RADIATION INDUCED VARIABILITY IN INTERSPECIFIC HYBRIDS INVOLVING *Abelmoschus esculentus* (L.) Moench AND *Abelmoschus manihot* (L.) Medic.

By

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THESIS

submitted in partial fulfilment of
the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF HORTICULTURE
Vellanikkara - Trichur

1986

DECLARATION

I hereby declare this thesis entitled "Radiation induced variability in interspecific hybrids involving *Abelmoschus esculentus* (L.) Moench and *Abelmoschus manihot* (L.) Medic" is a bonafide record of research work done by me during the course of research and 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.

Vellanikkara,
28·6·1986.

DALIA CHERIAN

CERTIFICATE

Certified that this thesis entitled "Radiation induced variability in interspecific hybrids involving *Abelmoschus esculentus* (L.) Moench and *Abelmoschus manihot* (L.) Medic" is a record of research work done independently by Miss Dalia Cherian under my guidance and supervision and that it has not previsouly formed the basis for the award of any degree, fellowship or associateship to her.

Vellanikkara,
28 6 1986.

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CERTIFICATE

We, the undersigned members of the Advisory Committee of Miss Dalia Cherian, a candidate for the degree of Master of Science in Hortifulture agree that the thesis entitled "Radiation induced variability in interspecific hybrids involving _Abelmoschus esculentus_ (L.) Moench and _Abelmoschus manihot_ (L.) Medic" may be submitted by Miss Dalia Cherian in partial fulfilment of the requirement for the degree.

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INTRODUCTION

Bhindi (Abelmoschus esculentus L.) Moench is an important fruit vegetable rich in vitamin A, thiamine, riboflavin, vitamin C and minerals like calcium, phosphorus, iron and potassium. The crop is extensively grown throughout India. The ease with which it can be cultivated and its adaptability to a wide range of growing conditions made bhindi popular among the vegetable growers.

The bhindi crop suffers due to several diseases among which yellow vein mosaic caused by a virus is the most destructive one, as it infects the crop at all growth stages. This viral disease occurs throughout India wherever bhindi is grown and causes heavy loss by influencing the quality and yield of fruits. The virus is transmitted by whiteflies (Bemisia tabaci Genn.), which cannot be controlled by the commonly available insecticides. Further, within Abelmoschus esculentus (L.) Moench there are no sources of resistance, except for the advent of 'Pusa Sawani', the symptomless carrier variety evolved at Indian Agricultural Research Institute, New Delhi. 'Pusa Sawani' also could not sustain its tolerance for long. Hence it is necessary that new varieties, resisting yellow vein mosaic virus, are to be developed so as to replace the present susceptible lines.

Attention was shifted to other related species of *Abelmoschus* possessing higher degree of tolerance than available within *Abelmoschus esculentus* (L.) Moench and which cross readily with *Abelmoschus esculentus* to a reasonable degree of success. Arumugam *et al*. (1975) reported that *Abelmoschus manihot* accessions introduced from Africa and Japan were symptomless carriers of yellow vein mosaic virus. In the absence of adequate degree of resistance to the disease, attempts were made to exploit the symptomless carrier type of host reaction present in *Abelmoschus manihot* (L.) Medic. Reports regarding crossability of *Abelmoschus manihot* with *Abelmoschus esculentus* are not consistant.

Use of radiation techniques may generate useful variability to isolate a mutant, resistant to yellow vein mosaic disease. There are indications that mutagenic treatments of F_1 would give a relatively wider spread (in frequency distribution) in F_2 for economic characters. The present studies were taken up with the following objectives.

1. To find out extent of cross compatability between *Abelmoschus esculentus* (L.) Moench. cv. 'Pusa Sawani' and three accessions of *Abelmoschus manihot* (L.) Medic.

2. To develop desirable variants in the interspecific hybrids through gamma radiation, so that useful lines possessing resistance/symptomless carrier nature to yellow vein mosaic disease could be made.

3. To assess effectiveness of irradiating the interspecific F_1 seeds to generate useful mutants in subsequent generations.

Review of Literature

REVIEW OF LITERATURE

Bhindi (Syn. Okra, Ladies finger, Gumbo) is an important rainy and summer season vegetable cultivated for its tender and fleshy fruits. The crop is grown extensively throughout India, because of its adaptability to a wide range of growing conditions. However, the main problem limiting the successful and economic cultivation of this crop is its susceptibility to yellow vein mosaic disease.

In India, this disease was first reported by Kulkarni (1934) and the viral nature of the disease was established by Uppal _et al_. (1940). The disease occurs throughout India whereever bhindi is grown and takes a heavy toll of the crop. Sastry and Singh (1973) reported 45-100% damage of the crop, in the absence of insecticidal spray within 20 days after germination. The disease is transmitted through insect vector, whitefly, _Bemisia tabaci_ (Genn.) (Capoor and Varma, 1950). The crop loss is a function of age of the plant at which the first incidence is noted and spread of the inoculum, favoured at high temperature and humidity (Varma, 1952). There is very little reduction in the incidence of yellow vein mosaic even if repeated prophylatic control measures are taken against the whitefly (Sandhu _et al_., 1976). The most logical and economic way to manage the disease appears to be through varietal resistance. The earlier attempts in India to breed a field tolerant variety led to the development of 'Pusa Sawani' (Singh *et al*., 1962). This widely cultivated variety, reported to be a symptomless carrier of the virus, has recently lost this reaction due to various genetic and agroclimatic factors (Singh and Thakur, 1979). A large number of cultivars tested, did not carry any source of resistance to yellow vein mosaic (Nariani and Seth, 1958; AICVIP, 1974-'76, 1977-'78; Arumugam, 1977; Chauhan *et al*., 1981; AICVIP, 1982-'84). In the absence of adequate resistance in the cultivated varieties, a search for source of resistance was made in related wild species. Nariani and Seth (1958) screened eight species of *Abelmoschus* and four species of *Hibiscus* for their reaction to yellow vein mosaic by grafting as well as by feeding viruliferous whiteflies. They reported that *Abelmoschus manihot* var. *pungens*, *Abelmoschus crinitus* Wallich, *Hibiscus vitifolius* L. and *Hibiscus panduraeformis* L. were immune to infection. Singh and Bhatnagar (1975) observed that the Ghana bhindi belonging to the Guinean group, *Abelmoschus* sp. with 2n = 194 Chromosomes, was tolerant to yellow vein mosaic. Arumugam *et al*. (1975) reported high resistance to yellow vein mosaic disease in two accessions of *Abelmoschus manihot* L. The two accessions were received from Ghana and Japan. Arumugam *et al.* (1975) side-grafted a diseased scion of *Abelmoschus esculentus* (L.) Moench on a healthy *Abelmoschus manihot* L. rootstock. The rootstock later did not show any symptoms of the disease. They later took scionic piece from *Abelmoschus manihot* L. and grafted on a healthy *Abelmoschus esculentus* (L.) Moench plant. On grafting, healthy *Abelmoschus esculentus* (L.) Moench, the plant became susceptible indicating thereby 'symptomless carrier' nature of *Abelmoschus manihot* L. Field resistance to yellow vein mosaic disease was observed in a wild species of *Abelmoschus manihot* L., by many workers (Arumugam and Muthukrishnan, 1978; Singh and Thakur, 1979). Resistance to yellow vein mosaic was observed in *Abelmoschus manihot* L. and *Abelmoschus manihot* ssp. *tetraphyllus* Roxburgh ex Horneman (Chelliah and Srinivasan, 1983; AICVIP, 1982-'84).

Interspecific hybridisation for improvement of bhindi

Interspecific hybridisation provides means to transfer a few of the valuable characters from wild or economically inferior species to the agronomically superior cultivated species. Interspecific hybridisation was carried out in the genus *Abelmoschus* for the last half a century with different objectives. The reports of the earlier work include a successful cross between *Abelmoschus esculentus* and *Abelmoschus manihot* (Tezima, 1930; Teshima, 1933; Ustinova, 1937, 1949). During the recent past, crosses were attempted amongst the different species of Abelmoschus with varying levels of success by Pal et al. (1952); IARI (1956); Joshi and Hardas (1956); Kuwada (1957, 1974); Singh et al. (1962, 1975); Gadwal et al. (1968); Thakur (1976); Hossain and Chattopadhyay (1976); Ugale et al. (1976); Singh and Thakur (1979); Mamidwar et al. (1979); Jambhale and Nerkar (1981a, 1981b, 1982a, 1982b); Martin (1982) and Nirmaladevi (1982).

Tezima (1930) attempted interspecific hybridisation between Abelmoschus manihot L. and Abelmoschus esculentus L. Moench. Abelmoschus manihot L. x Abelmoschus esculentus L. Moench was fertile but its reciprocal yielded no seeds. Backcross of F_1 with Abelmoschus esculentus failed but when F_1 was used as male parent, the cross was successful. Teshima (1933) observed that the cross Abelmoschus manihot L. x Abelmoschus esculentus L. Moench was successful only when Abelmoschus esculentus L. Moench was used as female parent. Reciprocal crosses produced only abortive seeds. Even in successful crosses, fertility of F_1 was lesser than one per cent. He also observed that the back cross was successful only when Abelmoschus esculentus (L.) Moench was used as male parent. The above conflicting reports would either be due to varietal difference or method of pollination used in the above cases. Chizaki (1934) observed fertile F_1 plantsof Abelmoschus manihot L. x Abelmoschus esculentus (L.) Moench crosses. The F_1 showed hybrid vigour and was intermediate between parents. The work of Chizaki (1934) established cross between *Abelmoschus manihot* L. and *Abelmoschus esculentus* (L.) Moench. He observed that intense yellow flower colour of *Abelmoschus manihot* L. was dominant. Ustinova (1949) reported that the degree of sterility was high in interspecific F_1 hybrid of *Abelmoschus manihot* L. x *Abelmoschus esculentus* (L.) Moench, due to disruption of meiosis during microsporogenesis and embryosac development. Ustinova (1949) initiated vegetative hybridisation between *Abelmoschus manihot* L. as rootstock and *Abelmoschus esculentus* (L.) Moench as scion. Seeds from graft hybrids matured normally. The utility of such grafting in creating variability is only of academic interest which needs further detailed study.

Pal *et al*. (1952) observed that *Abelmoschus esculentus* (L.) Moench crossed readily with *Abelmoschus tuberculatus* Pal et Singh, *Abelmoschus manihot* L. and *Abelmoschus manihot* L. var. *pungens* and formed normal viable seeds, but crosses with *Abelmoschus ficulneus* Wight and Arnott ex Wight resulted in only shrivelled or empty seeds. The many F_1 hybrids studied were sterile, and the fruits formed were either seedless or developed only a few empty seeds. Backcrosses and crossing of the hybrids in various combinations failed to produce viable seeds. The F_1 hybrid of *Abelmoschus tuberculatus* Pal et Singh ($n = 29$) x *Abelmoschus ficulneus*

Wight and Arnott ex Wight (n = 35) had 2n = 65 and was totally sterile with an average of one to six pairs/cell, while the F_1 of *Abelmoschus manihot* L. var. *tetraphyllus* Roxburgh Horneman (n = 69) x *Abelmoschus esculentus* (L.) Moench (n = 65) had 2n = 134 and was also sterile, but had 20.42 chromosome pairs/cell (IARI, 1956). According to Joshi and Hardas (1956) meiosis and seed setting in *Abelmoschus esculentus* (L.) Moench (2n = 130) and *Abelmoschus tuberculatus* Pal et Singh (2n = 58) were normal. The F_1 hybrid obtained from reciprocal crosses between the above two species were totally sterile. In pollen mother cells, they observed the most frequent association 29 IIS + 36 IS and suggested that the cultivated bhindi with 65 chromosome bivalents is an alloploid comprising two genomes, one with 29 and the other with 36 chromosomes. Kuwada (1957) observed a chromosome number 2n = 96 with three to seven bivalents, in the cross between *Abelmoschus manihot* L. var *tetraphyllus* (n = 69) x *Abelmoschus esculentus* (L.) Moench (n = 65). This indicated a very poor chromosome homology between chromosomes of the two species. Obviously fertility of hybrid was low. Kuwada (1957) reported that in the backcross of the hybrid to *Abelmoschus esculentus* L. Moench (2n = 152), the meiotic configuration observed was 28 to 34 IS, 56 to 62 IIS, and 0-6 IIIS. In the backcross to *Abelmoschus manihot* L. the configuration was 60 IS, 36 IIS and 2 IIIS.

The above figures indicated a certain extent of chromosomal homology between the two species. According to Kuwada (1962), sterility in interspecific hybrid was associated with inability of pollen to reach the ovule and also with embryosac abnormalities. He also observed that fruit size of hybrid depended on female parent indicating considerable cytoplasmic effect. Singh *et al*. (1962) reported that resistance in *Abelmoschus pungens* Roxb., *Abelmoschus manihot* L., *Abelmoschus tuberculatus* Pal et Singh, *Abelmoschus angulosus* W. et A., and *Abelmoschus crinitus* Wallich could not be exploited successfully as sterility was observed in varying degrees when these species were crossed with the cultivars. In the case of cross with *Abelmoschus tuberculatus* Pal et Singh, they found complete sterility and no viable seeds were obtained even from backcrosses. Gadwal *et al*. (1968) employed *invitro* culture of ovules and embryos to obtain viable hybrids in different species combinations in the genus *Abelmoschus* and successfully produced hybrid offspring of the cross *Abelmoschus esculentus* (L.) Moench x *Abelmoschus tuberculatus* Pal et Singh. Kuwada and Okuno (1968) reported that fertility of the amphidiploid interspecific F_1 was affected by gene concerned with fertility and a relation existed between genome and cytoplasm. Kuwada (1974) observed that the F_1 hybrid *Abelmoschus tuberculatus* Pal et Singh (2n = 58) x *Abelmoschus manihot* L. (2n = 68) showed heterosis but was totally sterile. Arumugam *et al.* (1975) could produce fertile F_1 hybrid between *Abelmoschus manihot* L. and *Abelmoschus esculentus* (L.) Moench, but there was 90 per cent sterility in F_2. Hossain and Chattopadhyay (1976) reported that *Abelmoschus esculentus* (L.) Moench x *Abelmoschus ficulneus* Wight and Arnott ex Wight hybrids were self sterile, but produced many fruits without seeds or with only rudimentary seeds. The hybrid resembled their wild parent in several morphological characters and inherited its resistance to yellow vein mosaic. Ugale *et al.* (1976) studied the F_1 generation of the cross *Abelmoschus esculentus* (L.) Moench (2n = 72) x *Abelmoschus tetraphyllus* Roxb. ex Horneman (2n = 130) and observed that most of the characters were intermediate in expression and resistance to virus was observed.

Thakur (1976) attempted cross between *Abelmoschus esculentus* (L.) Moench and a bhindi introduction from Ghana, which was identified as *Abelmoschus manihot* L. He found the crosses successful only when *Abelmoschus esculentus* (L.) Moench was used as female. Mamidwar *et al.* (1979) observed that in crosses of *Abelmoschus esculentus* (L.) Moench with three wild forms, fruit set was the highest when *Abelmoschus esculentus* (L.) Moench was the female parent and it ranged from 83.33% in *Abelmoschus esculentus* (L.) Moench x *Abelmoschus manihot* L. to 57.5%

in *Abelmoschus esculentus* (L.) Moench x *Abelmoschus tetraphyllus* Wall. These two hybrids produced seedless fruits or fruits with shrivelled seeds. Occurrence of spontaneous amphidiploidy was reported in an interspecific cross of *Abelmoschus esculentus* (L.) Moench and *Abelmoschus tetraphyllus* Wall (Jambhale and Nerkar, 1981a). They (1981b) could get success in reciprocal crosses using *Abelmoschus manihot* ssp. *manihot*, introduced from Ghana. The crosses were successful in both the directions. Manifestation of heterosis over the better parent was seen for internodal length, branches/plant, plant height, fruits/plant, days to opening of first flower and days to marketable maturity. To overcome sterility in the crosses *Abelmoschus esculentus* (L.) Moench x *Abelmoschus manihot* ssp. *manihot* and *Abelmoschus esculentus* (L.) Moench x *Abelmoschus tetraphyllus* Wall, amphidiploidy was induced in the F_1 (Jambhale and Nerkar, 1982a and 1982b). The amphidiploids showed more or less regular chromosome pairing. Martin (1982) attempted hybridisation between common bhindi and the West African type. The F_1 hybrids were somewhat sterile, pod set ranged from 0 to 72 per cent, while seeds/pod ranged from 0 to 28. Nirmaladevi (1982) reported that *Abelmoschus manihot* L. was crossable with *Abelmoschus esculentus* (L.) Moench. The interspecific F_1 hybrid exhibited significant heterobeltiosis for many of the economic characters. She observed significant genetic distance between *Abelmoschus manihot* L. and *Abelmoschus esculentus* (L.) Moench.

Mutation breeding for crop improvement

Brock (1970) suggested mutation breeding as a potential alternative to plant introduction and hybridisation. Appropriate selection can pick out desirable variant(s) from the variability created through mutation. Smith (1970) reported that seeds are the preferred experimental material for mutation breeding.

Reports on mutation breeding in bhindi are limited. Substantial work has been carried out in related crop cotton and the doses of radiation used varied from 0.5 to 30 kR γ rays (Gulamov *et al.*, 1968); 20 to 40 kR γ rays (Bashanova and Eminov, 1970); 5 to 30 kR γ rays (Rakhimkulov, 1971); 20 to 50 kR γ rays (Mustafaev and Kuleiva, 1979); 1 to 20 kR γ rays (Azimova *et al.*, 1979) 25 kR γ rays (Raut and Panwar, 1980); 10 to 50 kR γ rays (Sarkhanbeili, 1982).

Kuwada (1967) induced resistance to *Phytophthora* in *Abelmoschus manihot* L. by irradiating seeds with ^{60}Co γ rays and X-rays. Plant height, stem thickness and number of nodes varied according to the type and concentration of radiation. Kuwada (1970) treated dry seeds of bhindi with X-rays and observed plants in M_1 generation having more number of nodes and branches. M_2 showed increased variation in plant height, pods/plant and seeds/plant. Nandpuri *et al*. (1971) obtained increased variation in plant height, days to flower and yield in M_1 generation. Rao and Giri Raj (1975) treated bhindi (var. Pusa Sawani) with three doses of X-rays and four doses of γ- rays. There was significant difference between treatments which indicated the creation of new variability in bhindi by irradiation. Yashwir (1975) reported that when seeds of selfed *Abelmoschus esculentus* (cv. Pusa Sawani) were treated with 40 to 80 kR γ- rays, height reduction in the M_1 was observed. Koshy and Abraham (1978) irradiated bhindi seeds with 20 to 100 kR γ- rays and in the M_1 they observed stem dichotomy, changes in phyllotaxy, reduction in size of flowers, abnormal development of petals, androecium, gynoecium and occurence of twin fruits. Fatokun *et al*. (1979) obtained supernumerary inflorescence in bhindi through mutation. As a result, instead of one fruit at each node, the plant had a potential to produce several fruits. Jambhale and Nerkar (1980) isolated 'Palmatisect', a new leaf mutant in bhindi after irradiation of the cultivar 'Pusa Sawani'. Jambhale and Nerkar (1982c) irradiated dry seeds of 'Pusa Sawani' and 'Vaishali Vadhu' with 40 to 80 kR γ- rays and EMS. They observed that plant mortality, sterility and chlorophyll chimeras in the M_1 increased with increase in dose of mutagen. Nirmaladevi (1982) reported that γ-radiation had the potential to produce vegetable type (s) in wild Abelmoschus manihot L. Paliwal et al. (1983) reported that γ-radiation of seeds reduced the growth and stimulated branching, fruit set and yield in bhindi.

Reports on mutagen induced variation in quantitative characters among crop varieties are available. Comparatively lesser attention was given to study the usefulness of mutagen treatment of F_1 hybrids in generating increased variability in F_2. Mutagen treatment of F_1 seed is expected to increase the variation by creating new alleles and/or increasing the range of recombinations by breaking linkage (Singh, 1984). Gregory (1956) suggested that radiation induced variation is cumulative with that induced by hybridisation. Comparisons were also made by irradiating the hybrids as well as purelines and their usefulness was found to be due to their additive effect (Gregory, 1961). Siddique (1971) studied the effects of irradiation in inducing interchanges in the hybrids of cotton species and it was found that the range of distribution of plot means was invariably wider in the treated population for almost all characters when compared with their respective controls. Autonomov (1979) reported that γ-radiation (5 to 15 kR) of the hybrids obtained by crossing purelines of wilt susceptible variety of cotton 'S4727' with wild wilt resistant form of *Gossypium hirsutum* ssp. *mexicanum* var. *nervosum*, increased level of wilt résistance. Kuleiv (1980) irradiated hybrid seeds of cotton with 10 kR and 20 kR γ-rays and produced good breeding material with useful characters. Savov (1980) reported that by combining hybridisation and irradiation, a new wheat cultivar 'Altimar-67' was obtained. This variety has got a unique combination of high productivity with resistance against the most important diseases, as well as very good quality grain accomplished in one genotype. Khan *et al*. (1981) reported that irradiation of a hybrid between two cotton varieties, with 10 to 35 kR γ-rays resulted in production of dwarf mutant with pest resistance, more hairs and better fibre quality than the hybrids. Gopimony *et al*. (1982) undertook irradiation of F_1 seeds of a cross between the cultivated brinjal variety 'Purple Giant' and *Solanum melongena* var. *insanum* to enhance recombination of resistance with economically required fruit and yield characters. They obtained 22 resistant and spineless mutant types by F_7M_7 generation. Kraevoi *et al*. (1982) hybridised the Soviet varieties of cotton, Tashkent 1 and 173 and the American varieties Acala Mesa and Acala S-21 and the F_0 seeds were γ-irradiated. They observed that the frequency and range of mutations in F_2M_2 were greater in the hybrids than in the corresponding progeny of the irradiated parents. They estimated that mutability of the hybrids was roughly twice that of their parents.

A good source of resistance to yellow vein mosaic has not been identified so far among the cultivated bhindi varieties. By use of radiation techniques, it may be possible to increase the genetic variability so that a mutant, resistant to mosaic may be identified. The present study is undertaken to develop desirable variants in the interspecific hybrids so that useful selection could be later made.

Materials and Methods

MATERIALS AND METHODS

The experiments were laid out during June-October, 1984, November-April, 1984-'85 and June-October, 1985 at the Instructional Farm, College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur. The research farm of the college is situated at an altitude of 22.25 m above MSL at 10° 32'N latitude and 76° 16'E longitude. The soil type is a deep and well drained sandy clay loam (pH = 5.1).

The experiments consisted of two main parts:

I. Cross compatibility between *Abelmoschus manihot* (L.) Medic and *Abelmoschus esculentus* (L.) Moench Cv. 'Pusa Sawani'.

II. Gamma-ray induced variability in M_0 generation and evaluation for host reaction to yellow vein mosaic virus.

I. Cross compatibility between *Abelmoschus manihot* (L.) Medic and *Abelmoschus esculentus* (L.) Moench Cv. 'Pusa Sawani'.

A. Materials

There were three accessions of *Abelmoschus manihot* obtained from different sources (Table 1). The accessions were:

Table 1. Source and morphological description of three accessions of *Abelmoschus manihot*

	Accession 1 (*Abelmoschus manihot*)	Accession 2 (*Abelmoschus manihot*)	Accession 3 (*Abelmoschus manihot* ssp. *tetraphyllus*)
Source	IARI, New Delhi	KAU, Vellanikkara	IIHR, Bangalore
Habit	Perennial Shrub	Perennial Shrub	Perennial Shrub
Stem	Thick, slightly rough with red tinge	Thick, slightly rough, light green	Thin, rough, purple
Leaves	Alternate, long stalked, cordate base, acute apex	Alternate, long stalked, cordate base, acute apex	Alternate, long stalked, cordate base, acute apex
Petiole	Long red	Long light green	Ventral side sparsely hairy green, dorsal side deep purple
Flower	Solitary, axillary stalked, large buds ovoid acute	Solitary, axillary stalked, large buds ovoid acute	Solitary, axillary stalked, small buds ovoid acute
Bracteoles	Large, with appressed stiff hairs	Large with appressed stiff hairs	Large with appressed stiff hairs
Calyx	Companulate, obtusely dentate at apex with red tinge	Companulate, obtusely dentate at apex with red tinge	Spathaceous, green with purple tinge

Table 1. (Contd.)

	Accession 1 (*Abelmoschus manihot*)	Accession 2 (*Abelmoschus manihot*)	Accession 3 (*Abelmoschus manihot* ssp. *tetraphyllus*)
Corolla	Large, sulphurous with purple eye	Large, sulphurous with purple eye	Lighter yellow with light purple eye
Androecium	Staminal tube white with pale yellow anthers	Staminal tube white with pale yellow anthers	Staminal tube white with pale yellow anthers
Gynoecium	Stigma globose dark red	Stigma globose dark red	Stigma globose light red
Fruit	Capsule with red tinge in immature stage, green when mature and broadly furrowed between ridges	Capsule green in immature and mature stage and narrowly furrowed between ridges	Capsule dark green in immature and mature stage
Seeds	Dark grey, hairy	Brownish, non-hairy	Black, hairy

Abelmoschus manihot - IARI (Plate I)

Abelmoschus manihot - KAU (Plate II)

Abelmoschus manihot ssp. *tetraphyllus* - IIHR (Plate III)

'Pusa Sawani' (*Abelmoschus esculentus*) was the other parent used in the study (Plate IV).

B. Methods

The four lines were grown during June-October, 1984. The three accessions of *Abelmoschus manihot* were crossed with 'Pusa Sawani' directly and reciprocally. About 200 crosses each were made. Synchrony in flowering in 'Pusa Sawani' and related species was ensured by temporal sowing of 'Pusa Sawani'. Observations were recorded on the following characters:

1) Percentage of fruitset in F_0 (A)
2) Percentage of fruitset in maternal parent
3) Seeds/fruit in F_0 (B)
4) Seeds/fruit in maternal parent
5) Percentage of germination in F_0 (C)
6) Percentage of germination in maternal parent.

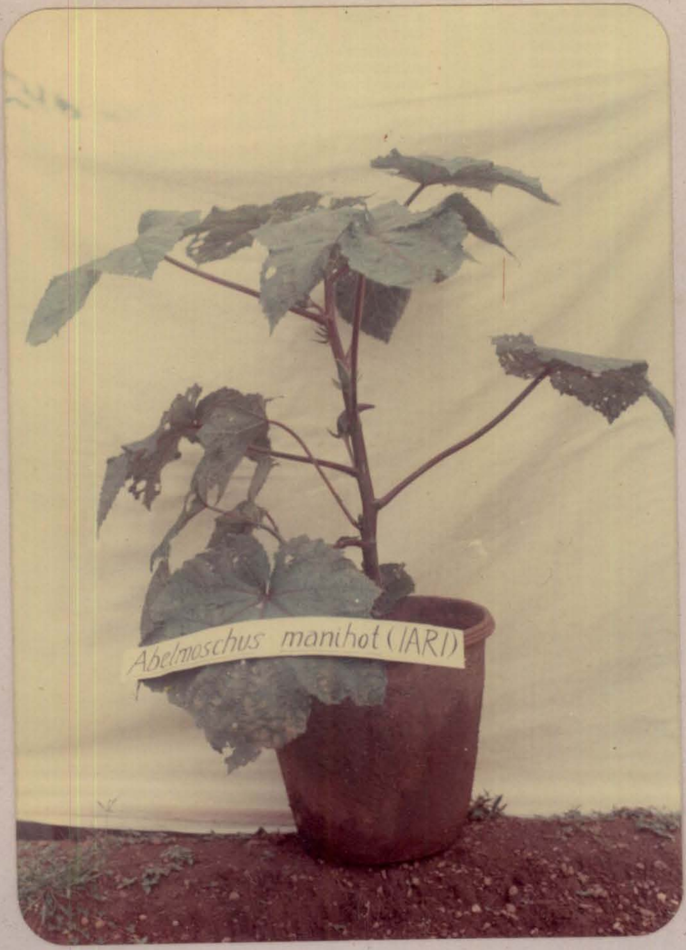
   Following parameters measuring the extent of cross compatibility were estimated

7) Percentage of success/fruit set

$$= \frac{\text{Number of fruitset} \times 100}{\text{Number of crosses made}}$$

Plate I *Abelmoschus manihot* - IARI source

Plate II *Abelmoschus manihot* - KAU source

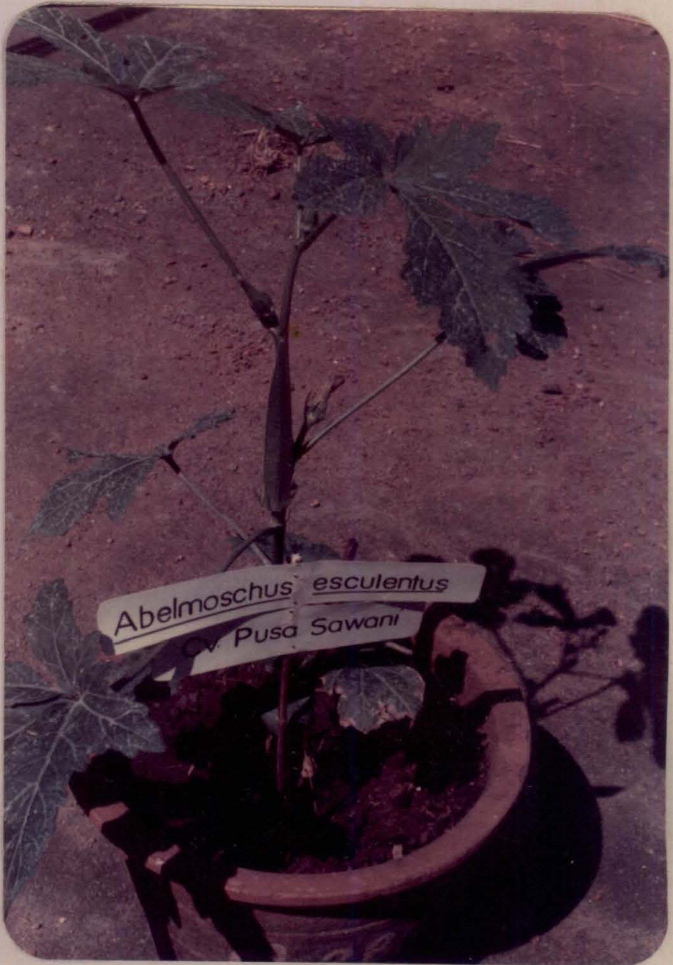

Abelmoschus manihot (IARI)


Abelmoschus manihot (KAU)

Plate III *Abelmoschus manihot* ssp. *tetraphyllus* - IIHR source

Plate IV *Abelmoschus esculentus* cv. Pusa Sawani


Abelmoschus tetraphyllus


Abelmoschus esculentus
Cv. Pusa Sawani

8) Percentage of germination of seeds

$$= \frac{\text{Number of seeds germinated} \times 100}{\text{Number of seeds sown}}$$

9) Crossability index (Rao, 1979)

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

$$= \frac{A^{c*} \times B^{c*} \times C^{c*} \times 100}{A^{s**} \times B^{s**} \times C^{s**}}$$

c* = crossed s** = selfed

10) Percentage of seed forming efficiency

$$= \frac{\text{Seeds in crosses} \times 100}{\text{Seeds in selfed maternal parent}}$$

11) The fertility of F_1 plant

The fertility of F_1 plant was estimated as percentage of fruit set in F_1 plants on selfing and as percentage of normal seeds.

Percentage of fruit set

$$= \frac{\text{Number of fruit set} \times 100}{\text{Number of selfings}}$$

Percentage of normal seeds

$$= \frac{\text{Number of normal seeds} \times 100}{\text{Total number of seeds}}$$

12) Pollen fertility of parents and F_1 plants

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

Percentage of viable pollen

$$= \frac{\text{Number of viable pollen x 100}}{\text{Total number of pollen under observation}}$$

II. Gamma ray induced variability in M_0 generation and evaluation for host reaction to yellow vein mosaic virus.

A. Materials

Interspecific F_1 seeds from the following crosses were irradiated with a ^{60}Co source (Gamma chamber - 900 of BARC) at a rate of 0.23 MR/hr, from the gamma source available at Radio Tracer Laboratory, Kerala Agricultural University, Vellanikkara. The doses given were 15 kR, 20 kR and 25 kR.

1) *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI)
2) *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus*
3) *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU)
4) *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus*
5) *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* (IIHR)

B. Methods

Sixteen entries from the first four crosses, consisting 12 M_1s and four F_1 hybrids were grown in large plots of size 350 m^2 accommodating 75-100 plants/entry during November-April, 1984-'85. The four entries of the cross *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* consisting of three M_1s and one F_1 hybrid were grown during June-October, 1985. Spacing was 60 x 45 cm. The axillary buds were clipped off as soon as they appeared to make sure the differentiation, growth and development of mutant tissues normally present in terminal bud. To ensure sufficient inoculum of yellow vein mosaic, 'Pusa Sawani' was grown in bulk during both the seasons. No chemical spraying was resorted, so as to favour the development of whitefly population.

C. Observations

1) The morphological description of the parents, interspecific F_1 hybrids and mutated F_1 hybrids were made based on the following characters:

a) Plant habit : Branched/unbranched

b) Pubescence

  i) Stem : Smooth/pubescent/warty

  ii) Lamina : Smooth/pubescent

  iii) Petiole : Smooth/pubescent

c) Pigmentation

- i) Stem : Green/green with red tinge/red with green tinge
- ii) Petiole : Green/green with red tinge/red with green tinge
- iii) Vein : Prominent/not prominent, green/whitish/green with red tinge/red with green tinge
- iv) Corolla throat : Present/absent

d) Leaf size : Small/medium/long

e) Leaf shape : Cardate/hastate/sagitate/others

f) Laminal margin : Deeply fid/narrowly fid/serrated

g) Leaf tip : Pointed/blunt

h) Flower

- i) Bud : Hairy/scaly/smooth/resinous
- ii) Corolla : Yellow/golden yellow, red throat/purple throat
- iii) Calyx : Hairy/smooth, fleshy/non-fleshy
- iv) Stigma : Bifid/multifild, purple/red/others, smooth/hairy

i) Fruits

- i) Immature fruit colour : Green/darkgreen/yellowishgreen/red/deep red/other
- ii) Size : Small/medium/long/extra long
- iii) Shape : Round/angular/ridged/straight/curved
- iv) Tip : Pointed/blunt
- v) Dehiscence at maturity : Dehiscent/indehiscent
- vi) Fruit hairiness : Present/absent, less hairy/highly hairy, only on ridges/entire fruit
- vii) Bending : Snaps/bends

j) Seeds

- i) Seediness : Low/medium/high
- ii) Shape : Round/depressed
- iii) Hairiness : Smooth/hairy

2) Following quantitative characters were also recorded

- a) Days to flower
- b) Nodes to first flower
- c) Plant height (m)
- d) Leaf length (cm)

e) Leaf width (cm)

f) Fruit length (cm)

g) Fruit girth (cm)

h) Primary branches/plant

i) Nodes on main stem

j) Fruiting nodes on main stem

k) Internodal length (cm)

l) Fruits/plant

m) Ridges/fruit

n) Seeds/fruit

o) Fruit yield/plant (kg)

3) Observations were also made on host reaction of different genotypes to yellow vein mosaic virus at 20 day intervals.

D. Statistical analysis of data

The details of the statistical analysis followed are as follows:

1) Analysis of variance

Before proceeding with the detailed statistical analysis of the plant characters, the data were analysed, as described by Ostle (1966) for a completely randomised design (CRD). This was performed to test the significance of differences among the genotypes. Analysis of variance was performed separately for M_1s and parents and F_1 hybrids taken together.

The variance due to genotypes was further broken up into variance due to parents, hybrids and parents vs hybrids.

The significance of difference, if any, among the irradiated F_1 genotypes was tested using student 't'.

2) Added vigour in F_1 due to irradiation

The vigour due to irradiation was calculated as follows:

$$\text{Vigour due to treatment 1 (15 kR)} = \frac{(\bar{X}_1 - \bar{X}_0) \times 100}{\bar{X}_0}$$

Where $\bar{X}_1$ = mean performance of M_1 at 15 kR

$\bar{X}_0$ = mean performance of untreated control

Likewise vigour due to 20 kR and 25 kR were estimated for different characters.

Equality of variances was tested using 'F' test, ahead to testing the significance of vigour due to irradiation. When the variances were homogeneous significance of vigour due to irradiation was tested using student 't' test (Panse and Sukhatme, 1978).

$$t = \frac{\left| \bar{X}_1 - \bar{X}_0 \right|}{\sqrt{\dfrac{(n_1-1)\ S_1^2 + (n_0-1)\ S_0^2}{n_1 + n_0 - 2} \left(\dfrac{1}{n_1} + \dfrac{1}{n_0} \right)}}$$

$\bar{X}_1$ - mean of treatment 1

$\bar{X}_0$ - mean of untreated control

s_1^2 - variance due to treatment 1

s_0^2 - variance due to untreated control

n_1 - number of observations in treatment 1

n_0 - number of observations in untreated control

When the variances were not homogeneous Cochrans approximate test (Snedecor and Cochran, 1937) was employed i.e.

$$tc = \frac{\left|\bar{X}_1 - \bar{X}_2\right|}{\sqrt{\dfrac{\sigma^2 x_1}{n_1 - 1} + \dfrac{\sigma^2 x_2}{n_2 - 1}}}$$

where $\bar{X}_1$ = mean of first population

$\bar{X}_2$ = mean of second population

$\sigma^2 x_1$ = variance of first population

$\sigma^2 x_2$ = variance of second population

n_1 = sample size of first population

n_2 = sample size of second population

The calculated value of 'tc' was tested against 't'

$$'t' = \frac{t_1 W_1 + t_2 W_2}{W_1 + W_2}$$

where t_1 and t_2 are table values of t for n_1-1 and n_2-1 degrees of freedom respectively at 5 per cent level.

$$W_1 = \frac{\sigma^2 x_1}{n_1 - 1}$$

$$W_2 = \frac{\sigma^2 x_1}{n_2 - 1}$$

3. Estimation of sensitivity of qualitative characters to gamma radiation

Data on qualitative characters were critically analysed and sensitivity to mutagenic treatments were estimated. From the frequency distribution, percentage of change in each character through mutation was calculated for each genotype. Change in each character was represented in bar diagrams.

4. Estimation of mutagenic efficiency

The mutagenic efficiency was calculated considering the characters plant height and leaf length as per Konzak _et al_. (1965).

$$\text{Mutagenic efficiency} = \frac{M_p}{S} \times 100$$

where M_p = chlorophyll or viable mutants per 100 M_o plants

S = % increase or decrease of the character

5. Estimation of pollen fertility of irradiated interspecific F_1 plants

Pollen fertility was counted using acetocarmine test. Observations from 10 randomly selected plants were recorded in each genotype. The pollen fertility was measured as percentage of viable pollen

$$\text{Percentage of viable pollen} = \frac{\text{Number of viable pollen} \times 100}{\text{Total number of pollen under observation}}$$

6. Quantification of host reaction to yellow vein mosaic virus

Plants exhibiting symptoms of yellow vein mosaic under natural and forced epiphytotic conditions were counted at 20 days interval in all genotypes. Epiphytotic condition was created by feeding viruliferous whiteflies employing microcages. Fasting for one hour was enforced before aquisition and inoculation feedings. Whiteflies were allowed to feed on the lower surface of third leaf from top. All the plants were observed for symptoms of yellow vain mosaic disease. Percentage of yellow vein mosaic incidence was calculated as follows:

$$= \frac{\text{Number of plants with symptoms of yellow vain mosaic} \times 100}{\text{Total number of plants observed}}$$

7. Estimation of maternal parental effect

The data on quantitative characters, collected from direct and reciprocal interspecific F_1 hybrids were analysed using student 't' test (Panse and Sukhatme, 1978) to estimate the maternal parental effect.

Results

RESULTS

The data collected in the present investigation were analysed and are presented below:

A. Cross compatibility between *Abelmoschus manihot* (L.) Medic and *Abelmoschus esculentus* (L.) Moench cv. 'Pusa Sawani'

B. Gamma rays induced variability in Mo generation and evaluation for host reaction to yellow vein mosaic virus

1) General analysis of variance
2) Added vigour in F_1 due to irradiation
3) Estimation of sensitivity of qualitative characters to γ-radiation
4) Estimation of mutagenic efficiency
5) Pollen fertility in irradiated interspecific F_1 hybrid plants
6) Quantification of host reaction to yellow vein mosaic
7) Estimation of maternal parental effect

A. Cross compatibility between *Abelmoschus manihot* (L.) Medic and *Abelmoschus esculentus* (L.) Moench cv. 'Pusa Sawani'

Cross compatibility between three accessions of *Abelmoschus manihot* and the cultivated species *Abelmoschus* *esculentus* was studied (Table 2). Crosses between different accessions of *Abelmoschus manihot* and *Abelmoschus esculentus* showed that the percentage of fruit set did not differ widely in direct and reciprocal crosses (80.00% - 94.80%). There was much difference in seeds/pod depending upon the maternal parent. Seed set/pod was higher in cases where maternal parent was *Abelmoschus esculentus*. It ranged from 52.30 to 77.20 . When *Abelmoschus manihot* was used as maternal parent, seed set/pod was only 14.38 - 19.60 .

The percentage of germination of hybrid seeds was less than the parents except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* (93.33%) and *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus* (81.33%).

The crossability index was the highest for *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* (95.36%) and the lowest in *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus* (49.55%).

The percentage of seed forming efficiency (Table 3) at F_0 level was the highest for *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU) (97.82%) and the lowest for *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus* (63.38%). There was not much of difference in the percentage of seed forming efficiency in direct and reciprocal crosses involving *Abelmoschus esculentus* and *Abelmoschus manihot* (IARI). In *Abelmoschus esculentus* x *Abelmoschus manihot*

Table 2. Compatibility between *Abelmoschus esculentus* (L.) Moench cv. Pusa Sawani and three accessions of *Abelmoschus manihot* (L.)

F_0	A^{c*}	B^{c*}	C^{c*}	Crossability index % (CI)
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	91.42	52.30	72.00	53.88
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	94.80	77.20	72.00	82.47
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus* (IIHR)	96.00	68.00	93.33	95.36
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	80.00	14.38	68.00	49.55
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	93.10	19.60	81.33	66.29

Maternal parent	A^{s**}	B^{s**}	C^{s**}
Abelmoschus esculentus (L.) Moench cv. 'Pusa Sawani'	92.00	78.92	88.00
Abelmoschus manihot (IARI)	92.00	22.69	74.66
Abelmoschus manihot (KAU)	100.00	28.46	78.66

c* = crossed

s** = selfed

A = fruitset(%)

B = average number of seeds/fruit

C = germination(%) of seeds

Table 3. Percentage of seed forming efficiency of the crosses at F_0 level

Genotypes	Seeds in selfed maternal parent	Seeds in crosses	Seed forming efficiency(%)
Abelmoschus esculentus cv. 'Pusa Sawani'	78.92	-	-
Abelmoschus manihot (IARI)	22.69	-	-
Abelmoschus manihot (KAU)	28.46	-	-
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	-	52.30	66.27
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	-	14.38	63.38
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	-	77.20	97.82
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	-	19.60	86.38
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus* 'IIHR)	-	68.00	86.16

(KAU) percentage of seed forming efficiency was 97.82%. In its reciprocal cross it was only 86.38%. The efficiency of seed formation in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* was 86.16%.

The fertility of F_1 hybrids was further evaluated by observing the percentage of fruit set at F_1 level and seeds/F_1 fruit (Table 4). The fruitset (%) ranged from 15.79 to 82.35. It was lowest in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* (15.79%) and highest in *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU) (82.35%). Even though hybrids exhibited high percentage of fruitset, seedset/F_1 fruit was very poor. It ranged from 2.1 to 5.9 seeds/F_1 fruit. The seeds, if at all formed, were shrivelled and were very small in size (Plate V). In all the cross combinations, percentage of normal seeds was low (0.5% - 1%).

Acetocarmine test of pollen fertility of parents and inter specific F_1 hybrids involving *Abelmoschus esculentus* and three accessions of *Abelmoschus manihot* provided useful information (Table 5). Pollen fertility in the parental species *Abelmoschus manihot* ssp. *tetraphyllus* was very high (98.41%). In the case of *Abelmoschus manihot* (IARI), *Abelmoschus manihot* (KAU) and *Abelmoschus esculentus* pollen fertility was 91.2%, 94.52% and 93.44% respectively.

Table 4. Fertility of direct and reciprocal F_1 hybrids of *Abelmoschus esculentus* cv. 'Pusa Sawani' and three accessions of *Abelmoschus manihot*

Hybrids	Number of selfings	Fruitset	Fruitset (%)	Seeds/fruit
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	18	12	66.67	4.20
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	20	12	60.00	5.20
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	17	14	82.35	4.70
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	15	10	66.67	5.90
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus* (IIHR)	19	3	15.79	2.10

In *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI) the fertility was around 19.00% in the direct cross and 15.00% in reciprocal cross. Unlike other interspecific hybrids, pollen fertility of the hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* was very high (74%).

B. Gamma rays induced variability in Mo generation and evaluation for host reaction to yellow vein mosaic virus

1) Analysis of variance

The analysis of variance for the seven genotypes (four F_1s and three parents) grown during November-April 1984-'85, indicated significant differences for all the characters under study (Table 6). Among parents, the differences were significant for days to flower, leaf length, fruit length, fruit girth, ridges/fruit, and fruit yield/plant. The mean square due to hybrids was significant for days to flower, fruit length, fruits/plant and fruit yield. Variance due to parent vs hybrids was significant only for fruit length and seeds/fruit.

Analysis of variance for three genotypes consisting of *Abelmoschus esculentus*, *Abelmoschus manihot* ssp. *tetraphyllus* and their direct F_1 hybrid revealed significant difference among the three genotypes for days to flower, nodes to first flower, leaf length, leaf width, internodal length, plant height, fruit length, seeds/fruit and fruits/plant (Table 7) (Plate VI). The genotypes were not significantly different for nodes on main stem, fruiting nodes on main stem, fruit girth and ridges/fruit.

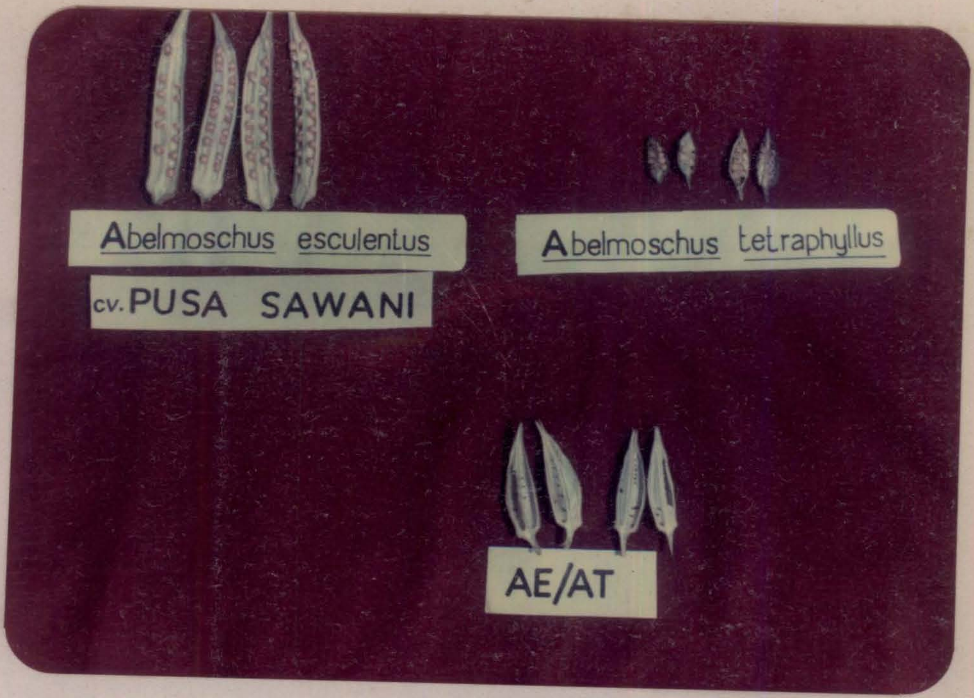
The analysis of variance for the 12 genotypes derived through γ- radiation of direct and reciprocal interspecific hybrids between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot* showed significant difference for days to flower, nodes to first flower, plant height, leaf length, leaf width, fruit length, fruit girth, primary branches/plant, nodes on main stem, fruiting nodes on main stem, internodal length, fruits/plant, ridges/fruit and seeds/fruit. The genotypes were not significantly different for fruit yield (Table 8).

Analysis of variance (Table 9) revealed that there was no significant difference among three genotypes derived through γ-radiation of the interspecific F_1 hybrid between *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* for a set of quantitative characters, except fruit girth.

The M_1 lines were grown and observed for 15 quantitative characters (Table 10). The different genotypes showed considerable variability for days to flower (54-61), nodes to first flower (5.45 - 6.71), plant height (0.61 - 1.02 m),

Plate V Complete absence of seeds in F_1 fruits of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*

Plate VI Medium sized fruits of F_1 plants of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*


Abelmoschus esculentus
cv. PUSA SAWANI
Abelmoschus tetraphyllus
AE/AT

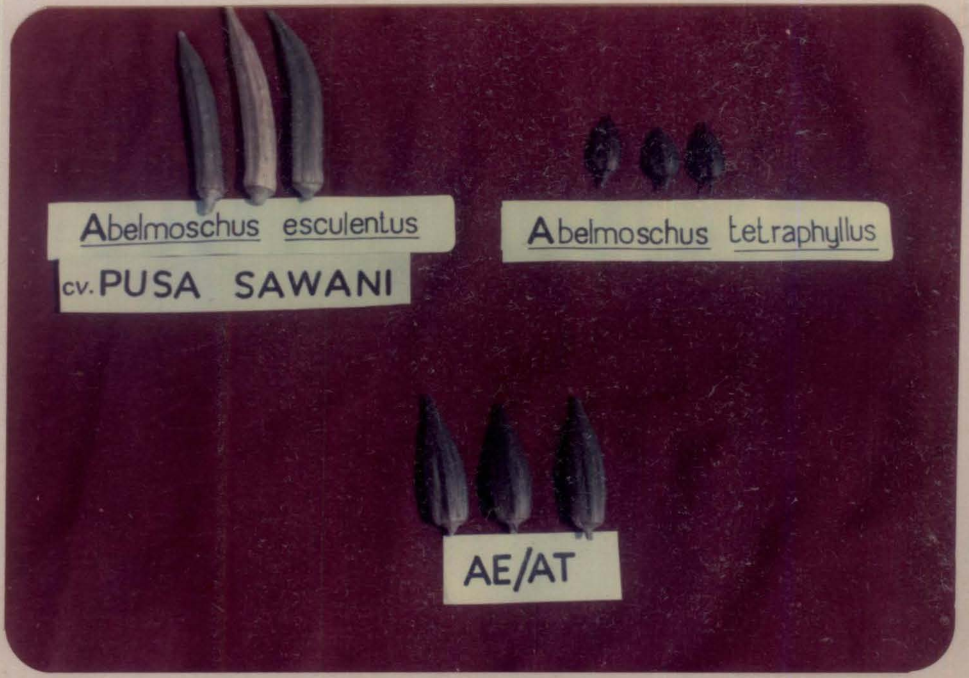

Abelmoschus esculentus
cv. PUSA SAWANI
Abelmoschus tetraphyllus
AE/AT

Table 6. Analysis of variance for seven genotypes including three parents and four F_1 hybrids from direct and reciprocal cross between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*

Sources of variation	df	Mean squares				
		Days to flower	Nodes to first flower	Plant height	Leaf length	Leaf width
Genotypes	6	1289.24**	5.498*	0.425**	1069.37**	715.73**
Parents	2	1647.02*	4.82	0.225	1971.80*	245.62
Hybrids	3	1405.30**	0.31	0.113	150.54	7.78
Parent vs Hybrids	1	226.47	22.42	1.760	2021.00	3779.83
Error	98	53.56	0.94	0.051	99.69	28.65

Sources of variation	df	Mean squares				
		Fruit length	Fruit girth	Primary branches/ plant	Nodeson main stem	Fruiting nodes on main stem
Genotypes	6	41.98**	27.78**	6.374*	264.77**	271.02**
Parents	2	12.95*	36.34*	0.415	3.49	19.29
Hybrids	3	9.40*	0.40	9.333	117.39	20.73
Parents vs Hybrids	1	197.76*	92.82	3.040	1229.47	1525.34
Error	98	0.58	0.75	1.292	13.97	8.47

* P = 0.05   ** P = 0.01

Table 6. (Contd.)

Sources of variation	df	Mean squares				
		Internodal length	Fruits/ plant	Ridges/ fruit	Seeds/ fruit	Fruit yield/ plant
Genotypes	6	14.34*	351.07**	12.43**	5889.26**	0.0765**
Parents	2	13.82	2.06	30.02*	748.29	0.0125
Hybrids	3	5.10	145.31	0.91	2.46	0.064*
Parent vs Hybrids	1	43.13	666.35**	71.82	33831.59*	0.241
Error	98	2.06	2.90	1.37	127.67	0.005

* P = 0.05 ** P = 0.01

Table 7. Analysis of variance for three genotypes consisting of *Abelmoschus esculentus*, *Abelmoschus manihot* ssp. *tetraphyllus* and their direct F_1 hybrid

Character	Mean squares	
	Sources of variation	
	Genotype	Error
Days to flower	319.64^{**}	2.33
Nodes to first flower	18.30^{*}	0.80
Plant height (m)	1.36^{*}	0.05
Leaf length (cm)	188.03^{*}	5.33
Lead width (cm)	346.68^{*}	8.08
Fruit length (cm)	464.23^{**}	2.66
Fruit girth (cm)	81.73	31.73
Nodes on main stem	22.94	3.19
Fruiting nodes on main stem	12.64	3.63
Internodal length (cm)	33.71^{*}	0.95
Fruits/plant	2394.64^{*}	42.40
Ridges/fruit	14.64	1.04
Seeds/fruit	6790.24^{**}	42.90

* $P = 0.05$ ** $P = 0.01$

Degrees of freedom for genotype = 2

Degrees of freedom for error = 27

Table 8. Analysis of variance for 12 mutated genotypes from direct and reciprocal crosses between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*

Character	Mean squares	
	Sources of variation	
	Genotype	Error
Days to flower	542.14^{**}	33.28
Nodes to first flower	12.20^{**}	1.45
Plant height (m)	1.15^{**}	0.11
Leaf length (cm)	1966.00^{**}	157.69
Leaf width (cm)	860.26^{**}	41.47
Fruit length (cm)	83.53^{**}	6.00
Fruit girth (cm)	14.89^{**}	1.64
Primary branches/plant	20.60^{**}	1.24
Nodes on main stem	120.86^{**}	22.89
Fruiting nodes on main stem	191.46^{**}	12.18
Internodal length (cm)	9.79^{*}	2.85
Fruits/plant	356.64^{**}	28.05
Ridges/fruit	22.04^{**}	1.53
Seeds/fruit	250.08^{**}	67.75
Fruit yield/plant	41.47	28.81

* P = 0.05 ** P = 0.01

Degrees of freedom for genotype = 11

Degrees of freedom for error = 1148

Table 9. Analysis of variance for three mutated genotypes from the cross *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*

Character	Mean squares	
	Sources of variation	
	Genotype	Error
Days to flower	65.53	8.39
Nodes to First flower	4.27	1.81
Plant height (m)	2.82	0.15
Leaf length (cm)	751.15	57.96
Leaf width (cm)	219.89	32.85
Fruit length (cm)	1.29	0.73
Fruit girth (cm)	23.69*	0.58
Primary branches/plant	5.17	0.99
Nodes on main stem	207.82	25.04
Fruiting nodes on main stem	100.36	20.33
Internodal length	2.45	5.04
Ridges/fruit	2.31	0.93
Seeds/fruit	352.55	76.30
Fruit/plant	759.30	586.02

* $P = 0.05$

Degrees of freedom for genotype = 2

Degrees of freedom for error = 277

Table 10. Mean performance of 12 genotypes derived through irradiation of direct and reciprocal interspecific F_1 hybrids between *Abelmoschus esculentus* cv 'Pusa Sawani' and two accessions of *Abelmoschus manihot*

Genotype		Days to flower	Nodes to first flower	Plant height (m)	Leaf length (cm)	Leaf width (cm)
P x I	Mo_1	54.20 ± 0.58^{a}	6.30 ± 0.12^{a}	1.00 ± 0.03^{ad}	53.98 ± 1.26^{a}	29.54 ± 0.64^{a}
	Mo_2	54.75 ± 0.59^{a}	6.01 ± 0.12^{ab}	1.02 ± 0.03^{a}	47.14 ± 1.27^{b}	25.07 ± 0.65^{b}
	Mo_3	54.60 ± 0.58^{a}	6.07 ± 0.12^{a}	0.98 ± 0.03^{ad}	48.49 ± 1.28^{b}	22.91 ± 0.64^{c}
I x P	Mo_1	58.34 ± 0.60^{b}	6.15 ± 0.13^{a}	0.91 ± 0.03^{d}	42.87 ± 1.31^{cgh}	21.08 ± 0.67^{cde}
	Mo_2	58.31 ± 0.59^{b}	5.71 ± 0.12^{bc}	0.80 ± 0.03^{b}	43.65 ± 1.28^{cgh}	22.35 ± 0.66^{ce}
	Mo_3	60.96 ± 0.66^{c}	5.45 ± 0.14^{c}	0.67 ± 0.04^{c}	39.56 ± 1.45^{cdfgi}	19.92 ± 0.74^{df}
P x K	Mo_1	55.04 ± 0.58^{a}	6.21 ± 0.12^{a}	0.94 ± 0.03^{a}	44.70 ± 1.26^{ceh}	29.64 ± 0.64^{a}
	Mo_2	57.39 ± 0.58^{b}	6.30 ± 0.12^{a}	0.95 ± 0.03^{a}	42.79 ± 1.26^{cefgh}	21.57 ± 0.64^{cde}
	Mo_3	58.29 ± 0.58^{b}	6.71 ± 0.12^{d}	0.76 ± 0.03^{bc}	41.27 ± 1.28^{g}	21.14 ± 0.64^{e}
K x P	Mo_1	54.04 ± 0.58^{a}	5.73 ± 0.12^{bc}	1.00 ± 0.03^{a}	45.23 ± 1.28^{bh}	21.54 ± 0.64^{cd}
	Mo_2	59.28 ± 0.58^{c}	5.59 ± 0.12^{bc}	0.91 ± 0.03^{a}	40.89 ± 1.26^{cdfg}	19.19 ± 0.64^{cef}
	Mo_3	59.55 ± 0.58^{bc}	5.78 ± 0.12^{bc}	0.80 ± 0.03^{b}	36.91 ± 1.26^{i}	18.19 ± 0.64^{f}

Mo_1 = 15 kR
Mo_2 = 20 kR
Mo_3 = 25 kR

P = *Abelmoschus esculentus*
I = *Abelmoschus manihot* (IARI)
K = *Abelmoschus manihot* (KAU)

Similarity of letters in columns indicate non-significance.

Table 10. (Contd.)

Genotypes		Fruit length (cm)	Fruit girth (cm)	Primary branches/ plant	Nodes on main stem	Fruiting nodes on mainstem
P x I	Mo$_1$	14.87 ± 0.25^{a}	10.74 ± 0.13^{ae}	2.91 ± 0.11^{a}	18.30 ± 0.48^{af}	9.50 ± 0.35^{a}
	Mo$_2$	15.38 ± 0.25^{ad}	11.21 ± 0.13^{b}	2.25 ± 0.11^{b}	16.95 ± 0.49^{ceg}	8.61 ± 0.35^{ae}
	Mo$_3$	14.69 ± 0.25^{a}	10.30 ± 0.13^{c}	2.26 ± 0.11^{b}	18.17 ± 0.48^{adh}	7.40 ± 0.35^{bfi}
I x P	Mo$_1$	14.56 ± 0.26^{ab}	10.29 ± 0.13^{c}	1.68 ± 0.12^{cef}	17.28 ± 0.50^{abcef}	6.50 ± 0.36^{bcgh}
	Mo$_2$	14.00 ± 0.26^{b}	10.29 ± 0.13^{abd}	1.68 ± 0.12^{d}	16.15 ± 0.49^{cde}	6.23 ± 0.36^{cgi}
	Mo$_3$	13.21 ± 0.28^{c}	10.15 ± 0.15^{c}	1.37 ± 0.13^{cd}	15.12 ± 0.55^{d}	3.85 ± 0.40^{d}
P x K	Mo$_1$	15.62 ± 0.25^{d}	10.68 ± 0.13^{ade}	1.90 ± 0.11^{e}	17.54 ± 0.48^{aef}	7.44 ± 0.35^{bf}
	Mo$_2$	17.01 ± 0.25^{e}	10.81 ± 0.13^{ade}	2.40 ± 0.11^{b}	18.65 ± 0.48^{a}	7.88 ± 0.35^{ef}
	Mo$_3$	15.25 ± 0.25^{ad}	10.11 ± 0.13^{c}	2.23 ± 0.11^{b}	16.67 ± 0.48^{e}	5.75 ± 0.35^{g}
K x P	Mo$_1$	14.81 ± 0.25^{a}	9.97 ± 0.13^{c}	1.88 ± 0.11^{b}	18.72 ± 0.48^{a}	7.25 ± 0.35^{bhk}
	Mo$_2$	15.07 ± 0.25^{ad}	10.49 ± 0.13^{e}	1.56 ± 0.11^{cdf}	17.05 ± 0.48^{f}	6.85 ± 0.35^{ijk}
	Mo$_3$	15.98 ± 0.25^{d}	10.42 ± 0.13^{c}	1.68 ± 0.11^{cef}	15.80 ± 0.48^{bcg}	5.86 ± 0.35^{g}

Mo$_1$ = 15 kR

Mo$_2$ = 20 kR

Mo$_3$ = 25 kR

P = *Abelmoschus esculentus*

I = *Abelmoschus manihot* (IARI)

K = *Abelmoschus manihot* (KAU)

Similarity of letters in columns indicate non-significance

Table 10. (Contd.)

Genotype		Internodal length (cm)	Fruits/ plant	Ridges/ fruit	Seeds/ fruit	fruit yield/ plant (g)
P x I	Mo_1	3.35 ± 0.17^{abch}	13.07 ± 0.53^{ae}	5.89 ± 0.12^{a}	8.07 ± 0.82^{ade}	233.83 ± 53.68^{a}
	Mo_2	2.95 ± 0.17^{ac}	10.32 ± 0.54^{b}	5.99 ± 0.13^{a}	9.03 ± 0.84^{a}	386.69 ± 54.50^{b}
	Mo_3	3.70 ± 0.17^{bde}	11.29 ± 0.53^{abd}	6.05 ± 0.12^{ac}	6.88 ± 0.82^{acdefh}	190.14 ± 53.68^{a}
I x P	Mo_1	3.75 ± 0.18^{be}	12.34 ± 0.55^{ad}	6.34 ± 0.13^{bce}	4.46 ± 0.86^{b}	205.17 ± 55.96^{a}
	Mo_2	3.59 ± 0.17^{bde}	8.94 ± 0.54^{cfg}	6.68 ± 0.13^{deg}	6.82 ± 0.84^{dceg}	174.50 ± 54.79^{a}
	Mo_3	3.24 ± 0.20^{cdgi}	8.55 ± 0.61^{c}	6.00 ± 0.14^{a}	4.63 ± 0.95^{bh}	143.11 ± 61.98^{a}
P x K	Mo_1	3.60 ± 0.17^{bde}	10.31 ± 0.53^{bf}	6.78 ± 0.12^{d}	4.46 ± 0.82^{b}	196.54 ± 53.68^{a}
	Mo_2	3.34 ± 0.17^{abg}	14.47 ± 0.53^{e}	6.65 ± 0.12^{de}	4.26 ± 0.82^{b}	250.19 ± 53.68^{a}
	Mo_3	3.88 ± 0.17^{ef}	10.78 ± 0.53^{b}	7.19 ± 0.12^{bh}	7.12 ± 0.82^{e}	164.33 ± 53.68^{a}
K x P	Mo_1	4.18 ± 0.17^{f}	7.73 ± 0.53^{c}	6.54 ± 0.12^{e}	4.46 ± 0.82^{b}	134.16 ± 53.68^{a}
	Mo_2	3.58 ± 0.17^{eg}	10.07 ± 0.53^{bg}	7.00 ± 0.12^{gh}	5.80 ± 0.82^{bfg}	209.72 ± 53.68^{a}
	Mo_3	3.55 ± 0.17^{eghi}	10.91 ± 0.53^{b}	7.24 ± 0.12^{h}	6.53 ± 0.82^{dg}	196.05 ± 53.68^{a}

Mo_1 = 15 kR

Mo_2 = 20 kR

Mo_3 = 25 kR

P = *Abelmoschus esculentus*

I = *Abelmoschus manihot* (IARI)

K = *Abelmoschus manihot* (KAU)

Similarity of letters in columns indicate non-significance leaf length (36.91 - 53.98 cm), leaf width (18.19 - 29.57 cm), fruit length (14.00 - 17.01 cm), fruit girth (9.77 - 11.21 cm), branches/plant (15.12 - 18.72), fruiting nodes on main stem (5.85 - 9.50), internodal length (2.95 - 4.18 cm), fruits/plant (7.73 - 14.47), ridges/fruit (5.89 - 7.24) and seeds/fruit (4.26 - 9.03).

In three genotypes derived through irradiation of the interspecific F_1 hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, significant variation was observed only for fruit girth (Table 11). It ranged from 6.33 to 7.26 cm. For all other characters, the mean performance of three genotypes were not significantly different.

2) Added vigour in F_1 due to irradiation

The irradiated F_1 genotypes were compared with untreated control (corresponding F_1 plants) for a set of quantitative characters (Table 12).

Days to flower

The γ-radiation induced earliness in the interspecific hybrids, except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*. When the interspecific F_1 hybrids *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus* took 71 days to first flower, the F_1s treated with γ-radiation took only 54-60 days. The interspecific hybrid *Abelmoschus manihot*

(IARI) x *Abelmoschus esculentus* when treated with γ-radiation took only 58-60 days to first flower, the F_1s took 73 days to first flower.

Nodes to first flower

Number of nodes to first flower remained more or less same in F_1s and treated F_1s (5-6 days) from direct and reciprocal cross between *Abelmoschus esculentus* and 2 accessions of *Abelmoschus manihot*. Only in the F_1, *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU) nodes to first flower increased substantially with γ-radiation

Plant height.

The gamma radiation increased plant height in interspecific hybrids, except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*. In interspecific hybrids involving *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*, plant height ranged from 0.63 m to 0.84 m. When the F_1s were treated with gamma rays plant height observed was from 0.75 m to 1.01 m. In the F_1, *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* plant height decreased from 1.27 m to 0.93 m with gamma radiation (15 kR).

Leaf length

Increase in leaf length was observed in all the irradiated interspecific hybrids. Maximum increase (45.29%)

was observed in *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus* with 15 kR of gamma radiation.

Leaf width

Leaf width was increased with gamma radiation in all the interspecific hybrids, except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*. The interspecific hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI) when treated with 15 kR γ-radiation, leaf width was 29.54 cm, while in F_1s the leaf width was only 18.13 cm. In F_1 hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* leaf width decreased from 7.78 cm (F_1s) to 6.87 cm with gamma radiation.

Fruit length

The irradiation decreased the fruit length significantly in all the interspecific hybrids, except in *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU). Maximum decrease in fruit length (15.75%) was observed in *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus* treated with 15 kR of gamma radiation.

Fruit girth

The gamma radiation increased the fruit girth significantly in all the interspecific hybrids, except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*.

In direct and reciprocal interspecific hybrids involving Abelmoschus esculentus and two accessions of Abelmoschus manihot, mean fruit girth ranged from 9.16 cm to 9.56 cm. In mutated F_1s the fruit girth ranged from 9.97 cm to 11.21 cm. In the F_1 Abelmoschus esculentus x Abelmoschus manihot ssp. tetraphyllus, gamma radiation decreased the fruit girth from 7.33 cm (in F_1s) to 6.33 cm, 7.11 cm and 7.26 cm for 15 kR, 20 kR and 25 kR doses respectively.

Nodes on main stem

Radiation treatments reduced the nodes on main stem in all the interspecific hybrids, except in Abelmoschus esculentus x Abelmoschus manihot ssp. tetraphyllus and in Abelmoschus manihot (KAU) x Abelmoschus esculentus received 15 kR gamma radiation. In Abelmoschus esculentus x Abelmoschus manihot (IARI) gamma radiation reduced the node number from 24 to 17 and in its reciprocal cross node number was reduced from 20 to 15. In Abelmoschus esculentus x Abelmoschus manihot ssp. tetraphyllus, increase in nodes on main stem was observed upto 28% with 20 kR gamma radiation.

Fruiting nodes on main stem

The gamma radiation significantly decreased the fruiting nodes on main stem in all hybrids, except in Abelmoschus esculentus x Abelmoschus manihot ssp. tetraphyllus. In all cases maximum decrease was in genotypes receiving 25 kR

Table 12. Increase or decrease in vigour due to irradiation as observed in F_1 generation

	Days to first flower	Increase or decrease(%) over control	Standard error	Nodes to first flower	Increase or decrease(%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	55.46			5.93		
Mo_1	54.20	-2.97	1.98	6.30	6.24	0.28
Mo_2	54.38	-1.99	1.98	6.01	1.35	0.28
Mo_3	54.59	-2.27	1.98	6.07	2.36	0.28
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	73.33			5.73		
Mo_1	58.34	-20.44**	1.98	6.15	7.33	0.28
Mo_2	58.31	-20.48**	1.98	5.72	-0.18	0.27
Mo_3	60.96	-16.87	2.00	5.45	-4.89	0.29
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	55.73			6.00		
Mo_1	55.05	- 1.22	1.97	6.21	3.50	0.28
Mo_2	57.39	- 2.98	1.97	6.30	5.00	0.28
Mo_3	58.29	4.59	1.97	6.71	11.80**	0.28
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	71.26			5.80		
Mo_1	54.04	-24.17**	1.97	5.73	-1.21	0.28
Mo_2	59.28	-16.81**	1.97	5.59	-3.62	0.29
Mo_3	59.55	-16.43**	1.97	5.78	-0.34	0.29
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	43.40			7.10		
Mo_1	47.17	8.69	0.58	6.78	-4.51	0.32
Mo_2	47.58	9.63	0.58	7.16	0.85	0.32
Mo_3	48.71	12.24	0.58	7.15	0.70	0.32

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR ** P = 0.01

Table 12. (Contd.)

	Plant height (m)	Increase or decrease(%) over control	Standard error	Leaf length (cm)	Increase or decrease(%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	0.837			37.66		
Mo_1	1.004	19.95*	0.066	53.98	43.34**	2.87
Mo_2	1.021	21.98*	0.067	47.14	25.17**	2.88
Mo_3	0.987	17.92	0.066	48.49	28.16**	2.87
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	0.707			33.60		
Mo_1	0.914	29.28**	0.068	43.65	29.90**	2.89
Mo_2	0.801	13.29	0.067	42.57	27.58**	2.88
Mo_3	0.790	8.30	0.070	39.56	17.73*	2.95
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	0.726			32.13		
Mo_1	0.935	28.78**	0.066	44.70	39.12**	2.87
Mo_2	0.750	3.31	0.066	42.79	33.17**	2.87
Mo_3	0.756	4.13	0.066	41.27	24.57**	2.87
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	0.630			31.13		
Mo_1	1.009	60.15**	0.066	45.23	45.29**	2.87
Mo_2	0.909	44.28**	0.066	40.89	31.35**	2.87
Mo_3	0.801	27.14**	0.066	36.91	18.57*	2.87
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	1.270			17.00		
Mo_1	0.930	-26.77**	0.079	17.13	0.76	1.08
Mo_2	1.230	-3.15	0.079	19.98	17.53**	1.08
Mo_3	1.229	3.23	0.079	19.63	15.47**	1.07

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR * P = 0.05; ** P = 0.01

Table 12. (Contd.)

	Leaf width (cm)	Increase or decrease (%) over control	Standard error	Fruit length (cm)	Increase or decrease (%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	18.13			17.12		
Mo_1	29.54	62.93**	1.52	14.87	-13.14**	0.314
Mo_2	25.07	38.28**	1.53	15.38	-10.65**	0.317
Mo_3	22.91	26.26**	1.52	14.69	-14.19**	0.314
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	16.60			15.68		
Mo_1	21.07	26.93**	1.53	14.56	-7.14**	0.322
Mo_2	22.35	34.64**	1.53	14.00	-10.70**	0.318
Mo_3	19.92	20.00*	1.57	13.21	-15.75**	0.344
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	16.86			16.49		
Mo_1	21.64	28.35**	1.52	15.62	-5.28**	0.314
Mo_2	21.57	27.94**	1.52	17.01	3.15	0.314
Mo_3	21.14	25.39**	1.52	15.24	-7.50**	0.314
Abelmoschus manihot (KAU) *Abelmoschus esculentus*	16.66			17.49		
Mo_1	21.54	29.29**	1.52	14.81	-15.39**	0.314
Mo_2	19.19	15.18	1.52	15.07	-13.84**	0.314
Mo_3	18.19	9.18	1.52	15.99	-8.58**	0.314
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	7.78			7.78		
Mo_1	6.87	2.48	1.08	6.87	-11.90	0.523
Mo_2	6.87	15.54**	1.08	6.87	-11.70	0.523
Mo_3	7.07	19.50**	1.06	7.07	-9.13	0.523

Mo_1 = 15 kr; Mo_2 = 20 kR; Mo_3 = 25 kR * P = 0.05; ** P = 0.01

Table 12. (Contd.)

	Fruit girth (cm)	Increase or decrease(%) over control	Standard error	Nodes on main stem	Increase or decrease(%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	9.56			23.60		
Mo_1	10.74	12.34**	0.258	18.29	-22.50**	1.075
Mo_2	11.21	17.26**	0.260	16.95	-28.18**	1.078
Mo_3	10.31	7.84**	0.258	18.17	-23.00**	1.075
Abelmoschus manihot (IARI) *Abelmoschus esculentus*	9.38			20.07		
Mo_1	10.29	9.70**	0.261	17.28	-13.90*	1.084
Mo_2	10.97	16.95**	0.251	16.15	-19.53**	1.080
Mo_3	10.15	8.21**	0.268	15.12	-24.66**	1.110
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	9.16			19.40		
Mo_1	10.68	16.59**	0.258	17.54	-9.59	1.075
Mo_2	10.82	18.12**	0.258	18.65	-3.87	1.075
Mo_3	10.09	10.15**	0.268	16.67	-14.07*	1.075
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	9.37			18.33		
Mo_1	9.97	6.40*	0.258	18.72	2.13	1.075
Mo_2	10.49	11.95**	0.258	17.05	-6.98	1.075
Mo_3	10.12	8.00**	0.258	15.80	-13.80*	1.075
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	7.33			19.60		
Mo_1	6.33	-18.64**	0.178	22.23	13.42**	0.773
Mo_2	7.11	-8.61**	0.178	25.13	28.21**	0.773
Mo_3	7.26	-6.68**	0.178	24.45	24.74**	0.773

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR * P = 0.05 ** P = 0.01

Table 12. (Contd.)

	Fruiting nodes on main stem	Increase or decrease(%) over control	Standard error	Internodal length (cm)	Increase or decrease(%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot*(IARI)	10.87			4.55		
Mo_1	9.50	-12.60	0.829	3.35	-26.37**	0.404
Mo_2	8.60	-20.88**	0.831	2.95	-35.16**	0.408
Mo_3	7.40	-31.92**	0.829	3.69	-18.90*	0.404
Abelmoschus manihot(IARI)x *Abelmoschus esculentus*	10.20			4.69		
Mo_1	6.50	-36.27**	0.835	3.74	-20.26*	0.409
Mo_2	6.23	-38.92**	0.831	3.59	-23.45**	0.408
Mo_3	3.83	-62.45**	0.727	3.24	-30.90**	0.418
Abelmoschus esculentus x *Abelmoschus manihot*(KAU)	12.00			5.09		
Mo_1	7.44	-38.00**	0.829	3.64	-28.49**	0.404
Mo_2	7.88	-34.33**	0.829	3.64	-34.38**	0.404
Mo_3	7.75	-52.08**	0.829	3.87	-23.26**	0.404
Abelmoschus manihot(KAU) x *Abelmoschus esculentus*	9.40			5.84		
Mo_1	7.25	-22.87*	0.829	4.18	-28.42**	0.404
Mo_2	6.85	-27.13**	0.829	3.58	-38.70**	0.404
Mo_3	5.86	-37.66**	0.829	3.71	-36.47**	0.404
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *Tetraphyllus*	10.50			5.36		
Mo_1	14.47	37.81**	0.767	5.36	0	0.389
Mo_2	16.54	57.52**	0.767	5.63	5.04	0.387
Mo_3	15.87	51.14**	0.756	5.65	5.41	0.382

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR * $P = 0.05$; ** $P = 0.01$

Table 12. (Contd.)

	Fruits/ Plant	Increase or decrease(%) over control	Standard error	Seeds/ fruit	Increase or decrease(%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot*(IARI)	17.80			5.00		
Mo_1	13.07	-26.57**	0.689	8.07	61.40	3.03
Mo_2	10.32	-42.02**	0.694	9.03	80.60	3.03
Mo_3	11.29	-36.57**	0.689	6.88	37.60	3.03
Abelmoschus manihot(IARI)x *Abelmoschus esculentus*	12.13			5.93		
Mo_1	12.54	3.38	0.706	4.50	-24.10	3.04
Mo_2	8.94	-26.29**	0.697	6.80	14.67	3.04
Mo_3	8.55	-29.50**	0.753	4.60	-22.40	3.07
Abelmoschus esculentus x *Abelmoschus manihot*(KAU)	13.93			5.67		
Mo_1	10.31	-25.98**	0.689	4.46	-21.34	3.03
Mo_2	14.47	3.87	0.689	4.26	-24.87	3.03
Mo_3	10.78	-22.61**	0.689	7.11	25.39	3.03
Abelmoschus manihot(KAU) *Abelmoschus esculentus*	10.66			5.33		
Mo_1	7.73	-22.48**	0.689	4.46	-16.32	3.03
Mo_2	10.07	-5.50	0.689	5.80	8.80	3.03
Mo_3	10.91	2.34	0.689	6.53	-22.50	3.03
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	39.90			0.50		
Mo_1	39.85	-0.13	3.260	6.21	1142.00*	2.27
Mo_2	43.12	8.07	3.290	9.69	13.38**	2.27
Mo_3	45.49	14.01	3.200	9.52	9.04*	2.25

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR * P = 0.05; ** P = 0.01

Table 12. (Contd.)

	Primary branches/ plant	Increase or decrease (%) over control	Standard error	Ridges/ fruit	Increase or decrease (%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	3.13			7.73		
Mo_1	2.91	-7.03	0.314	5.89	-23.80**	0.326
Mo_2	2.25	-28.11**	0.314	5.98	-22.64**	0.326
Mo_3	2.26	-27.87**	0.314	6.05	-21.73**	0.326
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	1.60			7.47		
Mo_1	1.68	5.00	0.315	6.33	-15.26**	0.328
Mo_2	1.35	-15.63	0.315	6.68	-10.58**	0.327
Mo_3	1.37	-14.38	0.326	6.00	-19.68**	0.334
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	2.87			7.80		
Mo_1	1.90	-33.80**	0.314	6.78	-13.08**	0.326
Mo_2	2.40	-16.38	0.314	6.65	-14.74**	0.326
Mo_3	2.23	-22.30*	0.314	7.19	-7.82	0.326
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	1.80			7.27		
Mo_1	1.88	4.44	0.314	6.54	-10.04*	0.326
Mo_2	1.56	-13.33	0.314	7.00	-3.71	0.326
Mo_3	1.68	-6.67	0.314	7.24	-0.41	0.326
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	4.96			5		
Mo_1	4.78	-3.62	0.291	5	0	-
Mo_2	4.84	-2.42	0.291	5	0	-
Mo_3	4.80	-3.23	0.291	5	0	-

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR * P = 0.05; ** P = 0.01

Table 12. (Contd.)

	Fruit yield per plant (kg)	Increase or decrease(%) over control	Standard error
Abelmoschus esculentus x *Abelmoschus manihot*(IARI)	0.217		
Mo_1	0.233	7.37	0.057
Mo_2	0.386	77.88**	0.057
Mo_3	0.219	0.92	0.057
Abelmoschus manihot (IARI) x *Abelmoschus esculentus*	0.140		
Mo_1	0.205	46.42	0.059
Mo_2	0.174	24.29	0.057
Mo_3	0.143	2.14	0.047
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	0.153		
Mo_1	0.196	28.10	0.057
Mo_2	0.250	63.39*	0.057
Mo_3	0.164	7.18	0.057
Abelmoschus manihot (KAU)x *Abelmoschus esculentus*	0.123		
Mo_1	0.134	8.94	0.057
Mo_2	0.209	69.90	0.057
Mo_3	0.196	59.30	0.057
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *Tetraphyllus*	-	-	-
Mo_1	-	-	-
Mo_2	-	-	-
Mo_3	-	-	-

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR * P = 0.05; ** P + 0.01

gamma radiation, which ranged from 31.92% to 62.45%. The interspecific hybrid *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus* when treated with 25 kR gamma radiation, the number of fruiting nodes on main stem was reduced to four, while the F_1s had ten fruiting nodes. In *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* fruiting nodes on main stem increased from ten (in F_1s) to 17 with 20 kR gamma radiation.

Internodal length

The radiation treatments decreased the internodal length of the F_1 hybrids between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*. In F_1 hybrids, the internodal length ranged from 4.55 cm to 5.84 cm, whereas in irradiated F_1 genotypes, it ranged from 2.94 cm to 4.18 cm only. In *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus*, internodal length was 5.84 cm. This was reduced to 3.58 cm when the F_1 was treated with 20 kR γ- radiation.

Fruits/plant

The irradiation reduced the fruits/plant in F_1 hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI). Where the F_1s had 18 fruits, fruits/plant was reduced to ten, when treated with 20 kR gamma radiation. The F_1s, *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus* had 12 fruits/plant, the irradiated F_1s had eight to nine fruits/plant. In *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU) fruits/plant was reduced from 14 (in F_1s) to 10 in irradiated F_1s (15 kR). In the reciprocal cross fruits/plant was reduced from 11 to 8 with gamma radiation (15 kR).

Seeds/fruit

Except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, gamma radiation did not create any significant variation for seeds/fruit. The interspecific hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* when treated with 15 kR, 20 kR and 25 kR gamma radiation seeds/fruit got enhanced to 6,10 and 10 respectively. The F_1 plants produced only one seed/fruit on an average.

Primary branches/plant

The gamma radiation decreased the primary branches/plant in all the hybrids, except in *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus* and *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus* treated with 15 kR gamma radiation. In *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* all the F_1s and irradiated F_1s had 5 branches/plant.

Ridges/fruit

Radiation treatments reduced ridges/fruit in all the F_1 hybrids involving *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*. In direct and reciprocal crosses of *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI), F_1s had eight ridges/fruit and irradiated F_1s had six ridges/fruit. Ridges/fruit was not altered by gamma radiation in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp *tetraphyllus*. All F_1s and irradiated F_1s had five ridges/fruit.

Fruit yield

The radiation treatments resulted in increase in fruit yield in all interspecific hybrids except in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*. *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI) when treated with 20 kr γ-radiation had 0.386 kg/plant. The F_1 plant yielded only 0.217 kg of fruit/plant. *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU) yielded 0.153 kg fruit/plant. In irradiated F_1s (20 kR) fruit yield was 0.25 kg/plant. Severe fruit shedding was observed in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, within seven days of flower opening and as such observations on fruit yield could not be taken.

3) Estimation of sensitivity of qualitative characters to γ-radiation

Morphological transformations in mutant generations were critically observed (Appendix I). Branched habit was dominant over unbranched habit. The γ-radiation altered branched habit to unbranched in 12.7% of interspecific hybrids between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*. In *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, the percentage of unbranched mutants was very low (0.7%). All the F_1 plants had smooth stem but 12.8% of mutant plants derived from direct and reciprocal crosses between *Abelmoschus esculentus* and *Abelmoschus manihot* had pubescent stem.

Leaf lamina and petiole were pubescent in all the direct and reciprocal F_1 plants of *Abelmoschus esculentus* x twoaccessions of *Abelmoschus manihot*. In the M_1 generation, 11.2% of the plants had smooth lamina and 7.3% of plants had smooth petiole. All the F_1s of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* had pubescent stem, lamina and petiole, while in the M_1 generation, 18.7% of plants had smooth stem, 16.3% had smooth lamina and 7.8% had smooth petiole.

Dominant characters, red stem and petiole colour got altered with γ-radiation. In M_0 generation, plants having red with green tinged stem and petiole were common. The direct and reciprocal F_1s involving *Abelmoschus esculentus* and *Abelmoschus manihot* (KAU) had green stem and petiole, while mutant plants having green with red tinged stem (32-48%) and petiole (55-67%) were observed.

No change was observed for pigmentation of veins and corolla throat, leaf shape, fruit shape and hairiness of stigma, fruit dehiscence at maturity, seed shape and hairiness of seeds, through irradiation.

Deeply fided leaf margin was dominant over narrowly fided leaf margin. In 37.9% of the γ-radiated plants, narrowly fided leaf margin was observed. The percentage of change was only 7% in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*. Pointed leaf tip character of the F_1 plants (97.5%) got mutated to blunt tipped leaf by 20.3% to 43.4% through γ-radiation.

Hairiness of flower bud and calyx in F_1 plant were also altered with γ-radiation. In M_1 generation, plants with smooth calyx and flower buds ranged from 7.3% to 16.1% and 9.7% to 17.1% respectively. Multifid stigma nature of the F_1 plants was changed to bifid stigma in 0.8% - 4.6% of irradiated F_1 plants.

Red tinged fruit colour was dominant in *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI). In irradiated F_1 generation, fruit colour varied widely from yellowish green (5.7% - 8.5%) to green (41.7% - 55.5%), green fruit colour was dominant in crosses involving *Abelmoschus esculentus* and *Abelmoschus manihot* (KAU). Colour variations in fruit like darkgreen (5.0% - 6.0%), yellowish green (0% - 2.0%), green with red tinge (55.0% - 58.0%) and red with green (4.0% - 5.0%) were observed in irradiated F_1 plants.

The percentage of small fruited plants was reduced in irradiated F_1 generation (1.6% - 3.0%) whereas in untreated control eight to ten per cent of plants had small fruits. Eighty per cent of the F_1 plants of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. tetraphyllus had small fruits. In irradiated F_1 plants, only 53 % of plants had small fruits.

Though γ-radiation changed the highly hairy nature of fruits to less hairy by nine per cent, none of the plants had fruits without any hairs, in direct and reciprocal crosses of *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*. In irradiated F_1s, majority of plants (65%) had tender fruits, whereas 33-47% of F_1 plants had tender fruits. In irradiated F_1, *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, 21% of plants had tender fruits as against nil in F_1s.

In 89% of irradiated F_1 plants of *Abelmoschus esculentus* x two accessions of *Abelmoschus manihot* seeds/fruit were comparatively very low like the F_1s. However, 11% of irradiated F_1s had medium seeded fruits as against five per cent in F_1s. Sensitivity of different characters to gamma radiation are presented in bar diagrams (Fig. 1, 2, 3 and 4).

4) Estimation of mutagenic efficiency

Two quantitative characters *viz*. plant height and leaf

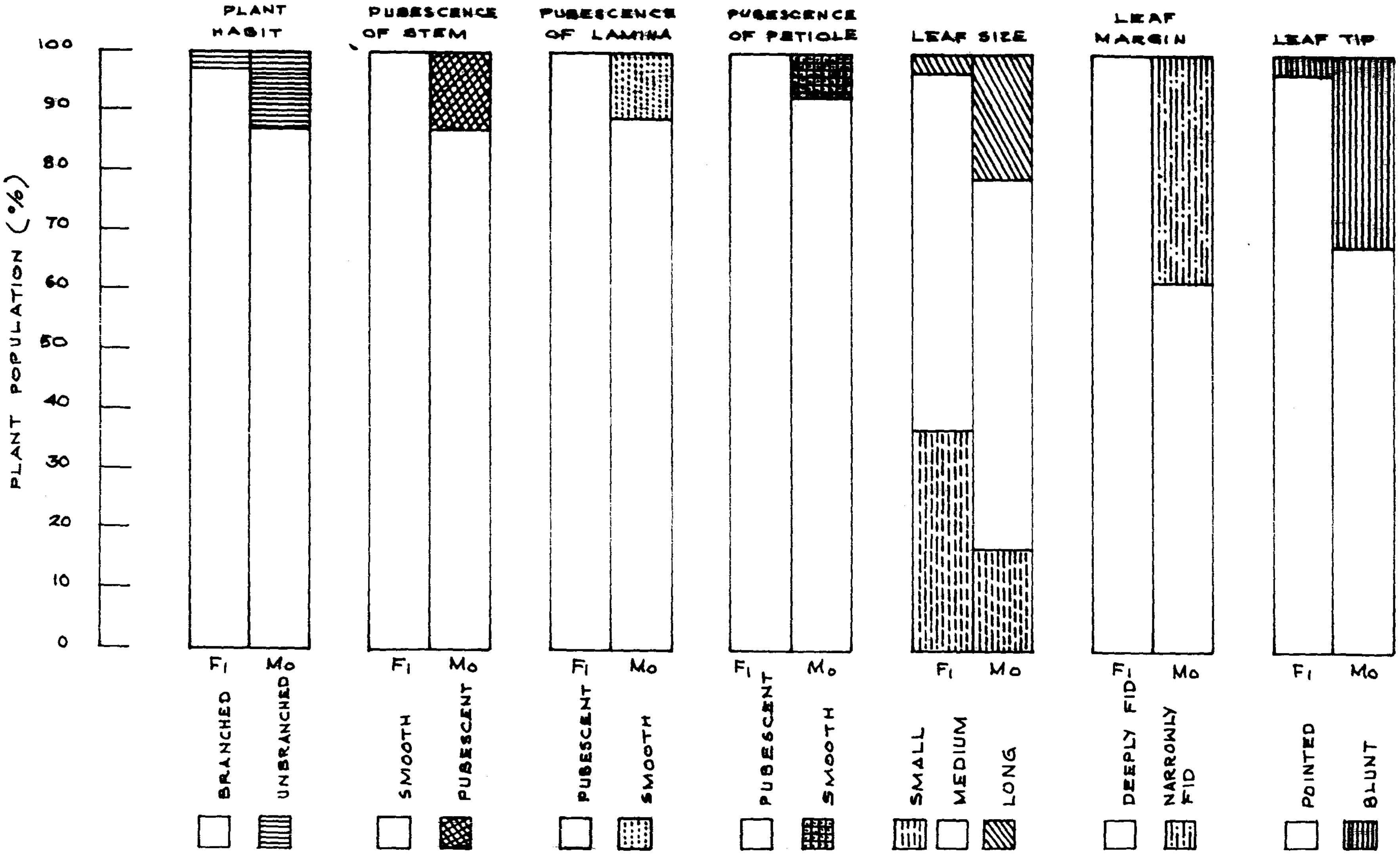


FIG. 1. SENSITIVITY OF VEGETATIVE CHARACTERS TO GAMMA RADIATION IN DIRECT AND RECIPROCAL INTERSPECIFIC F1 HYBRIDS BETWEEN *Abelmoschus esculentus* AND TWO ACCESSIONS OF *Abelmoschus manihot*

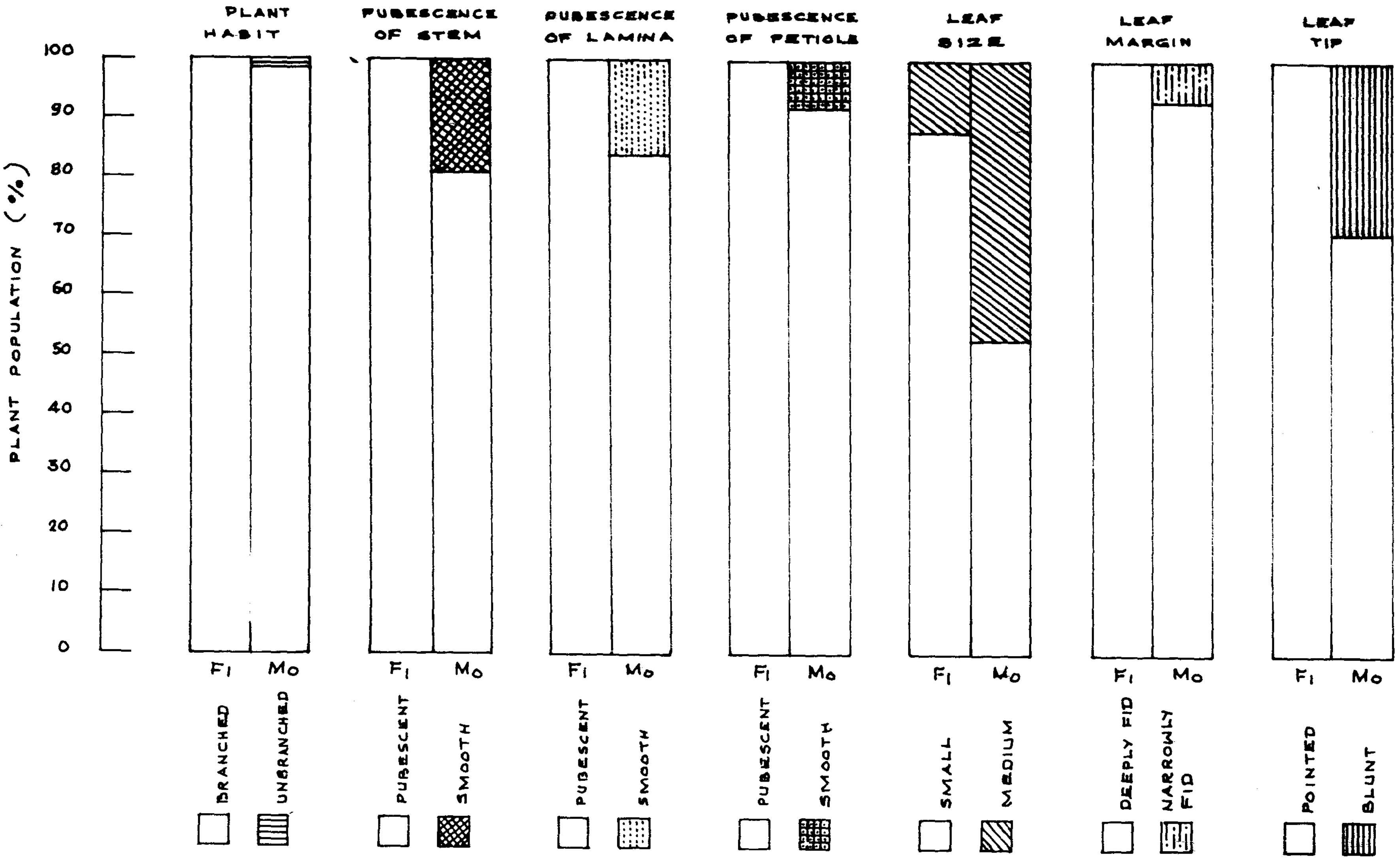


FIG: 2. SENSITIVITY OF VEGETATIVE CHARACTERS TO GAMMA RADIATION IN INTER-SPECIFIC F_1 HYBRID BETWEEN *Abelmoscus esculentus* AND *Abelmoschus manihot ssp. tetraphyllus*

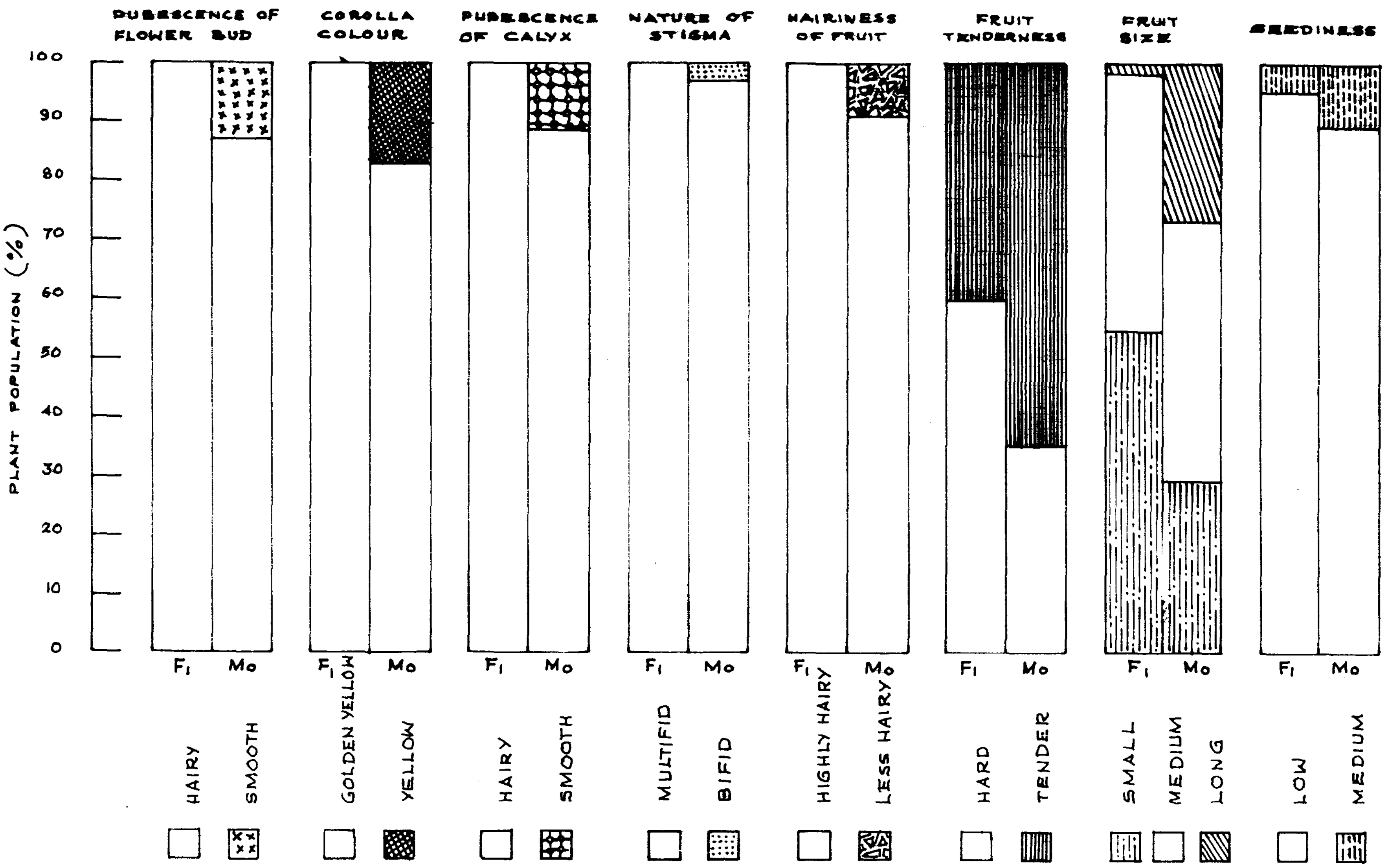


FIG. 3 SENSITIVITY OF REPRODUCTIVE CHARACTERS TO GAMMA RADIATION IN DIRECT AND RECIPROCAL INTERSPECIFIC F_1 HYBRIDS BETWEEN *Abelmoschus esculentus* AND TWO ACCESSIONS OF *Abelmoschus manihot*

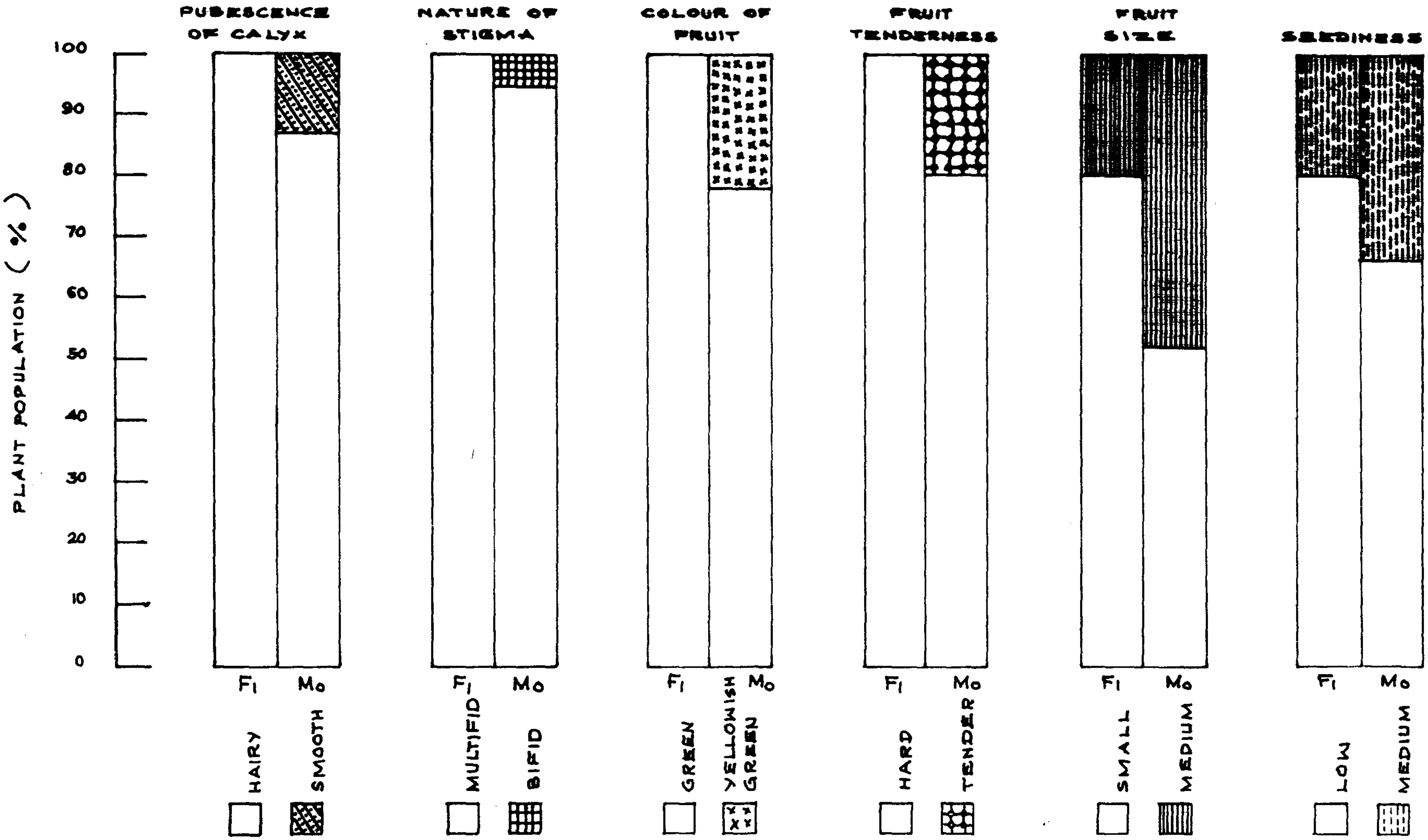


FIG: 4, SENSITIVITY OF REPRODUCTIVE CHARACTERS TO GAMMA RADIATION IN INTER-SPECIFIC F₁ HYBRID BETWEEN *Abelmoschus esculentus* AND *Abelmoschus manihot ssp. tetraphyllus* length were taken as dependable parameters for estimating the mutagenic efficiency. Relative effects of three doses of gamma radiation on plant height and leaf length were estimated by method suggested by Konzak *et al.* (1965) revealed that mutagenic efficiency increased with an increase in dose of gamma radiation (Table 13).

5) Pollen fertility in irradiated interspecific F_1 hybrid plants

Acetocarmine tests for pollen fertility of irradiated interspecific F_1 hybrids were conducted (Table 14).

Pollen fertility of the parental species (Table 5) were very high, ranging from 91.20% in *Abelmoschus manihot* (IARI) to 98.41% in *Abelmoschus manihot* ssp. *tetraphyllus*. In the F_1 hybrids the pollen fertility was comparatively low (15% to 19%) except in the cross *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* (74%).

In the F_1 hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI), average pollen fertility was only 18.95%. Pollen fertility in the three mutated F_1s (Mo_1, Mo_2 and Mo_3) of the above cross had fertility of 23%, 30% and 36% respectively. In the reciprocal of the above cross, pollen fertility increased with an increase in dose of γ-radiation (19%, 20% and 29% respectively for 15 kR, 20 kR and 25 kR of γ-radiation treatments). The F_1 pollen fertility was 15% only.

Table 13. Mutagenic efficiency of gamma radiation on plant height and leaf length of interspecific F_1 hybrid between *Abelmoschus esculentus* x 3 accessions of *Abelmoschus manihot*

	Plant height			Leaf length		
	Mo_1	Mo_2	Mo_3	Mo_1	Mo_2	Mo_3
Abelmoschus esculentus x *Abelmoschus manihot* (IARI)	501.25	441.31	558.04	230.73	385.38	355.11
Abelmoschus manihot (IARI) *Abelmoschus esculentus*	314.21	722.35	903.61	333.58	321.07	423.01
Abelmoschus esculentus x *Abelmoschus manihot* (KAU)	347.46	3021.15	2421.31	255.62	301.48	407.00
Abelmoschus manihot (KAU) x *Abelmoschus esculentus*	166.25	225.84	368.46	220.80	318.98	538.50
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus* (IIHR)	-343.67	-2920.63	-3034.06	370.68	502.56	592.02

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR

Table 14. Pollen fertility (%) in irradiated interspecific F_1 hybrid genotypes in the genus *Abelmoschus*

Abelmoschus esculentus x *Abelmoschus manihot*(IARI)			*Abelmoschus manihot*(IARI) x *Abelmoschus esculentus*		
Mo_1	Mo_2	Mo_3	Mo_1	Mo_2	Mo_3
50.44	29.32	49.84	8.72	20.44	31.37
41.88	84.53	68.74	41.27	19.91	14.80
24.66	52.19	30.03	24.62	19.40	22.50
15.23	20.54	19.57	14.07	19.85	48.52
12.53	16.49	31.91	18.30	19.57	54.60
24.10	32.85	41.20	18.71	18.66	38.66
11.85	52.97	27.08	17.36	19.59	21.34
20.08	16.09	19.49	21.13	21.62	24.70
15.80	30.56	30.07	8.18	25.31	14.60
15.53	25.00	45.65	20.56	20.86	30.67
Mean ± 23.11 ±	30.05 ±	36.39 ±	19.29 ±	20.52 ±	29.14 ±
SD 13.08	13.12	15.20	9.33	1.87	14.55

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR

Table 14.   (Contd.)

	Abelmoschus esculentus x *Abelmoschus manihot* (KAU)			*Abelmoschus manihot* (KAU) x *Abelmoschus esculentus*			*Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*		
	Mo_1	Mo_2	Mo_3	Mo_1	Mo_2	Mo_3	Mo_1	Mo_2	Mo_3
	11.64	14.30	19.21	29.82	26.23	46.09	80.98	93.75	84.03
	14.68	24.90	32.69	21.27	20.00	46.03	70.89	80.49	78.37
	8.51	20.85	23.02	14.34	24.79	29.00	78.38	83.80	85.16
	21.87	27.35	41.77	17.18	14.68	17.98	76.72	75.58	82.45
	14.20	13.22	17.91	15.11	16.12	34.71	88.83	88.06	72.10
	26.59	18.81	20.00	9.55	15.95	37.30	86.79	79.91	84.26
	9.84	18.39	17.61	17.10	29.96	46.56	92.58	89.64	49.77
	15.10	8.12	51.62	13.48	27.20	28.99	52.20	43.26	83.43
	9.50	14.07	26.57	28.03	15.77	19.63	72.60	77.07	88.93
	18.98	20.45	17.46	8.80	16.31	33.11	90.17	72.41	69.60
Mean±	15.09±	18.05±	26.79±	17.47±	20.60±	33.94±	78.99±	78.39±	81.81±
SD	5.83	5.78	11.75	7.05	5.65	10.40	12.03	14.03	6.62

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR

In *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU) the F_1 pollen fertility was 15%. The genotypes (Mo_1, Mo_2 and Mo_3) obtained through irradiation had pollen fertility of 15%, 18% and 27% respectively. In the reciprocal of the above cross pollen fertility was 16% in F_1, and its mutated genotypes (Mo_1, Mo_2 and Mo_3) had pollen fertility of 17%, 21% and 34% respectively.

Pollen fertility of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* was very high(74%) compared to other F_1 hybrids. Here also γ-radiation increased the fertility. Mean fertility observed were 79%, 78% and 81% for Mo_1, Mo_2 and Mo_3 genotypes respectively.

6. Quantification of host reaction to yellow vein mosaic

All the 15 plants in each of the three accessions of *Abelmoschus manihot* did not exhibit any symptoms of yellow vein mosaic under natural condition and artificial inoculation (Tables 15 and 16). The plants remained healthy even after feeding with viruliferous whiteflies. Under natural conditions, 75.36% of the plants of *Abelmoschus esculentus* cv. 'Pusa Sawani' did exhibit symptoms of yellow vein mosaic disease. After inoculation with whiteflies, 95% of the plants of 'Pusa Sawani' became infected by yellow vein mosaic virus.

Under natural conditions, symptoms of yellow vein mosaic disease were observed in 11% and 44% of the plants of 'Pusa Sawani' within 20 days and 60 days of sowings, respectively.

In interspecific F_1 hybrids involving *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*, number of plants exhibiting yellow vein mosaic disease ranged from nil to 6.6% under natural conditions. In 12 genotypes derived through γ radiation of interspecific F_1 hybrid seeds, percentage of infection by yellow vein mosaic virus ranged from one to nine per cent under natural conditions (Table 15). None of the F_1 hybrids or their mutants did exhibit symptoms of yellow vein mosaic disease, within 20 days of sowing.

Artificial inoculation of yellow vein mosaic virus by feeding plants with viruliferous whiteflies using micro-cages (Plate VII) accelerated the disease incidence even in interspecific hybrids (Table 16). Yellow vein mosaic incidence (%) ranged from 13.3% in *Abelmoschus manihot* (KAU) x *Abelmoschus esculentus* to 27% in *Abelmoschus esculentus* x *Abelmoschus manihot* (IARI).

In direct and reciprocal crosses involving *Abelmoschus esculentus* and *Abelmoschus manihot* (KAU), the incidence of yellow vein mosaic was 20% and 13.3% respectively. Under natural conditions, none of the mutants or F_1 plants between

Plate VII Microcage for forced inoculation of yellow vein mosaic virus

Plate VIII *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* treated with 20 kR gamma radiation with symptoms of yellow vein mosaic under forced inoculation


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Table 15. Reaction of 'Pusa Sawani' three accessions of *Abelmoschus manihot* direct and reciprocal interspecific F_1 hybrids and mutated inter specific F_1 hybrid genotypes to yellow vein mosaic under natural condition

	Number of plants infected on				Total number of plants	Number of plants infected	Yellow vein mosaic incidence (%)
	20th day	40th day	60th day	80th day			
Abelmoschus esculentus cv. 'Pusa Sawani' (P)	23	56	91	156	207	156	75.36
Abelmoschus manihot (IARI) (I)	0	0	0	0	15	0	0
Abelmoschus manihot (KAU) (K)	0	0	0	0	15	0	0
Abelmoschus manihot ssp. *tetraphyllus* (IIHR) (T)	0	0	0	0	15	0	0
P x I	0	0	1	1	15	1	6.6
Mo_1	0	2	8	9	97	9	9.2
Mo_2	0	1	3	3	100	3	3.0
Mo_3	0	2	8	8	100	8	8.0
I x P	0	0	0	0	15	0	0
Mo_1	0	3	7	7	92	7	7.6
Mo_2	0	3	5	5	96	5	5.2
Mo_3	0	1	4	4	75	4	5.3

Mo_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR

Table 15. (Contd.)

	Number of plants infected on				Total number of plants	Number of plants infected	Yellow vein mosaic incidence (%)
	20th day	40th day	60th day	80th day			
P x K	0	0	1	1	15	1	6.6
Mo_1	0	2	5	5	100	5	5.0
Mo_2	0	1	7	8	100	8	8.0
Mo_3	0	1	1	1	100	1	1.0
K x P	0	1	1	1	100	1	1.0
Mo_1	0	2	6	7	100	7	7.0
Mo_2	0	3	9	9	100	9	9.0
Mo_3	0	2	7	7	100	7	7.0

MO_1 = 15 kR; Mo_2 = 20 kR; Mo_3 = 25 kR

Table 16. Reaction of *Abelmoschus esculentus* cv. 'Pusa Sawani', two accessions of *Abelmoschus manihot* and direct and reciprocal interspecific F_1 hybrids to yellow vein mosaic virus by feeding viruliferous white flies

Parents	Inoculation by insects		Yellow vein mosaic incidence(%)
	inoculated	infected	
Abelmoschus esculentus cv. 'Pusa Sawani'(P)	86	82	95.35
Abelmoschus manihot (IARI) (I)	15	0	0
Abelmoschus manihot (KAU) (K)	15	0	0
Abelmoschus manihot ssp. *tetraphyllus* (IIHR) (T)	15	0	0
Hybrids			
P x I	15	4	26.70
I x P	15	2	13.30
P x K	15	3	20.00
K x P	15	2	13.30

Table 17. Reaction of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* and mutated F_1 genotypes to yellow vein mosaic under natural condition and by feeding viruliferous whiteflies

	Natural condition		Yellow vein mosaic incidence (%)	Inoculation by insects		Yellow vein mosaic incidence (%)
	Number of plants observed	Number of plants infected		Inoculated	Infected	
Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus*	15	0	0	15	4	26.67
Mo_1	92	0	0	20	5	25.00
Mo_2	92	0	0	20	3	15.00
Mo_3	98	0	0	20	4	20.00

Mo_1 = 15 kR

Mo_2 = 20 kR

Mo_3 = 25 kR

Abelmoschus esculentus x *Abelmoschus manihot* ssp. *tetraphyllus* exhibited symptoms of yellow vein mosaic (Table 17). Under forced epiphytotic condition, the F_1 plants of the above cross exhibited 26.67% incidence and in three mutated genotypes (Mo_1, Mo_2 and Mo_3) percentage of incidence observed were 25%, 15% and 20% respectively (Plate VIII).

7) Estimation of maternal parental effect

There was significant difference between direct and reciprocal crosses for days to flower, fruit length and fruits/plant in crosses between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot* (Table 18). Direct and reciprocal hybrids involving *Abelmoschus esculentus* and *Abelmoschus manihot* (IARI) differed significantly for fruit yield. Maternal effect was observed for fruiting nodes on main stem in *Abelmoschus esculentus* x *Abelmoschus manihot* (KAU). Maximum maternal effect was observed for days to flower. The maternal effects for nodes to first flower, plant height, leaf length, leaf width, fruit girth, primary branches/plant, internodal length, ridges/fruit and seeds/fruit were non significant.

Table 18. Maternal effects for 15 quantitative character in _Abelmoschus esculentus_ x _Abelmoschus manihot_ crosses

Characters	_Abelmoschus esculentus_ x _Abelmoschus manihot_(IARI) D	_Abelmoschus manihot_ (IARI) x _Abelmoschus esculentus_ R	D - R	_Abelmoschus esculentus_ x _Abelmoschus manihot_ (KAU) D'	_Abelmoschus manihot_(KAU)x _Abelmoschus esculentus_ R'	D'-R'	Standard error
Days to flower	55.47	73.33	17.86**	55.73	71.26	15.54**	2.67
Nodes to first flower	5.67	5.73	0.06	6.00	5.80	0.20	0.45
Plant height	0.84	0.71	0.13	0.73	0.63	0.10	0.08
Leaf length (cm)	37.67	33.60	4.07	30.80	31.13	0.33	3.65
Leaf width (cm)	18.13	16.60	1.53	16.87	16.67	0.20	1.95
Fruit length (cm)	17.12	15.68	1.44**	16.49	17.49	1.00**	0.28
Fruit girth (cm)	9.56	9.38	0.18	9.16	9.37	0.21	0.32
Primary branches/plant	3.13	1.60	1.53	2.87	1.80	1.07	1.71
Nodes on main stem	23.60	20.07	3.53*	19.40	18.33	1.07	1.36
Fruiting nodes on main stem	10.87	10.20	0.67	12.00	9.40	2.60*	1.06
Internodal length (cm)	4.53	4.69	0.14	5.09	5.84	0.75	0.52
Fruits/plant	17.80	12.13	5.67**	13.93	10.66	3.27**	0.62
Ridges/fruit	7.73	7.47	0.26	7.80	7.27	0.53	0.43
Seeds/fruit	5.00	5.93	0.93	5.67	5.33	0.34	4.13
Fruit yield/plant(kg)	0.217	0.140	0.077*	0.218	0.163	0.060	0.030

* P = 0.05   ** P = 0.01

Discussion

DISCUSSION

Bhindi is one of the most popular vegetables cultivated throughout India for its tender and fleshy fruits. The prospects for the export and transportation to distant places became brighter with the standardisation of techniques to dehydrate bhindi pods. Bhindi seed is also an ingredient for cattle feed.

The single major constraint for bhindi cultivation is the incidence of yellow vein mosaic disease. This is especially true during the Kharif season. This disease causes severe loss in fruit and seed yield (Sastry and Singh, 1974; Singh and Chakrabarthi, 1978). The disease is transmitted through whitefly Bemisia tabaci (Genn). Attempts were made by several workers to control the disease indirectly through the use of insecticides (Rao, 1959; Sastry and Singh, 1973). Mandahar (1978) opined that insecticidal application alone can not reduce the disease effectively, as the time taken for the vector to transmit the virus is only half an hour. Hence, the most logical and economical method to control the disease would be through varietal resistance. The popular variety 'Pusa Sawani' was reported to possess field resistance to the disease as it is a symptomless carrier of the virus (Singh et al., 1962). However, after several years of continuous cultivation, this variety became susceptible (Chauhan et al., 1980).

The different strategies of plant disease management include avoidence of the pathogen, choice of an appropriate chemical to reduce the inoculum potential of the pathogen and the use of a plant type which can resist the pathogen genetically. A homogenous blending of the above is envisaged in integrated disease management. Among the above, genetic manipulation through hybridisation or mutation is definitely the most successful and cheapest one. However, the programme of development of breeding for disease resistance has to be attempted continuously as the pathogen also breeds by their own method and thereby 'break' the resistant lines in course of time. In bhindi, genetic manipulation is the most practicable and economical measure, considering the availability of resistance in related Abelmoschus species.

Interspecific hybridisation was attempted to transfer desirable characters to Abelmoschus esculentus (L.) Moench. Crossability studies between Abelmoschus esculentus and Abelmoschus manihot were made as early as 1930 by Tesima, later by Teshima (1933) and Ustinova (1937). A few of the recent reports reveal attempts to transfer the tolerance of Abelmoschus manihot to yellow vein mosaic (Nariani and Seth, 1958) into cultivated bhindi.

In the present investigation, three accessions of *Abelmoschus manihot* were studied for crossability with *Abelmoschus esculentus* cv. 'Pusa Sawani'. *Abelmoschus manihot* ssp. *tetraphyllus* crosses readily with *Abelmoschus esculentus* (CI = 95%). Crossability index (CI), being a function of percentage of fruitset, viable seeds/fruit and percentage of germination in both crosses and selfed maternal parent reflected a measure of crossability (Rao, 1979). Fruit set (%) did not differ widely in direct and reciprocal F_1 crosses. The maternal parental effect was pronounced for seeds/pod. In crosses, where *Abelmoschus esculentus* was a maternal parent, seeds/fruit were high (52.3 -- 77.2). Evidently there was reciprocal difference in the crossability index values for crosses between *Abelmoschus esculentus* and *Abelmoschus manihot*.

Teshima (1933), Ustinova (1934) and Thakur (1976) also reported reciprocal differences in interspecific crosses for the crossability index values. Crossability index values indicated that *Abelmoschus manihot* ssp. *tetraphyllus* was the closest species to *Abelmoschus esculentus* (CI = 95,36) followed by *Abelmoschus manihot* (KAU) (CI = 82.47) and *Abelmoschus manihot* (IARI) (CI = 53.88). A graphical presentation of crossability is given in Fig.5. The high percentage of seed set in direct and reciprocal crosses of *Abelmoschus esculentus* and three accessions of *Abelmoschus manihot* substantiated further the crossability. Dhillon and Sharma (1982) and Martin (1982) also made similar observations.

The cross compatibility was further studied at F_1 level. In direct and reciprocal F_1 plants of *Abelmoschus esculentus* x *Abelmoschus manihot* had a fairly high fruit set (60% - 82%) (Plate IX). In contrast to this, the F_1 plants of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* had poor fruit set (16%) (Plate X). The conflicting reports on success of the interspecific hybridisation are mainly on the basis of above observation.

The F_1 plants did not possess normal seeds and F_2 generation could not be raised. The low seed set in F_1 hybrids observed by Pal *et al*. (1952), IARI (1956), Kuwada (1957), Singh *et al*. (1962) and Mamidwar (1979) further corroborated the present study.

Success in interspecific hybridisation depends on the amount of fertile pollen in the F_1 hybrids to generate F_2 population. In the present study, detailed observations were recorded on pollen fertility of the hybrids. The three accessions of *Abelmoschus manihot* being variable in pollen fertility, the hybrid population also showed wide variation for pollen fertility. *Abelmoschus manihot* ssp. *tetraphyllus* had higher pollen fertility (98%), whereas

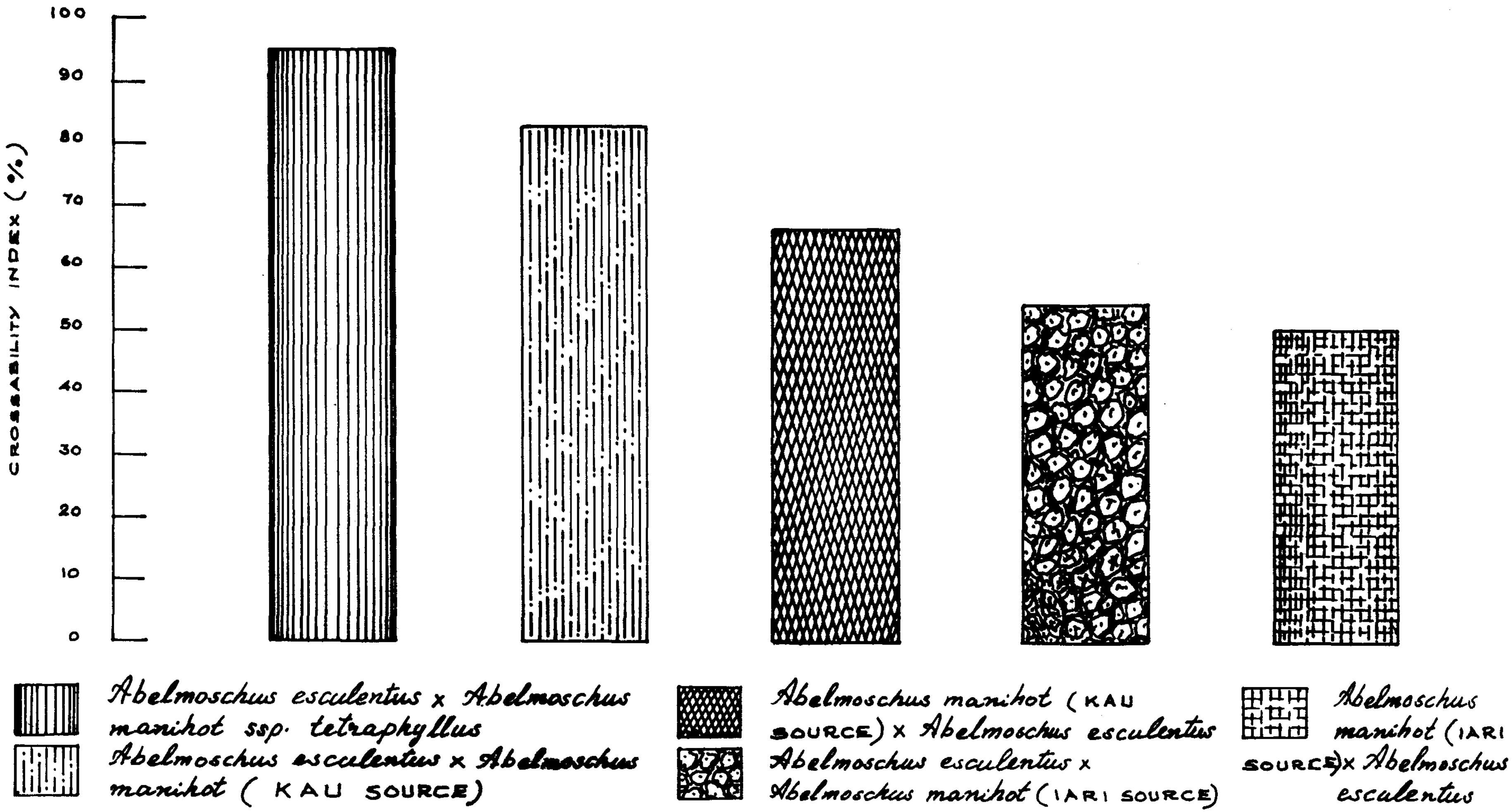

FIG: 5. CROSSABILITY (%) BETWEEN THREE ACCESSIONS OF *Abelmoschus manihot* AND *Abelmoschus esculentus* CV. PUSA SAWANI AS OBSERVED IN F_0 GENERATION

Plate IX A healthy plant with normal fruit set derived from Abelmoschus manihot (IARI) x Abelmoschus esculentus (15 kR)

Plate X Failure of fruitset in interspecific F_1 hybrid Abelmoschus esculentus x Abelmoschus manihot ssp. tetraphyllus


AM/AE 15Krad


AE/AT

Abelmoschus manihot (IARI) had a pollen fertility of 91% and *Abelmoschus manihot* (KAU) 95%. The pollen fertility of direct and reciprocal F_1 hybrids involving *Abelmoschus esculentus* and two assesions of *Abelmoschus manihot* were much lower (15% - 19%), while *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* had higher fertility (74%). The possible inference from this study is that *Abelmoschus manihot* and *Abelmoschus esculentus* being polyploids, variation in pollen fertility is quite expected. *Abelmoschus esculentus* is an amphidiploid with 2n = 130 (Gadwal *et al*., 1968; Joshi *et al*., 1974; Singh and Bhatnagar, 1975). Reports on the chromosome number of *Abelmoschus manihot* vary from 2n = 60 (Teshima, 1933), 2n = 66 (Skovsted, 1935) and 2n = 68 (Kuwada, 1957, 1974). Ugale *et al*. (1976) reported a chromosome number of 2n = 130 in *Abelmoschus esculentus* ssp. *tetraphyllus*

Added vigour in F_1 due to irradiation

Mutation breeding was successfully used to evolve high yielding varieties like S_{12} in tomato (Nandpuri, 1966), Pusa Parvati in french bean (Gill *et al*., 1979) and disease resistant varieties in cotton (Autonomov, 1979) and in wheat (Savov, 1980). Reports on mutation breeding in bhindi are, however, limited except for the work of Nandpuri *et al*. (1971); Dutta, (1972); Rao and Giriraj (1975); Nassar (1976); Koshy and Abraham (1978) and Nirmaladevi (1982).

In the present study three accessions of *Abelmoschus manihot* were used as source of resistance to yellow vein mosaic virus. All the accessions are wild and require modifications for being evolved into vegetable types. The wild species were crossed with *Abelmoschus esculentus* to generate useful variants. Kraevoi *et al*. (1982) reported that mutability of the hybrids would be twice that of their parents. Interspecific F_1 hybrids were subjected to three doses of gamma radiation, so as to widen the variation. Considerable variability was observed in irradiated F_1 generation itself for days to flower, plant height, leaf length, leaf width, fruit length, fruit girth, nodes on main stem, fruiting nodes on maid stem, internodal length, fruits/plant, ridges/fruit and fruit yield/plant.

Early flowering in F_1 plants (51 days) of *Abelmoschus esculentus* x two accessions of *Abelmoschus manihot* was observed through radiation. In *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, γ radiation delayed flowering by three to four days. The radiation treatments induced positive changes in plant height, leaf length and width. Irradiation reduced fruit length, nodes on main stem, fruiting nodes on main stem, internodal length, branches/plant, fruits/plant and ridges/fruit in many of the crosses. The gamma radiation induced considerable variability for quantitative characters in interspecific hybrids of the genus

Abelmoschus. Mutability of characters were high in *Abelmoschus esculentus* x 2 accessions of *Abelmoschus manihot* when compared to the mutability in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*. There is enough scope to select plant types with desirable characters.

Comparative observations on morphological characters in parents, F_1 hybrids and irradiated F_1 hybrids revealed interesting information. There was preponderance of characters of *Abelmoschus manihot* in the interspecific hybrids (Appendix I). Many of the forms of characters in *Abelmoschus esculentus* were recessive. Deeply fided lamina and pointed fruits of *Abelmoschus esculentus* cv. 'Pusa Sawani' were dominant and expressed in the F_1 hybrids. The F_1 hybrids resembled the wild parent for plant habit, pigmentation of vegetative parts, lamina size, corolla colour, and fruit hairiness. Characters like fruit colour and fruit tenderness had a partial dominance type of expression.

Considerable changes in discrete characters were observed in irradiated F_1 hybrids. Dominant characters like branched habit and pubescence of stem, lamina and petiole got mutated with gamma radiation. Unbranched plants with smooth stem, lamina and petiole were observed in irradiated F_1 generation. Red stem and petiole, deeply fided leaf margin, pointed leaf tip, hairy flower bud, calyx and fruit were observed to be dominant in interspecific hybrids. Plants with green tinged stem and petiole, narrowly fided lamina, blunt tipped leaf, smooth flower bud and calyx, tender and less hairy fruit which snap on bending were observed in irradiated F_1 generation from the cross *Abelmoschus esculentus* x two accessions of *Abelmoschus manihot*. This provides ample scope for useful selections.

It was observed that fruit tenderness was the most sensitive to gamma radiation followed by fruit colour, leaf margin, leaf tip, plant habit, pubescence of stem, flower bud, lamina, fruit and petiole in crosses between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*. Gamma radiation did not create much variability for seeds/F_1 fruit. Though 11% of plants had medium seeded fruits, seeds were hollow or incompletely filled.

The interspecific hybrid *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* resembled more to wild parent for branching habit, pigmentation of vegetative parts, hairiness of fruit, stem, lamina and petiole and fruit tenderness. Bristles, a characteristic of *Abelmoschus esculentus* ssp. *tetraphyllus*, were present in F_1 fruits. Fruit set (%) and seeds/fruit were substantially low in F_1 plants. Through gamma radiation, plants with smooth stem, lamina and petiole and narrowly fided lamina were obtained. Medium sized and tender fruited plants in Mo generation provided good scope for useful selection. Seeds from such plants were collected to raise subsequent generations.

In general mutagenic efficiency increased with an increase in dose of γ-radiation. With the doses 15 kR, 20 kR and 25 kR tried, both quantitative and qualitative characters were affected, though there appeared to be scope for the use of still higher dose of γ-rays for creating wider variability in interspecific hybrids.

The γ-radiation enhanced the pollen fertility in direct and reciprocal crosses. As the doses increased from 15 kR to 25 kR, the pollen fertility also increased correspondingly, in all cross combinations. High degree of sterility in interspecific hybrids of Abelmoschus esculentus x Abelmoschus manihot was attributed to the disruption of meiosis during microsporogenesis and megasporogenesis (Ustinova, 1949). The present study indicated that the ionising radiation had got some influence on microsporogenesis. Through irradiation, normal pollen (%) was increased, which in turn effected the fertility positively. Radiation induced pollen fertility might be the result of normal chromosome pairing, which was dependent on dose of γ- radiation. Perhaps this aspect has to be explained in future with more elaborate study on fundamental aspects of pollen cytology.

The parents, interspecific hybrids and the irradiated F_1s were evaluated for their reaction to yellow vein mosaic virus. Under natural conditions and artificial inoculation 'Pusa Sawani' was found susceptible. None of the wild parents exhibited any symptoms of yellow vein mosaic both under natural conditions and artificial inoculation. In the population consisting of four F_1s and 12 irradiated F_1s from the direct and reciprocal crosses involving *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*, raised during November - April 1984-'85, the viral disease symptoms developed to a milder degree under natural conditions (nil to 9%). Four F_1 hybrids consisting of direct and reciprocal crosses of *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot* raised during June - October, 1985, developed symptoms of yellow vein mosaic to a greater extent, under artifical inoculation (13 - 27%). None of the F_1 hybrids or mutants from *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* raised during June - October 1985, did exhibit symptoms of yellow vein mosaic disease under natural conditions. Artificial inoculation accelerated the disease incidence in F_1s and mutated F_1s upto 27%. Manifestation of symptoms in symptomless carrier plants is largely subject to the quantity of inoculam carried in the plant which may promote or mask the disease expression. When plants were subjected to forced inoculation, yellow vein mosaic incidence was accelerated.

Maternal parental effects were observed for quantitative characters like days to flower, fruit length, fruits/plant, fruiting nodes on main stem and fruit yield. Kuwada (1962) also made similar observations.

The most important drawback in interspecific hybridisation in the genus Abelmoschus is the sterility of F_1 hybrids. Though gamma radiation increased the pollen fertility of F_1 hybrids, no significant effect on seed fertility was observed. The doses tried were effective to eliminate undesirable dominant characters inherited from wild parents, though there appeared to be scope for the use of still higher doses of gamma radiation for creating wider variability. Appropriate selection under artificial inoculation can pick out desirable plant types having resistance to yellow vein mosaic.

Summary

SUMMARY

The present investigations on "Radiation induced variability in interspecific hybrids involving *Abelmoschus esculentus* (L.) Moench and *Abelmoschus manihot* L.) Medic". were conducted during June - October 1984, November - April 1984-'85 and June - October 1985, at the Instructional Farm of the College of Horticulture, Kerala Agricultural University, Vellanikkara, Trichur. The experiments consisted of two parts.

a) Cross compatibility between *Abelmoschus manihot* (L.) Medic and *Abelmoschus esculentus* (L.) Moench cv. Pusa Sawani.

b) Gamma rays induced variability in Mo generation and evaluation for host reaction to yellow vein mosaic virus.

The experimental materials comprised of three accessions of *Abelmoschus manihot* and *Abelmoschus esculentus* cv. 'Pusa Sawani'.

2. The cross compatibility between three accessions of *Abelmoschus manihot* and *Abelmoschus esculentus* cv. 'Pusa Sawani' was studied at F_0 and F_1 level. Maternal parental effect was significant for seed set/pod at F_0 level. There was significant maternal effect for crossability index also.

The crossability index was the highest in *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* (95.36%) and the lowest in *Abelmoschus manihot* (IARI) x *Abelmoschus esculentus* (49.55%). Poor pollen fertility and seed set were observed in F_1 plants which indicated sterility in interspecific F_1 hybrids of *Abelmoschus esculentus* and *Abelmoschus manihot*.

3. Variability was induced in interspecific F_1 hybrids between *Abelmoschus esculentus* and three accessions of *Abelmoschus manihot*, using 15 kR, 20 kR and 25 kR rays. Gamma radiation induced considerable variation in interspecific hybrids for days to flower (54 - 61 days), plant height (0.76 -1.01 m), leaf length (40 - 54 cm), leaf width (18 - 30 cm) fruit length (13.21 - 17.01 cm) fruit girth (9.97 - 11.21 cm), nodes on main stem (15 - 19), fruiting nodes on main stem (4 - 10), internodal length (2.95 - 3.87 cm), fruits/plant (8 - 14), primary branches/plant (1.35 - 2.91), ridges/plant (6 - 8) and fruit yield/plant (0.134 - 0.386 kg), in direct and reciprocal crosses involving *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*. The γ radiation did not significantly influence nodes to first flower and seeds/fruit.

4. Morphological transformations were recorded in mutated genotypes for plant habit, pubescence and pigmentation of vegetative parts, leaf characters like size, margin and tip of leaf, and hairiness of calyx, flower bud and fruits.

Gamma radiation altered branched habit to unbranched in 12.7% of F_1 plants. Many of the dominant characters expressed in interspecific F_1 generation got changed to its recessive forms through gamma radiation. In mutated F_1 generation, plants with smooth lamina and petiole, narrowly sided and blunt tipped leaf were observed. Nine percent of the irradiated F_1 plants had less hairy fruits as against highly hairy fruits of untreated F_1 hybrids. Mutants with smooth flower bud and calyx were also observed. No change was observed for pigmentation of veins and corolla throat, leaf shape, hairiness of stigma, fruit shape and fruit dehiscence at maturity, seediness of fruit, seed shape and hairiness of seeds in all interspecific hybrids. In *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus*, γ-radiation increased seeds/fruit substantially. Mutagenic efficiency was found accelerated with increase in dose.

5. Pollen fertility of the interspecific hybrids increased with increase in dose of γ-radiation. In interspecific hybrids between *Abelmoschus esculentus* and two accessions of *Abelmoschus manihot*, pollen fertility was poor (15% - 18.95%). Increase in pollen fertility was observed in irradiated F_1s (19% - 30%). Pollen fertility of *Abelmoschus esculentus* x *Abelmoschus manihot* ssp. *tetraphyllus* increased from 74% (in F_1s) to 81% in irradiated F_1s.

6. Reaction of parents, F_1s and irradiated F_1s to yellow vein mosaic virus were assessed both under natural conditions

and artificial inoculation. 'Pusa Sawani' was infected by yellow vein mosaic virus (75% - 95%), whereas none of the wild species did exhibit symptoms. Incidence of yellow vein mosaic disease was more (13% - 27%) upon artificial inoculation than under natural conditions (nil to 9%) in F_1s and irradiated F_1s of *Abelmoschus esculentus* and three accessions of *Abelmoschus manihot*.

7. Maternal parental effect was estimated in interspecific hybrids involving *Abelmoschus esculentus* and *Abelmoschus manihot*. Maximum maternal parental effect was observed for days to flower, followed by fruit length and fruits/plant.

There were differences in cross compatibility in interspecific hybrids involving three accessions of *Abelmoschus manihot* and *Abelmoschus esculentus*. It was noticed that sterility of the F_1 hybrids will hamper the progress of the breeding programmes. Though gamma radiation enhanced the pollen fertility, no significant increase in seed fertility of interspecific hybrids was observed. The result also indicated that gamma radiation could generate useful variability in F_1 hybrids by changing the undesirable dominant characters of wild parent.

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RADIATION INDUCED VARIABILITY IN INTERSPECIFIC HYBRIDS INVOLVING *Abelmoschus esculentus* (L,) Moench. AND *Abelmoschus manihot* (L.) Medic,

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Yellow vein mosaic is the most destructive viral disease of bhindi, which takes heavy toll of the crop, infecting at all growth stages. Attempts to isolate source(s) of resistance to yellow vein mosaic disease from cultivars and wild relatives were proved to be of limited success because of either incompatibility or sterility barriers between the cultivars and wild relatives. An experiment was planned and carried out during June - October, 1984; November - April, 1984-'85 and June - October 1985 at the Instructional Farm of the College of Horticulture, Vellanikkara, Trichur to induce variability in interspecific hybrids involving Abelmoschus esculentus (L.) Moench and Abelmoschus manihot (L.) Medic.

The three accessions of Abelmoschus manihot were observed cross compatible with Abelmoschus esculentus cv. 'Pusa Sawani'. Abelmoschus manihot ssp. tetraphyllus crossed readily with Abelmoschus esculentus (CI = 95%). This was proved through Fo fruit set, Fo seed set and germination of F_0 seeds. The F_1 plants did not bear normal seeds and F_2 generation could not be raised. The pollen fertility of F_1 hybrids were much lower than the parents. There was reciprocal difference in the crossability index.

γ-radiation created considerable variability in interspecific F_1 hybrids for days to flower, plant height, leaf length, leaf width, fruit length, fruit girth, nodes

on main stem, fruiting nodes on main stem, internodal length, fruits/plant, ridges/fruit and fruit yield/plant, in *Abelmoschus esculentus* x 2 accessions of *Abelmoschus manihot*.

There was preponderance of characters of *Abelmoschus manihot* in the interspecific hybrids. Considerable changes in discrete characters were observed in irradiated F_1 hybrids. Dominant characters like branched habit, pubescence and pigmentation of vegetative parts, and hairiness of fruit got changed with gamma radiation. Though the γ-radiation enhanced the pollen fertility of interspecific hybrids, they had seedless fruits or fruits with incompletely filled seeds. With the doses 15 kR, 20 kR and 25 kR tried, quantitative and qualitative characters were affected, though there appeared to be scope for the use of still higher dose of γ-rays to create wider variability in interspecific hybrids.

Under natural field conditions and artificial inoculation, 'Pusa Sawani' was infected by yellow vein mosaic virus, whereas none of the wild species did exhibit any symptoms. Artificial inoculation provides a means to select desirable plant types having resistance to yellow vein mosaic disease.