradiated hybrids were found to be significant for all the characters except number of leaves per plant in consonance with the findings of Rao (1977) The difference between irradiated and non-irradiated crosses was also found to be significant for most of the traits pointing towards the usefulness of irradiation in inducing recombinants in interspecific hybrids Nirmaladevi (1982) and Cheriyan (1986) could also induce wide variability in interspecific hybrids through irradiation similar to present findings Significant line x tester interaction was noted for most of the traits including fruit yield per plant, number of branches, length, girth and weight of fruits and days to flowering which indicated that both additive and non-additive gene actions might be involved in their inheritance

From the perusal of the results, it is evident that the variance associated with gca and sca was non-significant for majority of the characters in agreement with the reports of Rao (1977) However, Vijay and Manohar (1986) reported highly significant gca effects for most of the economic characters in Bhindi

Gene action

The ratio of genetic components indicated non-additive gene action for all the traits except first fruiting node, petiole length, and single fruit weight which exhibited additive gene action Stem girth and fruit yield were found to be predominantly non-additive in inheritance

However, additive gene action was also involved in the inheritance of these two traits The study of gene action in the irradiated hybrids also revealed almost the same results except for fruit length and leaf area which showed additive gene action This may be due to effect of irradiation affecting markedly the inheritance of these two characters

Majority of the present findings were in tune with several earlier reports With regard to days to flowering Sharma and Mahajan (1978) and Singh and Singh (1978b) reported non-additive gene action similar to the present findings However according to Vijay and Manohar (1986), both additive and non-additive gene effects were involved in the inheritance of this trait The non-additive gene action observed for number of fruits per plant, fruit length and thickness was also in agreement with the findings of Singh and Singh (1978b) Hence heterosis breeding could be useful to improve these traits

The ratio σ^2gca/σ^2sca indicated additive inheritance for single fruit weight which was in contrary to the findings of Vijay and Manohar (1986) Hence this character could be easily fixed by careful selection Non-additive gene action was found to be predominantly involved in the inheritance of fruit yield per plant Parthap *et al* (1981) also reported the involvement of both additive and non additive gene action for fruit yield in Bhindi Hence methods like heterosis breeding and reciprocal recurrent selection could be followed by careful selection of parents

The additive gene action exhibited by the first fruiting node was also in tune with the findings of Parthap *et al* (1981) and Vijay and Manohar (1986)

Plant height and number of branches per plant exhibited non-additive gene action in agreement with the findings of Singh and Singh (1978b) and Vijay and Manohar (1986) It would be worthwhile to explore the possibilities of heterosis breeding for improving these characters

Number of seeds per fruit also recorded non-additive gene action YVMD incidence also was found to be nonadditively inherited in contrary to the reports of Veeraragavatham (1989) and Vashisht (1990)

Contribution to the total variance

Testers contributed maximum to the total variance of majority of the characters including pod yield per plant and length, girth and weight of fruits Lines differed significantly for two traits, number of fruits per plant and number of seeds per fruit The variances of the characters like plant height, percentage of germination, days to first flowering, number of flowers and YVMD incidence were found to have contributed mainly through the LXT interaction Same results were obtained both in the irradiated as well as non irradiated crosses for most of the characters

Combining ability

In a recombination breeding programme, selection of parents and hybrid combinations assumes great importance In the evaluation of parents and hybrids, their combining ability estimates for different traits were considered first

Among the testers, T_1 (*A caillei*) was found to be the better combiner for majority of the yield components including length, girth and weight of single fruit and pod yield per plant T_1 also exhibited negative gca effects for YVMD incidence revealing its good combining ability for YVMD resistance Eventhough several of the recently evolved varieties owe their resistant genes to T_2 (*A tetraphyllus*) (IBPGR, 1990) in the present study, T_1 (*A caillei*) was found to be the better source for exploiting YVMD resistance through interspecific breeding programmes However T_2 was found to be the better general combiner for days to flowering number of flowers per plant and number of fruits per plant

Among the lines, L_1 (Aanakkompan) recorded significant gca effect for fruit girth expressing its ability as good combiner for increased fruit thickness Moreover, Aanakkompan also recorded greater gca effect than L_2 (Eanivenda) and L_3 (AE1) for leaf area, branches per plant, fruits per plant, fruits on branches, fruit length and weight of fruits per plant indicating its good combining ability for these yield components Moreover the gca effect of Aanakkompan was also found to be negative for days to flowering, first fruiting node and YVMD resistance L_2 (Eanivenda) recorded significant gca effects only for petiole length However, L_2 was found to be the better combiner for single fruit weight as compared to the other two lines

In the case of majority of the traits, all the cross combinations recorded non significant sca effect L_1 x T_1 (Aanakkompan x *A caillei*) recorded significant negative sca revealing its early flowering nature L_3 x T_2 (AE1 x *A tetraphyllus*) recorded significant positive sca effect for fruit girth whereas L_3 x T_1 (AE1 x *A caillei*) recorded significant negative sca effect for this trait All other sca estimates were found to be non-significant It was obvious from the present study that the hybrids with the highest *per se* performance did not record the highest sca effect This could be expected since the gca effects are only estimates Further the sca effect in a cross represented a deviation from the average gca effects of its two parents and the exceptional performance of a cross need not necessarily result in large sca effect Moreover in the present study reciprocals were also included and the selection of cross combinations based on *per se* performance also assumes great importance

The *per se* performance revealed the superior nature of Aanakkompan over other lines Among the testers, T_1 (*A cailleі*) recorded better performance for majority of the yield components than the wild relative, *A tetraphyllus* in agreement with the results of gca estimates

Among the cross combinations, L_1 x T_1 (Aanakkompan x *A caillei*) recorded maximum value for pod yield/plant followed by L_2 x T_1 (Eanivenda x *A caillei*) All the irradiated hybrids recorded very low values for pod yield which can be ascribed to the lethality of many of the mutants With regard to fruit length also L_1 x T_1 was found to be the best combiner whereas L_2 x T_1 recorded the maximum value for single fruit weight The reciprocals recorded lower mean values for the yield components particularly among the non-irradiated crosses

Heterosis

Manifestation of heterosis for various economic traits has been reported in Bhindi Vijayaraghavan and Warrier (1946) reported increase in fruit size, fruit weight and number of fruits per plant in the F_1 hybrids Manifestation of heterosis in interspecific hybrids of Bhindi has also been reported by Suresh Babu and Dutta, 1990

Morphologically all plants of the interspecific hybrids looked alike and represented more towards the respective wild parent (Plates 10 and 11) The plants were erect in habit, robust and vigorous The hybrid vigour varied significantly among the hybrid combinations

Majority of the interspecific hybrids displayed significant negative heterosis over the mid parental as well as the better parental value for plant height However, few hybrids showing very high degree of positive heterosis in all the three types of comparisons were also obtained These findings were in agreement with the observations of Ugale *et al* (1976) Suresh Babu and Dutta (1990) also reported 23 82 percent heterosis for this trait One of the hybrids, Aanakkompan x *A manihot* exhibited relative heterosis as high as 113 01 per cent in the present study All the irradiated hybrids recorded negative heterosis for plant height which could be attributed to the general growth reduction caused as a result of irradiation The stem girth also showed the same trend

The hybrids were characterised by a later flowering date than the parents In the crosses involving A *esculentus* as female parent an advance in precocity was observed compared to others Eventhough most of the hybrids recorded significant positive heterosis for this trait, one hybrids displayed desirable negative heterosis The present finding was in conformity with the reports of Nirmaladevi, 1982 Meshram and Dhapke (1981) also reported significant negative hetero-beltiosis for days to flowering in interspecific crosses of A *esculentus* x A *tetraphyllus* Majority of the hybrids manifested significant positive heterosis for first fruiting node in all the three types of heterosis comparisons in agreement with the reports of Singh *et al* (1975)

Majority of the hybrids registered significant negative heterosis for number of fruits per plant in all the comparisons However, six hybrids showed desirable positive standard heterosis for this trait The hybrids L_2 x T_2 T_1 x L_3 L_1 x T_2 and L_1 x T_1 appeared to be promising in this regard Significant positive heterosis for number of fruits per plant has been reported by several workers (Lal *et al* , 1975, Kulkarni and Virupakshappa 1977 Elangovan *et al* , 1981 Balachandran, 1984 and Radhika, 1988) These findings point towards the possibility for exploiting hybrid vigour for this important yield component in Bhindi Among interspecific hybrids also significant heterosis for fruits per plant has been reported by Ugale et al (1976) Present study suggests the possibility for isolating crosses displaying significant desirable heterosis among interspecific crosses of Bhindi

Regarding fruit length, only two hybrids exhibited positive standard heterosis Majority of hybrids exhibited negative heterosis for this trait contrary to the findings of Nirmaladevi (1981) in interspecific hybrids of Bhindi Fruit girth also recorded the same trend All the hybrids exhibited negative heterosis in all the three types of comparisons for single fruit weight as well as weight of fruits per plant The heterosis percentage was comparatively higher among the irradiated crosses compared to the non-irradiated counter parts The hybrids of Aanakkompan and A *caillei* displayed lower estimates of negative heterosis in all the four sets

All the hybrids manifested significant negative relative heterosis, hetero-beltiosis and standard heterosis for YVMD incidence (Plate 12) Hetero-beltiosis being a function of overdominant gene action would lead to the generation of considerable variability resulting in transgressive segregants for economic traits The expression of resistance to YVMD by all the hybrids was found to be similar to that of the wild parent in agreement with the reports of Suresh Babu and Dutta (1990) This highlights the possibilities for developing YVMD resistant hybrids coupled with high yield and other desirable attributes in Bhindi Therefore, it would be worthwhile to include segregants showing resistance to YVMD as one of the donor parents in further breeding programmes

Sterility

In the present study, the F_2 population showed various degrees of breakdown Number of seeds per fruit varied within the cultivated species between 60 and 90 The hybrids had a high level of parthenocarpic fruits or those with five seeds frequently empty seeds at the most There was considerable reduction in germination of the F_2 seeds while the parents and the F_1's recorded high germination This indicated the possibility of elimination of hybrids in the post zygotic stage (Hossain and Chattopadhyay 1976) Generally the pollen viability of an okra plant varies round about 80% In the interspecific hybrids, it decreased to about 20% All the hybrids recorded high percentage of pollen sterility This resulted in low fruit setting in most of the hybrids This was in conformity with the findings of

Stebbins (1958) that in interspecific hybrids, the male gametes are more easily affected than the female ones However, Suresh Babu (1987) reported high pollen fertility in the interspecific hybrids, between A *esculentus* and A *tetraphyllus* According to him, megaspores developmental stages were abnormal and the sterility of the hybrids was attributed to the breakdown of entire megaspores

Eventhough reciprocal differences were seen in pollen fertility of the F_1's no reciprocal difference in seed setting percentage had been observed Moreover, the irradiated crosses recorded very low percentage of pollen fertility than the non-irradiated counter parts This was in conformity with the findings of Jeevananandam *et al* (1986)

Formation of fruits without seeds is a regular feature observed among most of the plants of all the cross combinations The formation of normal fruits without seeds may be due to some kind of stimulation after pollination (Pawan Kumar, 1966)

In the present study, in the crosses of A *esculentus* and A *tetraphyllus*, F_2 embryos failed to develop in the initial stage itself In the crosses of A *esculentus* x A *caillei* embryo formation was observed However, the embryo started deterioration due to endosperm degeneration Milky endosperm was seen up to one week Multiple layers of endothelium were also present in the dry seeds Seed coat development was also normal as in the case of spontaneous hybrids This was in conformity to the observations of Bhargava (1989) that embryo in ovules resulting from crosses between *A manihot* and *A esculentus* started abortion five days after pollination Gadwal et al (1968) also observed the same phenomenon in the interspecific crosses of *Abelmoschus* It appears that there is an intimate functional relationship between the endosperm and embryo such that normal development of the endosperm is essential for the proper development of the embryo Krishnamurthy (1988) reported that the endosperm exercises a normal control on the growth and differentiation of embryo Johri (1989) opined that there is a compatibility relationship between the endosperm, the embryo and integuments The prevalence of endoploidy was also reported in the endosperm (Hemaprabha, 1986) The wild relatives used in the present study were already having very high 2n numbers (Table 1) The occurrence of endoploidy or genomic segregation may be the reason for the endosperm abortion observed in the F_2 seeds leading to hybrid inviability

Evaluation of segregants

The scope for selection in the breeding population depends on the extent of altered mean values and genetic variability present in the segregating generations

The F_2's and F_2M_2's showed a general trend of reduction in majority of the characters studied Germination showed general reduction in F_2's and F_2M_2's than the corresponding hybrid population This can be attributed to the inviability of F_2 embryos as discussed earlier The mean height also showed a reducing trend The mean height was less in F_2M_2's than the F_2 population This may be due to the growth reduction caused as a result of irradiation in the segregating population The segregants also showed reduction in stem girth All the progenies of the crosses involving *A tetraphyllus* had slender stem as compared to the progeny of *A caillei* The F_2's had more variability for this trait than the F_2M_2's The less variability in the F_2M_2's may be due to the growth reduction as a result of irradiation with high dose of gamma rays used for inducing recombinations

Both the F_2's and F_2M_2's showed marked increase in number of leaves per plant Leaf area also recorded similar trend The leaves of the segregants resembled more towards their respective wild parents However the mean values of the progeny tended to be higher than their respective wild parents

Days to flowering showed an increasing trend in the segregating population The hybrids of *A tetraphyllus* were found to be earlier than the progeny of *A caillei*

Generally the F_2's were very late compared to the corresponding F_2M_2 population This may be due to the release of variability as a result of irradiation of the hybrids As regards the first fruiting node also, the segregants resembled their respective wild parents Combining ability studies also showed maximum contribution by the testers for this character Majority of the F_2M_2's tend to fruit at lower nodes than the F_2's F_2M_2's were also found to be more branching than the corresponding F_2's Considerable variation was showed by the irradiated cross AE1 x *A tetraphyllus* for this character

There was a general reduction in the mean values of the important yield components like number of flowers and number of fruits per plant This maybe due to the presence of sterile weak plants in the progeny F_2M_2's showed lesser mean values for this trait A E1 x *A caillei*, *A tetraphyllus* x Eanivenda and *A caillei* x Eanivenda recorded high mean values for number of flowers per plant However, these hybrids recorded lesser mean values for number of fruits per plant as a result of excessive fruit drop The segregants of the cross *A caillei* x Aanakkompan recorded increased mean value for this character over 'Punjab Padmini'

A general reduction in mean values was observed for fruit components namely fruit length and single fruit weight However, reduction was not marked for fruit girth The presence of high variability was found to be restricted to certain combinations for these traits Only one cross (L_1 x T_1 I) exhibited increase in fruit length over the standard cultivar 'Punjab Padmini' When compared to the F_2's, the F_2M_2's recorded higher mean values for length, girth and weight of fruits

All the hybrids recorded reduction in mean fruit yield per plant when compared to their parents The cross T_1 x L_1 recorded higher mean value for fruit yield than its donor parent *A caillei* The reduction in mean values for weight of fruits per plant can be attributed to the preponderance of low yielding plants resembling wild parents in the segregating population Moreover higher degree of sterility also was observed among the segregants which resulted in general reduction in mean values for weight of fruits per plant

The segregants resembled wild parents with regard to yellow vein mosaic resistance Majority of the segregants showed complete resistance under heavy epidemic condition

Both the F_2's and the F_2M_2s showed a significant decrease in mean percentage of fruit borer infestation Among the parents, *A caillei* (T1) showed maximum resistance to this pest This finding is in agreement with the reports of Mathews (1986) and that of Chelliah and

Sreenivasan (1983) The progeny of the crosses involving T1 (*A caillei*) also showed less infestation *A tetraphyllus* (T2) exhibited maximum infestation by this pest The progeny of the crosses involving T2 also recorded high infestation by this pest which was attributed to the preponderance of plants having fruit characters of wild parents The hairy nature of the fruits of *A tetraphyllus* was found to be preferred by this pest for egg laying

Selection of recombinants

The frequency distributions showed a definite reversal of the F_2 plants towards the wild parent with regard to majority of the traits studied However, considerable variability existed in the population for majority of the economic attributes Few recombinants having the characters of the cultivated parents coupled with the YVMD resistance of the wild relatives were isolated The recombinants were more frequent among the irradiated progeny indicating the desirable effect of gamma irradiation in inducing recombinations resulting from the breakage of undesirable linkages Maximum number (11) of recombinants having mean fruit yield higher than the standard cultivar coupled with YVMD resistance was isolated from the progeny of T_1 x L_1 I and T_1 x L_2 I followed by T_1 x L_1 (10)

Eventhough the L_1 x T_1 was identified as the best cross based on the *per se* performance of the hybrid population only two recombinants were isolated from its F_2 progeny Reciprocals also showed poor performance in the F_1 generation However, more number of recombinants were obtained from the reciprocals as compared to the direct crosses

In the present study, maximum number of recombinants were isolated from the irradiated population as shown in table 57 Out of the twenty four cross combinations, only nine had plants having medium to high yield coupled with resistance Majority of the segregants were low yielding and resembled their wild parents in many of the attributes

The study confirmed the useful effect of gamma irradiation in inducing recombinants in interspecific crosses of *Abelmoschus* T_1 x L_1I (*A caillei* x Aanakkompan) and T_1 x L_2I (*A caillei* x Eanivenda) were identified a~ the best crosses for the isolation of recombinants The isolated recombinants can be used in future breeding programmes for evolving yellow vein mosaic resistant varieties in Bhindi

SUMMARY

SUMMARY

Bhindi (*Abelmoschus esculentus* (L) Moench) is grown as one of the major vegetable crops in India Owing to its wide adaptability under different agroclimatic conditions, it is being cultivated throughout the country either as a commercial crop or in home gardens Yellow Vein Mosaic Disease (YVMD) is the most important constraint that stands in the way of augmenting the production potential of this crop The loss in yield due to this dreadful virus disease ranges from 50 to 90 per cent The presently recommended varieties like Pusa Sawani, Punjab Padmini etc although had tolerance to this disease at the time of release, the same is breaking down gradually Since chemical control of the disease is neither feasible nor practical on account of many reasons, the situation warrants the development of resistant varieties suitable to specific localities Fortunately, wild relatives of Bhindi were found to possess genes for resistance to this dreadful disease However, strong linkage which exists between the wild characters and disease resistance makes the transfer of disease resistance to the cultivated species difficult Hence the present study was undertaken with the main objective of inducing recombinants with high yield potential of cultivated varieties coupled

with disease resistance of wild species The salient features of the study are summarized hereunder

A preliminary evaluation of 56 accessions of Bhindi was carried out in a replicated trial during May-August' 1990 at the College of Agriculture, Vellayani Eight accessions of wild relatives were also evaluated in a separate trial for compatibility and disease resistance during the same season

On the basis of seventeen characters, the fifty six accessions were grouped into four clusters Cluster I registered the highest mean values for most of the yield components Selection indices were also constructed to identify the best genotypes Based on this, three accessions *viz* Aanakkompan (L_1), Eanivenda (L_2) and AE1 (L_3) were selected for hybridization programme from the clusters II, IV and I respectively The accessions were also catalogued based on IBPGR descriptors so as to enable selection of appropriate accessions for future programmes

The genetic parameters like genotypic coefficient of variation, heritability and expected genetic advance were also estimated All the characters displayed moderate to high phenotypic as well as genotypic coefficients of variation except number of leaves per plant, days to flowering, fruit length and first fruiting node

High heritability estimates were obtained for all the traits except number of leaves per plant and fruit girth indicating the low influence of environment and the scope for direct selection of these characters based on phenotypic performance Weight of fruits per plant, height of plant leaf area and number of seeds per fruit recorded high heritability and genetic advance estimates indicating that these characters are under the control of additive genes

High phenotypic coefficient of variation was recorded by yellow vein mosaic intensity However, genotypic coefficient of variation was found to be low indicating the narrow range of genetic variation present in the Bhindi germplasm for this trait Low heritability coupled with very low genetic advance suggested the predominant role of environment in the inheritance of YVMD resistance

Correlation studies revealed significant association of fruit yield with number of leaves per plant, leaf area, number of flowers per plant, number of fruits per plant, fruit girth single fruit weight, branches per plant and fruits on branches Path analysis also indicated the direct influence of number of fruits per plant and single fruit weight on yield Yellow vein mosaic incidence recorded significant negative correlation with height of plant and fruit girth Among the different characters influencing YVMD incidence, number of branches per plant and single fruit weight recorded the maximum positive and negative direct effects, respectively Days to flowering also registered high positive direct influence on YVMD incidence The results suggested the selection of early flowering, shybranching types with increased fruit thickness for exploiting resistance

The wild relatives were also evaluated in a separate trial to identify the best donor parent for resistance Studies indicated complete incompatibility between *A moschatus* and cultivated Bhindi varieties indicating its reproductive isolation from all other species The production of natural hybrids was observed between *A caillei* (*A manihot* ssp *manihot*) and *A tetraphyllus* These spontaneous hybrids exhibited vegetative luxuriance coupled with high degree of YVMD resistance However, these hybrids produced unfilled seeds having well developed seed coat preventing their use in further breeding programmes Natural crossing was also observed between *A tetraphyllus* and *A esculentus* This indicates the possibility of involvement of *A tetraphyllus* as one of the common genomes in *A caillei* and *A esculentus* Based on resistance confirmed by grafting test, one accession each of *A caillei* (T_1) and *A tetraphyllus* (T_2) was selected as donor parents for hybridization programme The study also revealed varietal difference in compatibility of *A* *esculentus* and its wild relatives Compatibility as measured by the crossability index was found to be higher in the reciprocals than the direct crosses

A study was undertaken to standardize the dose for irradiation Based on this study, 60 Kr was selected for inducing recombinations in interspecific crosses of *Abelmoschus*

The three selected accessions of *A esculentus* were crossed with each of the two wild relatives and produced twelve hybrids including reciprocals The crossed seeds were subjected to gamma irradiation for inducing recombinations

The F_1's (non-irradiated hybrids) and F_1M_1's (irradiated hybrids) were evaluated along with their parents and the standard cultivar 'Punjab Padmini' during Jan May ι, 1991 Field conditions congenial for the occurrence and spread of the disease along with border rows of the highly susceptible variety 'Kilichundan' were provided for ensuring sufficient inoculum Heterosis and combining ability analysis were carried out so as to identify the best cross combinations for isolating recombinants

The analysis of variance for combining ability revealed that mean squares due to lines, testers and lines x testers were highly significant indicating wide genetic diversity among the genotypes for most of the characters studied The general and specific combining abilities (gca and sca) effects were found to be insignificant for most of the characters including fruit yield per plant The wild parents recorded significant combining ability for stem girth, leaf area, petiole length first fruiting node, number of branches per plant, length, girth and weight of fruit and fruit yield L_1 (Aanakkompan) recorded significant gca for fruit girth while L_2 (Eanivenda) for petiole length and L_3 (AE1) for leaf area, fruit length and girth

The ratio of genetic components indicated non-additive gene action for all the traits except first fruiting node, petiole length and single fruit weight

Based on the *per se* performance L_1 x T_1 (Aanakkompan x *A caillei*) and L_2 x T_1 (Eanivenda x *A caillei*) were identified as the best combinations The reciprocals recorded lower mean values for the yield components particularly among the nonirradiated hybrids

Morphologically, all plants of the interspecific hybrids resembled more towards their respective wild parents The hybrids were erect in habit, robust and vigorous Hybrid vigour varied significantly among the hybrid combinations All the hybrids were late in flowering with the exception of one early flowering type. Majority of the hybrids displayed significant negative heterosis for fruit yield in all the three types of heterosis comparisons

Six hybrids manifested desirable positive heterosis for number of fruits per plant As regards, fruit length, only two hybrids displayed desirable positive heterosis All the hybrids manifested negative heterosis for weight of fruits which can be attributed to the high seed sterility of the interspecific hybrids All the hybrids displayed significant desirable negative heterosis for YVMD incidence

All the available seeds of the F_1 and F_1M_1 generations were carried to the F_2 and F_2M_2 generations and evaluated in a replicated trial during May-Aug 1991 so as to isolate recombinants having high yield potential coupled with disease resistance A drastic reduction in the mean germination of F_2's and F_2M_2's was observed both under laboratory and field conditions This is attributed to the elimination of hybrid progenies in the post zygotic stage Majority of the F_2 seeds were unfilled ones with well developed seed coat Studies indicated endosperm degeneration leading to the abortion of the embryo Pollen sterility of the F_1 hybrids might be another reason for the formation of unfilled F_2 seeds

A decreasing trend in the mean values was observed for most of the characters studied in the F_2 and F_2M_2 generations However, days to flowering recorded an increasing trend The progeny of *A tetraphyllus* found to be early flowering than those of *A caillei* The F_2M_2's were found to be earlier as compared to the corresponding F_2 population As regards the yield components, majority of the F_2 and F_2M_2 progenies displayed a shift towards the wild parents There was a general reduction in the mean values of the important yield components like number of flowers and fruits per plant due to the presence of sterile weak plants in the population The progeny of T_1 x L_1(*A caillei* x Aanakkompan) recorded increase in mean value for these traits as compared to the standard cultivar 'Punjab Padmini' A general reduction in mean values was observed for fruit characteristics also

The progeny of only one hybrid, T_1 x L_1 (*A caillei* x Aanakkompan) recorded higher mean value for weight of fruits per plant as compared to the wild parents

The highest yielding parent L_2 (Eanivenda) showed maximum susceptibility to the yellow vein mosaic disease Among the donor parents, all the plants of *A caillei* were free from the disease However, five plants of *A tetraphyllus* recorded mild symptoms Among the progeny only ninteen plants showed severe symptoms while majority of the plants did not show any mosaic symptoms

Among the parents, *A caillei* exhibited maximum resistance to the shoot and fruit borer (*Earias vitella*) whereas *A tetraphyllus* showed high infestation by this pest The progeny of *A caillei* also recorded less infestation as compared to the progeny of *A tetraphyllus*

The study indicated a strong reversal of the segregants towards the wild types More number of transgressive segregants were obtained in the F_2M_2's as compared to the F_2 population This can be attributed to the release of variability through the breakage of undesirable linkage in the interspecific hybrids through irradiation

From the F_2 and F_2M_2 population, fifty seven plants were selected based on their superior performance These recombinants had higher yield than the standard parent 'Punjab Padmini' coupled with disease resistance Maximum number of recombinants were isolated from the crosses T_1 x L_1 I (11) and T_1 x L_2I (11) followed by T_1 x L_1 (10) and L_2 x T_1I These resistant lines can be utilized in further breeding programmes for evolving high yielding resistant varieties in Bhindi

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APPENDICES

APPENDIX I Characterization of Bhindi germplasm morphological chracters

Descriptor	Accession No																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Growth habit	1	1	1	1	2	1	1	2	1	1	2	1	1	1	2	1	1	1	1	2	1	1
Branching habit	1	2	1	2	1	2	1	1	2	2	1	2	1	1	2	1	1	2	1	1	2	2
Stem pubescence	2	1	2	1	2	1	1	2	1	1	2	1	2	2	2	1	2	1	2	2	2	1
Stem colour	3	1	3	2	2	2	2	2	1	1	1	1	2	1	1	1	1	1	2	2	1	1
Leaf shape	7	9	7	10	3	5	10	2	10	9	9	10	9	9	9	6	9	9	3	6	9	9
Leaf lobing	5	5	5	5	5	2	4	2	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Lamina margin	2	3	3	2	2	1	3	5	1	2	1	2	3	3	1	2	3	3	3	2	3	3
Leaf tip	2	1	2	1	2	1	1	2	2	1	2	2	1	1	2	1	1	1	1	2	1	1
Position of fruit on main stem	1	1	1	1	2	3	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fruit colour	4	2	4	2	1	2	2	3	3	3	2	2	6	2	6	6	2	3	1	1	2	2
Fruit shape	3	3	4	3	1	2	3	1	2	4	1	2	3	3	3	3	2	3	4	1	3	3
No of ridges per fruit	2	2	3	2	3	2	2	3	2	3	3	3	2	2	2	2	2	2	3	3	2	2
Fruit pubescence	2	1	3	2	2	2	1	2	2	1	2	1	2	1	1	2	2	1	1	1	1	1

(Contd)

(Appendix I Contd)

Descriptor	Accession No																			
	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
Growth habit	1	1	2	1	1	1	1	1	1	1	1	2	1	1	2	1	1	2	1	1
Branching habit	2	2	1	2	2	2	2	1	1	2	1	2	2	2	1	1	1	2	2	2
Stem pubescence	1	2	1	2	2	2	2	2	2	2	2	2	1	1	1	1	1	2	2	1
Stem colour	1	1	2	1	1	2	1	2	1	1	2	1	2	2	1	2	2	1	2	1
Leaf shape	9	9	9	10	9	10	3	3	4	9	1	10	11	9	4	4	9	9	4	9
Leaf lobing	5	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Lamina margin	3	2	3	1	2	2	3	3	3	3	2	2	2	2	2	2	3	3	2	1
Leaf tip	1	1	1	1	1	1	2	1	1	1	1	2	1	1	2	2	2	1	2	1
Position of fruit on main stem	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fruit colour	2	1	2	2	1	2	1	1	2	3	4	2	2	4	3	2	2	1	1	2
Fruit shape	3	3	3	3	3	3	3	4	3	1	4	3	3	2	7	3	3	1	2	3
No of ridges per fruit	2	2	2	2	2	2	3	3	2	3	2	2	2	2	1	2	2	3	3	2
Fruit pubescence	1	1	1	2	2	2	2	1	1	1	2	1	2	2	1	1	2	2	1	1

(Contd)

(Appendix I Contd)

Descriptor	Accession No													
	43	44	45	46	47	48	49	50	51	52	53	54	55	56
Growth habit	1	2	1	1	1	1	1	1	1	1	1	1	1	1
Branching habit	1	1	1	2	2	2	1	2	2	1	1	1	2	2
Stem pubescence	2	2	2	1	2	3	1	2	1	2	1	2	1	1
Stem colour	1	2	1	3	1	2	2	1	1	1	2	1	2	2
Leaf shape	9	9	9	4	10	4	9	10	9	9	9	9	10	10
Leaf lobing	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Lamina margin	3	2	3	2	1	2	3	3	2	3	2	1	3	2
Leaf tip	1	1	1	1	2	1	1	1	1	1	1	1	1	1
Position of fruit on main stem	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fruit colour	2	3	2	2	2	1	2	1	2	1	1	3	2	3
Fruit shape	3	1	3	2	3	2	3	3	3	1	3	3	3	3
No of ridges per fruit	2	3	2	2	2	2	2	2	2	3	2	2	2	2
Fruit pubescence	2	2	2	1	1	3	1	2	1	2	1	2	2	2

APPENDIX II Characterization of Bhindi germplasm biometrical chracters

Descriptor	Accession No											
	1	2	3	4	5	6	7	8	9	10	11	12
Plant height (cm)	138 6	122 9	128 8	147 5	67 3	149 5	71 5	70 4	61 0	82 1	147 7	80 8
Stem girth (cm)	7 0	6 1	7 4	6 4	6 5	8 5	6 9	6 2	6 4	5 8	7 5	6 3
No leaves/plant	24 1	19 3	20 1	23 6	19 4	23 1	29 9	21 6	23 2	18 2	23 1	18 8
Leaf area (cm^2)	348 2	188 0	271 3	276 7	353 0	346 8	269 2	244 0	250 8	277 5	450 2	89 5
Days to flowering	38 5	45 5	48 5	40 0	48 0	46 5	57 5	40 0	46 5	44 0	38 5	50 5
No of branches	0 1	0 1	1 4	0 5	1 6	2 5	5 7	1 5	0 4	0 5	1 0	0 6
First fruinting node	5 8	4 2	7 2	4 6	6 6	7 3	9 8	5 4	6 4	5 0	6 0	6 1
Fruit length (cm)	15 2	15 0	22 1	18 1	25 4	20 5	14 6	21 8	19 8	20 6	15 3	18 2
Fruit girth (cm)	6 5	5 8	6 7	6 4	7 5	6 9	6 0	6 5	7 0	6 6	6 2	6 5
Single fruit wt (g)	18 5	13 5	38 9	22 3	24 4	27 3	25 4	19 9	27 2	11 2	18 5	12 1
No of fruits/plant	15 6	12 5	7 4	16 5	17 5	15 5	12 2	10 2	16 5	8 2	15 2	9 8
Wt of fruits/plant per fruit	287 5	168 0	280 2	407 6	224 8	370 6	305 0	418 8	196 7	92 4	273 2	80 8

(Contd)

(Appendix II Contd)

Descriptor	Accession No											
	13	14	15	16	17	18	19	20	21	22	23	24
Plant height (cm)	84 9	176 3	148 1	139 6	69 0	87 1	145 1	88 3	122 3	89 9	129 8	159 8
Stem girth (cm)	8 2	8 4	8 4	7 3	5 9	7 9	7 5	7 2	6 6	5 8	6 2	6 3
No leaves/plant	21 4	23 9	23 7	18 3	18 7	28 1	24 5	21 4	19 8	17 0	21 6	22 6
Leaf area (cm^2)	288 7	171 5	407 5	507 2	106 8	450 7	267 5	442 3	269 2	175 8	317 3	201 5
Days to flowering	37 5	47 0	50 0	47 5	52 5	43 0	39 5	39 5	44 0	43 5	40 5	45 0
No of branches	6 3	1 7	1 7	0 3	0 3	0 3	1 3	0 5	1 1	0 3	0 9	0 7
First fruiting node	6 4	8 3	8 3	7 1	6 3	6 0	5 7	5 0	5 0	4 0	5 4	4 8
Fruit length (cm)	0 9	15 9	13 8	13 8	18 5	16 6	18 7	15 5	15 6	19 3	16 4	17 9
Fruit girth (cm)	6 4	7 1	7 2	7 3	7 2	5 6	5 8	6 6	5 8	5 8	6 3	6 7
Single fruit wt (g)	18 5	18 5	20 6	21 9	22 8	29 8	11 4	28 1	24 7	21 5	16 6	13 3
No of fruits/plant	13 3	13 7	13 9	8 2	7 9	7 6	15 8	12 2	12 2	11 4	15 3	17 5
Wt of fruits/plant per fruit	243 9	286 8	264 4	168 9	181 2	169 1	180 6	229 4	300 0	241 4	250 9	233 1

(Contd)

(Appendix II Contd)

Descriptor	Accession No											
	25	26	27	28	29	30	31	32	33	34	35	36
Plant height (cm)	119 8	146 6	141 5	99 5	118 6	139 0	119 0	104 7	165 9	66 1	117 8	129 1
Stem girth (cm)	6 9	6 6	6 9	6 0	6 2	6 7	7 0	6 6	7 6	7 7	7 5	8 3
No leaves/plant	21 6	25 6	23 9	16 0	19 9	25 7	22 0	16 9	26 9	16 0	23 8	24 8
leaf area (cm^2)	267 8	282 0	197 4	155 2	391 2	544 5	485 2	289 2	652 3	78 6	298 8	357 7
Days to flowering	46 5	37 0	49 0	54 0	52 0	47 0	45 0	50 0	39 0	45 0	40 5	38 5
No of branches	0 6	0 8	0 5	0 3	0 6	0 8	3 3	0 1	1 8	0 4	0 8	0 9
First fruiting node	5 2	6 0	5 5	5 0	6 9	7 4	6 0	5 3	5 2	5 2	5 8	7 1
Fruit length (cm)	15 9	16 2	15 4	16 7	15 1	13 9	17 5	17 1	14 1	14 4	17 6	15 6
Fruit girth (cm)	5 5	6 8	6 0	6 4	7 5	5 6	6 0	6 6	6 3	5 7	7 1	6 1
Single fruit wt (g)	16 8	11 8	16 1	26 2	17 2	13 8	14 6	18 3	17 2	13 2	17 5	12 3
No of fruits/plant	14 4	18 2	14 9	8 6	9 3	21 4	15 3	8 3	24 1	7 6	16 0	19 9
Wt of fruits/plant per fruit	242 3	214 2	220 9	225 4	158 9	289 5	221 6	151 7	341 1	98 1	277 9	243 5

(Appendix II Contd)

Descriptor	Accession No											
	37	38	39	40	41	42	43	44	45	46	47	48
Plant height (cm)	62 7	123 8	129 5	110 8	140 4	80 6	176 2	152 4	140 2	65 9	79 4	94 3
Stem girth (cm)	6 1	7 6	6 4	6 5	7 2	6 2	6 5	7 0	7 2	7 0	5 8	7 7
No leaves/plant	17 9	22 8	21 9	18 2	23 8	20 8	23 5	19 3	26 5	20 1	19 3	23 1
Leaf area (cm^2)	166 8	363 0	354 5	365 6	485 8	245 8	373 8	280 7	375 2	511 8	195 7	288 3
Days to flowering	48 0	50 0	46 0	45 0	45 5	48 5	51 0	39 0	44 5	44 5	41 0	44 5
No of branches	0 8	0 8	0 5	0 2	0 7	0 8	1 7	0 9	1 2	0 5	0 3	0 9
First fruiting node	6 8	5 8	6 3	7 4	5 1	5 8	8 8	5 7	5 8	9 9	5 7	7 0
Fruit length (cm)	14 8	16 0	18 5	19 5	15 5	13 9	17 2	16 3	14 7	15 6	14 8	21 2
Fruit girth (cm)	6 3	6 1	6 3	5 8	5 8	6 8	6 4	6 8	6 3	6 1	6 4	7 0
Single fruit wt (g)	14 3	15 1	15 6	14 9	13 9	20 0	19 2	11 2	13 8	12 3	23 8	20 1
No of fruits/plant	8 9	15 8	13 4	15 2	14 7	10 8	11 8	17 0	19 9	19 9	10 3	13 6
Wt of fruits/plant per fruit	127 5	238 3	207 8	252 5	200 8	215 0	221 1	189 9	249 3	243 5	225 4	277 7

(Contd)

(Appendix II Contd)

Descriptor	Accession No							
	49	50	51	52	53	54	55	56
Plant height (cm)	143 2	98 6	133 4	87 4	97 6	61 9	113 0	110 5
Stem girth (cm)	7 1	7 6	8 5	7 1	7 0	7 9	6 2	5 9
No leaves/plant	24 2	17 9	28 8	22 4	19 9	16 2	19 8	19 2
Leaf area (cm^2)	302 5	172 0	176 6	497 0	383 4	135 0	343 8	290 0
Days to flowering	50 0	45 0	48 0	48 5	46 5	47 5	45 0	45 0
No of branches	1 5	0 0	0 9	1 7	2 0	0 3	0 5	1 0
First fruinting node	7 5	4 8	7 6	5 4	6 0	4 2	6 0	5 7
Fruit length (cm)	15 3	14 6	17 3	17 3	18 2	18 2	16 5	12 5
Fruit girth (cm)	6 7	5 6	6 7	6 4	5 6	6 7	6 0	6 1
Single fruit wt (g)	25 6	14 7	9 9	14 4	23 7	19 5	19 6	15 5
No of fruits/plant	13 7	9 7	21 2	13 9	9 6	7 2	12 5	12 6
Wt of fruits/plant per fruit	347 8	142 3	209 8	200 5	223 0	138 7	238 8	195 7

ABSTRACT

INDUCTION OF GENETIC RECOMBINATIONS IN INTERSPECIFIC CROSSES OF *ABELMOSCHUS*

by

SHEELA M.N.

ABSTRACT OF THE THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR
THE DEGREE OF
DOCTOR OF PHILOSOPHY
FACULTY OF AGRICULTURE
KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANT BREEDING AND GENETICS
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM

1994

ABSTRACT

A study was undertaken at the College of Agriculture Vellayani during 1990-91 aimed at inducing recombinations of the economic attributes of Bhindi (*Abelmoschus esculentus* (L) Moench) and the yellow vein mosaic disease resistance of wild relatives A preliminary evaluation of 56 accessions revealed good genetic diversity in Bhindi germplasm The accessions were grouped into four clusters The characterization of germplasm was done based on IBPGR descriptors High genotypic coefficients of variation were exhibited by weight of fruits per plant leaf area, height of plant, number of fruits per plant, single fruit weight and number of branches per plant indicating scope for selection High heritability along with high genetic advance was recorded for weight of fruits per plant, height of plant leaf area and number of seeds per fruit Low heritability coupled with low genetic advance recorded for yellow vein mosaic disease incidence indicated the predominant role of environment in the inheritance of disease resistance

Correlation studies revealed that number of leaves per plant leaf area, number of branches per plant fruit girth and single fruit weight could be considered as the

major characters contributing to yield in Bhindi Among the yield components, number of fruits per plant and single fruit weight recorded the maximum positive direct effects on yield Number of branches per plant and single fruit weight recorded maximum positive and negative direct effects, respectively on yellow vein mosaic disease (YVMD) The selection of early flowering types with increased fruit weight is suggested for enhancing the level of YVMD resistance

Varietal difference in compatibility of *A esculentus* with the donor parents, *A caillei* and *A tetraphyllus* was noticed Reciprocal crosses registered higher compatibility than the direct crosses Natural crossing of *A tetraphyllus* with *A esculentus* and *A caillei* also was observed

The line x tester analysis with the three cultivated accessions as lines and the wild types as testers indicated the predominance of non-additive gene action for majority of the characters in interspecific hybrids *A caillei* (T_1) was found to be the better general combiner for majority of the yield components and yellow vein mosaic resistance Majority of the hybrids recorded negative heterosis for yield and its components However, few hybrids manifested significant desirable heterosis for days to flowering number of fruits per plant and fruit length All the hybrids were completely free from YVMD like the donor parents

High pollen sterility of the hybrids along with the degeneration of the endosperm resulted in the production of unfilled F_2 seeds Drastic reduction in the germination of F_2 and F_2M_2 seeds was recorded A preponderance of low yielding yellow vein mosaic resistant plants similar to the donor parents was observed among the F_2 and F_2M_2 populations indicating the presence of powerful genetic mechanisms preventing free recombination As compared to F_2's, the proportion of recombinants was higher in the F_2M_2 population indicating the breakage of undesirable linkages through irradiation Both positive and negative transgressive variants for the different characters were seen in the F_2 and F_2M_2 generation Based on superiority in performance fifty seven plants were selected in which six plants recorded an yield greater than 525 g per plant Maximum number of recombinants were identified in the irradiated crosses *A caillei* x Aanakkompan (T_1 x L_1I) and *A caillei* x Eanivenda (T_1 x L_2I) These recombinants had higher yield than the check variety 'Punjab Padmini' coupled with YVMD resistance confirmed by graft inoculation These lines can be utilized in further breeding programmes for evolving high yielding resistant varieties in Bhindi