INDUCED MUTATIONS IN INTERSPECIFIC HYBRIDS OF *ABELMOSCHUS* Spp.

By

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1996

DECLARATION

I here by declare that this thesis entitled "INDUCED MUTATIONS IN INTERSPECIFIC HYBRIDS OF *ABELMOSCHUS* Spp" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship fellowship or other similar title of any other University or society

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CERTIFICATE

Certified that the thesis entitled "INDUCED MUTATIONS IN INTERSPECIFIC HYBRIDS OF *ABELMOSCHUS* Spp" is a record of research work done independently by Mr ANIMON G , under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him

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Dedicated

to

Kunjamma

INTRODUCTION

INTRODUCTION

Recombination breeding through hybridisation of chosen parents followed by selection in the segregating population is a popular method of crop improvement to get new and better recombinants This helps in combining useful traits into a single genotype However, the full potentiality of the recombination is retarded by the presence of linkages between desirable and undesirable traits in autogamous crops like sesame (Alarmelu, 1992) As a consequence, required amount of variability is not generated limiting the scope for the selection of better genotypes

Modifications of the conventional breeding methods have been suggested by many workers In this context, the recombination in conjunction with mutation breeding has been suggested as an innovative approach to overcome the limitations of conventional breeding procedures Hetrozygosity in hybrids offer broad genetic base for the mutagen to act upon in creating greater variability providing much scope for selection Mutagenesis of hybrids is known to induce more micromutations (Frey, 1965), enhance recombination (Singh *et al* , 1974) break undesirable linkage blocks (Onkar Singh and Paroda, 1986 and Sheela, 1994) and generate greater variability than the sum of variance of mutagenised parents and segregating progenies of hybrids (Gregory 1955, and 1956) The possibility of obtaining enhanced variability in the succeeding generation after the mutagenic treatments of the hybrids has been evolved through this method in many crops

Okra or Ladies finger (*Abelmoschus esculentus* (L) Moench) is a sturdy annual fruit vegetable widely grown in tropics and subtropics and also in warmer temperate areas The major advantage of this crop is its wide adaptability and ability to survive adverse abiotic situations like heavy rain and intermittent drought But it is highly susceptible to one major disease namely yellow vein mosaic (YVM) caused by virus In Kerala all the local varieties of okra were found highly susceptible to this disease The known resistant variety namely \`Pusa Sawani' introduced in early 1960's was also found succumbed to the disease later The Plant Breeding Department of College of Agriculture, Vellayani, Thiruvananthapuram has developed a high yielding YVM tolerant variety named\`Kiran recently through selection from a local variety and released for cultivation in 1990 Even though this variety was superior in yield over \`Pusa Sawani and local cultivars under YVM disease free condition, it was found susceptible to the disease during summer season Since the crop is adapted to alternate day harvest during fruiting period, chemical control of the vector after flowering is not recommended Under these situations the present work was undertaken as part of larger project for the development of high yielding and YVM resistant varieties of okra through interspecific hybridisation using semi-wild species namely *Abelmoschus manihot* (L) Medikus as donor parent This was reported to be highly resistant to YVM disease (Dhillon and Sharma, 1982) but F_2 seggregants from the cross between *Abelmoschus esculentus* cultivars were reported to be more like wild parents than the latter (Mathews, 1986) Possibility of breaking strong linkage between the wild characters and YVM resistance in *A manihot* through irradiation of F_1 seeds was suggested by earlier workers (Sheela, 1994) Based on these previous experiences the present project was drawn up with a technical programme of crossing Kiran and *A manihot*, taking the latter as pollen parent and to irradiate the F_1 seeds with gamma rays under varying doses of 0,10,20,30 and 40 kR The parents and F_1's were raised under replicated field trial with a susceptible local variety grown as border plant without pesticide application to enhance disease incidence The results obtained from the F_1 generation are presented and discussed in the ensuing chapters

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The cultivated okra plant (*Abelmoschus esculentus* (L.) Moench) is an important fruit vegetable grown in the tropical and subtropical parts of the world. *Abelmoschus manihot* (L.) Medikus, a semi wild related species is a symptomless carrier of yellow vein mosaic virus and hence utilized in breeding programmes to transfer resistance to the cultivated ones.

I Origin

Okra is considered of African or Asiatic origin. There are several theories on the origin of *A. esculentus* which consider India (Masters, 1875), Ethiopia (Vavilov, 1951), West Africa (Chevalier, 1940) and Tropical Asia (Grubben, 1977) as its centre of origin.

All species and forms distinguished by Van Borssum Waalkes (1966) are present in S-E Asia which he considers as the centre of distribution. According to Joshi and Hardas (1956) bhindi may be polyphyletic in origin. They postulated that *A esculentus* (2n = 130) arose through hybridisation between one species with n = 29 and another with n = 36 followed by doubling of the chromosomes They also confirmed the presence of the genome of *A tuberculatus* (2n = 58) in *A esculentus* The second parental species of *A esculentus* with n = 36 is still unknown

II Taxonomy of Abelmoschus

The scientific name of okra is *Abelmoschus esculentus* (L) Moench Earlier it was named *Hibiscus esculentus* (L) Moench under the section *Abelmoschus* in the genus *Hibiscus* The German botanist Medikus (1787) proposed the generic name *Abelmoschus* for a group of species previously described under Hibiscus Candolle (1824) treated *Abelmoschus* only as a section within *Hibiscus*

Schumann (1890) recognised the genus *Abelmoschus* of Medikus on the basis of the deciduous nature of the calyx Hochreutiner (1924) identified the adnation of the calyx to the petals and the staminal column as a specific characteristic of the genus and the genus *Abelmoschus* has been given recognition and accepted

Borssum Waalkes (1966) classified the wild and cultivated forms of *Abelmoschus* He divided the genus *Abelmoschus* in two groups of which the first one included three species which have cultivated forms (*A esculentus*, *A manihot* and *A moschatus*) and the second group with three species occurring only in wild form (*A crinitus*, *A angulosus* and *A ficulneus*) The studies suggested that *A manihot* is a poly species complex

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

Based on the available cytogenetical evidence, International okra workshop (1990) adopted a classification which included a new cultivated species *A caillei* which was wrongly identified earlier as *A manihot* ssp *manihot*

III Reproductive biology

Okra is basically a self-pollinated crop However cross pollination to an extent of 4 to 42 per cent was reported by many scientists (Purewal and Randhawa, 1947, Venkitaramani, 1953, Mitidieri and Vencovsky, 1974, Martin 1983)

Engels and Chandel (1990) reported that depending on the species or variety, season and location, varying degrees of out crossing upto 60 per cent occurs in okra

Cross pollination occurs mainly due to entomophily and protogyny The extent of cross pollination in a particular place depends upon the cultivars, competitive flora, insect population, season et But self-pollination is more common than cross pollination in okra So it is designated as an often cross pollinated crop (5-12%)

IV Interspecific hybridisation

Interspecific hybridisation has been carried out in this genus as early as 1930's

Teshima (1933) reported a successful cross between *A esculentus* and *A manihot* Later Chizaki (1934), Skovsted (1935), Ustinova (1937) and Singh *et al* , (1938) also reported the success of the same cross

Attempts were made at IARI to transfer the true resistance of *A manihot* var *pungens* and `symptomless' type resistance of *A tuberculatus* These species were crossed with Pusa Makhmali, a variety of *A esculentus* In the case of crosses with *A tuberculatus*, the F_1 hybrids were completely sterile and no viable seeds were obtained even from back crosses (Pal *et al* , 1952) The chromosomes of the F_1 hybrids were doubled by colchicine treatment but the amphidiploid (2n = 188) although was seed fertile, was not free from yellow vein mosaic (Singh *et al* , 1962) Similarly the true resistance discovered in *A pungens* could not be made use of owing to the high sterility of the hybrids (2n = 134) with *A esculentus*

Joshi and Hardas (1956) reported heterotic hybrids between *A esculentus* and *A tuberculatus* They obtained a fertile plant from a colchicine treated sterile F_1 hybrid from this cross Kuwada (1961) reported that the hybrid between *A esculentus* and *A manihot* was particularly sterile In 1966, he found that the crosses between *A esculentus* and *A tuberculatus* were successful in both direction but the hybrids were completely sterile Gadwal *et al* , (1968) observed that in the genus *Abelmoschus*, the hybrid embryo failed to grow in cross combination of *A esculentus* x *A moschatus*, *A esculentus* x *A* *ficulneus*, *A tuberculatus* x *A moschatus* and *A ficulneus* x *A moschatus*, but through *in vitro* culture of embryos, it was possible to obtain viable hybrids in those species combinations Later, Kuwada (1974) reported that the hybridisation between *A tuberculatus* and *A manihot* was successful only when *A tuberculatus* was the female parent, but the hybrid was completely sterile

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

Interspecific hybrids of *A esculentus* and *A ficulneus* studied by Hossain and Chattopadhyay (1976) were resistant to yellow vein mosaic But they were self-sterile and produced many fruits without seeds or with only rudimentary seeds and resembled their wild parent in several morphological characters

Nair and Kuriachan (1976) reported a spontaneous hybrid between *A tuberculatus* and *A esculentus* which was highly pollen sterile and totally seed sterile in which selfing, open-pollination and backcrossing produced only fruits with empty seeds

The hybrids of *A esculentus* x *A tuberculatus* studied by Ugale *et al* , (1976) showed hybrid vigour Arumugam and Muthukrishnan (1978a) reported that F_1's of crosses involving two wild forms of *A manihot* and two susceptible cultivars of *A esculentus* namely Pusa Sawani and Co1 were resistant to yellow vein mosaic virus They also obtained good recombinants from the F_2 and F_3 generations Mamidwar *et al* , (1979) observed reciprocal difference in crosses between *A esculentus* and wild forms of *A manihot* and *A tetraphyllus* The fruit set was higher when *A esculentus* was used as the female parent with 83 33 as the mean value for percentage fruit set in the cross between *A esculentus* and *A manihot* Meshram and Dhapke (1981) reported that the hybrid between *A esculentus* and *A tetraphyllus* was spreading in habit and dwarf in stature and highly male sterile

Dhillon and Sharma (1982) reported successful interspecific crosses between two cultivars of *A esculentus*, susceptible to yellow vein mosaic virus and one resistant cultivar of *A manihot* The hybrids showed resistance to the virus

Interspecific hybrids between an unnamed West African species of *Abelmoschus* and *A esculentus* were studied by Martin (1982) The hybrids were comparatively sterile but a few produced germinable seeds Back crosses were more fertile with almost complete fertility in the BC_2

Siemonsma (1982) reported that there were two very distinct type of okra, Soudanien and Guineen and he suggested that one type might have derived from the other through interspecific hybridisation According to him, the Guineen type was an amphidipolid of *A esculentus* (2 n = 130 - 140) and *A manihot* (2n = 60 - 68)

Transfer of resistance from *A. manihot* to *A esculentus* var Pusa Sawani was effected by Jambhale and Nerkar in 1983 The hybrids from the crosses between the two species, though resistant were partially sterile Resistant segregates from the F_5 generation could not be carried further due to complete seed sterility However, the backcross of F_1 hybrid to Pusa Sawani was successful Some plants resistant to yellow vein mosaic virus were obtained from the backcross generation which had about 58 to 88 percent seed fertility

Unnikrishna Pillai (1984) obtained hybrid with complete resistance to yellow vein mosaic by crossing *A manihot* with four susceptible cultivar of *A esculentus* viz AE-87, Pusa Swani, Co1 and Kilichundan Selection 17 But none of them out yielded the highest yielding parent (KS-17)

Nerkar and Jambhale (1985) crossed *A tetraphyllus*, *A manihot* and *A manihot* ssp *manihot* with the cultivated okra *A esculentus* CV Pusa Sawani Approaches of growing straight generation, back crossing and use of amphidiploidy were followed They developed nine resistant lines with good agronomic traits and consumer qualities

Cheriyan (1986) found that *A manihot* and *A manihot* ssp *tetraphyllus* were cross compatible with *A sculentus* There were preponderance of characters of the wild species in the interspecific hybrids The F_1 plants did not bear normal seeds

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

Mathews (1986) observed a preponderance of low yielding YVM resistant plants similar to semi-wild parent among the F_2 population of the inter-specific hybrids between two YVM susceptible cultivars of *A esculentus* and YVM resistant semi-wild species *A manihot* Varying degree of sterility were observed in F_2 progenies

Prabha (1986) found that the inter specific crosses between *A esculentus* and *A manihot* were cross compatible with the absence of total hybrid sterility The hybrids inherited YVM disease resistance The recovery of viable seeds were very much low in hybrids presumably because of the cytogenetical disturbances arising out of chromosomal differentiation that had taken place during speciation in the genus and the origin of varieties within the cultivated species

Bhargava (1989) observed that embryo deterioration in ovules resulting from crosses between *A manihot* and *A esculentus* started five days after pollination

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

Sheela (1994) has attempted to transfer YVM resistance from the wild relatives namely *A caillei* (A chev) stevels and *A manihot* ssp *tetraphyllus* to the cultivated varieties She adopted two approaches for isolating recombinants from the crosses between the wild relatives and cultivated varieties One was screening the seggregating population and the other irradiation of hybrid seeds of the crosses A preponderance of low yielding YVM resistant plants similar to the donor parents was observed among the F_2 and F_2 M_2 populations indicating the presence of powerful genetic mechanisms preventing free recombination As compared to F_2's the proportion of recombinants was higher in the F_2 M_2 population, indicating the breakage of undesirable linkages through irradiation

V Yellow vein mosaic (YVM) disease resistance

1 History and nature of the disease

In India the disease was first reported by Kulkarni (1924) The viral nature of the disease was established by Uppal *et al* , (1940) who also named it as yellow vein mosaic The symptomatology and host range was described by Capoor and Varma (1950) The virus is neither sap nor seed transmissible, but it is readily transmitted by grafting and also through the white fly (*Bemisia tabaci* Gen), while jassids and aphids are ineffective (Capoor and Varma, 1950, Varma 1952)

Varma (1952, 1955) studied the virus-vector relationship He found that though a single white fly could transmit the virus, the transmission was more when large number of insects were employed Ability and efficiency of the white flies to acquire and transmit the virus was found to increase when the vectors were pre-fasted for one hour before acquisition feeding The incubation period of the virus was reported to be seven hours (Varma, 1952) The virus can perpetuate for several weeks in hosts Khan (1983) suspected 0 35 percent seed transmission under certain circumstances and studied the mechanism of spread of the disease under field conditions He established the seasonal nature of the incidence of this disease and the significance of the primary infection with respect to its subsequent spread

2 Nature of damage

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

3 Source of resistance

Attempts to locate resistance sources to yellow vein mosaic were made by many scientists. The variability in genus *Abelmoschus* in respect of mosaic resistance has been studied extensively at the Indian Agricultural Research Institute, New Delhi in 1948. None of the cultivars of *A. esculentus* showed true resistance to the disease. A line from West Bengal accessioned as IC 1542 which consistently showed freedom from the disease under field conditions, was found to be a symptomless carrier of the virus (Singh *et al.*, 1962). In 1952, a survey of over hundred cultivated varieties and hybrids of bhindi grown in IARI was made, but all were found to be susceptibile (Narlani and Seth, 1958). Arumugam and Muthukrishnan (1978b) screened 181 cultivars of bhindi in Coimbatore and reported that all of them proved susceptible to the disease both under controlled and field conditions. They suggested that the search for newer source of resistance to YVM of bhindi should be made only in wild relatives of bhindi.

According to Nariani and Seth (1958), *A manihot* var pungens, *A crinitus*, *H vitifolius* and *H panduriformis* were immune to YVM virus Sandhu *et al* , (1974) reported that resistance to YVM virus was confined to wild species, viz, *A manihot*, *A crinitus*, *A moschatus* and *A pungens* Arumugan *et al* , (1975) reported that acesion of *A manihot*, one each from Africa and Japan, were highly resistant to YVMD and the crosses made between *A esculentus* and *A manihot* yield viable F_1 seeds But there was 40 per cent sterility in the F_2 generation An accession of bhindi (EC-31830) from Ghana, identified as *Abelmoschus manihot* (L) Medikus ssp *manihot* by Royal Botanical garden, Kew, London was almost immune to yellow vein mosaic virus (Sandhu *et al* , 1974) However, Singh and Thakur (1979) later reported that this accession was a symptomless carrier type Chelliah and Srinivasan (1983) reported that *A manihot* ssp *tetraphyllus* and *A manihot* were resistant to YVM virus It was concluded by Nerkar and Jambhale (1985) that only wild species, viz, *A tetraphyllus* *A manihot* and *A manihot* ssp *manihot* could be used as suitable donors of resistance to improve susceptible adopted varieties They also reported that under field conditions of natural infection, four resistant lines derived from the back cross of *A esculentus* x *A manihot* showed only 4 09-19 37 per cent virus infection

The preliminary evaluation of Bhindi types under the research project on 'Maintenance and evaluation of germplasm of crop plants' on the Department of Plant Breeding, College of Agriculture, Vellayani have revealed that a semi-wild species, *A manihot* is completely resistant to yellow vein mosaic disease while twenty other cultures in the germplasm were severely affected by the disease (KAU, 1983)

4 Genetics of YVM resistance

Singh *et al* , (1962) reported that two recessive alleles at two loci conferred resistance to yellow vein mosaic virus The field resistant donor line (IC1542) was assigned the symbol $y\ v_1/y\ v_1$, $y\ v_2/y\ v_2$ and susceptible parent 'Pusa Makhmali', $Y\ v_1/Y\ v_1$, $Y\ v_2/Y\ v_2$

Thakur (1976) reported that resistance was conditioned by two complementary dominant genes, after studying a cross between *A esculentus* variety Pusa Sawani and *A manihot* ssp *manihot*

F_1 - F_3 segregation data from crosses involving 2 resistant wild forms of *A manihot* and susceptible varieties of *A esculentus* revealed that resistance was conditioned by a single dominant gene designated as `Y' (Arumugam and Muthukrishnan 1980) Similarly Jambhale and Nerkar (1981) reported the involvement of a single dominant gene in conferring resistance to the virus in *A manihot* and *A manihot* ssp *manihot*

Sharma and Dhillon (1983) studied the genetics of resistance to YVM from the segregation of back cross of *A esculentus* and *A manihot* and reported that YVM virus was controlled by two dominant complementary genes with additive effects Further it has been observed that some of the plants in *A manihot* ssp *manihot*, F_1's and transgressive segregants were not completely resistant and the characteristic symptoms of virus appeared either on the top or on the new shoot quite late in the season especially when the temperature started falling This suggests that the genes responsible for resistance to virus are sensitive to the environmental changes Therefore the possibility that the resistance to YVM virus in *A manihot* ssp *manihot* is conditioned by polygenes cannot be ruled out

Unnikrishna Pillai (1984) reported that resistance was controlled by dominant nuclear gene(s)

Mathews (1986) suggested the involvement of a single dominant gene in conferring resistance to the disease

Sadashiva (1988) reported that resistance is controlled by two pair of genes Resistance was important only when atleast one pair of genes is in homozygous dominant condition Intermediate expression was seen when both the genes were in a heterozygous condition

Veeraragavathatham (1989) reported preponderance of additive gene action for yellow vein mosaic incidence He also noticed inter allelic interaction of complementary nature for yellow vein mosaic resistance in terms of virus index in the F_2 generation

According to Vashisht (1990), the major dominant gene along with minor genes which acted as modifiers was involved in the inheritance of resistance to this virus The additive gene effects were found to be more important for the virus characteristics

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

5 Achievements

Varietal resistance to yellow vein mosaic in *A esculentus* is rare A partial resistance of symptomless carrier types observed in a West Bengal stock accessioned as IC1542 at IARI was utilized for breeding a field tolerant cultivar Pusa Sawani (Singh *et al* , 1962) Extensive cultivation of Pusa Sawani over two decades (Singh 1972) led to the break down of its resistance So attempts were made to identify resistant sources among the related species and to exploit them in breeding resistant bhindi varieties to yellow vein mosaic

Several varieties resistant to yellow vein mosaic had been evolved through interspecific transfer of resistance Punjab Padmini, a YVMD resistant variety had been evolved as a result of interspecific hybridisation between *A esculentus* and *A manihot* (L) Medikus ssp *manihot* (Sharma, 1982) Another YVMD resistant variety, Parbhani Kranthi was derived from the backcross of *A manihot* to *A esculentus* cv Pusa Sawani (Jambhale and Nerkar, 1986) Several selections from IIHR, like selection-4, selection-7, selection-9, selection-10 and selection-12 possessed resistance to the disease and was derived from *Abelmoschus manihot* var *tetraphyllus* (Markose and Peter, 1990) Recently two varieties namely Arka Anamika and Arka Abhay resistant to YVMD were evolved at IIHR, using *A manihot* ssp *tetraphyllus* (IIHR, 1991)

VI Mutation breeding in bhindi

Mutation experiments in bhindi for induction of variability was reported by Kuwada (1970) One bushy mutant was selected by Nandpuri *et al*, (1971) after gamma irradiation of seeds Thandapani *et al*, (1978) released a high yielding mutant bhindi variety, MDV-2 produced by treating the seeds of Pusa Sawani with 0 04 per cent of Diethyl Sulfoxide (dES) The mutant showed a higher level of resistance to yellow vein mosaic disease than Pusa Sawani under field conditions during winter season The mutant was shorter than Pusa Sawani due to reduction in internodal length High number of fruits per plant as well as increased weight of fruit contributed to the increased yield

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

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

Abraham (1985) isolated true breeding mutants following gamma ray, fast neutron or ethyl methane sulphonate treatments of seeds

Krishna (1985) treated bhindi seeds with 10,20,30,40,50 and 60 kR gamma rays to induce variability Higher doses reduced crop duration in M_1 In the M_2 there was a progressive decline in mean values for most of the characters depending on dose Pollen and seed sterility were high in higher doses of mutagen treatments

Abraham (1985) studied genetic status in relation to radiosensitivity, mutation frequency and spectrum in bhindi Gamma rays significantly reduced germination percentage, plant height, number of leaves and fruits ,fruit yield, fruit length and pollen and seed fertility in M_1 Both in M_1 and M_2, the character expression due to the gamma rays varied depending on the genic status of the material Hybrids were more sensitive to mutagen compared to varietal seeds

Jambhale and Nerkar (1985) isolated chlorina and variegated plants from the progenies of *A esculentus* seeds that had been subjected to 40 kR gamma radiation

Cheriyan (1986) reported that gamma radiation created considerable variability in interspecific F_1 hybrids in *A esculentus* x *A manihot* crosses 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 gamma radiation enhanced the pollen fertility of interspecific hybrids, they had seedless fruits with incompletely filled seeds She also suggested that higher doses (above 25 kR) should be used to create wider variability in interspecific hybrids In general, mutagenic efficiency increased with an increase in dose of gamma radiation

Regina (1986) reported higher variability in bhindi through gamma irradiation in M_4 generation than in the M_3 generation The irradiated hybrids showed maximum positive variability

Jeevanandam *et al* , (1987) irradiated seeds of *A esculentus* at 10,20,30,40,50 and 60 kR gamma rays The seeds of the M_1 plants were either forwarded to the M_2 (referred as single treatment) or again exposed to 20 kR of gamma rays (referred as recurrent treatment (RM1)) or pre-soaked in water for 4 hours and treated with 0 05 per cent Ethyl Methane Sulphonate (referred as alternate mutagen treatment (AM1)) The effectiveness of treatment and the number of chlorophyll and viable mutants increased with increasing dose of gamma rays upto 40 kR in all 3 treatments In general the alternate treatment (AM1) followed by the recurrent treatment (RM1) and single treatment was the most effective in producing both chlorophyll and viable mutants

Kulkarni and Nerkar (1992) irradiated seeds of *A esculentus* with doses of 40 kR and a short fruit mutant was isolated from the M_2 generation The M_3 and subsequent generations of the mutant named 'Parbhani Tillu', bred true The mutant is characterised by shorter fruit length, reduced plant height, and small leaves with shallow leaf lobules

Sheela (1994) irradiated the hybrid seeds of the interspecific crosses between *A caillei* and *A tetraphyllus* with *A esculentus* A preponderance of low yielding yellow vein mosaic resistant plants similar to the wild parents was observed among the F_2 and F_2M_2 population As compared to F_2 s the proportion of recombinants was higher in the F_2M_2 population, indicating the breakage of undesirable linkages between low yield characters and yellow vein mosaic resistance through irradiation

The irradiation of hybrid seeds increase the recombination rate and add more variability to the seggregating population It was Gregory (1961) who first suggested that mutagen treatment of hybrid seeds would produce extra variability and thus greater chance for success in selection in groundnut Exposure of hybrid seeds to mutagens for enhancing the recombination potential and to widen the spectrum of variation has also been reported in rice (Jalilmiah and Yamaguchi, 1965), cotton (Peter, 1976), wheat and rice (Virk *et al*, 1978), Sesame (Rangaswamy, 1980) and Brinjal (Gopimony, 1983)

VII Heterosis

Bhindi is an often cross pollinated crop and manifestation of heterosis for various economic traits has been reported

Singh *et al*, (1938) observed hybrid vigour in interspecific hybrids of bhindi The interspecific hybrids showed increased height, branching and number of fruits Vijayaraghavan and Warrier (1946) reported increase in fruit size, fruit weight and number of fruits per plant in the intervarietal hybrids Pal *et al*, (1952) observed strong heterosis in growth and fruiting of interspecific hybrids in bhindi According to Venkitaramani (1952), increase in yield contributed by number of fruits ranged from 5 4 per cent-14 5 per cent over the better parent The plant height of the hybrids was intermediate or slightly more than that of shorter parent

Joshi and Hardas (1956) reported heterosis in the crosses between *A esculentus* and *A tuberculatus* Joshi *et al*, (1958) reported the manifestation of heterosis for plant height, fruit size, number of fruits per plant and yield in the intervarietal hybrids Raman and Ramu (1963) observed heterosis for spread of plants, early flowering, fruit weight and yield in the intervarietal hybrids Significant heterosis was also observed by Sharma (1965) for plant height, early and late flowering, fruit weight, number of fruits and fruit yield

Kuwada (1966) reported heterosis in hybrids between *A esculentus* and *A tuberculatus* Mathews (1966) reported that the vigour for earliness exhibited in the F_1 generation of two intervarietal crosses persisted in the F_2 and F_3 generations Lal and Srivasthava (1973) observed positive heterosis with respect to plant height, number of branches per plant, fruit length, fruit thickness, number of fruits per plant and fruit yield Rao and Giriraj (1974) reported that ten out of fifteen hybrids studied gave higher yields of fruit than that of control, Pusa Sawani

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

Ugale *et al* , (1976) reported hybrid vigour in interspecific hybrids from a cross between *A esculentus* and *A tetraphyllus* Rao and Kulkarni (1977) found that the hybrids were taller, maturing earlier and producing more fruits

According to Sharma and Mahajan (1978) manifestation of heterosis over mid parental value was in the range of 0 03 per cent - 68 03 per cent in days to flowering, marketable maturity, number of fruits/plant, fruit length, weight and diameter, number of ridges, plant height and fruit yield per plant Singh and Singh (1978) reported substantial heterosis for days to flowerning, plant height, first fruiting node, number of branches, internodal distance, fruit length, number of fruits per plant and yield per plant Partap and Dhankar (1980) reported heterosis for fruit yield and fruit number per plant, fruit number/branch and fruit length

Elangovan *et al*, (1981) reported heterosis for plant height, number of branches, first fruiting node, earliness, fruit length, fruit width, fruit number, fruit yield and hundred seed weight Partap *et al*, (1981) and Thaker *et al*, (1982) also observed heterosis for fruit yield in bhindi

Singh (1983) reported heterosis over mid parent for more fruit number, fruit weight and longer fruits, higher marketable and total yield, tall plant, less number of nodes and days to first virus appearance Balachandran (1984) observed desirable heterosis for the major yield contributing characters namely number of fruits per plant and length and weight of fruits Elmaksoud *et al*, (1986) reported heterosis for plant height, pod weight and pod length and they justified the commercial utilization of hybrid vigour in okra Heterosis for fruit yield and number of fruits per plant was also reported by Radhika (1988) Sheela *et al*, (1988) also observed significant heterosis for number of fruits per plant and yield per plant In the cross between Punjab Padmini and Parbhani Kranti, Shukla and Gautam (1990) reported heterobeltiosis for yield and its components

Suresh Babu and Dutta (1990) reported heterosis for plant height and fruits per plant in the interspecific hybrids between *A esculentus* and *A tetraphyllus* of bhindi Sivagamasundhari *et al* , (1992) reported positive and better than average heterosis over the best parent, for fruits per plant, fruit weight and fruit length in hybrids of bhindi varieties

Sheela (1994) has reported that in the crosses of *A caillei* and *A tetraphyllus* with *A esculentus*, majority of the hybrids recorded negative heterosis for yield and its components However a few hybrids manifested significant desirable heterosis for days to flowering, number of fruits per plant and fruit length

MATERIALS AND METHODS

The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during January 1994 to March 1995 The investigation was carried out to study the effect of gamma rays on the interspecific F_1 hybrids of the cross between *Abelmoschus esculentus* C V Kiran and the semi- wild species *Abelmoschus manihot* (L) Medik as part of the larger objective of inducing useful recombinations in the seggregating generations

A Materials

The yellow vein mosaic susceptible cultivar of bhindi, *Abelmoschus esculentus* (L) Moench namely Kiran and *Abelmoschus manihot* (L) Medik, a semi-wild species resistant to yellow vein mosaic were used for the study Pure seeds of these were collected from the germplasm of bhindi maintained at the Department of Plant Breeding, College of Agriculture, Vellayani

B Methods

The following experiments were conducted for the study

MATERIALS AND METHODS

I Production of F_1 seeds and mutagen treatment

The parental varieties namely *A esculentus* (Kiran) and *A manihot* were grown and hybridisation was done taking Kiran as female parent to produce 1200 F_1 seeds A crossing plot consisting of three rows of eight plants each of *A manihot* and *A esculentus* Kiran were raised for the purpose Since *A manihot* is having a longer pre-flowering period compared to the other parent, phased planting was adopted for synchronisation of flowering The crossing technique as suggested by Giriraj and Rao, 1973 was followed

The mature flower buds which would open the next day morning were selected in the previous evening A shallow circular cut was made around the fused calyx at about one centimetre from its base Calyx cups along with corolla were removed as a hood exposing the stigma and the staminal tube The staminal tube was cut open lengthwise without injuring the ovary or style and removed carefully The calyx cone which was removed earlier was used for protecting the emasculated flower As an additional protection, a butter paper cover was also provided

Mature flower buds of the pollen parents were protected by butter paper covers on the previous day of flowering. Pollination was done on the next day morning between 8 and 11 am by rubbing the stigma of the emasculated flowers with the staminal column taken from the pollen parent. The pollinated flowers were again protected and labelled. The mature dry fruits were collected 30 to 40 days after pollination and seeds extracted after sun drying the fruits for three days.

The F_1 seeds were subjected to gamma irradiation at 0,10,20,30 and 40 kR doses in a Cobalt 60 gamma cell unit. Four samples of 240 seeds each were irradiated at four doses of gamma rays, viz. 10,20,30 and 40 kR. The irradiation was done at the Radio tracer laboratory, Kerala Agricultural University, Vellanikkara, Trichur.

II Evaluation of F_1 M_1 generation

A field experiment was conducted to evaluate the F_1 M_1 generation. A laboratory experiment in petridishes was also conducted for taking observation on germination and root-shoot ratio of the young seedlings.

a Laboratory studies

Samples of ten seeds per dose of gamma rays treatment were sown in petridishes with three replications and the following observations were recorded

1 Germination of seeds

Counts of germinated seeds in petridishes were made every day for eight days to estimate the percentage of germination

2 Root-shoot ratio

The seedlings raised in petridishes were carefully taken out on the eighth day of sowing and the length of primary shoot and root of each seedling was measured From this data, the root-shoot ratio was worked out

b Field studies

The evaluation was conducted in four complete randomized blocks with seven treatments The treatments were as follows

Treatments	Radiation level (kR)
T_1 (Control)	0
T_2	10
T_3	20
T_4	30
T_5	40
T_6	(Parent 1, Kiran)
T_7	(Parent 2, *A manihot*)

The F_1 seeds treated with gamma rays at 0,10,20,30 and 40 kR doses were raised along with the parents in the RBD field experiment with 30 plants per plot at 60 x 30 cm spacing Unsprayed field condition was provided for natural incidence of yellow vein mosaic A single row of the highly susceptible variety, Kilichundan, was grown around each replication as a border row to counter the border effect and to enhance the disease incidence All the agronomic practices except insecticidal sprays were followed as per the package of practices recommendations of the Kerala Agricultural University (KAU, 1993)

Observations recorded

The following observations were taken on ten randomly selected plants for each of the treatments

1 Germination percentage

Counts of germinated seeds for each treatment were made every day after sowing and the percentage of germination was estimated from the value taken on the day after which no germination was observed The emergence of plumule from the soil was taken as the criterion for germination

2 Days taken to complete germination

The duration from the date of sowing till the date of last sprout was calculated for each treatment for obtaining the number of days taken to complete germination

3 Survival count

Total number of plants surviving in each treatment was counted on the 30th, 60th, 90th and 120th day after sowing and the survival data estimated on the basis of the number of seeds sown and was expressed in percentage values

4 Chlorophyll and other morphological variants

i) Chlorophyll chimeras

The plants were examined at periodic intervals for chimeric plants exhibiting chlorophyll deficient patches or sectors on their leaves

ii) Morphological Variants

The population was examined at regular intervals for the presence of morphological variations, due to the direct effect of the mutagen

5 Number of branches per plant

Total number of primary branches were counted at 30,60,90 and 120 days after sowing

6 Number of leaves per plant

Total number of leaves from the base to the tip of the plant including the branches were counted at 30,60,90 and

120 days after sowing Dropped leaves were counted by their respective nodes

7 Internodal length

Length of five internodes from the fifth node was measured in each plant, their mean was calculated and expressed in centimetre at 30, 60, 90 and 120 days after sowing

8 Days taken for the first flowering

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

9 Days taken for the last fruiting

Number of days taken from sowing to the harvest of the last fruit in each plant was recorded

10 Number of flowers produced upto 120th days of sowing

The total number of flowers produced by each observational plant upto 120th day of sowing was recorded

11 Pollen fertility

Stainability with 1 1 glycerine-acetocarmine was used as the criterion to assess pollen fertility Observation from ten randomly selected plants was recorded for each parent or hybrid Mature flower buds produced during the early part of the flowering period were selected Unstained, under sized partially stained and shrivelled pollen grains were scored as sterile and the uniformly stained, properly filled pollen as fertile In each of the slides, 15 microscopic fields were scored and the data recorded Fertility of each plant was estimated as percentage of the number of fertile pollen grains to the total number of pollen grains scored The mean fertility of each treatment was estimated and expressed as the percentage with respect to the control

12 Number of fruits per plant upto 120th day of sowing

The total number of fruits produced upto 120th day of sowing by each plant was counted at every harvest and recorded

13 Weight of fruits per plant upto 120th day of sowing

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

14 Length of fruits

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

15 Girth of fruits

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

16 Number of seeds per plant

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

17 Plant height

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

18 Disease and Pest Scoring

(i) Yellow vein mosaic intensity

For the purpose of quantitative analysis, the disease intensity was scored using the rating scale developed by Arumugam *et al* , (1975) (Table 1)

Table 1 Yellow vein mosaic disease rating scale

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

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

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

(ii) Fruit borer incidence

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

(iii) Shoot borer incidence

The number of shoot infested plants by the borer in a treatment was counted and expressed in percentage

(iv) Leaf hopper population and hopper burn

The first observation on the population count was taken as soon as the leaf hopper nymphs were noticed on the plants Subsequent observations were taken at an interval of seven days till harvest Five plants were selected randomly from among the observational plants and in each plant, six leaves-two each from top, middle and bottom of the plants were examined The average population for plant was worked out (Teli and Dalaya, 1981)

Hopper burn was assessed by taking observations on the third, fourth and fifth leaves from the terminal end, as described by Jayaraj (1966) by placing a glass plate marked with square centimeters on the leaf surface and observing the affected leaf area The hopper burn area was expressed as a percentage to the total leaf area

In assessing susceptibility or otherwise of a treatment, the quantum of damage exhibited and the population were considered as criterion In classifying the treatments based on these criteria, those which showed hopper burn of (i) less than 20 percent with low population of upto 10 per plant unit were grouped as resistant (ii) 21 to 50 percent damage with medium population of 10-15 per plant unit as tolerant and (iii) 51 percent and above hopper burn with medium to high incidence of 10-20 and above per plant unit as susceptible varieties (Uthamaswamy *et al* , 1973) This classification follows a similar pattern of classification of castor varieties susceptible to *Empoasca flavescens* adopted by Jayaraj (1967)

(v) Cercospora leaf spot infection

The number of Cercospora infested leaf in each plant counted and expressed as precentage of the total number of leaf present in the plant at the time of taking the observation

(vi) Grafting trial to confirm the resistance of the semi-wild parent and F_1 plants

The resistance of the semi-wild parent and the F_1 plants were confirmed by grafting trials (Unnikrishna Pillai, 1984) Diseased shoots collected from yellow vein mosaic affected plants were grafted on to the semi-wild parent and the F_1 plants by wedge grafting method (Nariani and Seth, 1958) New shoots arising from the stock portion were observed for symptoms of the disease at weekly intervals

Statistical Analysis

The data collected for the various characters were tabulated and mean values were subjected to statistical analysis

I Analysis of Variance (ANOVA)

ANOVA was conducted for all the characters to find out the significant differences among the treatments in respect of the various characters

The data collected on various characters during different crop growth periods (monthly intervals) were analysed using ANOVA in spilt plot fashion with these intervals as subplot factor

The data recorded from the laboratory experiment were analysed in completely randomized design (CRD) using ANOVA

II Heterosis

The magnitude of heterosis was calculated in comparison with the mean of the cultivated parent Kiran as well as the semi-wild parent, *A manihot* Heterosis expressed as percentage increase or decrease of F_1's over the parents, were calculated using the following formula

$$\text{Heterosis over the parent} = \frac{\bar{F}_1 - \bar{P}}{\bar{P}} \times 100$$

where $\bar{F}_1$ = F_1 mean

$\bar{P}$ = parental mean

To test the significant of difference of F_1 mean ove the parental mean, critical difference was calculated as

$$CD_{(0\ 05)} = t_{e(0\ 05)} \sqrt{\frac{2\ MSE}{r}}$$

where MSE is the error variance

and $t_{e(0\ 05)}$ is the critical value of `t' corresponding to the error degree of freedom at 0 05 level of significance

III Estimation of mutagenic effectiveness and efficiency

The effectiveness and efficiency of the mutagen in inducing chlorophyll mutations were estimated adopting the formula suggested by Konzak *et al* , (1965) Mutagenic effectiveness = M/k rad

Mutagenic efficiency = M/L , M/I or M/S

where, M = mutations per 100 M_1 plants

k rad = dose of radiation in kilo rad

L = percentage survival reduction on 30DAS (Lethality)

I = percentage plant height reduction on 30DAS (Injury) and

S = percentage reduction in seed fertility (sterility)

RESULTS

RESULTS

The results of the experiments are presented below

I Variability analysis

The data collected both in the laboratory and field experiments on the various characters were subjected to analysis of variance and the results are presented in tables 2 to 4

A Laboratory studies

1 Germination percentage

A progressive decrease in the germination percentage with increasing dose of gamma rays was observed (Fig 2) The semi-wild parent recorded the highest germination percentage (86 67) and was on par with the cultivated parent, control (untreated hybrid) and the hybrids irradiated at 10 kR The hybrids irradiated at 40 kR has shown the lowest germination percentage (60 00) and was on par with 30 kR Germination percentage was not

Table 2 **Efffect of gamma rays on germination percentage and root-shoot ratio under laboratory conditions**

Hybrids (Treatments)	Gamma rays (Dose in kR)	Percentage germination	Root Shoot ratio
$P_1 \times P_2$	0	80 00	0 78
$P_1 \times P_2$	10	76 67	1 08
$P_1 \times P_2$	20	73 33	1 11
$P_1 \times P_2$	30	66 67	1 18
$P_1 \times P_2$	40	60 00	1 27
P_1	0	83 33	0 81
P_2	0	86 67	0 83
F(6,14)		5 06**	24 43**
SE		4 18	0 04
CD		12 68	0 12

** Significant at 1% level

Plate 1   Yellow vein mosaic disease symptom

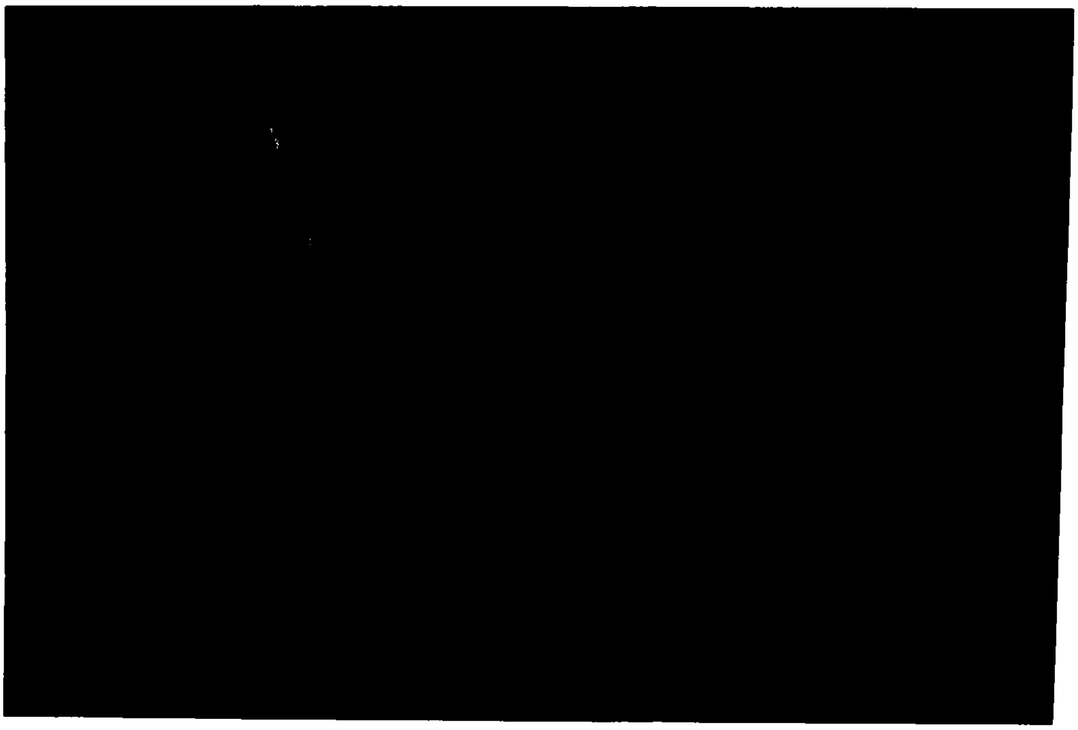


Plate 2 *Abelmoschus esculentus* cv Kiran

Plate 3 *Abelmoschus manihot*

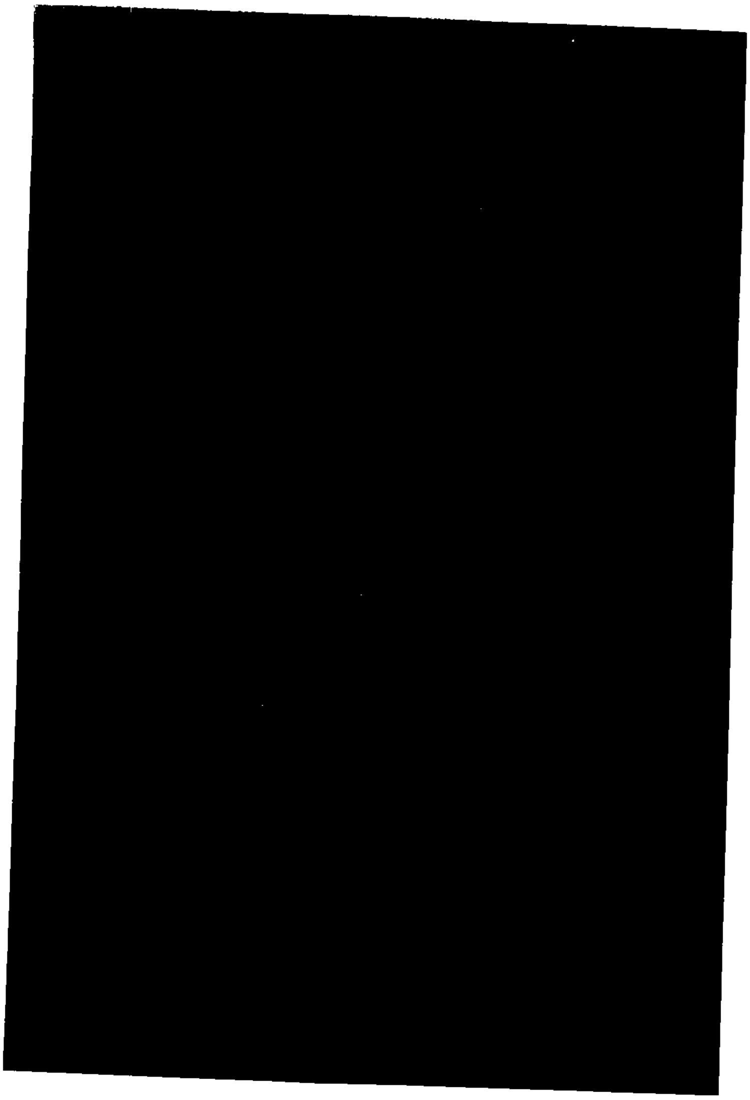
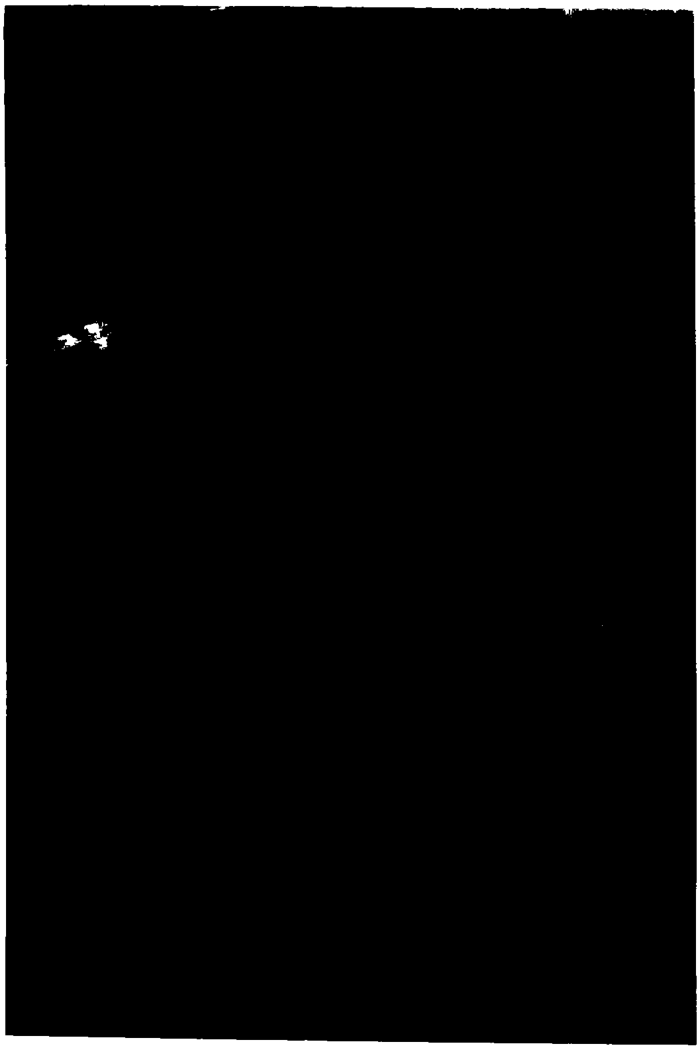


Plate 4 A high yielding resistant F_1 plant of the cross *A esculentus* x *A manihot*



significantly different at the lowest doses of gamma rays and untreated ones but significantly low at 30 and 40 kR doses (Table 2)

2 Root - shoot ratio of the seedlings

The highest value for root-shoot ratio was shown by the hybrids irradiated at 40 kR (1 27) and the lowest by the control (0 78) (Fig 1) Root-shoot ratio with respect to untreated hybrids and the parents were on par but it was significantly low from the treated hybrids Root-shoot ratio at the first three doses of gamma rays was on par but it was significantly high at 40 kR in comparison with 10 and 20 kR (Table 2)

B Field experiment

1 Germination percentage

The semi-wild parent has recorded the highest germination percentage (82 26) and the control and cultivated parent was on par with it (Table 4) The hybrids irradiated at 40 kR has shown the least germination (54 64) (Fig 3) Comparison the effect of control with other treated hybrids

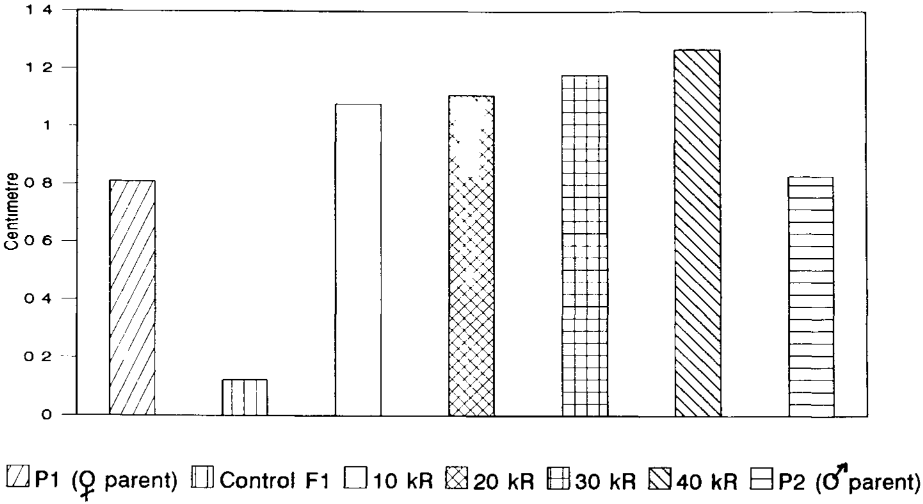


Fig. 1. Effect of gamma rays on the root-shoot ratio of the young bhindi seedlings grown under laboratory conditions

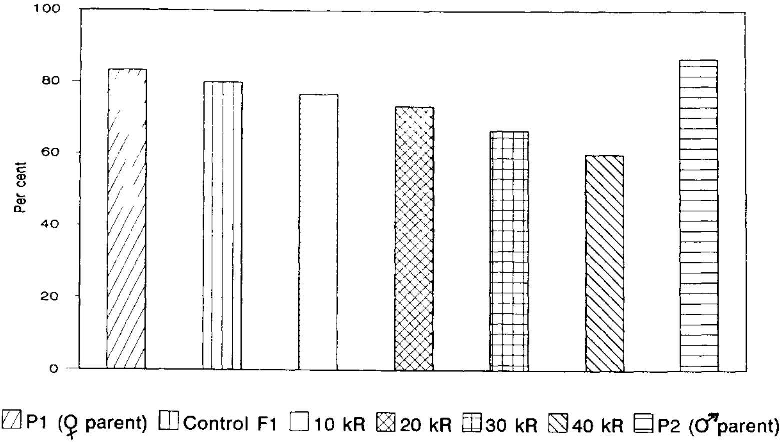


Fig. 2. Effect of gamma rays in the first generation on germination under Laboratory conditions

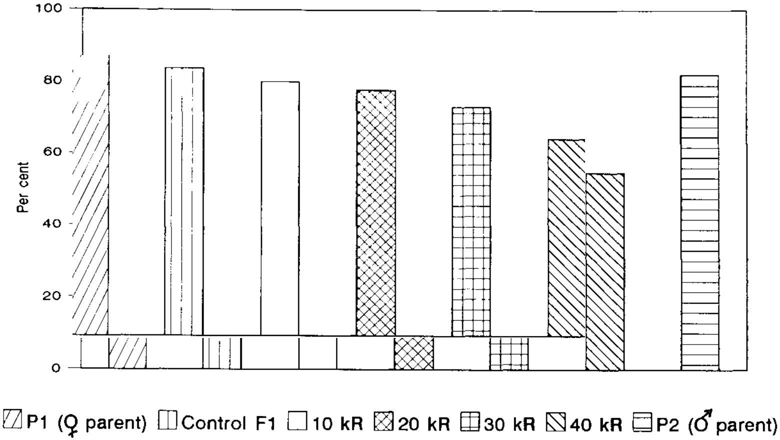


Fig. 3. Effect of gamma rays in the first generation on germination under Field conditions

revealed that it was on par with the effect of 10 and 20 kR The hybrids treated at 30 and 40 kR were on par but differed significantly from the rest of the treatments

2 Number of days taken to complete germination

The untreated hybrid has shown earlier germination (4 49 days) and was distinct from the cultivated parent and the gamma ray treated ones The effect of irradiated hybrids was on par with that of the cultivated parent The semi-wild parent has shown delay in completing germination (6 75 days) and differed significantly from rest of the treatments (Table 4)

3 Survival percentage of 30, 60, 90 and 120 days after sowing (DAS)

The survival percentage did not show any decrease after 60 DAS and therefore the survival percentages at 30 and 60 DAS were subjected to ANOVA

The results presented in Table 3 reveals that the treatments are significant with respect to survival The

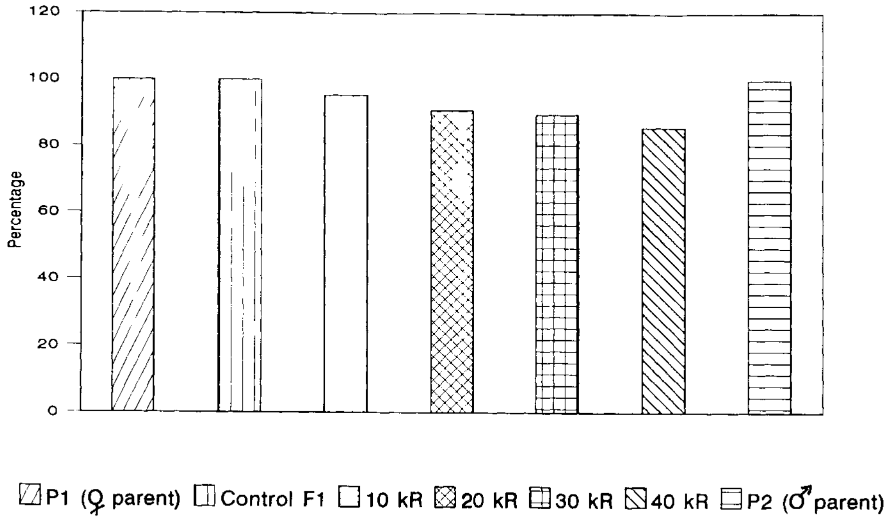


Fig. 4. Effect of gamma rays in the first generation on survival at 60th day after sowing

semi-wild parent, cultivated parent and the untreated hybrid recorded the maximum survival percentage (100 00) This was followed by 10 kR which was distinctly different from all others The hybrids irradiated at 40 kR recorded the lowest survival percentage (84 00) The hybrids irradiated at 20 and 30 kR performed similarly (Fig 4)

The survival rate with respect to days after sowing and the interaction of treatment with days after sowing were not significant

4 Number of branches per plant at 30, 60, 90 and 120 days after sowing (DAS)

The number of branches per plant at different durations after sowing are presented in Table 3

The untreated hybrid recorded the highest value (1 48) for the number of branches per plant and was on par with 10 kR The effect of 20, 30 and 40 kR were on par and was significantly different from cultivated parent which recorded the lowest value (0 98) (Fig 5)

The number of branches with respect to days after sowing were significantly different The highest number of branches was recorded at 120 DAS (3 44) and was distinctly higher The number of branches recorded at 60 and 90 DAS was similar The number of branches recorded the lowest value (1 43) at 30 DAS

The interaction of treatment with days after sowing was found significant

5 Number of leaves per plant at 30, 60, 90 and 120 days after sowing (DAS)

The number of leaves per plant at different durations after sowing are presented in Table 3

The highest number of leaves was produced in the hybrids irradiated at 40 kR (29 72) and was on par with 10 kR and the control The semi-wild parent has produced less number of leaves than the hybrids and was on par with the hybrids treated at 40 kR The control was found to be on par with hybrids irradiated at 10 and 40 kR and also with those at 20 and 30 kR The cultivated parent has produced the

Table 3 Effect of gamma rays on different characters observed during the crop growth period

Hybrid (Treatment)	Gamma rays (Dose in kR)	Percentage Survival			No of branches per plant				
		30 DAS	60 DAS	Mean	30 DAS	60 DAS	90 DAS	120 DAS	Mean
(1)	( )	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
P_1 x P	0	100 (90 00)	100 (90 00)	100	3 15	3 25	3 30	4 23	3 48
P_1 x P	10	95 45 (77 65)	95 45 (77 65)	95 45	2 48	2 55	63	3 93	2 89
P_1 x P	0	90 88 (7 39)	90 88 (72 39)	90 88	1 80	2 20	2 28	3 3	45
P_1 x P	30	89 76 (71 31)	89 76 (71 31)	89 76	0 90	1 78	2 25	3 13	2 01
P_1 x P_2	40	8 81 (67 85)	82 19 (65 01)	84 00	0 58	1 85	60	3 98	2 5
P	0	1) (0 00)	100 (90 00)	100	0 90	1 00	1 00	1 00	0 98
P	0	100 (90 00)	100 (90 00)	100	0 19	3 93	05	30	3 11
Mean		94 56	94 04		1 43	2 36	2 59	3 44	

F (Treatment)	181 490**	16 619**
F (Periods)	417	62 395**
F Treatment x Period	2 395	7 014**
SE (Treatment x Period)	0 489	0 277
CD (Treatment x Period	1 439	0 784

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

Contd

(Table 3 Contd)

Number of leaves per plant					Internodal length (cm)				
30 DAS	60 DAS	90 DAS	120 DAS	Mean	30 DAS	60 DAS	90 DAS	120 DAS	Mean
(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
13 05	2[illegible] 0	28 60	38 13	25 54	4 45	12 63	13 05	13 13	10 81
13 85	2[illegible] 10	31 35	40 73	27 51	[illegible] 75	11 60	11 95	12 03	10 08
1[illegible] 00	[illegible]1 58	[illegible]7 65	38 60	24 96	4 15	11 45	12 80	13 03	10 36
10 06	[illegible]0 68	[illegible]5 90	31 25	21 98	3 70	10 70	11 58	11 98	9 [illegible]9
10 00	[illegible]9 70	35 45	[illegible]3 73	[illegible]9 72	[illegible] 48	10 08	11 08	11 55	8 79
8 40	11 80	13 55	13 55	11 83	4 45	9 10	9 15	9 15	7 96
7 20	18 35	22 [illegible]3	24 80	18 14	2 48	6 68	8 50	9 68	6 53
10 65	1[illegible] [illegible]3	[illegible]6 39	32 97		3 78	10 32	11 16	11 50	

	Number of leaves per plant	Internodal length (cm)
F (Treatment)	11 630**	12 137**
F (Periods)	80 [illegible]26**	706 076**
F (Treatment x Period)	2 088*	5 362**
SE (Treatment x Period)	2 783	0 363
CD (Treatment x Period)	7 871	1 025

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

The internodal length with respect to days after sowing was significantly different The highest internodal length (11 50 cm) was shown at 120 DAS and was on par with 90 DAS The lowest internodal length (3 78 cm) was recorded at 30 DAS and was significantly different from all other treatments The internodal length at 60 DAS also was significantly different from all other treatments

The interaction of treatment with days after sowing was found significant

7 **Number of days taken for the first flowering**

Lower doses of irradiation (10, 20 and 30 kR) were found to be on par with the control with respect to the days taken for the first flowering The hybrids irradiated at 40 kR has taken the highest number of days (54 25) to flower and it differed significantly from all others The cultivated parent has taken the least number of days (41 25) to flower and it was significantly different from the semi-wild parent and the hybrids The semi-wild parent has taken more number of days (51) for the first flowering

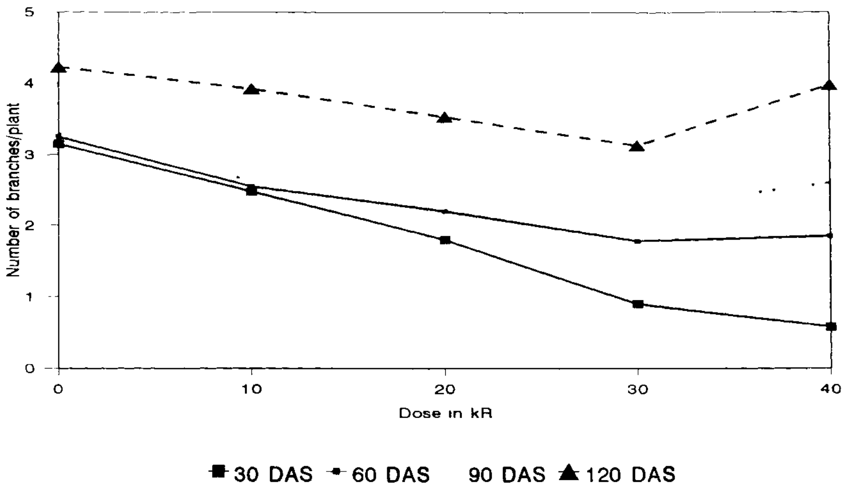


Fig. 5. Effect of gamma rays on number of branches produced during different periods of crop growth

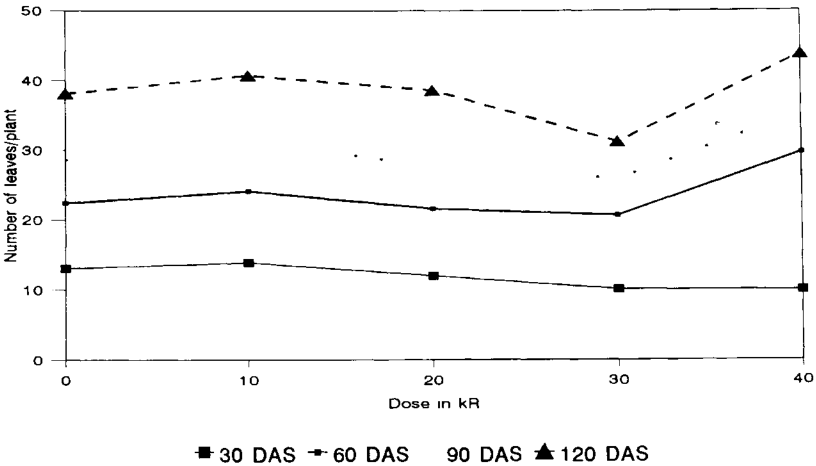


Fig. 6. Effect of gamma rays on number of leaves produced during different periods of crop growth

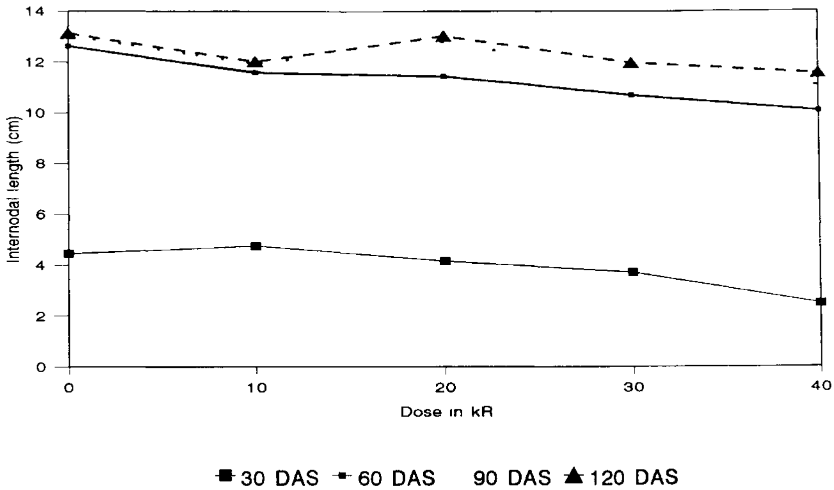


Fig. 7. Effect of gamma rays on internodal length of plants during different stages of crop growth period

and significantly differed from the cultivated parents and hybrids (Table 4)

8 **Number of days taken for the last fruiting**

No significant difference was observed between the hybrids irradiated at 10 kR and the control with the respect to da s taken for the last fruiting (Table 4) Similarly the treatments of 20 kR and 30 kR were found to be on par The highest number of days taken for last fruiting among hybrids was noticed in 40 kR (100 days) at it was significantly different from others The highest number of days taken for last fruiting was shown by the semi-wild parent (113 25) and the least by the cultivated parent (74 75) Both the parents were significantly different from the others

9 **Number of flowers produced upto 120th day of sowing**

The results presented in Table 4 reveals that hybrids which received irradiation doses of 10, 20, and 30 kR were found to be on par with the control but was significantly different from the 40 kR treated ones The highest number of flowers was recorded by hybrids irradiated

Plate 5 A F_1 M_1 plant in 30 kR treatment showing chlorophyll deficient patches in the leaf blade

Plate 6 A F_1 M_1 plant in 40 kR treatment showing chlorophyll deficient patches in the leaf blade

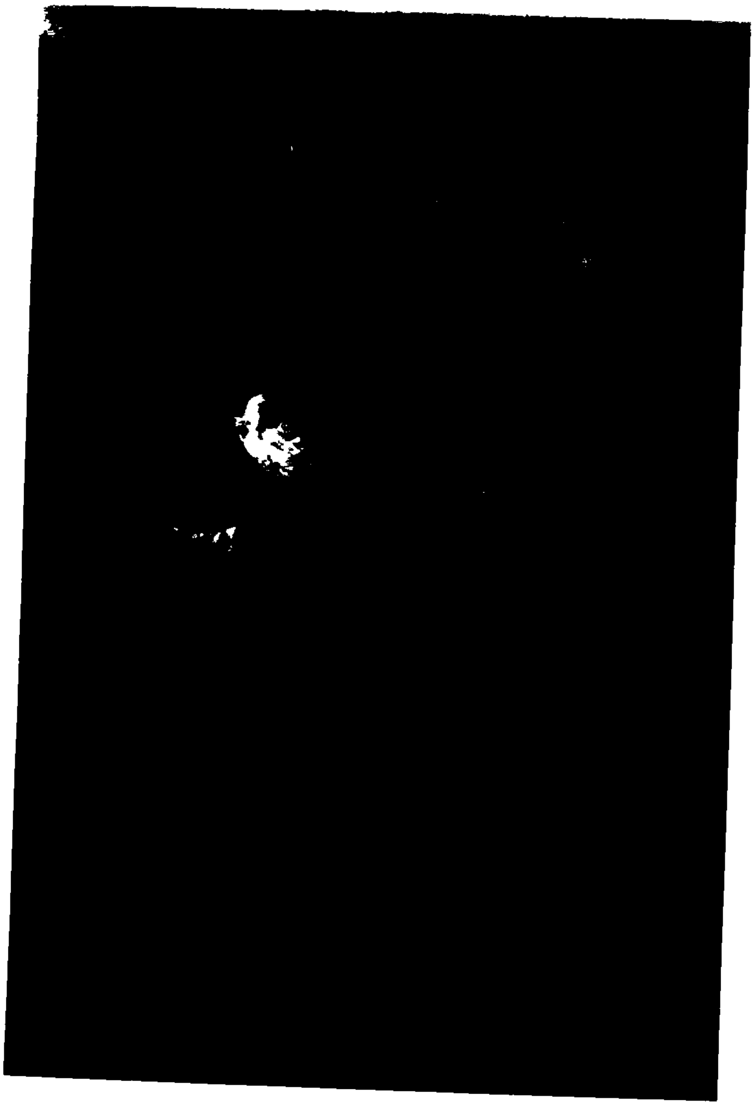
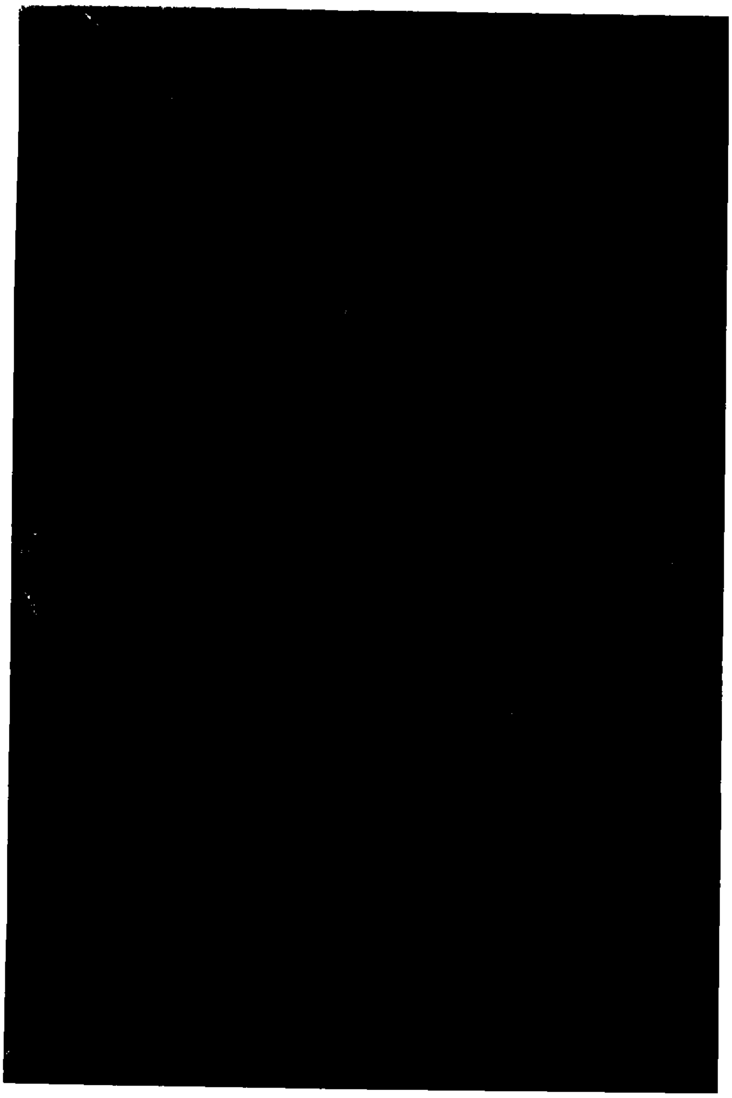
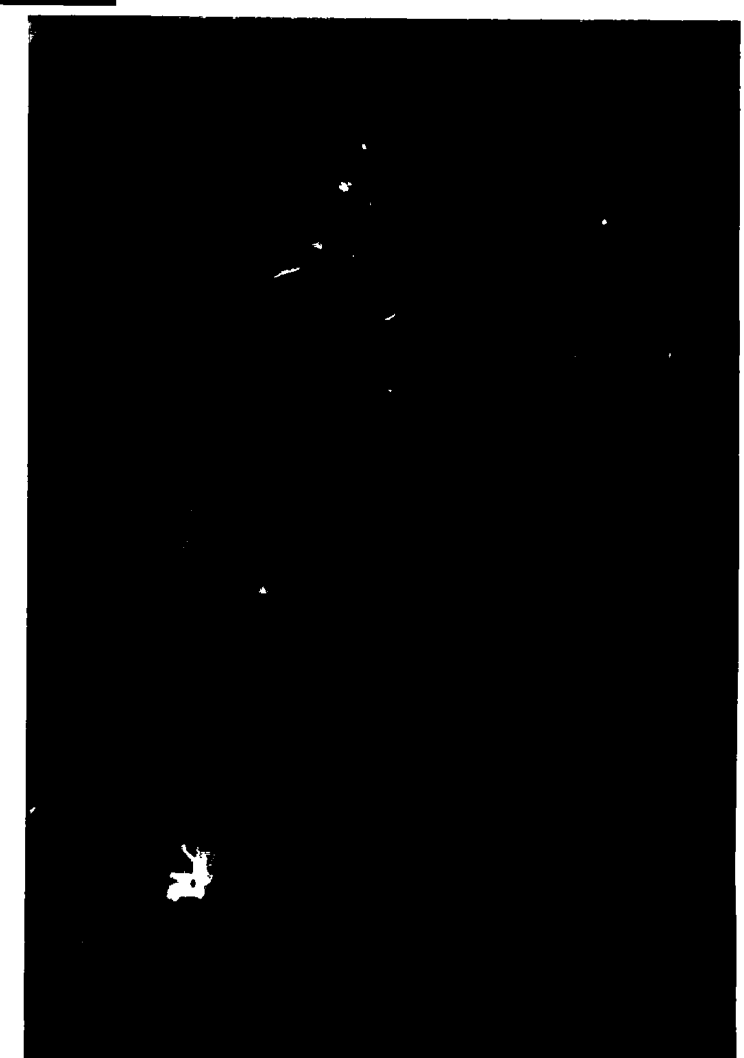


Plate 7 A F_1 M_1 plant in 30 kR treatment showing the production of two fruits at the same node

Plate 8 A F_1 M_1 plant in 40 kR treatment showing branches fused with the main stem





at 40 kR (23 98) and was on par with 10 and 20 kR The parents recorded the lowest value and remained on par but they were distinctly different from rest of the treatments

10 Percentage pollen fertility

The results showed that all the treatments were significantly different from one another with respect to pollen fertility (Table 4) The semi-wild parent recorded the highest pollen fertility (94 02%) followed by the cultivated parent (90 53%) The untreated hybrids recorded the lowest pollen fertility (15 24%) The treated hybrids recorded increase in pollen fertility when compared to the untreated hybrid (Fig 8)

11 Number of fruits per plant upto 120th day of sowing

The mean value for the number of fruits per plant in the treated hybrids ranged from 16 4 to 15 68 and were on par with the control (15 03) The effect of parents remained on par and was the lowest (Fig 10) But they were distinctly different from the hybrids (Table 4)

12 **Weight of fruits per plant upto 120th day of sowing**

The results presented in Table 4 shows that the weight of fruits produced by the irradiated hybrids which ranged from 306 40 gm to 270 85 gm was not significantly different from that of the control (265 27 gm) The semi-wild parent has shown significant difference from the hybrids but was on par with the cultivated parent and recorded the lowest value (152 69 gm) The highest weight of fruit per plant was recorded in the hybrid irradiated at 10 kR 306 40 gm) (Fig 11)

13 **Length of fruits**

The longest fruits were produced by the cultivated parent (14 83 cm) and the shortest one by the hybrids treated with 30 kR (9 35 cm) (Fig 12) & (Plate 9a) The hybrids which received 40 kR and the semi-wild parent were found to be on par with the control and also with 10 kR The hybrids treated with 20 kR was found to be on par with hybrids irradiated at 10 and 30 kR The cultivated parent differed significantly from all others (Table 4)

14 Girth of fruits

The effect of hybrids treated with 30 kR was found to be on par with the control and also with hybrids irradiated at 10 and 20 kR (Table 4) The semi-wild parent recorded the highest value (8 25 cm) and was significantly different from all others except the control The 40 kR treatment (6 85 cm) was found to be significantly different from all other treatment The lowest value was noticed in the cultivated parent (6 cm) which differed significantly from all others (Fig 13)

15 Number of seeds per fruit

The control did not differ significantly from the hybrids irradiated at 10, 20 and 30 kR (Table 4) No significant difference was observed among the irradiated hybrids The highest number of seeds per fruit was recorded in semi-wild parent (73 85) and the lowest in the hybrids irradiated at 40 kR (Fig 9) & (Plate 9b) Both the parents differed significantly from each other and also from the hybrids

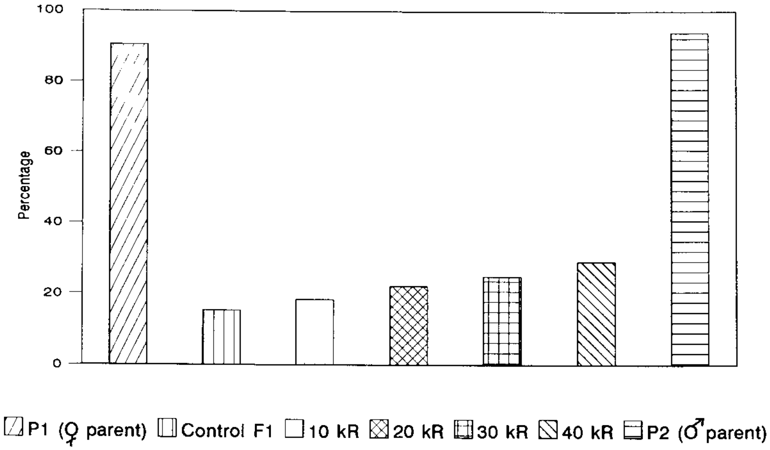


Fig. 8. Effect of gamma rays in the first generation on pollen fertility

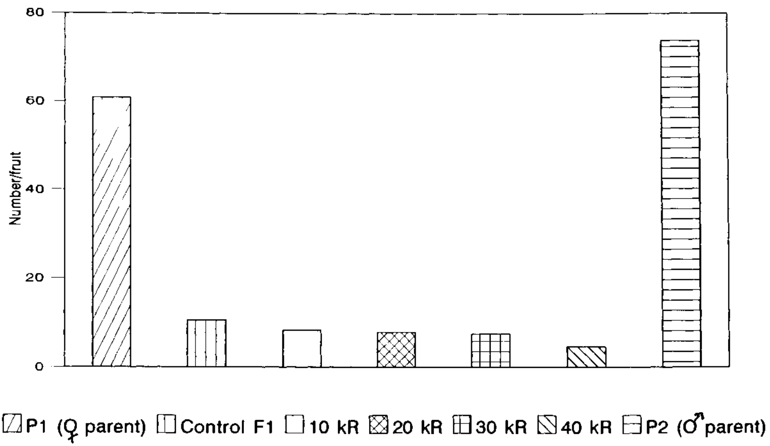


Fig. 9. Effect of gamma rays in the first generation on seed set

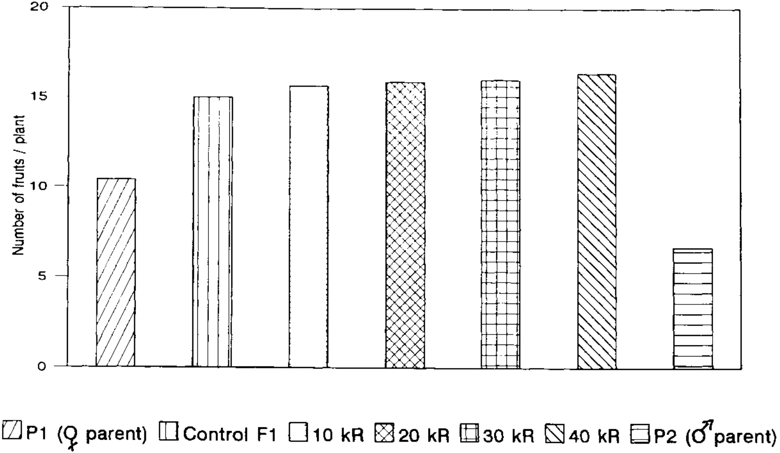


Fig. 10. Effect of gamma rays in the first generation on number of fruits / plant

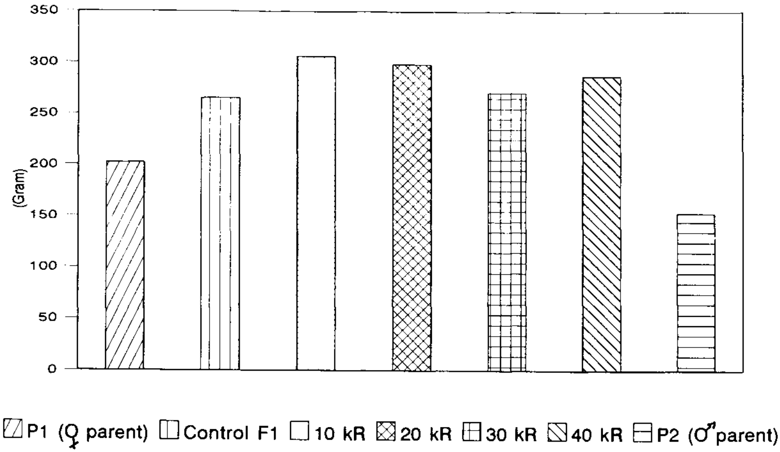


Fig. 11. Effect of gamma rays in the first generation on weight of frutis / plant

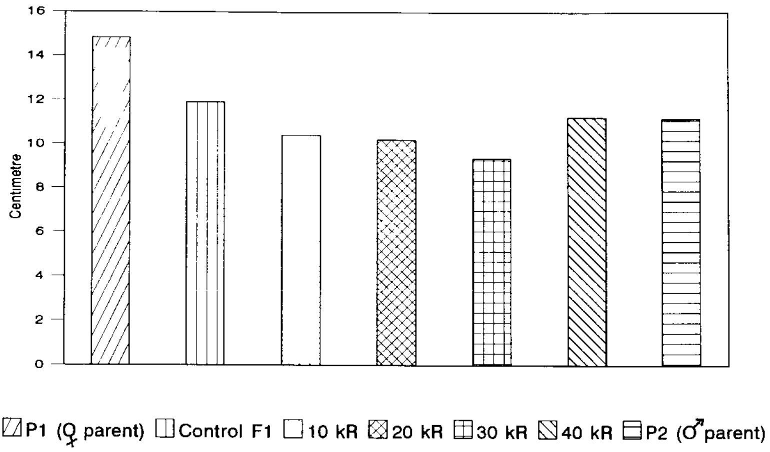


Fig. 12. Effect of gamma rays in the first generation on length of fruits

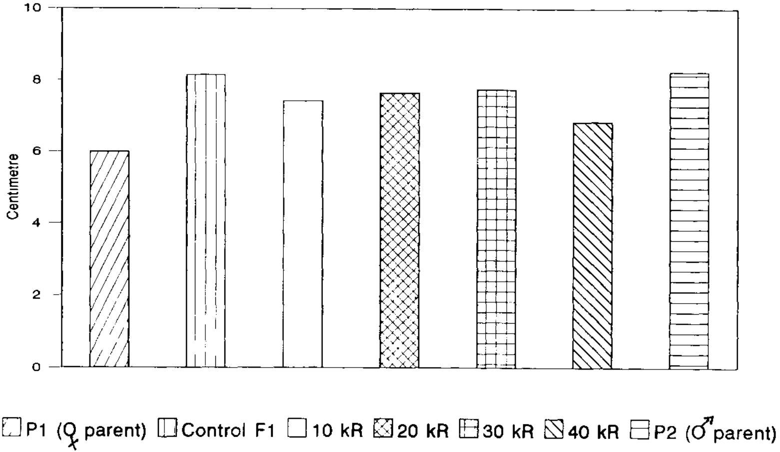
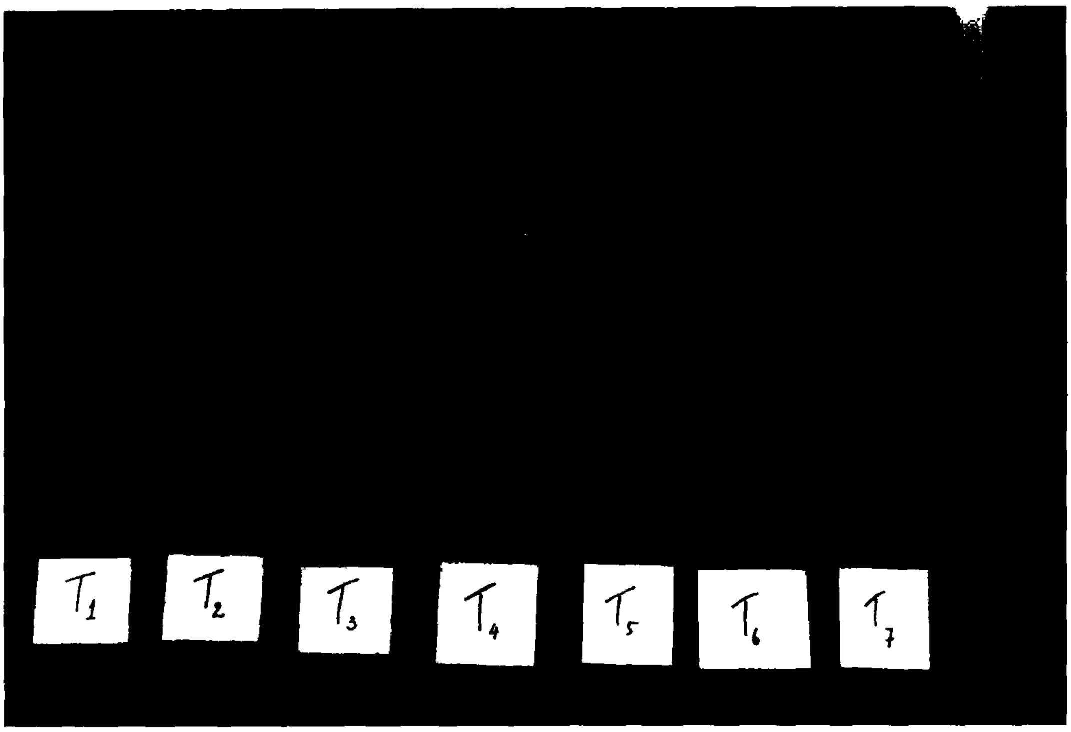
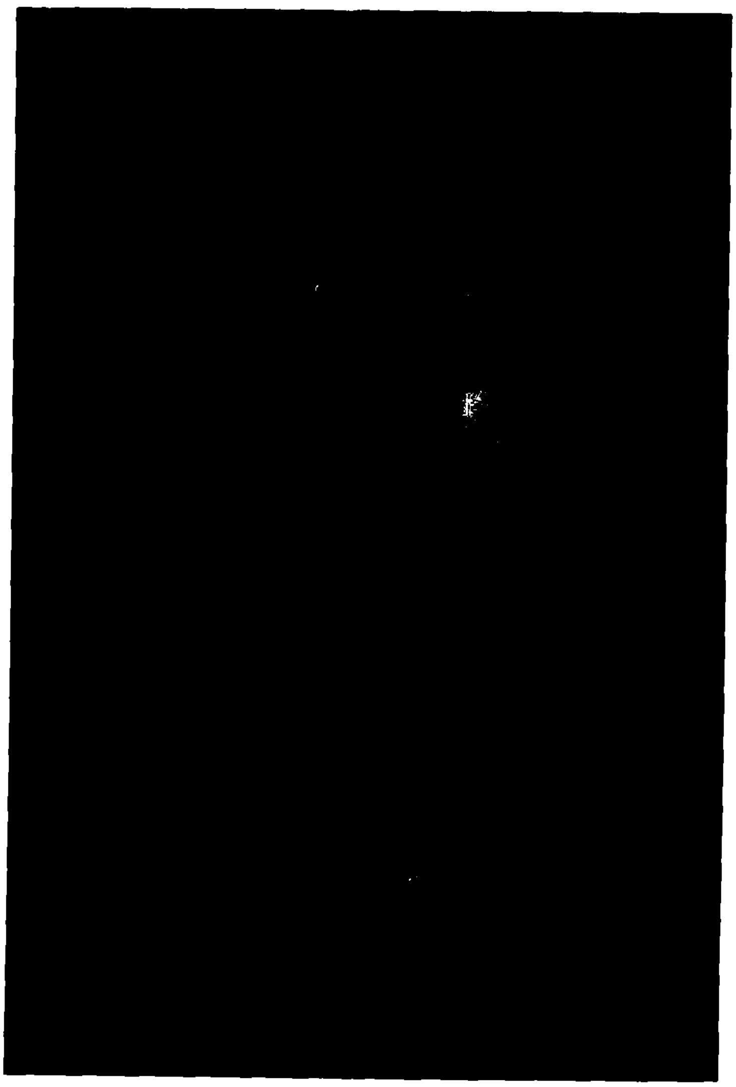


Fig. 13. Effect of gamma rays in the first generation on girth of fruits

Plate 9a The fruits of the parents and hybrids of the cross *A esculentus* x *A manihot*

Plate 9b The fruits (split open) of the parents and hybrids of the cross *A esculentus* x *A manihot*


T_1
T_2
T_3
T_4
T_5
T_6
T_7



16 **Height of plants**

There was a progressive decline in the height with increase in dose of gamma radiation (Fig 14) The control was on par with hybrids irradiated at 10 kR The hybrids treated with 30 kR was found to be on par with 20 and 40 kR The tallest plants were recorded in the control (155 85 cm) and the shortest in the cultivated parent (96 15 cm) No significant difference was observed in height between the parents The semi-wild parent was found to be on par with hybrids irradiated at 40 kR (Table 4)

17 **Yellow Vein Mosaic (YVM) incidence**

The hybrids and semi-wild parent have not shown any significant difference among them for yellow-vein mosaic incidence The cultivated parents differed significantly from all others (Table 4)

The grafting trials conducted has confirmed that the semi-wild parent and hybrids are completely resistant to yellow vein mosaic (Plate 10 & 11)

18 Fruit borer incidence

The lower doses of gamma irradiation (10 and 20 kR) were found to be on par with the control The fruit borer incidence recorded with hybrids irradiated at 30 and 40 kR were on par with that of the cultivated parent and was significantly different from other hybrids (Table 4) The lowest fruit borer incidence was shown by the semi-wild parent (5 51%) and was significantly different from all other treatments The highest fruit borer incidence was recorded by the cultivated parent (26 21%)

19 Population count of leaf hopper per plant

All the treated hybrids were found to be on par with the control The highest number of leaf hopper were noticed in the semi-wild type (13 76) and the lowest in the cultivated parent (4 34) Both the parents differed significantly from each other and also from the hybrids (Table 4)

20 Hopper burn percentage

The treated hybrids were found to be on par with the control with respect to the hopper burn symptom The parents were found to be significantly different from each

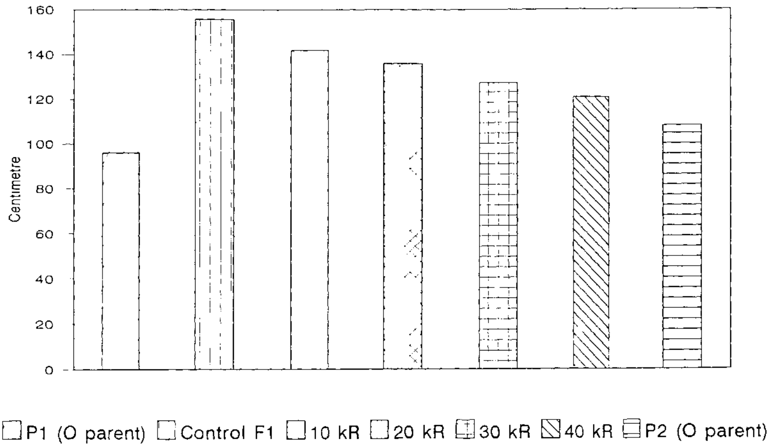


Fig. 14. Effect of gamma rays in the first generation on plant height at maturity

Plate 10 A graft inoculated *A manihot* plant showing no disease symptom

Plate 11 A graft inoculated F_1 plant of the cross *A esculentus* x *A manihot* showing no disease symptom

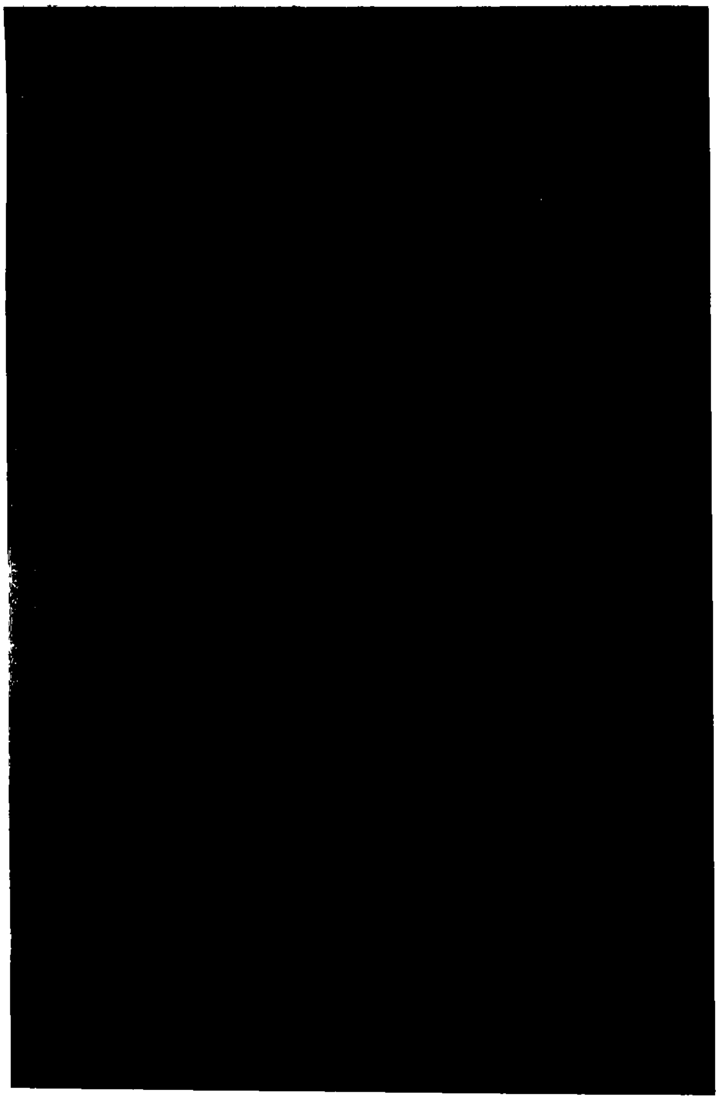


Table 4 Effect of gamma rays on different characters observed in field experiment

Hybrids (Treatment)	Gamma rays (Dose in kR)	Percentage germination	Days taken to complete germination	Days taken for first flowering	Days taken for last fruiting	No of flowers produced upto 120th day of sowing
(1)	(2)	(3)	(4)	(5)	(6)	(7)
$P_1 \times P_2$	0	74 21 (59 46)	4 50	46 50	88 00	19 28
$P_1 \times P_2$	10	70 47 (57 06)	5 75	45 50	88 25	20 93
$P_1 \times P_2$	20	68 11 (55 60)	5 75	45 50	92 75	20 43
$P_1 \times P_2$	30	63 45 (52 78)	5 50	48 50	92 75	19 58
$P_1 \times P_2$	40	54 64 (47 64)	5 75	54 25	100 00	23 98
P_1	0	79 19 (62 84)	5 25	41 25	74 75	12 25
P_2	0	82 26 (65 06)	6 75	51 00	113 25	8 50
F(6 18)		6 24**	9 10**	32 59**	79 64**	13 61**
SE		2 38	0 22	0 74	1 33	1 47
CD		7 07	0 66	2 20	3 94	4 38

** Significant at 1% level

(Transformed values are given in parantheses)

Contd

(Table 4 Contd)

Percentage pollen fertility	No of fruits per plant upto 120th days of sowing	Weight of fruits (gm)	Length of fruits (gm)	Girth of fruits (gm)	No of seeds per fruit	Height of plants (cm)
(8)	(9)	(10)	(11)	(12)	(13)	(14)
15 24 (22 97)	15 03	265 27	11 90	8 15	10 50	155 85
18 24 (2[illegible] [illegible]7)	15 68	306 40	10 40	7 43	8 25	141 95
22 00 (27 96)	15 93	298 60	10 20	7 65	7 80	135 90
24 75 (29 82)	16 05	270 85	9 35	7 75	7 45	127 10
29 00 (32 57)	16 40	287 00	11 23	6 85	4 55	120 70
90 53 (72 05)	10 43	202 25	14 83	6 00	60 95	96 15
94 02 (75 81)	6 68	152 70	11 18	8 25	73 85	108 00
3029 75**	8 13**	5 54**	27 46**	27 99**	1 365 12**	16 898**
0 41	1 31	24 02	0 34	0 15	1 54	4 95
1 23	3 89	71 38	1 00	0 44	4 57	14 71

** Significant at 1% level

(Transformed values are given in parantheses)

Contd

(Table 4 Contd)

Yellow vein mosaic incidence (15)	Fruit borer incidence percentage (16)	Population count of leaf hooper per plant (17)	Percentage hopper burn (18)	Shoot borer incidence (%) (19)	Cercospora leaf spot infection (%) (20)
1 00 (1 00)	10 02 (18 45)	11 25 (3 35)	22 41 (28 24)	5 09 (13 03)	62 27 (52 08)
1 00 (1 00)	11 27 (19 61)	11 83 (3 44)	23 07 (28 69)	6 33 (14 57)	61 23 (51 47)
1 00 (1 00)	11 44 (19 76)	11 40 (3 38)	23 74 (29 15)	6 79 (15 10)	61 15 (51 42)
1 00 (1 00)	16 34 (23 83)	10 90 (3 30)	24 91 (29 93)	8 39 (16 83)	60 43 (51 00)
1 00 (1 00)	17 00 24 33)	11 09 (3 33)	23 45 (28 95)	6 87 (15 19)	61 55 (51 66)
3 30 (1 82)	19 52 (26 21)	4 34 (2 08)	10 78 (19 16)	9 68 (18 12)	63 25 (52 66)
1 00 (1 00	5 51 (13 57)	13 76 (3 71)	17 02 (24 36)	2 12 (8 35)	2 56 (9 19)
1053 80**	12 73**	67 48**	30 08**	7 28**	37 24**
0 01	1 21	0 06	0 71	1 17	2 63
0 03	3 59	0 19	2 10	3 46	7 83

** Significant at 1% level

(Transformed values are given in parantheses) other and also from the hybrids The parents have shown lower percentages of hopper burn as compared with the hybrids (Table 4)

21 Shoot borer incidence

The control and the treated hybrids except 30 kR were statistically on par The highest incidence of shoot borer was noticed in the cultivated parent (9 68%) which was on par with the hybrids irradiated at 20, 30 and 40 kR The lowest incidence was noticed in the semi-wild parent (2 11%) which differed significantly from the rest (Table 4)

22 Cercospora leaf spot infection

The control was found to be on par with the irradiated hybrids and also with the cultivated parent (Table 4) The semi-wild parent (2 56%) differed significantly from all other treatments

II Heterosis

The extent of heterosis was calculated in comparison with the mean value of the cultivated parent, kiran and the semi-wild parent, *A manihot* The results are presented in Table 5

1 Germination percentage

The percentage heterosis over the cultivated parent has shown negative heterosis which ranged from -31 0 to -6 3 in all the hybrid treatments but only 20, 30 and 40 kR treatments were found to be significant (Table 5)

Significant negative heterosis for germination percentage was expressed in all the hybrid treatments except the untreated hybrids (control) The value for negative heterosis over the semi-wild parent ranged from -33 58 to -9 79 per cent (Table 5)

2 Number of days taken to complete germination

Significant negative heterosis over the cultivated parent was expressed by the untreated hybrid (-2 25%) But the treated hybrids exhibited positive heterosis which were insignificant (Table 5)

All the hybrid treatments have shown significant negative heterosis over the semi-wild parent and the values ranged from -33 38 to -14 84 per cent (Table 5)

3 **Survival percentage at 60 days after sowing**

Significant negative heterosis was observed in all the treated hybrids over both the parents The untreated hybrids did not exhibit any heterosis indicating no reduction in survival percentage when compared to the parents (Table 5)

4 **Number of branches per plant at 120 days after sowing**

All the hybrids treatments have shown significant heterosis over the cultivated parent and the values ranged form 213 to 323 per cent (Table 5)

Negative heterosis over the semi-wild parent was shown by all the hybrid treatments but only the 30 kR treatment (-27 21%) was found to be significant (Table 5)

Significant positive heterosis over the semi-wild parent was observed for the 40 kR treated hybrid but the other hybrid treatments expressed significant negative heterosis with a range of -10 78 to -4 9 per cent (Table 5)

8 Number of days taken for the last fruiting

The extent of percentage heterosis over the cultivated parent ranged from 17 73 (untreated hybrid) to 33 78 (40 kR treatment) and was significant in all the cases (Table 5)

All the hybrid treatments had significant heterosis over the semi-wild parent but was negative The value of the negative heterosis over the semi-wild parent ranged from -11 7 to 22 30 per cent (Table 5)

9 Number of flowers produced upto 120th day of sowing

The highest value of heterosis over the cultivated parent (95 76%) and the semi-wild parent (182 12%) was shown by the hybrid irradiated at 40 kR Significant heterosis over the cultivated parent and the semi-wild parent was exhibited by all the hybrid treatments (Table 5)

10 Percentage pollen fertility

Significant negative heterosis over the semi-wild parent was exhibited by all the hybrid treatments The extent of percentage heterosis over the cultivated parent ranged from -83 17 to -67 97 and over the semi-wild parent from -83 79 to -69 16 (Table 5)

11 **Number of fruits per plant upto 120th day of sowing**

The highest value of percentage heterosis over the cultivated parent (57 24) and the semi-wild parent (145 51) was expressed in the hybrids irradiated at 40 kR The percentage heterosis over the cultivated parent and the semi-wild parent recorded an increase with the increase in level of radiation and was significant in all the hybrid treatments (Table 5)

12 **Weight of fruits**

Heterosis over the cultivated parent ranged from 31 6 to 51 6 per cent and the hybrids treated with 10, 20 and 40 kR were found significant (Table 5)

Significant heterosis over the semi-wild parent was expressed in all the hybrid treatments with a range from 73 73 to 100 67 per cent (Table 5)

13 Length of fruits

Significant negative heterosis over the cultivated parent was observed for all the hybrid treatments with a range from -36 95 to -19 76 per cent (Table 5)

Heterosis over the semi-wild parent has shown a positive value for the control and the 40 kR treatment but was not significant Significant negative heterosis over the semi-wild parent was observed in the 30 kR treatment (-16 34%) The hybrids irradiated at 10 kR and 20 kR recorded at negative value for heterosis over the semi-wild parent but was not significant (Table 5)

14 Girth of fruits

Significant heterosis for girth of fruits over the cultivated parent was shown by all the hybrid treatments and the value ranged form 14 17 to 35 83 per cent (Table 5)

Significant negative heterosis over the semi-wild parent was shown by all the hybrid treatments except the control The control exhibited an insignificant negative value for heterosis over the semi-wild parent The value for percentage heterosis over the semi-wild parent ranged from -16 97 to -1 21 (Table 5)

15 **Number of seeds per fruit**

All the hybrid treatments recorded significant negative heterosis over both the parents for the number of seeds per fruit The values for percentage heterosis over the cultivated parent ranged from -92 53 to -82 77 and that of the semi-wild parent ranged from -93 84 to -85 78 (Table 5)

16 **Height of plants**

Significant heterosis for plant height over the cultivated parent was shown by all the hybrid treatments and the values ranged from 25 53 to 62 09 per cent (Table 5)

Percentage heterosis over the semi-wild parent ranged from 11 76 to 44 31 for plant height and was significant in all the hybrid treatments except the 40 kR treatment (Table 5)

17 Yellow vein mosaic incidence

The cultivated parent recorded a high mean disease score of 3 30 and displayed significant negative heterosis (-69 70%) over other treatments The semi-wild parent and the hybrids has recorded a mean disease score of 1 (Table 5)

18 Fruit borer incidence

Negative heterosis over cultivated parent ranged from -48 67 to -12 96 per cent and the control, 10 and 20 kR treatments were found significant (Table 5)

Significant heterosis over semi-wild parent was displayed by all the hybrid treatments and the value ranged from 81 85 to 208 35 per cent (Table 5)

19 Population count of leaf hopper per plant

All the hybrid treatments have shown significant heterosis over the cultivated parent and the range was from 151 15 to 172 58 per cent (Table 5)

Significant negative heterosis with values ranging from -20 78 to -14 03 per cent was recorded over the semi-wild parent by all the hybrid treatments (Table 5)

20 Hopper burn percentage

Significant heterosis over the cultivated parent and the semi-wild parent was exhibited by all the hybrid treatments The extent of percentage heterosis over the cultivated parent ranged form 107 88 to 131 08 and the semi-wild parent ranged from 31 67 to 46 36 (Table 5)

21 Shoot borer incidence

Negative heterosis was shown by all the hybrid treatments over the cultivated parent but none was significant (Table 5)

Positive heterosis with a range from 141 23 to 297 63 per cent was shown by all the hybrid treatments over the semi-wild parent and all were significant except the control (Table 5)

Table 5 Mean values of parents and hybrids and percentage of heterosis over the cultivated parent, kiran (P_1) and the semi-wild parent, *A manihot* (P_2) for different characters

Parents and Hybrids	Dose of gamma rays (kR)	Percentage germination	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2	Days taken to complete germination	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
P_1		79 19			5 24		
P_2		82 26			6 74		
P_1 x P_2	0	74 21	-6 30	-9 79	4 49	14 31*	-33 38*
P_1 x P_2	10	70 47	-11 01	-14 33*	5 74	9 54	-14 84*
P_1 x P_2	20	68 11	-13 99*	17 20*	5 74	9 54	14 84*
P_1 x P_2	30	63 45	-19 87*	22 87*	5 49	4 77	18 55
P_1 x P_2	40	54 64	31 00*	33 58*	5 74	9 54	14 84
CD(0 05)		7 07			0 85		

*Significant at 5% level

Contd

(Table [illegible] Contd)

Percentage survival at 60 DAS	Percentage heterosis over		No of branches per plant at 120 DAS	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(9)	(10)	(11)	(12)	(13)	(14)
100 00			1 00		
100 00			4 30		
100 00	0	0	4 23	323*	1 63
95 33	4 67*	4 67*	3 93	293*	8 60
90 81	9 19*	9 19*	3 53	253*	17 91
89 67	10 33*	10 33*	3 13	213*	27 21*
82 08	17 92*	17 92*	3 98	298*	7 44
2 49			0 94		

* Significant at 5% level

(Table 5 Contd)

No of leaves per plant at 120 DAS	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2	Internodal length at 120 DAS	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2
(15)	(16)	(17)	(18)	(19)	(20)
13 55			9 15		
24 80			9 68		
38 13	181 40*	53 75*	13 13	43 50*	37 70*
40 73	200 59*	64 23*	12 03	31 48*	25 68*
38 60	184 87*	55 65*	13 03	42 40*	36 61*
31 25	130 63*	26 00	11 98	30 93*	25 14*
43 73	222 73*	76 33*	11 55	26 23*	20 44*
13 21			1 50		

Significant at 5% level

Contd

(Table 5 Contd)

Days taken for the first flowering	Percentage heterosis over		Days taken for the last fruiting	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(21)	(22)	(23)	(24)	(25)	(26)
41 25			74 75		
51 00			113 25		
46 50	12 73*	-8 82*	88 00	17 73*	-22 30*
45 50	10 30*	-10 78*	88 25	18 06*	22 08*
[illegible] 0	10 30*	10 78*	92 75	24 08*	18 10*
8 50	17 58*	-4 90*	92 75	24 08*	-18 10*
54 25	31 52*	6 37*	100 00	33 78*	-11 70*
2 20			3 94		

* Significant at 5% level

Contd

(Table 5 Contd)

No of flowers produced upto 120 DAS	Percentage heterosis over Parent 1	Percentage heterosis over Parent2	Percentage pollen fertility	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2
(27)	(28)	(29)	(30)	(31)	(32)
12 25			90 53		
8 50			94 02		
19 28	57 39*	126 82*	15 24	83 17*	83 79*
20 93	70 86	146 24*	18 24	79 85*	80 60
20 43	66 78*	140 35*	22 00	-75 70*	-76 60*
19 58	59 84*	130 35*	24 75	72 66*	-73 68*
23 98	95 76*	182 12*	29 00	-67 97*	69 16*
4 38			1 23		

* Significant at 5% level

Contd

(Table 5 Contd)

No of fruits per plant upto 120 DAS	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2	Weight of fruits (gm)	Percentage heterosis over Parent 1	Percentage heterosis over Parent 2
(33)	(34)	(35)	(36)	(37)	(38)
10 43			202 25		
6 68			152 69		
15 03	44 10*	125 00*	265 27	31 16*	73 73*
15 68	50 34	134 73*	306 40	51 60*	100 67*
15 93	52 73*	138 47*	298 60	47 64*	95 56*
16 05	53 88*	140 27*	270 85	33 92*	77 39*
16 40	57 24*	145 51*	287 00	41 90*	87 96*
3 89			71 38		

Significant at 5% level

(Table 5 Contd)

Length of fruits (cm)	Percentage heterosis over		Girth of fruits (cm)	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(39)	(40)	(41)	(42)	(43)	(44)
14 83			6 00		
11 18			8 25		
11 90	19 76*	6 44	8 15	35 83*	1 21
10 40	29 87*	-6 98	7 43	23 83*	-9 94*
10 20	31 22*	-8 77	7 65	27 50*	7 27*
9 35	36 95*	-16 34*	7 75	29 17*	6 06*
11 23	24 28*	0 45	6 85	14 17*	-16 97*
[illegible] 99			0 44		

* Significant at 5% level

Contd

(Table 5 Contd)

No of seeds per fruit	Percentage heterosis over		Height of plants (cm)	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(45)	(46)	(47)	(48)	(49)	(50)
60 95			96 15		
73 85			108 00		
10 50	82 77	-85 78	155 85	62 09*	44 31*
8 45	86 46*	-88 83	141 95	47 63*	31 44*
7 80	87 20	-89 44*	135 90	41 34*	25 83*
7 45	87 78	-89 91*	127 10	32 19*	17 69*
4 55	-92 53	-93 84*	120 70	25 53*	11 76*
4 57			14 71		

* Significant at 5% level

(Table 5 Contd)

Yellow vein mosaic incidence	Percentage heterosis over		Fruit borer incidence (%)	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(51)	(52)	(53)	(54)	(55)	(56)
3 30			19 52		
1 00			5 51		
1 00	69 70*	0	10 02	-48 67*	81 85*
1 00	69 70*	0	11 27	-42 26*	104 54*
1 00	69 70*	0	11 44	-41 39*	107 62*
1 00	69 70*	0	16 34	16 29	196 55*
1 00	69 70	0	16 99	12 96	208 35*
0 03			3 59		

* Significant at 5% level

(Table 5 Contd)

Population count of leaf hooper per plant	Percentage heterosis over		Percentage hopper burn	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(57)	(58)	(59)	(60)	(61)	(62)
4 34			10 78		
13 76			17 02		
11 25	159 22*	-18 24*	22 41	107 88*	31 67*
11 83	172 58*	-14 03*	23 07	114 01*	35 55*
11 40	162 67*	-17 15*	23 74	120 22*	39 48*
10 90	151 15*	-20 78*	24 91	131 08*	46 36*
11 09	155 53*	-19 40*	23 45	117 53*	37 78*
0 19			2 10		

Significant at 5% level

Contd

(Table 5 Contd)

Shoot borer incidence (%)	Percentage heterosis over		Cercospora leaf spot infection (%)	Percentage heterosis over	
	Parent 1	Parent 2		Parent 1	Parent 2
(63)	(64)	(65)	(66)	(67)	(68)
9 68			63 25		
2 11			2 56		
5 09	47 42	141 23	62 27	1 55	2332 42*
6 33	34 61	200 00*	61 23	3 19	2291 80*
6 79	29 86	221 80*	61 15	-3 32	2288 67*
8 39	13 33	297 63*	60 43	-4 46	2260 55*
6 87	-29 03	225 59*	61 55	-2 69	2304 30*
5 71					

* Significant at 5% level

2.2 Cercospora leaf spot infection

Negative heterosis was recorded by all the hybrid treatments over the cultivated parent but none was significant (Table 5)

All the hybrid treatments recorded highly significant positive heterosis over the semi-wild parent for cercospora leaf spot infection (Table 5)

III Mutagenic effectiveness and efficiency

The mutagenic effectiveness and efficiency of different doses of gamma rays in inducing chlorophyll mutations were estimated and are presented in Table 6

The mutagenic effectiveness was found to increase with increase in the dose of gamma rays

The mutagenic efficiency estimated on the basis of lethality and injury increased with increase in dose of gamma rays On sterility basis, the 30 kR treatment has shown the highest mutagenic efficiency

Table 6 Mutagenic effectiveness and efficiency in inducing chlorophyll mutations

Dose of gamma rays (Krad)	No of mutation per 100 M_1 plants (M)	M_1 damage: % survival reduction (Lethality (L))	M_1 damage: % height reduction (Injury (I))	M_1 damage: % seed fertility reduction (Sterility (S))	Mutagenic effectiveness $\frac{M \times 100}{Krad}$	Mutagenic efficiency $\frac{M \times 100}{L}$	Mutagenic efficiency $\frac{M \times 100}{I}$	Mutagenic efficiency $\frac{M \times 100}{S}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
10	3 12	4 55	8 92	21 43	31 20	68 57	34 98	14 56
20	8 11	9 12	12 80	25 71	40 55	88 93	63 34	31 54
30	13 24	10 24	18 45	29 05	44 13	129 30	71 76	45 58
40	21 56	14 19	22 55	56 67	53 90	151 94	95 61	38 04

DISCUSSION

DISCUSSION

From the studies on the hybrids between *A esculentus* and *A manihot*, it has been found that no useful recombinants were obtained from the conventional combination breeding programme because of the strong linkage between YVM resistance and wild characters of *A manihot* (Mathews, 1986) The usefulness of subjecting such problematic hybrid genotypes to mutagenic treatments to enhance recombination potential and to widen the spectrum of variation in segregating generations has been realised Hybrid seeds have been exposed to mutagens with the above objective in ground nut (Gregory, 1961), rice (Jalilmiah and Yamaguchi, 1965), cotton (Peter, 1976) wheat and rice (Virk *et al* , 1978), sesame (Rangaswamy, 1980), Brinjal (Gopimony, 1983) and Bhindi (Cheriyan 1986 and Sheela 1994)

The present investigation envisaged to study the effect of gamma rays on the interspecific F_1 hybrids of the cross between *A esculentus* (L) Moench and the semi-wild species *A manihot* (L) Medik as part of the larger objective of inducing useful recombinations in the segregating generations The results obtained are discussed in the following sections

I Effect of mutagen on the hybrids

The induction of mutations by a mutagen is invariably associated with the production of undesirable changes in the biological material The undesirable changes resulting from chromosome aberrations and toxicity are manifested as M_1 damages such as lethality, injury and sterility For a particular mutagenic treatment there is a correlation between M_1 damages and M_2 mutation frequency (Gaul, 1959) Therefore a quantitative determination of M_1 damage should be a routine procedure in mutation breeding experiments Damage to plants in the M_1 generation resulting from the biological effects induced in seeds by mutagens could be measured by several criteria such as reduction in germination and survival, reduction in plant growth, reduction in fertility, increase in the frequency of chromosomal aberrations and increase in the frequency of chlorophyll deficient chimeras

1 Germination

In general there was a progressive reduction in the mean values for percentage germination in both laboratory and field conditions The germination percentage was found to decrease with the increase in the level of irradiation, however at lower doses the reduction was not significant Such a decrease in germination at higher doses of gamma rays was reported by Ayyamperumal (1977) in ragi, Rangaswamy (1980) in sesame and Gopimony (1983) in brinjal

The treated hybrids have shown delayed germination compared to the F_1 control Similar results were reported by Oommen (1980) in cowpea and Sree Ramulu (1970) in sorghum The late germination may be due to the influence of mutagens on plant hormones and plant growth regulators which caused a delay in the initiation of germination (Casarett, 1968)

2 Survival of plants

The percentage of survival was found to decrease with increase in the dose of gamma rays But at the lowest dose this reduction was not remarkable An inversely proportional relationship between survival and dose was observed by Krishna (1985) in bhindi Similar results were obtained by Yu (1961) in tomato

The reduction in survival is an index of post-germination mortality in treated plants as a result of cytological and physiological disturbances due to radiation effect The cytological abnormalities may lead to structural changes in the chromosomes This interferes with the normal growth and development of organs which might have led to the reduction in survival percentage with irradiation

3 Plant growth

Number of branches per plant was not significantly different in untreated and 10 kR treated hybrids and signifiacntly low at higher doses but not significantly different at 20, 30, 40 kR doses

Number of leaves per plant was not signficantly different at earlier days of crop, but at later stages the parents produced less number of leaves Among hybrids 30 kR treated plants produced less number of leaves compared to other treated plants and untreated control at 120DAS

Internodal length was not significantly different between the cultivated and the semi-wild parent from 90DAS onwards though at initial stages the cultivated parent was not found to be superior to the semi-wild parents The highest internodal length was observed in the control F_1 and was on par with the hybrids treated at 10 and 20 kR

Plant height was not significantly different between untreated hybrids and 10 kR treated hybrids No significant difference was observed among 20, 30, 40 kR treated plants

The observations on internodal length, number of branches and leaves and final height of the plants showed that the rate of growth was reduced by the mutagen Krishna (1985) observed a reduction in growth of bhindi plants following irradiation with gamma rays Similar results were obtained by Woodstock and Justice (1967) in maize, wheat, sorghum and radish

Growth rate reduction could be due to auxin destruction (Smith and Kersten, 1942) Evans and sparrow (1961) suggested that the influence of ionising radiations on growth can be attributed basically to the genic loss due to chromosomal aberrations Evans *et al* , (1957) and Evans and

Scott (1964) reported mitotic delay as the major cause of growth retardation in irradiated populations, resulting in reduced growth rate Quastler *et al* , (1952) found that growth inhibition in mung beans following irradiation was not due solely and directly to radiation effects on mitosis, but also due to induced physiological changes

The irradiated hybrids have shown an increase in the root-shoot ratio compared to the control With high doses of gamma rays the shoot growth was more affected than the root growth Similar result was reported by Oommen (1980) in cowpea

4 Sterility

A progressive decrease in pollen sterility was observed with the increase in radiation dose This result is in agreement with Cheryian 1986, who has irradiated interspecific hybrids of bhindi with gamma rays Radiation induced pollen fertility might be the result of normal chromosome pairing, which was dependent on dose of gamma radiation

The increase in pollen fertility may indicate the possibility of obtaining highly fertile segregants in the succeeding generations of the irradiated population

The reduction in the number of seeds per fruit with increasing doses of gamma ray indicates sterility The number of seeds per fruit was not significantly different in the irradiated hybrids but significantly high in untreated hybrids in comparison with 40 kR treated hybrids The increased pollen fertility did not have any effect on the seed set in the irradiated hybrids Radiation induced sterility might be due to detectable chromosome aberrations and cryptic deficiencies (Gaul *et al* , 1966) In the present investigation, no attempts were made for studying the meiotic aberrations in order to assess the nature and degree of the chromosomal aberrations that were induced As pointed out by Gaul (1970), sterility counts are better than meiotic investigation for a quantitative determination of the sum total of chromosome mutations which have survived the sporophytic generation

5 Chlorophyll and other morphological variants

Chlorophyll deficient yellow patches were seen on the leaves of the irradiated population which were considered as chlorophyll mutants Blixt and Gelin (1965) in legumes, found a close correlation between leaf spotting and mutation rate and advocated to use it as a criterion for selecting in the M_1 generation for plants giving higher yield of mutations in the M_2 generations In the present investigation, the number of chlorophyll mutations increased with increase in the dose of gamma rays

Modifications in leaf size and shape compared to the control is seen in the population irradiated at higher doses Koshy and Abraham (1978) noticed progressive reduction in size, distorted shape, irregular lobing and change in texture of leaves in bhindi following gamma ray treatment Stem branch and petiole dichotomy was observed in the irradiated population This might be the result of the death of apical cells in the irradiated materials and regeneration of two apices Koshy and Abraham (1978) observed dichotomy of the stem in bhindi following gamma irradiation Mackey (1951) stated that dichotomy of stem could be explained on the basis of regeneration of affected meristem in barley Bishop and Aalders (1955) attributed it to the delayed expression of some chromosomal effect Some of the plants irradiated at higher doses produced two fruits at the same node Krishna (1985) observed two or three fruits at the same node and fused double fruits in M_1 generation of bhindi raised after exposure to higher doses of gamma rays

6 Other characters studied

The hybrids treated with 10 and 20 kR doses and untreated hybrid took less number of days for first flowering The minimum number of days for first flowering was taken by the cultivated parent The cultivated parent took less number of days for last fruiting also while the maximum by the hybrids treated at 40 kR dose The untreated hybrid and 10 kR treated hybrid took more or less the same number of days The flower production was less in the parents and no significant difference was noticed among treated and untreated hybrids except at 40 kR dose

The number of fruits/plant was not significantly different among treated and untreated hybrids but significantly less in the parents Fruit weight was not significantly different in treated and untreated hybrids but high compared to the parents Length of fruit was not significantly different among 10, 20, 30 kR treated plants but lesss compared to untreated hybrids The lengthiest fruit was recorded for the cultivated parents Fruit girth is significantly low in treated hybrids compared to untreated hybrid Highly irradiated plants produced low girth fruits Maximum girth of fruit was recorded for the semi-wild parent

Yellow vein mosaic incidence was not significantly different among treated and untreated hybrids, but the incidence was found to be high in the cultivated parent Fruit borer incidence was low in untreated and 10, 20 kR treated hybrids but significantly high at 30, 40 kR treated hybrids and the cultivated parent The fruit borer incidence was significantly low in the semi-wild parent Leaf hopper/plant was low in the cultivated parent and high in the semi wild parent and no significant difference was noticed in the treated and untreated hybrids Percentagae hopper burn was comparatively less in the cultivated parent than the semi-wild parent and no significant difference was noticed in the treated and untreated hybrids Shoot borer incidence was not significantly different in treated and untreated hybrids except 30 kR treated one and was very low in the semi wild parent Leaf spot infection was not significantly different in treated and untreated plants but the incidence was only marginal in the semi-wild parent Thus in the present study it could be seen that irradiation did not have much effect in changing the behaviour towards diseases and pests in the M_1 generation except in the case of fruit borer attack where the hybrids irradiated at higher doses had become more susceptible

II Heterosis

All the hybrid treatments have shown significant positive heterosis over the cultivated parent for number of branches per plant, number of leaves per plant, internodal length and height of plants Most of the hybrid treatments have also shown significant positive heterosis over the semi-wild parent for characters such as number of leaves per plant, internodal length and height of plants Sheela (1994) observed that the interspecific hybrids show considerable heterosis and the plants resembled more towards the wild parent and were erect in habit, robust and vigorous

Significant negative heterosis over the semi-wild parent for percentage germination was shown by all the treated hybrids and also over the cultivated parent, except at 10 kR All the treated hybrids exhibited significant negative heterosis over the cultivated parent and semi-wild parent for percentage survival These could be attributed to the reduction in germination and survival caused as a result of irradiation

All the hybrid treatments exhibited significant positive heterosis for days taken for first flowering and last fruiting over the cultivated parent But they have shown significant negative heterosis for these characters over the semi-wild parent All the hybrid treatments exhibited significant positive heterosis for number of flowers and number of fruits produced over both the cultivated parent and semi-wild parent This points towards the possibility for exploiting hybrid vigour for increasing yield in bhindi Among interspecific hybrids, significant heterosis for fruits per plant has been reported by Ugale *et al* , (1976) and Sheela (1994) The hybrids exhibited significant positive heterosis over both the parents for weight of fruits per plant, contrary to the findings of Sheela (1994) in interspecific hybrids of bhindi Significant negative heterosis over the cultivated parent was shown for fruit length by all the hybrid treatments But only hybrids at 30 kR have shown significant negative heterosis over the semi-wild parent for this trait Sheela (1994) has reported that majority of the interspecific hybrids exhibited negative heterosis for fruit length

All the hybrid treatments manifested significant positive heterosis over the cultivated parent for population count of leaf hopper per plant and percentage hopper burn and over the semi-wild parent for fruit borer incidence, percentage of Cercospora leaf spot infection and percentage of hopper burn This indicates the susceptibility of the hybrids to these diseases and pests in comparison to the parents All the hybrid treatments have shown significant negative heterosis over the semi-wild parent for population count of leaf hopper per plant Significant negative heterosis over the cultivated parent was shown for fruit borer incidence by the control and the hybrids irradiated at 10 and 20 kR This shows tolerance of the hybrids to these pests in comparison to the parents

All the hybrid treatments manifested significant negative heterosis over the cultivated parent for YVMD incidence The expression of resistance to YVMD by the hybrid treatments was found to be similar to that of the wild parent and results are in agreement with the reports of Suresh Babu and Dutta (1990) and Sheela (1994)

All the hybrid treatments were found to be giving higher yields and showed resistance to YVMD The heterosis for the characters studied may have resulted from the genetic divergence existing between the two species involved in the cross The superiority of hybrids over the parents may have resulted from overdominant gene action If that assumption comes true from further studies we can expect considerable variability resulting in transgressive segregants for economic characters Such lines may be included as donor parents to breed for resistance to YVMD

III Mutagenic effectiveness and efficiency

Konzak *et al*, (1965) proposed the term effectiveness as a measure of mutations in relation to dose and efficiency as an estimate of mutation rate in relation to other biological effects induced such as lethality, injury and sterility High mutagenic effectiveness as well as efficiency are needed for successful utilization of mutagens in plant breeding

Chlorophyll mutations have been widely employed for assessing the effectiveness and efficiency of mutagenic treatments in higher plants (Gaul 1964, Kawai, 1969) The chlorophyll mutations are taken as a basis for effectiveness and efficiency estimations on the assumption that other types of mutations are induced with frequencies parallel to that of chlorophyll mutations (Kawai, 1969)

In the present investigation the mutagenic effectiveness in inducing chlorophyll mutations was found to increase with increase in dose of gamma rays This indicates that there is scope for using still higher doses in inducing mutations

The mutagenic efficiency estimated on the basis of lethality and injury had shown similar trend with increasing doses of gamma rays This shows that these two criteria have parallel dose-effect relationship On sterility basis, the 30 kR treatment has shown the highest mutagenic efficiency The reason for lower efficiency on sterility basis at still higher dose may be because sterility increased at a faster rate than the mutations with increase in dose of gamma rays

Selfed seeds from all the fertile F_1M_1 plants along with the parents were collected separately for each individual plants Progeny lines from these plants have to be raised as F_2M_2 lines for screening of recombinants These have to be forwarded to F_3M_3 progenies for confirmation of the disease resistance, high yield and good quality This programme is suggested as the future line of work

SUMMARY

SUMMARY

A resistance breeding programme, involving gamma irradiation of interspecific hybrids between one susceptible cultivar *Abelmoschus esculentus* cv Kiran and an yellow vein mosaic resistant semi-wild species *Abelmoschus manihot* (L) Medikus was initiated in 1994 in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani, Thiruvananthapuram The F_1 seeds of the inter specific hybrid were exposed to four different doses of gamma rays (10, 20, 30 and 40 kR) to induce useful recombinations of yellow vein mosaic resistance found in the semi-wild species with better fruit and yield characters of the cultivated parent, in the segregating generations

Studies were undertaken to obtain information on the effects of gamma rays in the first generation The effectiveness and efficiency of different doses of mutagen in inducing chlorophyll mutations were estimated Estimation of heterosis for various quantitative characters was also done The various findings obtained in the study are summarised below

I Effect of mutagen on the hybrids

There was a progressive reduction of germination both in the field and laboratory conditions The treated hybrids have shown delayed germination compared to the control

The survival of the plants was found to decrease with increase in dose of the mutagen

The rate of growth of plants was reduced by the mutagen The plant height showed reduction with increased doses of mutagen The irradiated hybrids have shown an increase in root-shoot ratio compared to the control

An increase in pollen fertility was noticed in the irradiated hybrids Increased pollen fertility did not show any effect on the seed set No significant difference was observed among the irradiated hybrids for percentage seed set

The number of chlorophyll mutations/100 M_1 plants was found to increase with increase in the dose of gamma rays The size and shape of the leaves of some plants raised after mutagen treatment was found to be altered from the control F_1 Stem, branch and petiole dichotomy was noticed in some plants of the irradiated population In the higher exposures, some of the treated plants produced two fruits at the same mode

The mean values have shown increase in number of days taken for the first flowering and last fruiting with increase in doses of gamma rays The irradiated hybrids, except 40 kR, did not differ significantly from the control F_1 in case of the number of flowers produced The mean values for the number and weight of fruits did not differ significantly and was on par with the control F_1 The irradiated hybrids have shown lower mean values for the length and girth of fruits compared to the control F_1

The treated hybrids were found to be on par with the control F_1 for most of the important diseases and pests affecting bhindi The hybrids and the semi-wild parent have shown complete resistance to YVMD - incidence This was confirmed through grafting trials However the hybrids irradiated at higher doses had become more susceptible to fruit borer incidence

II Heterosis

The estimation of percentage heterosis over the cultivated parent and the semi-wild parent have shown that the inter specific hybrid exhibited considerable heterosis over both the parents for most of the economic characters

The hybrids resembled more towards the wild parent and were highly vigorous in growth habit compared to the parents

The treated hybrids exhibited significant negative heterosis over both the parents for percentage germination and survival

The hybrid treatments exhibited significant positive heterosis for days taken to first flowering and last fruiting over the cultivated parent But they have shown significant negative heterosis for these characters over the semi-wild parent The hybrid treatments exhibited significant positive heterosis for number of flowers, number of fruits and weight of fruits over both the parents Significant negative heterosis over the cultivated parent was shown for fruit length by all the hybrid treatments. The hybrids treated at 30 kR alone have shown significant negative heterosis over the semi-wild parent for fruit length.

The control F_1 and the hybrids irradiated at 10 and 20 kR have displayed significant negative heterosis over the cultivated parent for fruit borer incidence. All the hybrid treatments manifested significant negative heterosis over the cultivated parent for YVMD - incidence. The hybrid treatments are found to be giving higher yield coupled with resistance to YVMD.

III. **Mutagenic effectiveness and efficiency**

The mutagenic effectiveness in inducing chlorophyll mutations was found to increase with increase in dose of the gamma rays.

Among the doses employed, 30 kR was the most efficient, when estimated on the basis of sterility. The mutagenic efficiency estimated on the basis of lethality and injury was found to increase with increase in dose of gamma rays.

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INDUCED MUTATIONS IN INTERSPECIFIC HYBRIDS OF *ABELMOSCHUS* Spp.

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ABSTRACT OF THE THESIS
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ABSTRACT

The F_1 seeds of the cross between *Abelmoschus esculentus* cv Kiran and the semi-wild species, *Abelmoschus manihot* were exposed to four different doses (10,20,30 and 40 kR) of gamma rays and their effects in the first generation were studied

The percentage of seed germination decreased with increasing doses of gamma rays The treated hybrids have shown delayed germination compared to the control

The survival of plants was found to decrease with increase in dose of the mutagen

The rate of growth of plants and plant height were found to decrease by the treatment with gamma rays Various hlorophyll and morphological variants were observed in the irradiated population

An increase in pollen fertility was noticed in the irradiated hybrids But the increased pollen fertility did not show any effect on the seed set

Irradiation delayed the formation of flowers and fruiting The mean values for number and weight of fruits did not differ significantly among irradiated treatments and was on par with the control F_1 The irradiated hybrids have shown lower mean values for the length and girth of fruits compared to control F_1

The treated hybrids were found to be on par with the control F_1 for yellow vein mosaic disease incidence and the important diseases affecting bhindi The hybrids irradiated at higher doses had become more susceptible to fruit borer incidence

The hybrids represented more towards the semi-wild parent and have shown considerable heterosis over the cultivated parent and semi-wild parent for most of the economic characters

The hybrids were vigorous in growth habit compared to the parents.

The hybrid treatments exhibited significant positive heterosis for days taken to first flowering and last fruiting over the cultivated parent

The hybrids treatments exhibited significant positive heterosis for number of flowers, number of fruits and weight of fruits over both the parents Significant negative heterosis over the cultivated parent was shown for fruit length by the hybrid treatments

Significant negative heterosis over the cultivated parent for fruit borer incidence was shown by the control and the hybrids irradiated at 10 and 20 kR All the hybrid treatments manifested significant negative heterosis over the cultivated parent for YVMD incidence

The mutagenic effectiveness in inducing chlorophyll mutations was found to increase with increase in dose of the gamma rays

The mutagenic efficiency estimated on the basis of lethality and injury increased with increase in dose of gamma rays On sterility basis, the 30 kR treatment was the most efficient