INDUCED MUTATIONS IN BANANA var. NENDRAN

BY

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DECLARATION

I hereby declare that this thesis entitled "Induced mutations in banana var. nendran" 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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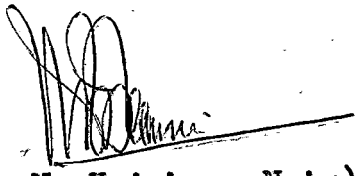
CERTIFICATE

Certified that this thesis entitled "Induced mutations in banana var. nendran" is a record of research work done independently by Smt. D.S. Radha Devi under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.



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INTRODUCTION

INTRODUCTION

Banana, the queen of tropical fruits is one of the most widely grown fruit crops of India. Nendran is the most popular dual purpose commercial variety of banana occupying nearly 30 per cent of the total area under banana cultivation in Kerala. This variety (AAB genome) is triploid, heterozygous and seed sterile. Only induced variability can create a base population for further crop improvement in this particular crop variety (Broertjes and Harten, 1978). Due to the polyploid and heterozygous nature a wide variability can be expected.

The main advantage of mutation induction in vegetatively propagated crops is its ability to change one or a few characters of an otherwise outstanding cultivar without altering the remaining and often unique part of the genotype. Vegetatively propagated crops are a very suitable group of plants for the application of mutation breeding methods (Broertjes and Harten, 1978). Mutations are the only source of variability in sterile plants or in obligate apomicts. A very effective method, important in practical aspects, with regard to the performance of mutation breeding in vegetatively propagated species is the so-called adventitious bud technique (Broertjes, 1969 a, b; 1972 b). These buds originate very often from

a single meristematic cell. Due to mutation induced in this cell, a plant having the same genotypic constitution in all its organs arises which is thus not a chimera. This is a great advantage. If mutated and non-mutated cells are present in a chimeric M_1 plant, diplontic selection occurs. Very often, the mutant cells are not fully competitive with the non-mutant ones. This behaviour results in a low frequency of mutants and a narrow mutation spectrum. This unfavourable situation is avoided in many ornamentals derived from a single mutant cell. In this way, very high mutation frequencies as well as a wide genetic variability are obtained. Moreover, there are good prospects to avoid chimerism in clonally propagated plants by treating tissue cultures (Skirvin, 1978).

The shoot tip multiplication method obviously has a great potential for producing multiples of specimens from breeding efforts not ordinarily available quickly and for producing specific pathogen free planting materials in large numbers. Since they are asepetic, shoot-tips can also be used to maintain bacteria and fungus free stock for germplasm exchange, transfer and shipment (Stover, 1977).

As part of modern biotechnology, <u>in-vitro</u> culture of plants also underwent a rapid development, not only

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for rapid and virus-free multiplication but also for use in mutation breeding to prevent or restrict chimera formation (Broertjes et al., 1976). Experience in applying radiation or chemical mutagens to in-vitro cultured plant material is limited and only few reports are available about successful selection of mutations after in-vitro application of mutagens (Malepszy et al., 1977). A major advantage is expected for mutation breeding by using haploids, usually derived from anther culture (Sharp et al., 1984).

The clonal variation exists in majority of vegetatively propagated plants including banana. It varies depending on varieties. Nendran is a banana variety having the lowest fraquency of seed set while crossing and is without much clonal variation. The lack of clonal variability and the limitation of getting further crop improvement in Nendran by hybridization tempted us to adopt induced mutagenesis in this particular variety to create a base population for further selection and isolation of desirable types.

The present investigation was carried out with the following objectives:

1. To standardise the technique of treatment for induced mutagenesis in banana suckers

2. To create as much variability as possible by using gamma rays

3. To isolate out the viable mutants including dwarf types if any

4. To create a base population with as much variability in all the productive traits to apply the selection process

5. To analyse the extent of created variability

6. To isolate out high yielders with dwarf stature and early maturity

7. To standardise techniques for in-vitro propagation of banana adopting shoot tip culture techniques

8. To standardise technique of gamma ray exposure adopting in-vitro methods and also

9. To standardise the ex-vitro techniques in banana for successful induced mutagenesis

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Mutations are the ultimate source of variability in organisms. Variability caused by induced mutations is not essentially different from variability caused by spontaneous mutations during evolution (International Atomic Energy Agency, 1970). Induced mutation enables crop improvement through enhanced genetic variability (Konzak, 1984). The enhanced genetic variability through induced mutation can serve as the basis for widening the desirable attributes of crop plants.

The term mutation was derived from the latin word 'mutare' to denote change. The history of induced mutation starts from De Vries who reported this phenomenon in 1901. The use of X-rays for induced mutation was first reported by Muller (1927) in Drosophila. This was followed by the report of Stadler (1928) in barley and maize.

Physical agents like gamma rays (Sparrow and Singleton, 1953), ultra violet rays (Altenburg, 1934; Stadler, 1941; Stadler and Roman, 1943), fast neutrons (Mackey, 1954; Ehrenberg, 1954), beta rays (Ehrenberg *et al.*, 1949) and thermal neutrons (Caldecott *et al.*, 1954) are used extensively to increase variability and enhance the scope of selection procedures.

A number of chemical agents also produce mutations in plants when applied singly or combined with other chemicals and in succession or simultaneously with radiation (Ehrenberg et al., 1961 and Konzak et al., 1965). Auerbach and Robson (1944) brought to light the effect of mustard gas on Drosophila. Methyl methane sulphonate (MMS) (Heiner et al., 1960 and D'Amato et al., 1962), Ethyl methane sulphonate (EMS) (Froese-Gertzen et al., 1964) and ethylene imine (EI) (Wagner et al., 1968) are found to be highly mutagenic. But majority of the varieties developed by mutation was by irradiation with physical mutagens (Sigurbjornsson and Micke, 1969).

A. Induced mutations in vegetatively propagated plants

a) General

Vegetatively propagated plants are a very suitable group of plants for the application of mutation breeding, due to their higher degree of heterozygosity and frequent polyploid nature. Both these factors are serious handicaps in conventional breeding. Mutations are the only source of variability in sterile/polyploid plants as in banana or in obligate apomicts. The main advantage of mutation induction in vegetatively propagated crops is the ability to change one or a few characters of an otherwise outstanding cultivar without altering the remaining and often

unique part of the genotype and the direct propagation of the variants to get the succeeding generations. The main bottlenecks in mutation breeding of vegetatively propagated plants are chimera formation and diplontic selection, both being complications caused by multicellular nature of the bud-apex due to the fact that mutation is an one-cell event (Broertjes and Harten, 1978).

Irradiation of bulbs, tubers, rhizomes, cuttings, grafts, other plant part or whole plants, all having buds with multicellular apices composed of a number of fairly autonomous cell layers, automatically leads to the formation of chimeras. This is the main obstacle in mutation breeding, especially in species, in which there is no ontogenetically young stage of buds to be irradiated (Broertjes and Harten, 1978).

Some vegetatively propagated crops, especially certain ornamentals, proved to be well suited for the application of mutagenesis in order to improve their breeding value. In this case since we are going for easily detectable characters like flower colour, size, etc., desirable mutants can be easily identified, even in the 1st generation of irradiation works (Gottschalk and Wolff, 1983).

Most mutation breeders prefer ionising radiations for mutating vegetative parts. Physical mutagens like X-rays, gamma rays etc. are widely used to induce mutations in all kinds of plant parts. Small materials are more conveniently X-rayed. For vegetative parts that are bulky a Cobalt 60 (^{60}Co) or Caesium-137 (^{137}Cs) source of 50-200 curie may be a more convenient one. Ultra violet rays are not generally preferred for irradiating vegetative parts due to their poor penetration capacity (IAEA, 1970).

For inducing mutations in vegetatively propagated plants, chemical mutagens are not usually considered, mainly because the number of cases in which they have been applied successfully has been small (Broertjes and Harten, 1978). The lack of success is probably a consequence of poor uptake and penetration of the chemical compound (Bowen, 1965; Moes, 1966). Moreover, bulky material like bulbs, scions for grafting and plants are difficult to be treated with chemicals in a reproducible way. Successful application of chemical mutagens to pineapple was reported by Singh and Iyer (1974), Kaul and Kak (1973, 1975) to peppermint and Mee et al. (1969) to sugarcane.

For inducing the mutation, the mutagenic agents can affect different plant organs such as freshly cut

leaves Streptocarpus and Achimenes leaf stalks of African violet, tubers of Potato and Dahlia, young rhizomes of Alstroemeria and Cynodon, bulbs of Iris, dormant buds of fruit trees, roses and grapes, cuttings of Cherries and dormant stolons of peppermint and Bermuda grass (Gottschalk and Wolff, 1983).

A very effective method, important in practical aspects, with regard to the performance of mutation breeding in vegetatively propagated species, is the so-called adventitious bud technique (Broertjes, 1972 b). Many plant species can be stimulated to form adventitious buds on isolated leaves (Broertjes et al., 1968). These buds originate very often from a single meristematic cell. If mutational events have been induced in this cell, a plant having the same genotypic constitution in all its organs arises which is not a chimera. This is a great advantage. If mutated and non mutated cells are present in chimeric M_1 plant, diplontic selection occurs. Very often, the mutant cells are not fully competitive with the non-mutated ones. This behaviour results in a low frequency of mutants and a narrow mutation spectrum. This unfavourable situation is avoided in many ornamentals derived from a single mutant cell. In this way, very high mutation frequencies as well as wide genetic variability are obtained. Examples

for such a situation are Streptocarpus, African violet Achimenes, Kalanchoe (Broertjes, 1969 a, b, 1972 a; Broertjes and Leffring, 1972), and Begonia (Doorenbos and Karper, 1975) among others.

The improved characters of the vegetatively propagated plants, controlled by the mutant genes, cover a range of traits. An increase in genetic variability was obtained with regard to flower colour and shape in many ornamentals, earliness and lateness in almost all the crops exposed, shortening of internodes length in fruit trees and ornamentals, alterations of the plant type in ornamentals, improvement of the resistance behaviour and desirable biochemical alterations in some fruit trees, tea plants and in other crops (Gottschalk and Wolff, 1983). Distinct genes were found to be influencing fruit shape and fruit colour (Lapins, 1973; Ikeda, 1974) and reduced amount of russeting in fruit skin (Lapins, 1973) in apple.

The number of mutants selected in a few vegetatively propagated crops are: 1650 mutants in Streptocarpus (Broertjes, 1969 b); more than 300 mutants in Ribes nigram (Bauer, 1974), about 160 flower mutants in bulbous Iris (Hekstra and Broertjes, 1968) and more than 300 mutants in Bermuda grass (Cynodon sp. Powell, 1976).

X-ray treatments of potatos were performed by Johnson (1937) and Sprague and Lenz (1929). High energy protons were used by Tarasenko (1977) in potato and protons were found to be as effective as neutrons. Konkel No. 45 and Mariline 2 are the two induced mutants reported in potato. In potato, high degree of chimerism is reported in EMS treatment, which however was considerably lower after X-irradiation (Miedema, 1973).

Moh (1963) irradiated cassava nodes upto 4 kR of gamma rays and found that the LD 50 value was 3 kR.

Kukimura and Takemata (1975) reported that mutants with increased as well as reduced sugar contents were obtained in sweet potato after treatment of shoots, dormant root tubers and seeds with ^{60}Co gamma rays. Sweet potato varieties, Tameyutaka and Okinawa-100 were treated with gamma rays. Irradiation was more effective for improving tuber yield. The frequencies of clones which significantly exceeded the parents were 1.7×10^{-3}, 2.2×10^{-3} and 1.1×10^{-3} for tuber yield, dry matter content and total sugar content respectively (Kukimura, 1981). Kukimura and Kovyama (1982) studied mutation breeding in sweet potato (Ipomoea batatas L.Lam). A total of 37 different genotypes were subjected to gamma rays. Analysis on the effect of irradiation on quantitative characters, such as

dry matter content, and total sugar content in tubers, was also done in hybrid populations. It was found that mutant clones were superior to control in dry matter content and total sugar content.

In Alstroemaria, M_1 plants without chimerism were obtained after X-ray treatment of young rhizomes, although the buds have probably multicellular apices (Broertjes and Verboom, 1974). It should be mentioned that the mutation frequency, obtained after X-ray and neutron irradiation of Achimenes was found to be 20-40 times higher in autotetraploid material as compared to the diploid initial material.

An added advantage of mutagenesis in ornamentals is that even mutations from the dominant to recessive state of a gene become already discernible in M_1 generation. Recent findings of this kind have been obtained in Carnation (Badr and Etman, 1977). This is due to the fact that many ornamentals are highly heterozygous. After application of mutagens, the homozygous recessive condition is realized in some of these gene pairs. The genes involved influence leaf size, internode length, spreading rate and herbicide and nematode resistance among others (Burton, 1974, 1976; Powell et al., 1974; Powell, 1976). In Bahia grass (Paspalum notatum) and Kentucky blue grass

(Poa pratensis), mutants with increased seed set and with improved disease reaction were selected (Powell, 1976). In Brachiaria brizantha after gamma irradiation of seeds and cuttings, a prospective mutant was isolated showing short internodes, profuse tillering, erect growth habit, reduced pubescence, and rapid regrowth (Ganashan, 1970).

The sensitivity of tea to gamma irradiation varied with the cultivar and the organs being irradiated. When seeds were irradiated, the time for emergence was delayed, and the rate of emergence decreased at irradiation doses above the optimum (5 Kilo Roentgen (kR)), and the lethal dose was 7 kR. Except in the cultivar Fudingdabal, the survival rate of cuttings and their growth rate decreased at doses above optimum (0.5 - 1 kR) and the lethal dose was 2 kR. (Dong et al., 1985).

Results of the mutation study conducted at the Cardamom Research Station, Pampadumpara showed that cardamom seeds irradiated at 20 kR and above failed to germinate and there was a decrease in germination at doses of 10 kR and above. The LD 50 was found to be between 8-10 kR. At doses upto 4 kR (0.5, 1.0, 2.0 and 4.0 kR), the variety Mysore showed maximum germination, while variety Malabar showed the least. In Vazhukka variety the germination was intermediate (Benny Joseph, 1987).

Khairwal et al. (1984) treated sugarcane (cultivar Co.1148) with gamma rays at 2, 4 and 6 kR and surviving clones were inoculated with Colletotrichim falcatum and scored. Infected clones, uninfected clones and clones that were still healthy at maturity showed an increase over the control for most quality characters and 8 early maturing and high sugar mutants were isolated.

Krishna et al. (1984) isolated two mutants in the M_2 following gamma irradiation of seeds in Rhodes grass. The non-arrowing mutant had broad leaves and short stems, tillered heavily and bore no inflorescence. It had a 17 per cent higher green forage yield than the control and almost double the contents of crude protein, nitrogen and calcium.

Kaicker and Swarup (1972) induced colour mutations in the rose cultivars, Christian Dior, Queen Elizabeth and Kiss of Fire, by treating dormant buds with gamma rays. The economic dose ranged from 5-10 kR and higher doses were lethal. Gamma ray induced mutants of rose cultivar, Montezuma was studied by Lata and Gupta (1975). They found pink and reddish orange flowered mutants. Kaicker (1982) found striped or multicoloured petals on gamma irradiation. Datta and Gupta (1983) irradiated budwood of 15 cultivars of rose with 3 to 5 kR of gamma rays and

found that most suitable dose for induction of mutation was 3 kR. Six of the gamma ray induced mutants of rose have been multiplied and assessed for release as new cultivars. Datta (1985) irradiated budwood of nine cultivars of rose with gamma rays at 3, 4 and 5 kR and the buds were budded on Rose indica var. ordorata. Reduction in sprouting and survival was observed and it increased with the dose, with the cultivar orange sensation being the most sensitive and "Kiss of fire" the most resistant. Reduction in height was also noted, with "Kiss of Fire" being the least and 'Zambra' the most affected. Gamma radiation at 3 kR was applied by Huang and Chen (1986) to the green shoots of several rose cultivars including Crimson Glory, Superstar, Cordesa, de Sastago, Peare, Pink peare and south seas. In the vM_1, vM_2 and vM_3 generations mutants were selected for leaf and flower characteristics. Between 3-8 kR treatments, 15 per cent of the plants have mutant branches and produced chimeric flowers. Four new cultivars were established from stable mutant clones.

Seeds of the citrus clones lemons Meyer, New Georgian and the orange Mestnyi (Local), buds of the mandarins Unshiu and Kawanowase, the lemon Meyer and the Orange Washington Navel, and plants of Kawanowase, Meyer and Washington Navel were gamma irradiated by Kerkadze (1979)

with various doses. The material obtained included polyploids, aneuploids, albinos and variegated forms. Some mutants were obtained with altered growth rate, leaf morphology fruit shape and size and mutants with an increased photosynthetic activity. Kerkadze and Kutateladze (1979) reported that in citrus, mutation frequency in the second generation did not exceed 1 to 3 per cent. Dwarf mutants with early ripening and good fruit quality were obtained. Three useful mutants were obtained; 1461, obtained from the mandarin Kawanowase with a 5 kR gamma ray dose, 1438, obtained from Kawanowase with 3 kR gamma ray dose and 2128 obtained from the lemon Meyer with 5 kR gamma ray dose. Huang and Ji (1983) studied segregation in the M_2 of Citrus sinensis cultivar Jincheng. Segregation for leaf shape, leaf size, spine and internode length was observed in 8 M_2 scions out of 14 clonal lines selected from scions of Jincheng irradiated with 3, 4, 5 kR gamma rays at a rate of 1 kR/h. Roy et al. (1985) exposed budwood of lemon cultivar Eureka to gamma rays at 2, 4 and 6 kR. Buds from vM_1 plants were budded on to sour orange rootstocks along the non-irradiated buds. From 600 vM_2 plants, several bore seedless or nearly seedless fruits. One selection exposed to 6 kR, was consistently seedless over 4 consecutive seasons. Plants (vM_3) from this tree also bore seedless fruit even in mixed plantations.

Akhund-Zade (1979) studied the effect of radiation on subtropical fruit crops. When pomegranate, fig, feijoa, almond and pistachio seeds were gamma irradiated, the widest range of useful mutations were obtained with 5-7 kR doses. Dwarf mutants were the most common. The dwarf pomegranate Khyrda, reaching only 80 cm in height, forms small leaves and fruits and flowers profusely upto 577 flowers/bush. The fig Bol (Abundant) and the pomegranate Karabakh were produced by radiation-induced mutagenesis.

Scions from three varieties of mango (Mangifera indica L) were exposed to gamma rays, ethyl methane sulphonate and N-nitroso-N-methyl urea (NMU) and grafted into one year old seedlings. The LD 50 for gamma-irradiation of Neelum and Dashehari and Mallika were 3.9, 2.9 and 2.4 kR respectively. A few plants appeared promising for dwarfness and in some fruit quality was improved (Sharma et al., 1983).

Paprstein and Blazek (1985) induced mutations in apples. Following gamma ray treatment (17-34 Gy) of mature buds of cultivar, Mc Intosh, 19 selections with compact growth were grafted on to M_9 stock. All selections produced fruits of more intense colour and four showed longer fruit storability than the parent.

b) Banana

The use of induced mutations in banana breeding has been suggested in several occasions (Champion, 1963; De Langhe, 1969). Initial studies were performed by many workers including Stotzky et al., 1964; Moh and Alan, 1965 and Azzam and Linden, 1965. Stotzky et al. (1964) reported the effects of gamma-irradiation in seeds of the wild diploid banana, Musa sapientum. Moh and Alan (1965) briefly outlined the behaviour of banana plants in a gamma field and studied the radiosensitivity. Azzam and Linden (1965) performed some preliminary investigations with cultivar Gross Michel. The work was continued by Fortuno and Maldonado (1972) to isolate a resistant clone of more attractive Gross Michel. They irradiated suckers with 2.5 to 40 kR gamma rays. There was no survival after doses higher than 5 kR. Two mutants, one with drastic leaf aberrations and the other with more intense pigmentation and various smaller morphological changes were selected in vM_2 for further testing.

Panton and Menendez (1972) and Menendez (1973) applied EMS to seeds of a diploid breeding line of Musa acuminata in an attempt to obtain plants with decreased plant height. They expressed the opinion that induction of resistance to several diseases using mutation methods appears to be quite

feasible in banana. They also suggested the use of adventitious buds obtained from callus as starting material. This approach has also been suggested by latter workers (De Guzman, 1975; De Guzman et al., 1976).

Nendran suckers treated with gamma rays from 1 to 8 kR at 1 kR intervals showed that L.D.50 was at 3.3 kR and the production of suckers and survival decreased with the increasing doses of radiation (Gopimony and Kannan, 1978).

B. Shoot tip culture of Banana

Barker (1959) has shown that aseptic culture methods and use of growth regulators on excised shoot tips of dessert bananas are capable of yielding entire plants. Ma and Shii (1972) reported the in-vitro formation of adventitious buds in banana shoot apex following decapitation using semisolid and liquid media. Berg and Bustamante (1974) obtained only a single plant per excised shoot apex while attempting the micropropagation of banana. The applicability of the excised shoot tip culture technique to a number of banana clones was assessed by De Guzman et al. (1976).

Apical meristems, aseptically removed from rhizomes cut with 7-12 vertical incisiions and placed on modified

Murashige and Skoog (1962) (MS) medium developed a cluster of shoots after one month. Individual shoots were transferred to fresh medium. Plantlets had well developed shoot and root systems after two months (Vessey and Rivera, 1981).

Bower and Fraser (1982) have reported that growing points of Williams banana variety when cultured on MS medium supplemented with kinetin (Kn) 5 ppm, Benzyladenine (BA) 2 ppm and 2 ppm Naphthalene acetic acid (NAA), 92 per cent of the plants showed shoot growth and incipient rooting after four weeks and most of these could be transplanted into polythene covered pots after six weeks.

Swamy et al. (1983) reported clonal propagation of Musa acuminata L. Robusta from excised shoot tips cultured on MS medium. Excised shoot tips with the youngest leaves produced only one plantlet and shoot tips with several older sheathing leaf bases enclosing the axillary buds regenerated multiple plantlets. The plantlets obtained from both types of explants have been successfully transplanted to soil and grown to maturity.

Rapidly multiplying cultures of dessert banana clones ('Philippine Lacatan' and 'Grande Naine') and plantain clones ('Saba' and 'Pelipita') were established

from isolated shoot tips on modified MS medium supplemented with 5.0 mg/l BA. (Cronauer and Krikorian, 1983).

Hwang et al. (1984) obtained plantlets from the decapitated shoot apex and adventitious bud explants of a banana sucker established well under field conditions and gave rise to mature plants with uniform growth and normal yield of fruit.

Krikorian and Cronauer (1984) could induce multiple shoots by releasing dormant buds at the leaf bases. Sub-culturing could be carried out from the proliferating mass of shoots. Protocorm like bodies were formed at the newly formed shoot bases which inturn produced multiple shoots.

Vuylsteke and Langhe (1984) reported high prolife-rative growth of adventitious buds, by culturing pre-existing meristems on a medium with high cytokinin concen-tration. Regenerated plantlets are ready for soil trans-plantation within 3 to 4 months. Varietal differences in the proliferation rates could be grouped according to genome type, the AAB, ABB genomes showing the highest multiplication potential.

Bakry et al. (1985) cultured explants from inflore-scence apices of cavendish and wild species of banana on

a medium with MS salts and vitamins with or without growth regulators. With the plantain subgroup, 10-15 plants/ explant were obtained compared with 50 plants or more with the AAA subgroup and Musa acuminata.

Terminal floral apices of Musa acuminata cultivar dwarf cavendish were isolated and cultured on modified MS medium supplemented with N6-Benzylaminopurine (BAP) (5 mg/l) and 10 per cent coconut water. The rooted plantlets were obtained by treating plants with the auxin, NAA (1 mg/l) and activated charcoal (0.025%) (Cronauer and Krikorian, 1985).

In-vitro culture of Saba banana (Musa balbisiana cultivar Saba (BBB)) was done by Damasco and Barba (1985). Corm sections and shoots obtained from plantlets derived from the cultured explants formed multiple shoots on MS medium supplemented with 10 mg/l BA. Subculture of shoot tips to fresh medium of the same composition increased the number of shoots produced with each culture cycle. Shoots cultured for one month in MS medium without growth regulators initiated roots and were readily transplanted to soil. By subculturing every two months, 200,000 plantlets could be derived from one explant in ten months.

Jarpet et al. (1985) initiated shoot tip cultures of two clones of banana (Saba and Pelipita genome ABB) on a modified MS medium supplemented with 3 mg/l BA and 1 mg/l Indole acetic acid (IAA). Propagation cultures were initiated by spliting shoot tips along their longitudinal axis and reculturing the individual pieces on MS medium supplied with 5 mg/l B.A.

Sun (1985) observed that ninety three out of 103 clones, including one accession each of Musa acuminata and Musa textilis developed adventitious buds in meristem culture on MS medium supplemented with 5 ppm BA and 2 ppm IAA. Plantlets were regenerated after transfer to a medium containing 0.1 per cent activated charcoal.

Apical meristem culture, which has applications in germplasm preservation was studied in two Musa acuminata cultures and 3 Musa acuminata x Musa balbisiana cultivars. Suckers were planted in soil and grown at 38-40°C for 14 days before culture of the apical meristems on modified MS medium. Each meristem produced upto 13 rooted plants within 10-12 weeks and these plantlets were free of mosaic disease (Gupta, 1986).

Novak et al. (1986) established shoot-tip cultures from 9 Musa clones on MS medium. Shoot proliferation in

clones, Saba and Pelipita was compared between solid and liquid media. Rapidly proliferating cultures were established on MS medium containing 20 μM BA. The banana and plantain clones differed in micropropagation ability. The most suitable ones were Musa acuminata clones - diploid (AA), triploid (AAA) and tetraploid (AAAA).

Wong (1986) found that in shoot-tip explants with apical dome, a total of 22 cultivars (genomes AA, AAA, AAAA, AAB, AB and ABB) were successfully cultured on modified MS medium containing BA and indole butyric acid (IBA). Shoot-tip explants were induced to produce multiple shoot initials in the presence or absence of apical domes. But the survival rates were higher when apical domes were retained. Rooted plantlets were successfully established in soil.

C. Induced mutagenesis adopting in-vitro techniques

a) General

Plant modification using tissue culture induced mutagenesis is a novel and very interesting field of research among the various techniques available in tissue culture. Bajaj (1971), based on a study of direct and indirect effects of gamma irradiation on the seeds, seedlings, callus tissue cultures, excised roots, ovules and

embryos has observed that callus tissue cultures are more radio-resistant than intact seedlings. Yoshida and Ogawa (1983) reported that individual plant cells or pollen grains grown in culture media can serve as mutable material for establishing entire plants.

Skirvin (1978) suggests a novel approach to intra-clonal plant improvement which will utilize both the natural and induced variation associated with clonally propagated plants through various in-vitro and in-vivo procedures. Many plants obtained are of single cell origin and hence of pure mutant type avoiding the chimerism.

Johnson (1980) using gamma irradiation achieved in-vitro induced separation of chimeral genotypes in Carnation (Dianthus caryophyllus) from meristem culture and macerated shoot tip culture.

Micropropagation of two genotypes of Begonia hiematis was achieved through in-vitro cultured leaf disc explants and subsequent transplantation to soil using explant parts with adventitious shoots. After irradiation of detached leaves with different doses of X-rays and two cycles of adventitious shoot formation on in-vitro cultured leaf disc explants, plantlets were produced. About 30 per cent of these plants were mutated with respect to colour, size

and form of the leaves and flowers (Roest et al., 1980).

Liu and Deng (1985) suggested that callus irradiation is not potentially useful for inducing superior mutants. They cultured shoot tips of orange (Citrus sinesis) on modified MS medium with growth regulators followed by redifferentiation on bud and rooting media. Three new clones (nucellar clones) gave higher rates of callus growth and redifferentiation than did the old clones (a chimera cultivar). It is suggested that callus irradiation is not potentially useful for inducing superior mutants.

In potato (Solanum tuberosum L) adventitious sprouts of cultivar Desiree that arise by in-vitro, X-irradiation of leaf explants (rachis, petiole, leaflet disc) produced a very high mutation frequency (74.3%), a wide mutation spectrum and low rate of chimerism in subterranean and aerial parts in three vegetative generations (Harten et al., 1980). Roest and Bokelmann (1980) studied the vegetative propagation by means of in-vitro adventitious bud techniques in mutation breeding of potato. A method for producing plantlets through adventitious shoot and root formation from rachis, petiole and leaflet-blade explants through irradiation with X-rays was reported. Sunnino et al. (1984, 1986) proposed a procedure for in-vitro mutation breeding of potato. Two hundred and thirty five plantlets obtained

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from buds of cultivar 'Desiree' cultured on modified MS medium were irradiated with 3 kR of gamma rays and single node pieces were subcultured twice. After about 40 days, vM_1 plantlets were cut into single-node pieces and transferred to fresh medium. Among the 1094 plants available at the adult stage, 158 mutations were detected; 36 of leaf size and shape, 39 of leaf colour (dark green, pale green), 24 of flower colour (white or dark purple) 1 of flower shape (exerted style), 7 of anthocyanin-deficient stems, 5 of dwarf type and 46 of tuber skin colour (yellow, dark purple or spotted). Of 102 mutants 78 were apparently homogeneous while 24 appeared to be chimeric. X-irradiation of tuber eye-pieces of the potato cultivar Burmania (B-173) has resulted in a plant with aberrant leaves which has been designated as "ivy leaf" and when subjected to further investigations it has been found that ivy leaf is dominant without any pleiotropic effects (Harten et al., 1973).

Espino et al. (1985) have irradiated shoot tissues, seeds, seedlings and scion wood with gamma rays. Both seeds and plantlets cultured in-vitro led to retardation of shoot and root growth, inhibition of germination, leaf deformities and chlorophyll streaking. The species used included Banana (3 cultivars), Citrus spp, Artocarpus spp, Mango (4 cultivars) and Nephelium lappaceum L.

Walther and Sauer (1986 a) analysed the radiosensitivity of rose cultivars as a basic requirement for in-vitro somatic mutagenesis. Nodal basal segments of in-vitro grown shoots of the tetraploid cultivars, Mercedes, Gabiaella, Lorena, Ilseta 8151-1 and Duftwolke were exposed to X-irradiation (30, 40, 50 or 60 Gy). Data on survival rates of explants and axillary shoot production were tabulated. Mercedes was the most and Ilseta was the least sensitive to irradiation.

A broad spectrum of variability was induced by applying X-ray doses between 25 and 60 Gy to basal segments of in-vitro derived micro-shoots of the cultivar Ilseta followed by repeated cutting off of axillary shoots from treated mother explants. The mutations comprise of 73 per cent flower mutants (size, colour, number) 14 per cent with altered growth and 13 per cent with modified leaves (Walther and Sauer, 1986 b).

b) Banana

The work done so far is very little in gamma irradiation prior to excision and culturing of the meristem or growing point (Menendez, 1973; Menendez and Loor, 1979; De Guzman et al., 1980; 1982). This field may be of some real potential for bananas, since the plantlets produced

by aseptic meristem multiplication procedure are tiny, they are well suited to mutagenesis manipulation (Broertjes and Van Harten, 1978; Gottschalk and Wolff, 1983).

Kao (1979) and Huang and Kao (1979) worked on shoot apex isolates of banana cultivars "Hsien-jen-Chiao" and "Peichiao". They were exposed to gamma rays at 2.5 kR and cultured on semi-solid culture media. A total of 377 apices were treated and 49 plantlets were obtained from the first stage of the experiment. In the second stage, the plantlets were raised in small pots. Transplanting of plants to shade and to open field constituted the third and fourth stages. The total time involved was two years. Mutations were observed throughout the four stages of the experiment. Some major mutants observed in the field were of short stature and high yield, early double suckering, pale green pseudo-stem, red leaf mid-ribs, and variation in the leaf-ratio.

Yang and Lee (1981) obtained leaf-shape mutants when tissue cultured plantlets from Hsien-jen-chiao with 10-15 cm height were treated with 0.01-1 per cent EMS 0.01 per cent DES and 0.1 per cent sodium azide. From this, dwarf mutants were obtained in which shoot height was 50 cm less than in the original cultivar. Callus induction was achieved from embryos of Musa formosana and

from male buds of cultivar Giant Cavendish treated with 0.05 per cent colchicine.

When shoot tip explants cultured in modified MS medium were irradiated with 1.0 kR gamma rays in Bungulan variety, it stimulated several morphological aberrations and explant growth was observed even at 2.5 kR. A culture strain with fast and continuous proliferation was isolated. In-vitro derived plants were established in the field and those derived from irradiated explants were similar to or sometimes better than those from unirradiated explants with respect to height, girth, sucker production and number of hands per bunch and fingers per bunch (DeGuzman et al., 1982).

Silayoi et al. (1985) cultured shoot tip segments from the banana clone Kluai Hom Thong (AAA) on MS medium. By gamma irradiation at 1, 2, 3 and 4 krad, 500 plantlets were produced within 5 months. The higher doses gave rise to more plants showing chlorosis and necrosis.

Novak et al. (1986 a) worked on the radiation sensitivity in shoot tip cultures of banana and plantain. Shoot tip cultures were established from 9 Musa clones and shoot proliferation in clones Saba and Pelipita. Shoot tips of Saba were exposed to gamma radiation, radiosensitivity was assessed as fresh weight gain and shoots clump ratio

during the four weeks following irradiation. A 50 per cent decrease was recorded in fresh weight gain and shoot clump ratio after irradiation of 30 to 45 Gy. They obtained most suitable Musa acuminata clones diploid (AA), triploid (AAA) and tetraploid (AAAA) from meristem culture by gamma irradiation and EMS treatment (0.75 to 1.0 per cent).

MATERIALS AND METHODS

MATERIALS AND METHODS

Preliminary investigation to standardise the techniques for induced mutagenesis *in-vivo* and *in-vitro* in banana variety Nendran (*Musa paradisiaca* L.) comes under the sub group plantain with AAB genome (Simmonds, 1959). The suckers of this variety were grown under uniform conditions, adopting the recommendations of the package of practices of the Kerala Agricultural University. The study was carried out in the Department of Agricultural Botany, College of Agriculture, Vellayani during 1985-'88 and in the plant tissue culture Laboratory attached to the Department of Plantation Crops, College of Horticulture, Vellanikkara, Thrissur during 1986-'88. The project was envisaged to analyse induced *in-vivo* mutagenesis and induced *in-vitro* and *ex-vitro* shoot-tip culture of banana. The details of the various procedure adopted are presented hereunder.

I. Induced mutagenesis *in-vivo*

The suckers used for the investigation were marked separately depending on the date of their emergence and then grouped according to maturity into one month, two months and three months old corms. The collected rhizomes were smeared with cowdung slurry and ash for protection

against pests and diseases. After drying them for three days, these corms were stored under shade for five days arranged horizontally on planks. These suckers were used for gamma irradiation.

The following types of corms were used for treatments. Twenty five to 75 per cent of the pseudostem was excised off at the time of exposure.

T_1 - One month old whole corm

T_2 - One month old corm with 75 per cent pseudostem

T_3 - Two months old whole corm

T_4 - Two months old corm with 75 per cent pseudostem

T_5 - Two months old corm with 50 per cent pseudostem

T_6 - Three months old corm with 75 per cent pseudostem

T_7 - Three months old corm with 50 per cent pseudostem

T_8 - Three months old corm with 25 per cent pseudostem

Gamma source

The irradiation of suckers was done using ^{60}Co gamma cell unit installed at the Radio Tracer Laboratory, Kerala Agricultural University, Vellanikkara, Thrissur. The gamma source is stationary and irradiation was done by moving down a cylindrical gasket carrying the material.

METHODS

Gamma irradiation

Ten suckers from each group of one month old and two months old full corm, one month old, two months old and three months old corm with 75 per cent pseudostem, two months old and three months old corm with 50 per cent stem and three months old corm with 25 per cent stem were exposed to 1.0, 1.5, 2.0, 2.5 and 3.0 kR at a dose rate of 0.228 MR/h. Planting was done on the day after the exposure in Split Plot Design with two replications.

Raising vM_1 generation

The irradiated corms along with their controls were planted upright in the centre of pits of size 50 cm^3 with 5 cm of pseudostem remaining above the soil at a spacing of 2M x 2M in two replications of 5 suckers each. Wood ash at the rate of 2 kg, lime at the rate of 1 kg and phorate 10 per cent G at the rate of 25 gms were applied to each pit at the time of planting. Fertilizers were applied at the rate of 190 gm N, 115 gm P_2O_5 and 300 gm K_2O per plant per year in two equal splits ie in the second and fourth months after planting. Cowdung was applied at the rate of 10 kg/pit for all treated and control plants. Irrigation was provided as and when required.

Uniform field conditions were provided for these plants till harvest. All the field experiments relating to this were conducted in the experimental area attached to the Department of Agricultural Botany, College of Agriculture, Vellayani. The experiment was conducted during 1985-'86.

Observations

The observations taken in the present study were grouped under eight major heads. All the eight observations were taken from vM_1 generation. The first observation ie direct effect of ^{60}Co gamma rays on sprouting was eliminated in vM_2 and vM_3 generations as it is not pertinent to these two later generations.

A. vM_1 generation

The direct effect of ^{60}Co gamma rays was expressed in the vM_1 generation.

1. Sprouting

   a. Days taken to start sprouting

   b. Days taken to complete sprouting

   c. Mean sprouting percentage

   d. Survival percentage

2. Growth characters (90 days after planting)

   a. Plant height

   b. Number of functional leaves per plant

   c. Girth of pseudostem

3. Growth characters at the time of harvest

   a. Plant height

   b. Number of functional leaves per plant

   c. Girth of pseudostem

4. Shooting characters

   a. Days taken to shooting

   b. Days taken from shooting to harvest

   c. Total duration

5. Bunch characters

   a. Weight of bunch

   b. Length of bunch

   c. Number of hands per bunch

6. Fruit characters

   a. Number of fingers per bunch

   b. Number of fingers per hand

   c. Length of finger

   d. Girth of finger

   e. Weight of finger

7. Fruit quality Analysis

a. Total soluble solids

b. Total sugar

c. Acidity

d. Sugar : acid ratio

8. General observations

a. Chlorophyll deficiency

b. Morphological variants

A. VM_1 generation

Observations on various growth parameters were recorded by adopting the method of Yang and Pao (1962).

1. Sprouting

a. Days taken to start sprouting

Number of days taken to start sprouting was calculated from the date of planting to the date of first emergence of sprouts on each treatment.

b. Days taken to complete sprouting

Number of days taken to complete sprouting was calculated from the date of planting to the day of emergence of the last sprout in each treatment.

c. Mean sprouting percentage

Sprout counts were taken at five day intervals from 5th day to 30th day of planting. Total sprouting percentage was estimated from the values taken on the day after which no further sprouting was observed. The number of suckers sprouted was expressed in percentage values.

d. Survival percentage

Survival percentage on 30th day of sprouting of the sprouted suckers per treatment was calculated.

2. Growth characters (90 days after planting)

a. Plant height

The height was measured from ground level to the point between the youngest and subtending leaf axils. Height was taken on the third month after planting. The average plant height for each treatment was calculated and expressed in cm.

b. Number of functional leaves per plant

Fully opened functional leaves present on the third month of planting was recorded. The leaves produced per plant were counted separately and the average values per plant per treatment were determined.

c. Girth of pseudostem

Girth of pseudostem was measured at a height of 20 cms from ground level at 90 days after planting. The average values per plant per treatment were calculated and expressed in cm.

3. Growth characters at the time of harvest

a. Plant height

The height was measured from ground level to the point between the youngest and subtending leaf axils. Height was taken at the time of harvest.

b. Number of functional leaves per plant

Fully opened functional leaves present at the time of harvest was recorded. The leaves produced per plant were counted separately and the average values per plant per treatment were determined.

c. Girth of pseudostem

Girth of pseudostem was measured at a height of 20 cms at harvest. The average values per plant per treatment were calculated and expressed in cm.

4. Shooting characters

a. Days taken to shooting

The date of shooting of each plant per treatment

was observed, based on which the number of days taken for shooting by each plant was worked out and averaged.

b. Days taken from shooting to harvest

Based on the dates of shooting and harvest, the number of days taken for bunch maturation was estimated and average values per each treatment were worked out.

c. Total duration

Based on the dates of planting and harvest, the total duration taken by each plant per each treatment was recorded and averaged.

5. Bunch characters

Bunches were harvested when fully mature as indicated by the disappearance of angles from fingers (Simmonds, 1959). The following observations were made on bunch characters.

a. Weight of bunch

Peduncles of the harvested bunches were cut, leaving 22.5 cm above the first hand and 5.0 cm below the last hand. The bunches of the plants per treatment were weighed and the weight recorded in kilogram.

b. Length of bunch

Length of bunch was measured from the point of

attachment of the first hand to that of the last hand. Average length of bunches per treatment was worked out and expressed in centimetres.

c. Number of hands per bunch

The number of hands in the bunches produced by each treatment was counted and averaged.

6. Fruit characters

a. Number of fingers per bunch

The number of fingers in the second hand of the bunches produced by each treatment was counted and averaged following (Gottreich et al., 1964).

b. Number of fingers per hand

The number of fingers in the second hand of the bunches produced per each treatment was counted and the values recorded (Gottreich et al., 1964).

c. Length of fingers

The length of the middle finger on the top row of the second hand (Gottreich et al., 1964) of the bunches produced per treatment was averaged. The length of the fruit was measured as the distance between the stalk and the apex recorded in cm.

d. Girth of finger

The girth was measured at the middle portion of the middle finger on the top row of the second hand and average value per treatment was recorded in cm.

e. Weight of the finger

The weight of the middle finger from the top row of the second hand was taken, averaged and recorded in gms.

7. Fruit quality analysis

The fruits collected from well ripe bunches were used for quality analysis. The middle fruit in the top row of the second hand was selected as the representative sample. Samples were taken from each fruit from three portions viz. top, middle and bottom. These triplicate samples were used for analysis as detailed below:

a. Total soluble solids (TSS)

Triplicate samples as mentioned above were used for the analysis of total soluble solids (TSS) which was found out using a pocket refractometer and expressed as percentage.

b. Total sugar

The total sugar of the samples were determined as per the method described by AOAC(1965).

Estimation of total sugar

Pipetted 20 ml of pulped solution and added 5 ml conc. Hydrochloric acid. It was kept for 12 hours. On next day added 1.0 N sodium hydroxide till the litmus paper turns blue. This was made upto 100 ml. Pipetted out 5 ml each of Fehling's solution A and Fehling's solution B into a 250 ml conical flask. Added 40 ml of water and 2 or 3 glass beads when the contents boiled vigorously, added made up solution from the burette till the blue colour just turned into reddish. Then added 0.5 ml of methylene blue and allowed it to boil for 1 minute. While the contents are boiling continued the addition of pulped solution drop by drop till the blue colour just disappeared and permanent brick colour persisted. Noted the volume of pulped solution ran down from the burette.

c. Acidity

Ten grams of the macerated sample were taken from 3 plants for each treatments mixed with distilled water and made upto a known volume. An aliquot of the filtered solution was titrated against 0.1 N sodium hydroxide using phenolphthalein as indicator. The acidity was expressed as percentage of citric acid (AOAC, 1965) as an average measurement for each treatment.

d. Sugar : acid ratio

This was arrived at by dividing the total sugars with titrable acidity.

8. General observations

a. Chlorophyll deficiency

The plants were examined at frequent intervals in the early morning hours to assess the chlorophyll deficient variants.

b. Morphological variants

The plants were periodically examined to isolate morphological variants.

B. VM_2 generation

Selection of materials for VM_2 generation

VM_1 plants were harvested and suckers were collected.

Five suckers per each treatment were smeared with cowdung slurry and ash. After drying them for three days, these corms were stored under shade for five days arranged horizontally on planks. These were planted as per schedule given for vM_1 generation. The crop was raised during 1986-'87 at the College of Agriculture, Vellayani. Detailed observations were taken from five plants each per treatment in vM_2 on all characters as listed above excluding the first character.

C. vM_3 generation

Selection and raising of materials for vM_3 generation

vM_2 plants were harvested and 10 suckers per each treatment were selected to raise vM_3 generation. All suckers were smeared with cowdung slurry and ash. After drying for three days, these corms were stored under shade for five days. These suckers were carried forward to raise vM_3 generation. The planting, manuring and irrigation were done as described earlier. The crop was raised during 1987-'88 at the College of Agriculture, Vellayani. Special care was taken to provide uniform field conditions for the entire crop till harvest.

Detailed observations were taken from 10 plants per each treatment as explained earlier for vM_2 generation.

II. Induced mutagenesis - *in-vitro*

MATERIALS

The materials used for the *in-vitro* culture were shoot tips of banana (var. Nendran) isolated from suckers collected from field, which were grown under uniform conditions as mentioned earlier.

METHODS

Three modifications of the MS medium were tried for the investigation. They are liquid medium of Krikorian and Cronauer (1984), semi solid media of Swamy *et al.* (1983) and Bower and Fraser (1982). Out of these the medium formulated by Krikorian and Cronauer was found to be more effective for banana.

Shoot tips were isolated from growing suckers. The outer leafsheaths were removed till the growing shoot apex measured approximately 1 cm across the base and were 2 cms height. The shoot apex was excised by making four incisions with a scalpet into the corm beneath the apex. The excised apex was sterilized using Mercuric Chloride (0.05%) and washed with sterile distilled water. The sterilized apex was transferred to culture medium using sterile forceps.

The liquid medium for the shoot apex culture contained MS salts supplemented with 5.55 micromolar (μ m)

inositol, 2.97 μ m thiamine HCl, 22.00 μ m BAP, 0.12 M sucrose and 15 per cent coconut water. The pH of the medium was adjusted to 5.80 using NaOH. The growing apex turned green within 10 days and then they were transferred to solid medium solidified with 0.7 per cent agar for shoot formation.

Single shoots formed were forced into producing many smaller shoots simply by cutting them into half longitudinally through the apex. The blackened shoot bases were trimmed off and when the new side shoots were clearly visible they were transferred to fresh medium. These cultures were maintained by transferring to fresh culture medium and separating the multiple shoots in the same way every 3-4 weeks routinely.

Gamma irradiation

Ten conical flasks containing multiple shoots were exposed to each of the 0.50, 0.75, 1.00, 1.25 and 1.50 kR treatments of ^{60}Co gamma irradiation.

Roots were routinely induced by transferring irradiated single shoots to culture medium supplemented with 0.25 per cent (w/v) charcoal along with unirradiated control. The addition of IBA enhanced rapid root formation. In the presence of charcoal white or cream coloured roots

were seen at the shoot base within 4-5 days. Single shoot-lets were transferred to pro-mix-vermiculite medium in small country pots two weeks after rooting. They were transferred to normal green house conditions on the 10th day. On the 90th day the plantlets were transplanted to the field. The plants grew vigorously.

Detailed observations were taken from five plants per each treatments for the seven characters as per schedule given for vM_2 generation in <u>in-vivo</u> induced mutagenesis.

RESULTS

RESULTS

The data collected on the various observations pertaining to in-vivo and in-vitro mutagenesis in banana variety Nendran in the three age groups in three generations were statistically analysed and their results are presented below.

I. Induced mutagenesis in-vivo

Direct effect of ^{60}Co gamma rays (as expressed in vM_1 generation)

1. Sprouting

Effect of different exposures of gamma rays on sprouting in suckers of different age groups and sizes is presented in Table 1. Significant variations among treatments and exposures were noticed for days taken to start and complete sprouting, and also in the percentage sprouting and survival.

a) Days taken to start sprouting

The number of days taken to start sprouting in control population and those exposed at 1.0 kR showed a similar range of 7.0 (T_6) to 11.0 (T_5) (Table 1a). At 1.5 and 2.0 kR the range varied from 7.5 (T_6) to 11.0 (T_1 to T_5), 8.5 (T_6) to 12.0 (T_4) whereas in 2.5 kR it

Table 1. Effect of Gamma rays on sprouting (vM_1 generation)

Size of suckers	a. Days taken to start sprouting						b. Days taken to complete sprouting						c. Mean percentage sprouting						d. Percentage survival after 1 month (seedling stage)					
	Control	Gamma ray Exposures					Control	Gamma ray Exposures					Control	Gamma ray Exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3.0 kR		1 kR	1.5 kR	2 kR	2.5 kR	3.0 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR
T_1	10.00	10.00	11.00	11.00	12.00	13.50	21.50	21.50	22.50	22.50	23.50	25.00	41.00	40.00	31.00	30.00	29.00	28.00	80.50	65.00	55.00	47.50	45.00	44.00
T_2	10.50	10.00	11.00	11.50	12.50	13.00	22.00	21.50	22.50	23.00	24.50	25.00	25.00	24.50	24.50	23.00	22.00	20.00	60.00	50.00	55.00	50.00	49.00	47.50
T_3	10.00	10.00	11.00	11.00	12.00	12.00	21.00	22.00	23.00	23.00	23.50	23.50	51.50	51.00	51.00	48.50	47.00	46.00	90.00	87.50	89.00	75.00	50.00	49.00
T_4	10.50	10.50	11.00	12.00	12.00	12.50	22.00	21.50	22.50	24.00	24.00	24.50	45.50	45.00	45.00	44.00	43.50	44.00	80.00	75.50	74.00	50.00	49.00	47.50
T_5	11.00	11.00	11.00	11.50	12.00	12.50	22.00	23.00	23.00	23.50	23.50	24.00	36.50	37.00	36.00	36.50	35.00	34.00	70.00	69.00	65.00	65.50	62.50	50.00
T_6	7.00	7.00	7.50	8.50	9.50	10.00	19.50	19.50	20.00	21.50	22.00	22.00	99.00	90.00	89.00	87.00	86.50	85.00	100.00	99.00	97.50	85.00	75.00	54.00
T_7	7.50	7.50	9.50	9.00	9.00	10.00	20.00	20.00	22.00	21.00	21.00	22.00	99.00	91.50	85.00	85.50	84.00	82.00	99.00	95.00	95.50	72.50	55.00	49.00
T_8	8.00	9.00	9.00	9.50	10.00	10.50	20.00	21.00	21.00	21.50	22.00	22.50	99.00	89.00	87.50	75.00	71.50	64.00	97.50	90.00	77.50	70.00	50.00	49.00

Analysis of variance

Source	F value	CD value
Treatments	19.07**	1.04
Exposures	12.07**	0.80
Interaction	0.26	

F value	CD value
7.62**	1.24
22.34**	0.60
0.74	

F value	CD value
606.33**	3.61
43.82**	1.88
5.55**	5.32

Analysis of variance

Source	F value	CD value
Treatments	20.41**	9.1
Exposures	42.29**	5.92
Interaction	2.33**	16.74

was from 9.0 (T_7) to 12.5 (T_2). The maximum range was noted in 3.0 kR (10.0 days in T_6 and T_7 and 13.5 days in T_1). In all the suckers of different age groups and sizes the maximum delay was observed in the highest exposure. The range was from 10.0 to 13.5 for T_1, 10.5 to 13.0 for T_2, 10.0 to 12.0 for T_3, 10.5 to 12.5 for T_4, 11.0 to 12.5 for T_5, 7.0 to 10.0 for T_6, 7.5 to 10.0 for T_7, and 8.0 to 10.5 for T_8, for control and 3.0 kR respectively.

b) Days taken to complete sprouting

The total number of days taken to complete sprouting ranged from 19.5 (T_6) to 22.0 (T_2, T_4, T_5) in control population (C), 19.5 (T_6) to 23.0 (T_5) in 1.0 kR, and 20.0 (T_6) to 23.0 (T_3, T_5) in 1.5 kR gamma ray exposures (Table 1b). The range was from 21.0 (T_7) to 24.0 (T_4) in 2.0 kR and 21.0 (T_7) to 24.5 (T_2) in 2.5 kR. Maximum delay to complete sprouting (22.0 days in T_6 and T_7 and 25.0 days in T_1 and T_2) was found on 3.0 kR treatment. The suckers in control population completed sprouting relatively earlier than those under 3.0 kR gamma exposure. The suckers in control population, irrespective of their size completed sprouting within 19.5 to 22.0 days.

c) Mean sprouting percentage

The sprouting percentage ranged from 25 (T_2) to 99

(T_6, T_7, T_8) in control. Under treatments, the lowest sprouting percentage was shown by 3.0 kR treatment in T_2 (20.0) and the highest value was in T_7 (91.5) under 1.0 kR treatment (Table 1c). The lowest mean values were noted in T_2 in all the exposures. Irrespective of the sizes of suckers, the mean percentage sprouting reduced with increase in exposures.

d) Survival percentage

The lowest values were noted in T_1 in three higher exposures (47.5 to 44.0 under 2.0 to 3.0 kR) and the highest values in T_6 (Table 1d). The percentage survival in T_6 ranged from 100.0 in control to 54.0 in 3.0 kR exposure. The lowest survival percentage of 44.0 was noted in T_1 under 3.0 kR exposure.

2. Growth characters (90 days after planting)

Effect of different exposures of gamma rays on growth characters (90 days after planting) in suckers of different age groups and sizes is presented in Table 2. Significant variation among treatments, exposures and their interactions was noted with respect to girth of pseudostem. Plant height and number of leaves showed significant variation only among treatments and different exposures of gamma rays.

Table 2. Direct effect of gamma rays on growth characters (vM_1 generation)

Size of suckers	a. Plant height (90 days after planting) (cm)						b. Number of leaves (90 days after planting)						c. Girth of pseudostem (90 days after planting) (cm)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1 kR	15 kR	2.0 kR	2.5 kR	3.0 kR		1 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR
T_1	137.50	136.50	136.50	135.00	134.50	130.00	6.00	5.50	5.50	5.00	5.00	4.50	19.25	19.20	17.75	17.74	18.55	18.18
T_2	139.00	139.00	137.50	137.00	135.00	134.50	5.50	5.00	5.00	4.50	3.50	4.50	18.25	18.20	16.80	16.90	17.75	17.10
T_3	137.50	136.50	136.50	135.00	134.50	130.00	8.50	8.00	8.00	7.50	7.00	7.00	20.98	20.94	21.36	21.40	21.00	20.75
T_4	140.00	138.00	137.50	137.50	137.00	137.00	7.50	7.50	7.50	7.00	7.00	6.50	21.65	21.45	21.25	20.47	20.55	20.95
T_5	139.50	140.00	138.50	136.50	137.50	137.00	7.00	7.00	6.50	6.00	5.50	5.50	21.40	20.68	19.25	18.80	18.70	17.90
T_6	140.00	139.00	136.50	135.00	134.50	134.50	9.00	8.50	8.50	7.50	8.00	7.50	27.70	26.90	26.70	26.90	26.70	26.40
T_7	141.00	139.50	139.50	139.50	138.50	138.00	8.50	8.50	7.50	7.00	7.00	6.50	26.75	25.85	25.75	25.65	24.75	24.40
T_8	154.00	149.00	148.00	148.00	146.00	140.00	8.50	7.50	7.50	7.00	6.00	6.00	25.10	24.65	23.45	21.10	21.50	20.60
F value		128.23**		26.75**		1.68		11.58**		9.43**		0.27		5598.62**		220.11**		26.86**
CD value		1.18		1.14				1.21		0.59				0.15		0.14		0.39

a) Plant height (in cm)

In control population, the mean plant height ranged from 137.5 (T_1 and T_3) to 154.0 cm (T_8) (Table 2a). The range was from 136.5 to 149.0 in 1.0 kR, 136.5 to 148.0 in 1.5 kR, 135.0 to 148.0 in 2.0 kR, 134.5 to 146.0 in 2.5 kR and 130.0 to 140.0 cm in 3.0 kR. In all the suckers of different age groups and sizes, the maximum mean plant height was recorded by the control and the minimum by 3.0 kR exposed populations. Among the treatments the lowest height of 130.0 cm recorded by T_1 and T_3 under 3.0 kR and the highest value of 149.0 cm was shown by T_8 in 1.0 kR.

b) Number of functional leaves per plant

The mean number of functional leaves per plant ranged from 5.5 (T_2) to 9.0 (T_6) in control population, 5.0 to 8.5 in 1.0 kR, 5.0 to 8.5 in 1.5 kR, 4.5 to 7.5 in 2.0 kR, 3.5 to 8.0 in 2.5 kR and 4.5 to 7.5 in 3.0 kR respectively (Table 2b). In all the different age groups and sizes of suckers the mean leaf number was the highest in control population and the lowest in 3.0 kR. The mean number of leaves per plant in T_1 to T_8 ranged from 4.5 to 6.0, 3.5 to 5.5, 7.0 to 8.5, 6.5 to 7.5, 5.5 to 7.0, 7.5 to 9.0, 6.5 to 8.5 and 6.0 to 8.5 from treatments to control.

c) Girth of pseudostem (in cm)

The mean girth of pseudostem ranged from 19.25 (T_1) to 27.70 (T_6) in control, 18.20 (T_2) to 26.90 (T_6) in 1.0 kR, 16.80 (T_2) to 26.70 (T_6) in 1.5 kR, 16.90 (T_2) to 26.90 (T_6) in 2.0 kR, 17.75 (T_2) to 26.70 (T_6) in 2.5 kR, 17.10 (T_2) to 26.40 cm (T_6) in 3.0 kR (Table 2c). The control population of T_6 recorded the highest girth of pseudostem (27.70 cm). Under treatments, the highest pseudostem girth (26.9 cm) was seen in 1.0 kR of T_6 while the lowest (17.10 cm) was recorded in T_2 under 3.0 kR exposure.

3. Growth characters at the time of harvest

Effect of various exposures of gamma rays on growth characters at the time of harvest in different age groups and sizes of suckers is presented in Table 3. Treatments and exposures differe significantly with respect to number of leaves and girth of pseudostem. In plant height, gamma ray exposures and the interaction between treatments and exposures showed significant variation.

a) Plant height (in cm)

In control population, the mean plant height ranged from 299.55 (T_8) to 306.00 (T_3) and in 1.0 kR gamma ray exposures, it was from 299.35 (T_8) to 306.30 cm (T_3)

Table 3. Direct effect of gamma rays on growth characters at the time of harvest (vM_1 generation)

Size of suckers	a. Plant height (cm)						b. Number of leaves						c. Girth of pseudostem (cm)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR
T_1	305.40	300.50	300.60	302.80	300.05	293.95	11.00	10.50	10.00	10.00	10.00	9.50	45.00	44.95	43.050	43.10	42.15	41.55
T_2	303.65	299.80	299.70	300.50	299.10	292.95	10.50	10.00	9.50	7.00	6.00	6.00	43.00	42.90	41.60	41.50	41.05	40.25
T_3	306.00	306.30	300.10	299.10	299.40	297.20	13.50	13.00	13.00	12.50	12.00	12.00	48.00	46.55	46.25	46.05	45.90	45.05
T_4	300.40	302.60	298.45	298.25	298.20	296.65	12.50	12.50	12.50	12.00	12.00	11.00	47.00	46.90	46.55	45.40	44.25	43.75
T_5	301.75	299.55	299.45	298.75	298.65	297.90	11.50	11.50	11.00	10.50	10.00	10.00	45.45	44.05	44.00	43.75	43.45	42.45
T_6	304.95	304.80	300.20	300.15	296.65	296.55	14.00	13.50	13.50	12.50	12.50	12.00	55.40	54.25	52.55	50.65	49.45	49.45
T_7	303.85	303.30	299.30	299.50	297.85	296.15	13.50	13.00	12.00	11.50	11.5	11.00	52.55	51.20	49.25	48.30	47.55	48.25
T_8	299.55	299.35	299.60	296.60	294.75	294.65	13.00	12.00	12.00	11.50	10.50	10.00	50.50	48.80	47.15	46.40	46.00	45.30

Analysis of variance

Source	F value	CD value	F value	CD value	F value	CD value
Treatments	0.65		35.41**	0.89	35.79**	1.88
Exposures	183.68**	0.56	8.55**	0.87	7.76**	1.53
Interaction	8.59**	1.60	0.46		0.22	

(Table 3a). In the rest of the treatments the values ranged from 299.30 (T_7) to 300.60 (T_1) in 1.5 kR, 296.60 (T_8) to 302.80 (T_1) in 2.0 kR, 294.75 (T_8) to 300.05 (T_1) in 2.5 kR and 292.95 (T_2) to 297.90 cm (T_5) in 3.0 kR. The highest exposure (3.0 kR) recorded the lowest range. A decrease in mean plant height was noticed with increasing doses of gamma ray exposures in all the different age groups and sizes of suckers, except in T_3 and T_4. Here 1.0 kR was found more effective than control.

b) Number of functional leaves per plant

Number of functional leaves per plant in control population ranged from 10.5 in T_2 to 14.0 in T_6 while in treatments the range was from 10.0 to 13.5 in 1.0 kR, 9.5 to 13.5 in 1.5 kR, 7.0 to 12.5 in 2.0 kR, 6.0 to 12.5 in 2.5 kR and 6.0 to 12.0 in 3.0 kR (Table 3b). The maximum number of leaves per plant was recorded by control and the minimum by 3.0 kR in almost all the sizes of suckers. The leaf number per plant decreased progressively from control to treatment upto 3.0 kR with the range of decrease from 11.0 to 9.5 in T_1, 10.5 to 6.0 in T_2, 13.5 to 12.0 in T_3, 12.5 to 11.0 in T_4, 11.5 to 10.0 in T_5, 14.0 to 12.0 in T_6, 13.5 to 11.0 in T_7 and 13.0 to 10.0 in T_8.

c) Girth of pseudostem (in cm)

The mean girth of pseudostem in control population

ranged from 43.00 in T_2 to 55.40 cm in T_6 (Table 3c). The range in mean value based on different sizes of suckers were 42.90 to 54.25 in 1.0 kR, 41.60 to 52.55 in 1.5 kR, 41.50 to 50.65 in 2.0 kR, 41.05 to 49.45 in 2.5 kR and 40.25 to 49.45 in 3.0 kR. Except in T_7 in all other treatments control population recorded the maximum value.

4. Shooting characters

Effect of various exposures of gamma rays on shooting characters in suckers of different ages and sizes is presented in Table 4. Statistical analysis of the data showed significant variation among treatments, gamma ray exposures and their interactions except in the case of days taken to shooting.

a) Days taken to shooting

The days taken to shooting in T_1 to T_8 control population ranged from 223.00 to 201.85 (Table 4a). The range in mean days taken to shooting due to the effect of different exposure of gamma rays were 201.85 to 224.05 in 1.0 kR, 202.30 to 224.45 in 1.5 kR, 203.05 to 225.50 in 2.0 kR, 202.55 to 225.95 in 2.5 kR and 203.25 to 226.90 in 3.0 kR. The flowering duration increased with increase in gamma ray exposures. In T_1 to T_8 except in T_3 and T_4, control took the lowest number of days of 223.00, 218.60, 208.55, 206.15, 203.00 and 201.85 days for shooting while

Table 4. Direct effect of gamma rays on shooting characters (vM_1 generation)

Size of suckers	a. Days taken to shooting						b. Days taken from shooting to harvest						c. Total duration (in days)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1	223.00	224.05	224.45	225.50	225.95	226.90	97.60	97.70	97.70	98.10	98.35	98.10	320.60	321.75	322.15	323.60	324.30	325.50
T_2	218.60	220.05	220.65	222.20	223.25	225.45	98.05	98.25	98.35	98.45	99.50	98.70	316.65	318.30	319.00	320.65	322.75	324.15
T_3	215.95	216.00	216.50	215.65	215.30	213.75	94.05	94.25	94.95	96.55	97.85	97.35	310.05	310.25	311.45	312.20	313.15	315.15
T_4	216.75	216.10	215.90	216.90	217.55	217.45	95.00	96.55	97.35	97.80	99.10	98.40	309.60	310.05	310.40	311.55	312.85	312.85
T_5	208.55	212.70	214.45	214.30	212.25	218.60	95.45	95.85	96.45	97.00	99.00	98.50	304.00	308.55	310.40	311.30	311.25	312.10
T_6	206.15	207.00	207.80	207.85	207.95	208.50	88.80	89.15	89.30	89.40	89.00	89.50	295.65	296.15	297.10	297.25	297.85	297.95
T_7	203.00	206.00	203.10	204.45	205.05	206.10	89.60	90.15	90.20	90.20	90.60	90.45	292.60	293.10	293.25	294.65	295.65	296.55
T_8	201.85	201.85	202.30	203.05	202.55	203.25	91.15	91.30	91.40	91.60	92.70	92.25	293.00	293.15	293.70	294.65	295.25	295.50

Analysis of variance

Source	F value	CD value
Treatments	55.69**	3.59
Exposures	9.31**	0.86
Interaction	2.03	

Source	F value	CD value
Treatments	3719.80**	0.20
Exposures	116.49**	0.21
Interaction	8.38**	0.60

Source	F value	CD value
Treatments	2165.20**	0.82
Exposures	243.00**	0.32
Interaction	8.57**	0.90

3.0 kR took the maximum number of days of 226.90, 225.45, 218.60, 208.50, 206.10 and 203.25 respectively for shooting. In T_3, 1.5 kR took the maximum days (216.50) and 3.0 kR the minimum 213.75 but the values were not significantly different. Similarly in T_4 2.5 kR took the maximum days 217.55 while 1.5 kR the minimum (215.90).

b) Days taken from shooting to harvest

The days taken from shooting to harvest ranged from 88.80 to 98.05 in control, 89.15 to 98.25 in 1.0 kR, 89.30 to 98.35 in 1.5 kR, 89.40 to 98.45 in 2.0 kR, 89.00 to 99.50 in 2.5 kR and 89.5 to 98.70in 3.0 kR in T_6 and T_2 respectively ie. in all the exposures (Table 4b). T_6 showed the minimum value and the maximum was recorded in T_2. Maximum number of days for maturity of bunch was taken by 2.5 kR and the minimum by control population.

c) Total duration (in days)

The total crop duration was maximum in T_1 and minimum(T_7 and T_8). The values ranged from 320.60 to 292.60 in control, 321.75 to 293.10 in 1.0 kR, 322.15 to 293.25 in 1.5 kR, 323.60 to 294.65 in 2.0 kR, 324.30 to 295.25 in 2.5 kR and 325.50 to 295.50 days in 3.0 kR (Table 4c). As the dose of gamma rays increased total duration also increased. From T_1 to T_8, the total crop

duration in control was the lowest and it was the highest in 3.0 kR.

5. Bunch characters

Effect of different exposures of gamma rays on bunch characters in different age groups and sizes of suckers is presented in Table 5. Significant variation among treatments and exposures was noted with respect to weight of bunch, length of bunch and number of hands per bunch. With respect to weight and length of bunch interactions between treatments and exposures were also found to be significant.

a) Weight of bunch (in kg)

The lowest bunch weight was shown by T_2 and it ranged from 7.40 in control population to 5.01 kg in 3.0 kR. T_6 showed maximum bunch weight and it ranged from 9.45 (kg) in control population to 9.25 kg in 3.0 kR exposure (Table 5a). In T_1, T_2, T_3, T_7 and T_8 increase in the dose of gamma exposure resulted in a decrease in bunch weight; in control it was 7.42, 7.40, 8.05, 8.95 and 8.41 kg while in 3.0 kR it was 5.10, 5.01, 6.30, 6.05 and 6.65 kg. The bunch weight ranged from 6.05 (3.0 kR) to 7.97 (1.0 kR) in T_4, 6.00(3.0 kR) to 7.87 (1.0 kR) in T_5 and 9.25 (3.0 kR) to 9.55 kg (2.0 kR) in T_6.

Table 5. Direct effect of gamma rays on bunch characters

Size of suckers	a. Weight of bunch (in kg)						b. Length of bunch (in cm)						c. Number of hands/bunch					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1	7.42	7.13	6.90	6.81	5.62	5.10	29.45	28.19	26.19	26.05	24.05	21.20	4.00	4.00	4.00	3.50	3.50	3.00
T_2	7.40	7.11	6.84	6.69	5.60	5.01	29.35	28.05	26.00	23.19	23.49	21.05	4.00	3.50	3.00	3.00	3.00	3.00
T_3	8.05	7.69	7.73	6.90	6.55	6.30	31.19	30.19	30.04	29.04	26.30	21.05	4.75	4.50	4.50	4.50	4.00	4.00
T_4	7.94	7.97	7.02	7.05	6.27	6.05	20.45	29.15	27.55	27.60	26.25	26.15	4.00	4.00	4.00	4.00	3.50	3.00
T_5	7.84	7.87	6.95	6.90	6.20	6.00	27.95	26.85	26.55	24.95	23.95	21.95	3.50	3.50	3.50	3.00	3.00	2.50
T_6	9.45	9.40	9.35	9.55	9.50	9.25	35.60	35.00	34.55	33.90	33.50	31.50	5.00	4.50	4.50	4.50	4.50	4.00
T_7	8.95	8.85	8.66	8.20	7.21	6.05	34.00	33.35	33.45	33.25	32.50	32.15	4.50	4.50	4.00	4.00	4.00	3.50
T_8	8.41	7.74	7.79	7.82	6.75	6.65	32.90	32.60	32.25	31.55	31.30	30.25	4.50	4.50	4.00	4.00	3.50	3.50

Analysis of variance

Source	F value	CD value
Treatments	464.65**	0.15
Exposures	342.47**	0.11
Interaction	11.19**	0.32

Source	F value	CD value
Treatments	1280.30**	0.34
Exposures	641.72**	0.20
Interaction	87.21**	0.57

Source	F value	CD value
Treatments	8.78**	0.54
Exposures	8.66**	0.35
Interaction	0.31	

b) Length of bunch (in cm)

The length of bunch ranged from 20.45 (T_4) to 35.6 (T_6) in control population and 26.85 (T_5) to 35.00 (T_6) in 1.0 kR (Table 5b). In 1.5, 2.0 and 2.5 kR the values ranged from 26.00 to 34.55, 23.19 to 33.90, and 23.49 to 33.50 in T_2 and T_6 respectively. The bunch length ranged from 21.05 in T_2 and T_3 to 32.15 cm in T_7 under 3.0 kR exposure. In all these treatments 3.0 kR gave the lowest value while the highest was recorded in control population.

c) Number of hands per bunch

The number of hands per bunch ranged from 3.50 to 5.00 in control population, 3.50 to 4.50 in 1.0 kR, 3.00 to 4.50 in 1.5, 2.0 and 2.5 kR and 2.50 to 4.00 in 3.0 kR (Table 5c). The number of hands per bunch ranged from 3.00 (3.0 kR) to 4.00 in T_1 and T_2, 4.00 to 4.75 in T_3, 3.00 to 4.00 in T_4, 2.50 to 3.50 in T_5, 4.00 to 5.00 in T_6, 3.5 to 4.5 in T_7 and 3.50 to 4.50 in T_8.

6. Fruit characters

Effect of different exposures of gamma rays on fruit characters in different age groups and sizes of suckers is presented in Table 6. Significant variation among treatments, gamma ray exposures and their interactions were noted with respect to number of fingers and

Table 6. Direct effect of gamma rays on fruit characters (M_1 generation)

Size of suckers	a. No. of fingers/bunch						b. No. of fingers/hand						c. Length of finger (cm)						d. Girth of fruit (cm)						e. Weight of fruit (gm)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR
T_1	37.70	36.10	37.40	31.40	35.50	29.30	8.82	8.41	8.83	7.71	8.91	7.58	19.50	19.25	18.00	18.10	17.00	15.10	12.50	12.00	11.90	11.90	11.80	11.00	194.25	193.25	190.00	187.50	182.90	173.50
T_2	38.05	34.75	32.35	29.50	33.90	28.30	8.95	8.42	7.84	7.44	8.95	7.71	16.80	15.10	13.20	13.00	13.10	12.90	11.50	10.80	9.20	9.00	9.20	9.00	193.25	190.60	187.00	182.50	181.15	168.50
T_3	47.95	47.75	45.50	44.80	40.20	34.70	10.20	10.16	9.77	9.28	9.69	9.23	23.95	23.85	23.95	24.30	24.00	22.70	13.40	12.90	12.50	12.30	12.60	12.20	198.50	183.50	169.45	160.00	145.50	106.50
T_4	47.50	43.60	42.90	41.90	40.20	32.40	9.91	9.66	9.63	9.71	9.51	7.86	23.00	21.00	20.60	21.20	19.20	20.10	12.75	12.60	11.90	11.90	11.80	11.80	199.45	177.60	172.35	170.35	155.10	142.50
T_5	43.55	31.70	30.05	30.30	30.10	28.70	9.00	7.08	6.83	6.68	7.09	7.10	22.00	19.90	19.20	19.10	16.00	15.90	12.50	11.20	10.60	10.70	10.80	10.80	197.00	194.05	191.50	174.50	171.50	170.00
T_6	50.50	50.60	49.90	49.00	48.65	48.00	10.45	10.47	10.61	10.44	10.93	10.71	25.90	24.75	24.40	24.10	24.00	22.45	15.50	15.00	14.60	14.50	14.60	14.30	211.65	208.10	207.05	206.95	206.40	206.05
T_7	48.50	48.00	47.50	47.50	47.00	47.00	10.10	10.12	10.21	10.32	10.93	10.22	24.75	24.50	24.20	23.25	23.50	22.45	15.50	14.80	14.00	13.00	12.90	12.50	210.65	208.00	206.55	206.80	206.05	205.05
T_8	46.50	46.15	45.10	45.00	44.50	42.55	9.60	10.14	10.14	10.11	10.12	9.35	24.00	23.70	23.50	23.05	22.95	22.40	15.50	14.10	12.30	11.70	11.40	10.90	209.65	207.50	206.55	205.40	204.90	204.85

Analysis of variance

Source	F value	CD value	F value	CD value	F value	CD value	F value	CD value	F value	CD value
Treatments	679.30**	1.03	56.71**	0.50	274.02**	0.75	102.48**	0.51	2739.74**	1.14
Exposures	149.13**	0.67	9.10**	0.30	33.48**	0.57	21.04**	0.49	2396.99**	0.61
Interaction	14.10**	1.91	2.47**	0.86	2.00		1.30		330.60**	1.71

hands per bunch, length, girth and weight of finger, but interactions were not significant with respect to length and girth of finger.

a) Number of fingers per bunch

The number of fingers per bunch ranged from 37.70 (T_1) to 50.50 (T_6) in control, 31.70 (T_5) to 50.60 (T_6) in 1.0 kR, 30.05 (T_5) to 49.90 (T_6) in 1.5 kR, 29.50 (T_2) to 49.00 (T_6) in 2.0 kR, 30.10 (T_5) to 48.65 (T_6) in 2.5 kR and 28.30 (T_2) to 48.00 (T_6) in 3.0 kR (Table 6a). The maximum number of finger per bunch in general was found in control population and the lowest in 3.0 kR exposure.

b) Number of fingers per hand

The number of fingers per hand ranged from 8.82 (T_1) to 10.45 (T_6) in control, 7.08 to 10.47 in 1.0 kR, 6.83 to 10.61 in 1.5 kR, 6.88 to 10.44 in 2.0 kR, 7.09 to 10.93 in 2.5 kR and 7.25 to 10.71 in 3.0 kR of T_5 and T_6 respectively (Table 6b). The number of fingers per hand varied depending on the exposures and the sizes of suckers, and in majority of the cases 3.0 kR gave the lowest number of fingers per hand.

c) Length of finger (in cm)

The range in length of finger varied from 16.80 to

25.90 in control population, 15.10 to 24.75 in 1.0 kR, 13.20 to 24.40 in 1.5 kR and 13.00 to 24.10 in 2.0 kR, in T_2 and T_6 respectively (Table 6c). In 2.5 kR and 3.0 kR it ranged from 13.10 (T_2) to 24.00 (T_3) and 12.80 (T_2) to 22.70 (T_3).

d) Girth of finger (in cm)

The girth of the finger was also affected by different exposures and sizes of suckers. The values ranged from 11.5 to 15.5 in control, 10.8 to 15.0 in 1.0 kR, 9.2 to 14.8 in 1.5 kR, 9.0 to 14.5 in 2.0 kR, 9.2 to 14.6 in 2.5 kR and 9.0 to 14.3 cm in 3.0 kR in T_2 and T_6 respectively (Table 6d). The girth of finger decreased with increase in gamma ray exposures.

e) Weight of finger (in g)

In control population, the value ranged from 193.25 (T_2) to 211.65 (T_6) and 177.60 (T_4) to 208.10 g (T_6) in 1.0 kR (Table 6e). In 1.5 kR, 2.0 kR, 2.5 kR and 3.0 kR it ranged from 169.45 to 207.05, 160.00 to 206.95, 145.50 to 206.40 and 106.50 to 206.05 in T_2 and T_6 respectively. In T_1 to T_8 finger weight decreased with increase in dose of gamma ray exposures.

7. Effect of gamma rays on fruit quality

Effect of various exposures of gamma rays on fruit

quality analysis is presented in Table 7. Significant variation among treatments and exposures was noted with respect to total soluble solids (TSS), total sugar, acidity, and sugar : acid ratio. Interactions were also found to be significant with respect to TSS, acidity and sugar : acid ratio.

a) TSS (in %)

TSS in fruits ranged from 18.85 (T_2) to 25.55 (T_6 and T_7) in control, 18.75 (T_2) to 25.45 (T_6) in 1.0 kR, 18.55 (T_2) to 25.05 (T_6 and T_7) in 1.5 kR, 18.35 (T_2) to 21.50 (T_4) in 2.0 kR, 18.05 (T_2) to 21.00 (T_4) in 2.5 kR and 18.05 (T_2) to 23.05 per cent (T_3) in 3.0 kR (Table 7a). The data clearly show that the TSS in fruits varied depending on sizes of suckers and the exposures tried.

b) Total sugar (in %)

The values in total sugar ranged from 31.84 (T_1) to 34.49 (T_3) in control, 32.11 (T_1) to 34.59 (T_3) in 1.0 kR, 32.73 (T_1) to 36.10 (T_7) in 1.5 kR, 33.34 (T_2) to 37.43 (T_6) in 2.0 kR, 33.61 (T_2) to 38.02 (T_6) in 2.5 kR and 32.55 (T_8) to 39.84 per cent (T_6) in 3.0 kR (Table 7b). Total sugar was also found to increase with increase in the level of gamma ray exposures.

c) Acidity (in %)

Fruit acidity also varied depending on size of

Table 7. Direct effect of gamma rays on fruit quality (M_1 generation)

Sire of the suckers	a. Total soluble solids (%)						b. Total sugar (%)						c. Acidity (%)						d. Sugar : acid ratio					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1.0 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR
T_1	18.95	19.05	18.95	18.85	18.45	18.25	31.84	32.11	32.73	34.72	33.97	35.27	0.52	0.51	0.50	0.49	0.46	0.44	19.90	20.39	20.91	22.93	23.30	25.46
T_2	18.85	18.75	18.55	18.35	18.05	18.05	32.30	32.59	32.97	33.34	33.61	35.95	0.54	0.53	0.50	0.49	0.48	0.46	18.98	20.02	21.06	22.01	22.33	24.55
T_3	23.25	22.25	20.25	20.05	20.05	23.05	34.49	34.59	35.31	36.00	36.84	37.64	0.58	0.53	0.47	0.42	0.38	0.33	19.16	20.65	23.95	27.68	30.70	32.81
T_4	22.50	22.50	21.50	21.50	21.00	20.90	33.52	33.66	34.27	35.73	36.17	37.36	0.52	0.48	0.47	0.45	0.44	0.46	20.96	22.81	23.34	24.99	26.11	25.97
T_5	20.05	19.85	19.25	19.05	19.00	19.00	32.93	33.09	33.43	33.56	33.68	34.14	0.51	0.52	0.48	0.46	0.45	0.42	20.65	20.49	22.51	24.35	23.97	26.07
T_6	25.55	25.45	25.05	20.15	19.85	19.80	34.24	34.47	34.94	37.43	38.02	39.84	0.45	0.45	0.45	0.45	0.43	0.42	24.46	24.71	25.04	26.83	28.92	30.84
T_7	25.55	25.35	25.05	20.15	19.85	19.80	34.06	34.35	36.10	37.24	37.81	39.34	0.46	0.46	0.45	0.44	0.44	0.42	23.56	23.94	25.73	26.99	27.58	29.78
T_8	22.55	22.45	21.05	20.15	19.85	18.65	33.99	33.75	34.68	35.29	36.34	32.55	0.46	0.46	0.54	0.58	0.52	0.45	23.47	23.29	20.52	19.16	22.50	23.25

Analysis of variance

Source	F value	CD value	F value	CD value	F value	CD value	F value	CD value
Treatments	10084.67**	0.06	37.16**	0.73	155.26**	0.006	115.22**	0.65
Exposures	429.42**	0.17	17.13**	0.07	160.05**	0.006	79.69**	0.73
Interaction	61.76**	0.47	1.22		29.38**	0.01	5.86**	2.06

suckers and the gamma ray exposures tried. The values in acidity ranged from 0.45 (T_6) to 0.58 (T_3) in control, 0.45 (T_6) to 0.53 (T_2 and T_3) in 1.0 kR, 0.45 (T_6 and T_7) to 0.54 (T_8) in 1.5 kR, 0.42 (T_3) to 0.58 (T_8) in 2.0 kR, 0.38 (T_3) to 0.52 (T_8) in 2.5 kR, 0.33 (T_3) to 0.46 per cent (T_2 and T_4) in 3.0 kR (Table 7c). The higher doses of gamma exposures decreased fruit acidity. The range in value was from the highest 0.58 to the lowest 0.37 in control and 3.0 kR respectively.

d) Sugar : acid ratio

The sugar : acid ratio ranged from 18.95 (T_2) to 24.46 (T_6) in control population, 20.02 (T_2) to 24.71 (T_6) in 1.0 kR, 20.91 (T_1) to 25.73 (T_7) in 1.5 kR, 19.16 (T_8) to 27.68 (T_3) in 2.0 kR, 22.50 (T_8) to 30.70 (T_3) in 2.5 kR and 23.25 (T_8) to 32.81 (T_3) in 3.0 kR (Table 7d). Here also the values were higher in treated population compared to control.

Effect of ^{60}Co gamma rays in vM_2 and vM_3 generation

7. Growth characters (90 days after planting)

Effect of different exposures of gamma rays on growth characters (90 days after planting) in suckers of different age groups and sizes in vM_2 and vM_3 generation is presented in Table 8. Significant variation among

Table 8. Growth characters, 90 days after planting (vM_2 and vM_3 generation)

Size of suckers	a. Plant height (in cm)						b. Number of leaves						c. Girth of pseudostem (in cm)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1 vM_2	161.15	160.55	159.75	158.90	155.50	151.60	8.45	6.40	6.25	6.05	5.95	5.30	20.25	20.20	18.75	18.79	19.55	19.18
vM_3	162.45	160.85	159.90	159.80	157.55	155.50	9.70	7.05	6.75	6.50	6.40	6.40	24.55	24.40	24.35	24.00	23.45	23.25
T_2 vM_2	160.10	159.80	157.90	157.90	154.50	150.50	9.45	7.05	6.70	6.30	6.30	6.30	19.25	19.20	17.80	17.90	18.85	18.10
vM_3	160.60	160.80	160.60	158.90	155.50	151.50	8.55	6.75	6.25	6.15	6.10	5.40	23.90	23.00	23.00	22.00	21.50	20.05
T_3 vM_2	161.15	160.55	158.90	158.90	155.50	151.60	9.70	9.50	9.35	8.85	8.70	7.50	21.98	21.94	22.36	22.40	22.00	21.77
vM_3	162.30	162.30	159.70	157.70	156.35	153.35	9.85	9.60	9.45	9.00	8.95	8.75	28.00	27.55	27.50	26.50	26.40	25.10
T_4 vM_2	161.05	160.05	158.50	158.50	152.50	151.25	8.95	8.90	8.35	8.35	8.35	8.05	22.65	22.45	22.30	21.50	21.00	21.50
vM_3	161.20	160.30	160.10	159.30	159.20	153.50	9.40	9.35	8.85	8.70	8.60	8.30	25.45	24.55	24.50	24.05	23.10	23.75
T_5 vM_2	160.20	159.30	158.30	158.30	158.20	152.50	9.55	9.50	8.50	7.30	7.35	7.20	22.40	21.73	20.35	19.80	19.90	18.90
vM_3	159.10	158.80	153.80	152.80	152.95	153.50	9.75	9.45	9.50	8.80	7.50	7.45	24.30	23.45	22.55	22.40	22.05	21.00
T_6 vM_2	165.10	165.10	162.50	162.50	162.85	160.50	10.85	10.95	10.45	10.40	10.10	9.85	28.70	27.90	27.70	27.40	26.75	26.40
vM_3	166.10	166.10	163.10	163.50	163.85	161.50	10.90	10.95	10.70	10.55	10.20	9.90	33.00	33.05	32.10	32.05	31.75	31.05
T_7 vM_2	164.15	164.10	161.90	161.90	161.90	160.70	10.95	10.69	10.10	9.85	9.75	9.65	27.90	26.90	26.75	26.40	25.75	25.40
vM_3	165.15	164.60	161.50	162.90	162.90	161.70	10.80	10.70	10.15	10.00	9.85	9.65	31.55	31.60	31.05	30.25	29.90	28.50
T_8 vM_2	161.30	160.90	159.40	157.90	157.90	155.50	10.60	10.65	9.85	9.80	9.65	8.65	26.10	25.65	24.45	22.10	24.50	21.60
vM_3	162.30	161.90	161.20	160.40	160.90	156.50	10.95	10.80	10.10	10.00	9.90	9.85	29.45	28.50	28.55	27.60	27.50	27.05

Analysis of variance

Sources	a. Plant height (in cm)				b. Number of leaves				c. Girth of pseudostem (in cm)			
	F value		CD value		F value		CD value		F value		CD value	
	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3
Treatments	113.13**	42.50**	0.73	1.46	1048.40**	606.28**	0.15	0.20	4098.11**	77.98**	0.17	1.39
Exposures	352.56**	216.24**	0.43	0.46	422.11**	576.45**	0.01	7.69	210.50**	14.07**	0.16	0.72
Interaction	11.07**	9.38**	1.21	1.31	22.40**	37.56**	0.28	0.22	19.79**	0.31	0.44	

treatments, exposures and their interactions were noted with respect to plant height and number of leaves in vM_2 and vM_3 generation and girth of pseudostem in vM_2 generation.

a) Plant height (in cm)

In all the different age groups and sizes of suckers, the maximum mean plant height was recorded by the control and the minimum by 3.0 kR exposed population. In control the suckers from T_1 to T_8 recorded a mean plant height of 160.10 to 165.10 while it was 150.50 to 160.70 cm under 3.0 kR exposure (Table 8a). The mean plant height in vM_2 ranged from 160.10 (T_2) to 165.10 (T_6) in control, 159.30 (T_5) to 165.10 (T_6) in 1.0 kR, 157.90 (T_2) to 162.50 (T_6) in 1.5 kR, 157.70 (T_2) to 162.50 (T_6) in 2.0 kR, 152.50 (T_4) to 162.85 (T_6) in 2.5 kR and 150.50 (T_2) to 160.70 cm (T_7) in 3.0 kR.

The mean plant height in vM_3 ranged from 159.10 to 166.10 in control, 158.80 to 166.10 in 1.0 kR, 153.80 to 163.10 in 1.5 kR, 152.80 to 163.50 in 2.0 kR, 152.95 to 163.85 cm in 2.5 kR in T_5 and T_6 respectively. In 3.0 kR the range was from 151.50 (T_2) to 161.70 (T_7) (Table 8a). In all the different age groups and sizes of suckers, the maximum mean plant height was recorded by the control and the minimum by 3.0 kR exposed populations.

b) Number of functional leaves per plant

The gamma ray exposed materials showed a reduction in mean leaf number. The mean leaf number in vM_2 ranged from 8.45 (T_1) to 10.95 (T_7) in control, 6.40 to 10.95 in 1.0 kR, 6.25 to 10.45 in 1.5 kR, 6.05 to 10.40 in 2.0 kR, 5.95 to 10.10 in 2.5 kR and 5.30 to 9.85 in 3.0 kR in T_1 and T_6 respectively (Table 8b). From T_1 to T_8, the mean leaf number was the lowest in 3.0 kR and it ranged from 5.30 to 9.85.

The mean leaf number in vM_3 ranged from 8.55 (T_2) to 10.95 (T_8) in control, 6.75 to 10.95 in 1.0 kR, 6.25 to 10.70 in 1.5 kR, 6.15 to 10.55 in 2.0 kR, 6.10 to 10.20 in 2.5 kR and 5.40 to 9.90 in 3.0 kR in T_2 and T_6 respectively (Table 8b). As in vM_2 generation also the leaf number per plant was lowest in 3.0 kR in all treatments.

c) Girth of pseudostem (in cm)

The mean girth of vM_2 in control population, 1.0, 1.5, 2.0, 2.5 and 3.0 kR was 19.25, 19.20, 17.80, 17.90, 18.85 and 18.10 in T_2 which showed the lowest values and 28.70, 27.90, 27.70, 27.40, 26.75 and 26.40 cm in T_6 which recorded the highest girth values (Table 8c). The girth ranged from 17.80 (1.5 kR) to 28.70 (Control).

The mean girth of pseudostem in vM_3 ranged from 23.90 to 33.00 (c), 23.00 to 33.05 (1.0 kR), 23.00 to 32.10 (1.5 kR), 22.00 to 32.05 (2.0 kR), 21.50 to 31.75 (2.5 kR) and 20.05 to 31.05 cm (3.0 kR) in T_2 and T_6 respectively (Table 8c).

9. Growth characters at the time of harvest

Effect of different exposures of gamma rays on growth characters at the time of harvest in suckers of different age groups and sizes is presented in Table 9. Treatments, exposures and interactions were significant with respect to number of leaves and girth of pseudostem. Different exposures tried showed significant differences in plant height.

a) Plant height (in cm)

The mean plant height in vM_2 ranged from 300.55 to 307.00 in control and 300.35 to 306.80 cm under 1.0 kR in T_8 and T_3 respectively (Table 9a). In 1.5 and 2.0 kR the range was between 299.75 and 299.45 in T_4 and 301.45 and 303.80 in T_1. In 2.5 kR and 3.0 kR it was from 296.20 (T_8) to 301.05 (T_1) and 293.95 (T_2) to 298.90 (T_5) respectively. A decrease in mean plant height was noticed with increasing doses of gamma ray exposures in comparison with the control in suckers of different ages and sizes. In T_1 the plant

Table 9. Growth characters at the time of harvest (vM_2 and vM_3 generation)

Size of suckers	a. Plant height (in cm)						b. Number of leaves						c. Girth of pseudostem (in cm)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1 vM_2	306.40	301.40	301.45	303.80	301.05	294.50	11.95	11.60	11.60	11.60	11.60	11.60	52.85	50.85	50.70	50.30	49.10	49.70
vM_3	307.40	302.40	302.45	304.80	302.10	296.00	12.20	12.15	11.85	11.80	11.75	11.65	53.85	51.85	51.70	51.30	50.40	50.70
T_2 vM_2	306.15	300.85	300.70	301.50	300.10	293.95	11.90	11.30	11.25	11.20	11.20	11.05	51.70	49.80	49.60	48.85	49.30	49.55
vM_3	307.15	301.75	301.70	302.50	301.10	294.95	12.15	11.90	11.50	11.35	11.25	11.20	52.70	50.80	50.60	49.85	50.30	50.55
T_3 vM_2	307.00	306.80	301.10	300.10	300.40	298.20	12.65	12.65	12.60	12.45	12.40	12.40	53.60	54.15	53.90	54.55	54.15	54.05
vM_3	308.00	307.80	302.10	301.10	301.40	299.20	13.65	13.50	13.15	13.00	12.55	12.45	54.60	55.15	54.95	55.55	54.65	55.05
T_4 vM_2	301.40	303.60	299.75	299.45	299.65	298.65	12.55	12.55	12.60	12.40	11.75	11.75	53.60	53.10	52.70	52.35	51.75	51.45
vM_3	302.40	304.20	300.75	300.45	300.65	299.65	12.85	12.70	12.65	12.70	12.60	12.50	54.70	54.10	53.70	53.35	52.75	52.45
T_5 vM_2	302.75	300.80	299.95	299.95	299.65	298.90	12.90	12.30	12.30	12.10	11.90	11.90	51.65	51.30	51.10	50.85	50.10	50.00
vM_3	303.75	301.80	300.95	300.55	300.65	299.90	13.00	12.50	12.50	12.20	11.90	11.55	52.65	52.30	52.10	51.85	51.10	51.00
T_6 vM_2	305.95	305.30	301.20	301.15	298.65	297.55	13.05	13.05	13.00	12.55	12.25	12.45	61.65	61.75	60.65	60.35	59.80	59.60
vM_3	306.95	305.80	302.20	302.13	299.65	298.55	13.30	13.15	13.25	13.10	12.90	12.75	63.45	63.35	63.30	54.95	54.85	53.90
T_7 vM_2	304.85	304.45	300.30	300.55	296.95	296.20	13.03	13.13	12.15	12.40	12.30	12.15	62.45	62.35	62.30	53.95	53.85	52.90
vM_3	305.85	305.45	301.40	301.55	297.95	297.00	14.03	13.13	12.95	12.90	12.80	12.60	62.45	62.35	62.25	54.90	54.90	53.90
T_8 vM_2	300.55	300.35	300.60	297.10	296.20	295.95	11.00	10.70	10.35	10.20	8.85	8.35	61.45	61.35	61.25	53.90	53.90	52.90
vM_3	301.55	301.35	301.60	298.10	297.20	296.95	12.00	11.70	11.35	11.20	10.85	10.35	63.05	62.35	61.65	61.20	60.80	60.60

Analysis of variance

Source	a. Plant height (in cm)				b. Number of leaves				c. Girth of pseudostem (in cm)			
	F value		CD value		F value		CD value		F value		CD value	
	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3
Treatments	0.54	0.52	-	-	377.54**	527.81**	0.16	0.11	6193.57**	14361**	0.17	0.110
Exposures	169.14**	177.23*	0.60	0.58	354.60**	319.38**	0.06	5.91	1221.40**	1048.78**	0.13	0.140
Interaction	8.33**	8.79**	1.69	1.63	40.77**	12.86*	0.16	0.16	219.51**	182.21**	0.37	0.40

height decreased from 306.40 to 294.50, in T_2 306.15 to 293.95, in T_3 307.00 to 298.20, in T_4 301.40 to 298.65, in T_5 302.75 to 298.90, in T_6 305.95 to 297.55, in T_7 304.85 to 296.20 and in T_8 300.55 to 295.95 cm in control and 3.0 kR respectively.

The mean plant height at harvest in vM_3 ranged from 301.55 (T_8) to 308.00 (T_3) in control, 301.35 (T_8) to 307.80 (T_3) in 1.0 kR, 300.75 (T_4) to 302.45 (T_1) in 1.5 kR, 298.10 (T_8) to 304.80 (T_1) in 2.0 kR, 297.20 (T_8) to 302.10 (T_1) in 2.5 kR and 299.90 (T_5) to 294.95 cm (T_2) in 3.0 kR (Table 9a). The plant height decreased from 307.40 to 296.00 (T_1), 307.15 to 294.95 (T_2), 308.00 to 299.20 (T_3), 303.75 to 299.90 (T_5), 306.95 to 298.55 (T_6) and 305.85 to 297.00 cm (T_7) in control and 3.0 kR respectively. In T_4 and T_8 it decreased from 304.20 (1.0 kR) to 299.65 (3.0 kR) and 301.60 (1.5 kR) to 296.95 (3.0 kR).

b) Number of functional leaves per plant

The number of leaves in the vM_2 generation ranged from 11.00 (T_8) to 13.05 (T_6) in control population, 10.70 (T_8) to 13.13 (T_7) in 1.0 kR, 10.35 (T_8) to 13.00 (T_6) in 1.5 kR, 10.20 (T_8) to 12.55 (T_6) in 2.0 kR, 8.85 (T_8) to 12.40 (T_3) in 2.5 kR and 8.35 (T_8) to 12.45 (T_6) in 3.0 kR (Table 9b). The leaf number decreased in 3.0 kR in all the sizes of suckers tried.

The number of leaves in the vM_3 generation ranged from 12.00 (T_8) to 14.03 (T_7) in control, 11.70 (T_8) to 13.50 (T_3) in 1.0 kR, 11.35 (T_8) to 13.25 (T_6) in 1.5 kR, 11.20 (T_8) to 13.10 (T_6) in 2.0 kR, 10.85 (T_8) to 12.90 (T_6) in 2.5 kR and 10.35 (T_8) to 12.75 (T_6) in 3.0 kR (Table 9b). From T_1 to T_8 number of leaves decreased from 12.20 to 11.65, 12.15 to 11.20, 13.65 to 12.45, 12.85 to 12.50, 13.00 to 11.55, 13.30 to 12.75, 14.03 to 12.60, 12.00 to 10.35 in control and 3.0 kR respectively.

c) Girth of pseudostem (in cm)

The girth of pseudostem was determined by age and size of suckers and also by the exposures tried, as in other biometric characters.

The mean girth of pseudostem in vM_2 ranged from 51.65 (T_5) to 62.45 (T_7) in control, 49.80 (T_2) to 62.35 (T_7) in 1.0 kR, 49.60 (T_2) to 62.30 (T_7) in 1.5 kR, 48.85 (T_2) to 60.35 (T_6) in 2.0 kR, 49.10 (T_1) to 59.80 (T_6) in 2.5 kR and 49.55 (T_2) to 59.60 cm (T_6) in 3.0 kR (Table 9c).

The mean girth of pseudostem in vM_3 ranged from 52.65 (T_5) to 63.45 in control, 50.80 (T_2) to 63.35 (T_6) in 1.0 kR, 50.60 (T_2) to 63.30 (T_6) in 1.5 kR, 49.85 (T_2) to 61.20 (T_8) in 2.0 kR, 50.30 (T_2) to 60.80 (T_8) in 2.5 kR, and 50.55 (T_2) to 60.60 cm (T_8) in 3.0 kR (Table 9c).

10. Flowering characters

Effect of different exposures of gamma rays on VM_2 and VM_3 generations on flowering characters in different age groups and sizes of suckers is presented in Table 10. Treatments, exposures and their interactions were significant in days taken to shooting, days taken from shooting to harvest and total duration.

a) Days taken to shooting

The days taken to shooting in VM_2 ranged from 202.75 (T_8) to 223.55 (T_1) in control population, 202.85 to 225.05 in 1.0 kR, 202.80 to 225.50 in 1.5 kR, 204.05 to 226.60 in 2.0 kR and 203.55 to 228.00 in 2.5 kR. In 3.0 kR the range was from 204.25 (T_8) to 226.60 (T_2) (Table 10a). When the dose of the gamma exposures was increased, the flowering duration was also increased.

In VM_3 also the days taken to shooting varied depending on the exposures, age groups and sizes of suckers. It ranged from 226.05 to 204.85 in control, 227.10 to 204.85 in 1.0 kR, 227.40 to 205.30 in 1.5 kR, 228.55 to 206.05 in 2.0 kR, 229.05 to 205.55 in 2.5 kR and 230.40 to 206.25 in 3.0 kR in T_1 and T_8 respectively (Table 10a). On increasing the dose of gamma ray exposures, days taken to shooting were also increased.

Table 10. Flowering duration (vM_2 and vM_3 generation)

Size of suckers		a. Days taken to shooting						b. Days taken from shooting to harvest						c. Total duration (in days)					
		Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
			1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1	vM_2	223.55	225.05	225.50	226.60	228.00	225.45	98.60	98.70	98.70	99.10	99.35	99.10	322.15	323.75	324.30	325.70	327.35	324.55
	vM_3	226.05	227.10	227.40	228.55	229.05	230.40	99.55	99.65	99.75	100.05	100.25	100.10	325.60	326.15	327.15	328.60	329.30	330.50
T_2	vM_2	219.60	221.10	221.65	223.20	224.35	226.60	99.05	99.25	99.35	99.45	100.50	99.70	318.65	320.35	321.00	322.65	324.85	326.30
	vM_3	221.60	223.05	223.65	225.20	226.30	228.45	100.05	100.25	100.35	100.45	101.45	100.70	321.65	323.30	324.00	325.65	327.75	329.15
T_3	vM_2	217.05	217.15	217.45	216.60	216.25	218.80	95.00	95.15	96.00	97.55	98.85	98.35	312.05	312.30	313.45	314.15	314.70	317.15
	vM_3	219.05	219.35	219.45	218.65	218.30	220.80	96.00	96.15	97.00	98.55	99.85	99.35	315.05	315.25	316.45	317.20	318.15	320.15
T_4	vM_2	215.60	214.50	214.05	214.80	215.35	215.95	96.00	97.55	97.85	98.80	99.50	98.90	311.60	312.05	312.40	313.60	314.85	314.85
	vM_3	217.60	216.50	216.05	216.75	217.35	217.95	97.00	98.55	99.35	99.80	100.50	99.90	314.60	315.05	315.40	316.55	317.85	317.85
T_5	vM_2	209.70	212.70	214.05	215.30	213.25	214.60	96.45	96.85	97.45	98.00	100.00	99.50	306.15	309.55	311.50	313.30	313.25	314.60
	vM_3	211.55	215.70	216.95	217.30	215.30	217.15	97.45	97.85	98.45	99.00	100.95	99.95	309.00	313.55	315.40	316.30	316.25	317.10
T_6	vM_2	207.85	208.00	208.80	208.85	208.95	208.95	89.80	90.15	90.30	90.40	90.90	90.50	297.65	298.15	299.10	299.25	299.85	299.45
	vM_3	209.15	210.00	210.80	210.85	210.95	211.51	90.80	91.15	91.30	91.40	91.90	91.45	300.65	301.15	302.10	302.25	302.85	302.95
T_7	vM_2	203.90	204.05	204.05	205.45	206.35	207.70	90.70	91.05	91.20	91.20	91.30	90.85	294.60	295.10	295.25	296.65	297.65	298.55
	vM_3	205.90	206.05	206.05	207.45	208.35	209.70	91.70	92.05	92.20	92.20	92.30	91.85	297.60	298.10	298.25	299.65	300.65	301.55
T_8	vM_2	202.75	202.85	202.80	204.05	203.55	204.25	92.15	92.30	92.40	92.60	93.70	93.25	295.00	295.15	295.20	296.65	297.25	297.50
	vM_3	204.85	204.85	205.30	206.05	205.55	206.25	93.15	93.30	93.40	93.60	94.70	94.25	298.00	298.15	298.70	299.65	300.25	300.50

Analysis of variance

Sources	F value		CD value		F value		CD value		F value		CD value	
	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3
Treatments	666.19**	773.29**	1.03	0.97	1239.80**	2650.29**	0.35	0.24	1790.83**	1804.17**	0.89	0.89
Exposures	18.59**	68.33**	0.67	0.39	225.85**	232.33**	0.14	0.14	62.93**	216.89**	0.62	0.34
Interaction	2.75**	7.24**	1.90	1.11	18.90**	19.62**	0.41	0.39	2.82**	7.49**	1.75	0.96

b) Days taken from shooting to harvest

The days taken from shooting to harvest in vM_2 in the various treatments ranged from 99.05 to 89.80 in control, 99.25 to 90.15 in 1.0 kR, 99.35 to 90.30 in 1.5 kR, 99.45 to 90.40 in 2.0 kR, 100.50 to 90.90 in 2.5 kR and 99.70 to 90.50 in 3.0 kR in T_2 and T_6 respectively (Table 10b). Increasing the dose of gamma rays delayed the harvesting of bunch.

Days taken from shooting to harvest in vM_3 ranged from 100.05 to 90.80 in control, 100.25 to 91.15 in 1.0 kR, 100.35 to 91.30 in 1.5 kR, 100.45 to 91.40 in 2.0 kR, 101.45 to 91.90 in 2.5 kR and 100.70 to 91.45 in 3.0 kR in T_2 and T_6 respectively (Table 10b). Days taken to maturity of bunch increased from control to 2.5 kR while in 3.0 kR treatment, the values decreased slightly in all treatments.

c) Total duration (in days)

The total duration of the crop maturity ranged from 322.15 (T_1) to 294.60 (T_7) in control, 323.75 (T_1) to 295.10 (T_7) in 1.0 kR, 324.30 (T_1) to 295.20 (T_8) in 1.5 kR, 325.70 to (T_1) to 296.65 (T_7 and T_8) in 2.0 kR, 327.35 (T_1) to 297.25 (T_8) in 2.5 kR and 326.30 (T_2) to 297.50 days (T_8) in 3.0 kR (Table 10c). Gamma ray exposures

increased the total duration of crop compared to their respective controls.

The total duration in vM_3 ranged from 325.60 (T_1) to 297.60 (T_7) in control, 326.15 (T_1) to 298.10 (T_7) in 1.0 kR, 327.15 (T_1) to 298.25 (T_7) in 1.5 kR, 328.60 (T_1) to 299.65 (T_7 and T_8) in 2.0 kR, 329.30 (T_1) to 300.25 (T_8) in 2.5 kR and 330.50 (T_1) to 300.50 days (T_8) in 3.0 kR. Days taken for harvest from T_1 to T_8 ranged from 325.60 (C) to 330.50 (3.0 kR) (Table 10c). In vM_3 also a delay in total maturity was noticed under all the gamma ray exposures compared to their respective controls.

11. Bunch characters

Effect of various exposures of gamma rays on bunch characters in vM_2 and vM_3 generations in different age groups and sizes of suckers is presented in Table 11. Significant variation among treatments and exposures was noted with respect to weight and length of bunch and number of hands per bunch. Interactions were also significant with respect to bunch length.

a) Weight of bunch (in kg)

The bunch weight in vM_2 ranged from 5.85 (T_5) to 9.05 (T_6) in control, 5.80 (T_5) to 8.95 (T_6) in 1.0 kR, 5.10 (T_2) to 9.05 (T_6) in 1.5 kR, 5.15 (T_2) to 8.80 (T_6)

Table 11. Bunch Characters (vM_2 and vM_3 generation)

Size of suckers	a. Weight of Bunch (in kg)						b. Length of Bunch (in cm)						c. No. of hands/bunch					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3.0 kR		1 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR		1 kR	1.5 kR	2.0 kR	2.5 kR	3.0 kR
T_1 vM_2	6.75	6.50	7.90	6.50	6.30	5.90	30.45	29.19	27.19	27.05	25.05	22.20	4.10	4.00	4.40	3.80	3.78	3.75
vM_3	8.41	8.13	7.90	7.81	6.62	6.10	31.45	30.19	28.19	28.05	26.05	23.20	4.50	4.35	4.35	4.20	4.10	4.00
T_2 vM_2	6.50	5.90	5.10	5.15	4.90	4.85	30.35	29.05	27.00	24.79	24.47	22.05	3.90	3.90	3.75	3.65	3.65	2.63
vM_3	8.39	8.11	7.84	7.69	6.60	6.01	31.35	30.15	28.00	25.79	25.49	23.05	4.35	4.25	4.20	4.10	3.90	3.80
T_3 vM_2	7.80	7.45	6.90	6.75	6.50	6.65	32.19	31.19	31.04	30.04	27.30	22.05	4.41	4.25	4.23	4.15	4.10	4.05
vM_3	9.05	8.65	8.74	7.90	7.55	7.30	29.95	28.85	28.10	26.95	25.95	23.95	4.95	4.65	4.55	4.55	4.40	4.10
T_4 vM_2	6.75	6.50	6.35	6.30	5.75	5.10	21.45	30.15	28.55	28.60	27.25	27.15	4.15	4.18	4.15	4.05	4.00	3.93
vM_3	9.70	8.97	8.02	8.05	7.27	7.05	32.69	32.19	32.09	31.04	28.30	23.05	4.90	4.65	4.50	4.45	4.35	4.25
T_5 vM_2	5.85	5.80	5.65	5.55	5.38	5.25	28.95	27.85	27.55	25.95	24.95	22.95	4.50	4.45	3.95	3.93	3.90	3.83
vM_3	8.84	8.59	7.06	7.35	6.05	5.55	22.45	31.15	29.55	29.60	28.25	28.15	4.80	4.65	4.25	4.30	4.10	4.00
T_6 vM_2	9.05	8.95	9.05	8.80	8.05	7.65	36.60	36.00	35.55	34.90	34.50	32.50	4.99	4.75	4.65	4.60	4.45	4.40
vM_3	8.41	8.74	8.79	8.82	7.75	7.65	34.75	31.25	28.25	28.60	26.75	23.85	5.45	5.45	5.30	5.30	5.10	5.05
T_7 vM_2	8.75	8.70	8.30	8.30	8.15	7.50	35.00	34.35	34.45	34.25	33.50	33.15	4.50	4.50	4.38	4.35	4.40	4.30
vM_3	9.42	8.89	8.69	8.30	7.65	6.65	34.85	34.35	31.45	30.05	29.05	27.70	4.90	4.85	4.75	4.70	4.65	4.65
T_8 vM_2	8.10	8.50	8.40	7.50	7.35	7.30	33.90	33.60	33.25	32.55	32.30	31.25	4.30	4.10	4.10	4.00	3.90	3.90
vM_3	9.41	8.85	8.66	8.20	7.21	6.05	33.85	28.35	26.65	27.70	25.90	24.85	4.95	4.65	4.55	4.55	4.45	4.30

Analysis of variance

Sources	F value		CD value		F value		CD value		F value		CD value	
	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3	vM_2	vM_3
Treatments	35.53**	396.33**	0.68	0.07	1303.55**	683.17**	0.34	0.18	6.41**	60.81**	0.41	0.15
Exposures	12.13**	4792.31**	0.38	0.04	641.98**	2705.46**	0.20	0.14	12.22**	14.64**	0.16	0.16
Interaction	0.76	98.39**	1.06	0.11	87.24**	230.22**	0.67	0.39	1.37	0.30	0.43	0.44

in 2.0 kR, 4.90 (T_2) to 8.15 (T_7) in 2.5 kR, and 4.85 (T_2) to 7.65 kg (T_6) in 3.0 kR (Table 11a). From T_1 to T_8 increase in the dose of gamma exposures resulted in a decrease in bunch weight.

The bunch weight in vM_3 ranged from 8.39 (T_2) to 9.70 (T_4) in control, 8.11 (T_2) to 8.97 (T_4) in 1.0 kR, 7.06 (T_5) to 8.79 (T_6) in 1.5 kR, 7.35 (T_5) to 8.82 (T_6) in 2.0 kR, 6.05 (T_5) to 7.75 (T_6) in 2.5 kR and 5.55 (T_5) to 7.65 kg (T_6) in 3.0 kR (Table 11a). Here also bunch weight decreased due to the effect of different exposures of gamma rays in different sizes and age groups of suckers.

b) Length of bunch (in cm)

The bunch length in vM_2 ranged from 21.45 (T_4) to 36.60 (T_6) in control, 27.85 (T_5) to 36.00 (T_6) in 1.0 kR, 27.00 (T_2) to 35.55 (T_6) in 1.5 kR, 24.79 (T_2) to 34.90 (T_6) in 2.0 kR, 24.47 (T_2) to 34.50 (T_6) in 2.5 kR and 22.05 (T_2) to 33.15 cm (T_7) in 3.0 kR (Table 11b). From T_1 to T_8 except T_4 bunch length was decreased from control to 3.0 kR.

The bunch length in vM_3 ranged from 22.45 (T_5) to 34.85 (T_7) in control, 28.35 (T_8) to 34.35 (T_7) in 1.0 kR, 26.65 (T_8) to 32.09 (T_4) in 1.5 kR, 25.79 (T_2) to 31.04 (T_4) in 2.0 kR, 25.49 (T_2) to 29.05 (T_7) in 2.5 kR, and 23.05 (T_4)

to 28.15 (T_5) cm in 3.0 kR (Table 11b). From T_1 to T_8 except T_5, the bunch length decreased from control to 3.0 kR.

c) Number of hands per bunch

The number of hands per bunch in vM_2 ranged from 3.90 to 4.99 (control), 3.90 to 4.75 (1.0 kR), 3.75 to 4.65 (1.5 kR), 3.65 to 4.60 (2.0 kR), 3.65 to 4.45 (2.5 kR), 2.63 to 4.4 (3.0 kR) in T_2 and T_6 respectively (Table 11c). From T_1 to T_8 except T_4 number of hands decreased from control to 3.0 kR.

In vM_3 the range was from 4.35 to 5.45 (control), 4.25 to 5.45 (1.0 kR), 4.20 to 5.30 (1.5 kR), 4.10 to 5.30 (2.0 kR), 3.90 to 5.10 (2.5 kR) and 3.80 to 5.05 (3.0 kR) in T_2 and T_6 respectively.

The number of hands per bunch decreased when the dose of gamma ray exposures increased in all the different age groups and sizes of suckers.

12. Fruit characters

Effect of various exposures of gamma rays on fruit characters in different age groups and sizes of suckers is presented in Table 12. Significant variation among treatments, gamma ray exposures and interactions were noted

Table 12. Fruit characters (vt_2 and vt_3 generation)

Name of mutants	a. Number of fingers/bunch						b. Number of fingers/hand						c. Length of finger(cm)						d. Girth of finger(cm)						e. Weight of finger(g)					
	Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1 vt_2	38.70	38.70	38.40	32.40	36.50	30.30	9.76	8.92	8.63	8.09	9.30	10.83	24.90	24.35	23.10	22.67	21.85	21.85	13.90	13.85	13.80	12.80	11.10	11.05	196.00	195.15	187.70	183.40		43
vt_3	40.00	37.05	38.85	32.40	36.50	30.40	8.10	7.36	7.21	7.44	9.01	7.55	26.90	26.85	24.05	23.10	23.10	22.65	15.25	15.45	14.90	13.80	12.10	12.05	210.00	196.55	188.35	183.50		175
T_2 vt_2	35.70	35.75	33.55	30.50	34.90	29.30	9.20	9.02	8.68	8.27	9.41	7.82	24.75	24.75	23.05	21.95	21.85	20.85	13.75	13.25	13.15	12.65	11.95	9.63	194.50	193.95	186.70	181.95	179.25	138.50
vt_3	38.90	38.70	34.60	30.50	35.15	29.50	8.00	7.64	7.36	6.48	7.39	6.33	25.75	25.75	24.05	22.95	22.85	21.80	15.30	15.25	14.65	13.65	12.95	10.83	205.45	193.50	187.15	182.50	180.15	133.10
T_3 vt_2	50.95	48.75	46.50	45.30	42.70	37.70	11.46	10.47	10.34	10.34	10.05	9.25	24.75	24.25	24.10	23.30	20.41	20.20	14.05	13.92	13.12	12.65	12.65	11.45	199.50	194.00	169.85	160.75	161.95	104.50
vt_3	48.80	46.55	44.00	42.90	41.25	34.10	9.93	9.19	9.09	9.03	8.54	7.25	25.75	25.25	25.10	24.30	21.41	23.10	14.95	14.80	14.65	13.55	13.45	13.40	200.50	198.15	187.70	169.90	161.40	140.15
T_4 vt_2	43.30	44.00	43.90	42.90	41.20	33.60	10.83	10.85	11.24	8.40	8.60	7.83	23.85	23.94	21.85	22.00	21.85	21.75	13.70	13.33	13.25	12.65	11.65	11.55	200.45	177.60	173.35	171.35	156.10	143.50
vt_3	50.00	48.00	37.50	36.00	32.95	31.70	10.31	10.31	8.07	8.38	7.77	7.63	24.65	24.84	22.85	23.05	22.35	22.65	14.49	13.33	13.25	12.65	12.65	12.35	207.50	178.50	174.05	173.35	158.10	143.85
T_5 vt_2	34.35	33.70	31.05	31.10	31.10	29.10	9.75	7.21	7.61	7.72	7.73	7.49	23.50	23.15	23.15	22.05	21.50	21.00	13.75	13.15	13.05	12.05	11.45	11.40	197.45	195.05	191.35	174.35	171.25	171.00
vt_3	44.85	33.20	33.05	32.30	33.00	30.20	9.09	6.84	6.60	6.88	6.83	6.79	26.50	25.45	25.15	24.05	24.75	24.65	13.65	13.13	13.12	12.65	12.45	11.95	199.50	195.15	191.65	174.50	171.85	171.30
T_6 vt_2	51.50	51.60	50.90	50.00	49.65	49.00	11.12	11.17	11.74	11.67	11.85	12.81	26.90	25.75	25.45	24.65	24.90	23.45	16.10	15.95	14.85	14.25	15.80	13.20	216.65	218.05	208.45	207.45	206.95	167.55
vt_3	40.50	40.20	43.90	41.10	38.10	32.05	8.35	8.46	9.75	9.23	9.30	8.13	27.90	26.75	26.45	24.65	25.90	23.45	16.10	15.95	15.85	15.25	16.80	14.20	234.70	219.05	181.10	206.95	218.45	167.85
T_7 vt_2	49.50	49.00	48.50	48.50	48.00	47.50	11.29	11.71	11.84	11.98	12.13	12.10	25.80	25.25	24.65	23.10	23.75	20.45	16.25	14.73	14.63	14.63	13.49	13.41	215.75	215.50	213.00	212.50	211.50	176.50
vt_3	40.85	39.90	39.00	38.30	37.10	36.00	8.74	8.76	8.59	8.61	7.97	7.90	26.80	26.25	25.65	24.10	24.75	23.45	17.25	15.33	15.63	15.63	14.69	14.41	233.50	215.90	189.45	205.20	214.90	165.05
T_8 vt_2	47.10	47.15	46.10	46.00	45.00	42.55	10.34	10.35	10.31	10.34	10.13	9.95	25.85	24.05	24.20	24.15	23.70	23.50	16.20	14.10	14.40	14.70	13.35	11.41	210.50	206.95	192.80	187.70	181.85	159.95
vt_3	40.05	38.75	38.25	37.50	36.00	35.40	8.71	8.42	8.22	8.07	7.23	8.44	26.05	25.05	26.20	26.15	25.20	24.50	17.10	15.10	15.40	15.70	14.35	12.30	214.95	207.40	192.85	187.70	181.85	159.95

Source	a. F value		a. CD value		b. F value		b. CD value		c. F value		c. CD value		d. F value		d. CD value		e. F value		e. CD value	
	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3	vt_2	vt_3
Treatments	665.11**	571.21**	0.87	0.41	21.98**	87.81**	0.97	0.25	46.69**	172.14**	0.39	0.21	129.40**	94.45**	0.29	0.37	213.09**	1433.44**	0.96	1.10
Exposures	169.90**	1279.54**	0.67	0.29	6.20**	76.28**	0.38	0.15	273.59**	849.09**	0.23	0.13	284.74**	264.95**	0.17	0.18	16129.11**	8304.71**	0.46	0.68
Interaction	12.11**	106.91**	1.91	0.82	5.21**	20.11**	1.08	0.43	10.31**	45.41**	0.65	0.37	12.20**	16.69**	0.19	0.50	496.03**	247.81**	1.30	1.86

with respect to number of fingers per bunch, number of fingers per hand, length, girth and weight of finger.

a) Number of fingers per bunch

The number of fingers per bunch in vM_2 ranged from 38.90 (T_2) to 51.50 (T_6) in control, 32.70 (T_5) to 51.60 (T_6) in 1.0 kR, 31.05 (T_5) to 50.90 (T_6) in 1.5 kR, 30.50 (T_2) to 50.00 (T_6) in 2.0 kR, 31.10 (T_5) to 49.65 (T_6) in 2.5 kR and 29.30 (T_2) to 49.00 (T_6) in 3.0 kR (Table 12a). The number of fingers per bunch recorded by T_1 to T_8 in control population was highest compared to the irradiated populations.

Number of fingers per bunch in vM_3 ranged from 38.90 (T_2) to 50.00 (T_4) in control, 33.20 (T_5) to 49.00 (T_4) in 1.0 kR, 32.05 (T_5) to 44.00 (T_3) in 1.5 kR, 30.50 (T_2) to 42.90 (T_3) in 2.0 kR, 32.00 (T_5) to 41.25 (T_3) in 2.5 kR and 29.50 (T_2) to 36.00 (T_1) in 3.0 kR (Table 12a). The number of fingers per bunch recorded by T_1 to T_8 in control population was the highest compared to the different gamma ray treated populations.

b) Number of fingers per hand

The number of fingers per hand ranged from 9.20 (T_2) to 11.46 (T_3) in control, 7.21 (T_5) to 11.71 (T_7) in 1.0 kR,

7.61 (T_5) to 11.84 (T_7) in 1.5 kR, 7.72 (T_5) to 11.98 (T_7) in 2.0 kR, 7.73 (T_5) to 12.13 (T_7) in 2.5 kR and 7.43 (T_4) to 12.41 (T_6) in 3.0 kR (Table 12b). From T_1 to T_8 the range was from 7.21 (1.0 kR) to 12.41 (3.0 kR).

The number of fingers per hand in vM_3 ranged from 8.00 (T_2) to 10.31 (T_4) in control, 6.84 (T_5) to 10.31 (T_4) in 1.0 kR, 6.60 (T_5) to 9.75 (T_6) in 1.5 kR, 6.48 (T_2) to 9.23 (T_6) in 2.0 kR, 6.83 (T_5) to 9.30 (T_6) in 2.5 kR and 6.33 (T_2) to 8.44 (T_8) in 3.0 kR (Table 12b).

c) Length of finger (in cm)

Finger length in vM_2 ranged from 23.55 (T_5) to 26.90 (T_6) in control, 23.45 (T_5) to 25.75 (T_6) in 1.0 kR, 21.85 (T_4) to 25.45 (T_6) in 1.5 kR, 21.95 (T_2) to 24.15 (T_8) in 2.0 kR, 20.41 (T_3) to 24.90 (T_6) in 2.5 kR and 20.85 (T_2) to 22.50 cm (T_8) in 3.0 kR (Table 12c). The value ranged from 20.41 (2.5 kR) to 26.90 (control).

Finger length in vM_3 ranged from 24.85 (T_4) to 27.90 (T_6) in control, 24.94 (T_4) to 26.85 (T_1) in 1.0 kR, 22.85 (T_4) to 26.45 (T_6) in 1.5 kR, 22.95 (T_2) to 26.15 (T_8) in 2.0 kR, 21.41 (T_3) to 25.90 (T_6) in 2.5 kR, 21.45 (T_7) to 24.50 cm (T_8) in 3.0 kR (Table 12c). Irrespective of the sizes and ages of suckers, all the higher doses of

gamma rays reduced the finger length in vM_3 generation.

d) Girth of finger (in cm)

The finger girth in vM_2 ranged from 13.35 (T_5) to 16.25 (T_7) in control, 13.15 (T_5) to 15.95 (T_6) in 1.0 kR, 13.05 (T_5) to 14.85 (T_6) in 1.5 kR, 12.05 (T_5) to 14.79 (T_8) in 2.0 kR, 11.10 (T_1) to 15.80 (T_6) in 2.5 kR, 9.83 (T_2) to 13.41 cm (T_7) in 3.0 kR (Table 12d). Increasing the dose of gamma ray exposures, finger girth was decreased from T_1 to T_8 except in T_6.

Girth in vM_3 ranged from 13.55 (T_5) to 17.25 (T_7) in control, 13.13 (T_5) to 16.95 (T_6) in 1.0 kR, 13.12 (T_5) to 15.85 (T_6) in 1.5 kR, 12.65 (T_4 and T_5) to 15.79 (T_8) in 2.0 kR, 12.10 (T_1) to 16.80 (T_6) in 2.5 kR and 10.83 (T_2) to 14.41 cm (T_7) in 3.0 kR (Table 12d). The girth was found to decrease in vM_1 generation also, with increasing gamma ray exposures.

e) Weight of finger (in g)

The finger weight ranged from 194.50 (T_2) to 218.65 (T_6) in control, 177.60 (T_4) to 218.05 (T_6) in 1.0 kR, 169.85 (T_3) to 213.00 (T_7) in 1.5 kR, 160.75 (T_3) to 212.50 (T_7) in 2.0 kR, 145.95 (T_3) to 211.50 (T_7) in 2.5 kR and 104.50 (T_3) to 176.50 g (T_7) in 3.0 kR (Table 12e). Finger weight decreased when gamma ray exposure increased. It

ranged from 104.50 (3.0 kR) to 218.65 (control).

The finger weight in vM_3 ranged from 199.50 (T_5) to 234.70 (T_6) in control. 178.50 (T_4) to 219.05 (T_6) in 1.0 kR. 174.05 (T_4) to 192.85 (T_8) in 1.5 kR. 169.90 (T_3) to 206.95 (T_6) in 2.0 kR. 158.10 (T_4) to 218.45 (T_6) in 2.5 kR. 126.75 (T_1) to 171.30 g (T_5) in 3.0 kR (Table 12e). In vM_3 also finger weight decreased when dose of gamma exposure increased.

13. Fruit quality analysis

Effect of various exposures of gamma rays on fruit quality in different age groups and sizes of suckers is presented in Table 13. Significant variation among treatments and exposures were noted with respect to sugar acid ratio. Treatments, exposures and their interactions were significant in TSS, Total sugar, acidity and sugar:acid ratio.

a) Total soluble solids (in per cent)

The total soluble solids in vM_2 ranged from 20.01 (T_2) to 26.70 (T_7) in control. 20.02 (T_2) to 26.45 (T_6) in 1.0 kR. 19.01 (T_2) to 26.05 (T_6 and T_7) in 1.5 kR. 18.50 (T_5) to 21.15 (T_6 and T_8) in 2.0 kR. 18.95 (T_4) to 20.85 (T_6, T_7 and T_8) in 2.5 kR and 17.45 (T_4) to 20.80 per cent (T_6 and T_7) in 3.0 kR (Table 13a). In general

Table 13. Fruit Quality Analysis (VM_2 and VM_3 generation)

Size of suckers		a. T.S.S.(%)						b. Total sugar (%)						c. Acidity (%)						d. Sugar acid ratio					
		Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures					Control	Gamma ray exposures				
			1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR		1 kR	1.5 kR	2 kR	2.5 kR	3 kR
T_1	VM_2	20.05	20.15	20.00	20.10	20.40	20.20	32.04	32.31	32.93	34.78	34.17	35.42	0.51	0.47	0.47	0.45	0.44	0.41	20.67	21.89	22.31	24.48	25.00	31.54
	VM_3	21.80	21.80	20.50	20.90	21.30	21.20	32.24	32.51	33.13	35.13	34.37	35.62	0.49	0.48	0.48	0.46	0.44	0.41	20.20	21.92	23.48	24.68	25.05	27.56
T_2	VM_2	20.01	20.02	19.01	19.10	20.06	19.15	32.50	32.78	33.17	33.84	33.81	36.15	0.52	0.49	0.47	0.45	0.45	0.44	20.63	22.38	22.78	23.84	24.82	26.77
	VM_3	21.01	21.02	20.01	20.10	21.06	20.15	32.70	33.01	33.36	33.74	34.01	35.05	0.51	0.47	0.47	0.45	0.44	0.41	20.20	21.45	22.64	23.70	24.06	26.47
T_3	VM_2	21.05	20.85	20.55	20.15	20.20	20.05	34.69	34.28	35.52	36.17	37.54	37.84	0.48	0.49	0.44	0.43	0.49	0.39	23.49	21.51	27.79	28.47	31.20	34.27
	VM_3	22.05	21.85	21.55	21.15	21.20	21.35	34.88	34.93	35.71	36.40	37.74	39.04	0.48	0.48	0.41	0.39	0.38	0.36	23.60	22.63	25.64	27.11	28.66	31.27
T_4	VM_2	21.35	20.45	20.40	19.05	18.95	17.45	33.73	34.06	33.97	35.93	36.37	37.36	0.48	0.44	0.44	0.43	0.41	0.43	22.70	26.67	27.02	29.38	30.86	30.67
	VM_3	21.85	20.85	20.25	20.20	21.20	20.35	33.93	34.27	34.17	36.13	36.57	37.75	0.48	0.41	0.39	0.38	0.38	0.41	22.33	24.60	24.89	27.02	28.31	28.06
T_5	VM_2	21.15	20.65	20.05	18.50	19.25	18.85	33.14	33.29	33.65	33.75	33.82	34.04	0.54	0.51	0.44	0.38	0.35	0.33	20.22	22.71	26.55	30.97	34.48	35.00
	VM_3	21.20	20.80	20.10	19.10	18.45	18.85	33.34	33.50	33.84	34.07	33.97	34.46	0.51	0.48	0.41	0.36	0.31	0.31	19.49	21.14	24.47	28.12	30.75	32.80
T_6	VM_2	26.65	26.45	26.05	21.15	20.65	20.80	34.45	34.68	35.13	38.13	39.22	40.04	0.42	0.42	0.42	0.39	0.39	0.38	28.88	29.19	29.56	33.25	34.62	36.67
	VM_3	27.75	27.45	27.05	21.65	21.85	21.80	34.66	34.88	35.32	37.83	38.42	40.24	0.38	0.38	0.38	0.35	0.35	0.35	26.50	26.78	27.12	30.79	31.47	33.36
T_7	VM_2	26.70	26.40	26.05	20.65	20.85	20.80	34.25	34.54	36.30	37.44	38.01	39.53	0.43	0.44	0.44	0.41	0.41	0.39	27.79	27.14	29.08	31.93	32.52	35.64
	VM_3	25.50	24.50	23.50	22.05	22.20	21.85	34.46	34.75	36.50	37.64	38.21	39.74	0.39	0.39	0.39	0.38	0.37	0.34	30.47	25.88	26.79	29.25	29.81	32.41
T_8	VM_2	23.50	23.50	22.05	21.15	20.85	19.65	34.14	34.60	34.88	36.03	36.53	37.74	0.44	0.44	0.51	0.54	0.49	0.42	27.52	27.93	23.54	22.71	25.97	26.62
	VM_3	24.50	24.50	23.05	22.15	21.85	20.65	34.34	34.80	35.07	36.22	36.74	37.94	0.38	0.41	0.46	0.51	0.44	0.37	25.33	25.87	21.84	21.49	24.12	29.04

Analysis of variance

Source	F value		CD value		F value		CD value		F value		CD value		F value		CD value	
	VM_2	VM_3	VM_2	VM_3	VM_2	VM_3	VM_2	VM_3	VM_2	VM_3	VM_2	VM_3	VM_2	VM_3	VM_2	VM_3
Treatments	1001.86**	923.23**	0.18	0.18	43.99**	37.85**	0.69	0.75	73.65**	60.99**	0.009	0.01	51.42**	40.81**	1.39	1.20
Exposures	1113.50**	694.89**	0.11	0.11	121.89**	87.21**	0.37	0.48	159.57**	514.21**	0.006	0.003	61.37**	78.78**	1.11	0.84
Interaction	131.58**	89.78**	0.31	0.32	3.47**	1.93*	1.05	1.37	30.96**	85.45**	0.01	0.01	4.25**	4.75**	3.14	2.39

the values in TSS decrease with increase in dose of gamma rays.

Total soluble solids in vM_3 ranged from 21.01 (T_2) to 27.75 (T_6) in control, 20.80 (T_5) to 27.45 (T_6) in 1.0 kR, 20.01 (T_2) to 27.05 (T_6) in 1.5 kR, 19.10 (T_5) to 22.15 (T_8) in 2.0 kR, 18.45 (T_5) to 22.20 (T_7) in 2.5 kR and 18.85 (T_5) to 21.85 per cent (T_7) in 3.0 kR (Table 13a). The higher exposures gave a lower value in TSS in vM_3 generation.

b) Total sugar (in per cent)

The total sugar content in fruits ranged from 32.04 (T_1) to 34.68 (T_3) in control, 32.31 (T_1) to 34.60 (T_8) in 1.0 kR, 32.93 (T_1) to 36.30 (T_7) in 1.5 kR, 33.54 (T_2) to 38.13 (T_6) in 2.0 kR, 33.81 (T_2) to 38.22 (T_6) in 2.5 kR and 34.04 (T_5) to 40.04 per cent (T_6) in 3.0 kR (Table 13b). Total sugar content increased when dose of gamma exposure increased, in all the different age groups and sizes of suckers.

Total sugar content in vM_3, also increased with increase in exposure level and it ranged from 32.70 (T_2) to 34.88 (T_3) in control, 32.51 (T_1) to 34.93 (T_3) in 1.0 kR, 33.13 (T_1) to 36.50 (T_7) in 1.5 kR, 33.74 (T_2) to 37.83 (T_6) in 2.0 kR, 33.97 (T_5) to 38.42 (T_6) in

2.5 kR and 34.46 (T_5) to 40.24 per cent (T_6) in 3.0 kR (Table 13b).

c) Acidity (in per cent)

The acidity in vM_2 generation ranged from 0.42 (T_6) to 0.54 (T_5) in control, 0.42 (T_6) to 0.51 (T_5) in 1.0 kR, 0.42 (T_6) to 0.51 (T_5) in 1.5 kR, 0.38 (T_5) to 0.54 (T_8) in 2.0 kR, 0.35 (T_5) to 0.49 (T_3 and T_8) in 2.5 kR, 0.33 (T_5) to 0.44 per cent (T_2) in 3.0 kR (Table 13c). Acidity decreased when the dose of gamma exposure increased from T_1 to T_8 except in T_8.

Acidity in vM_3 generation ranged from 0.38 (T_6 and T_8) to 0.51 (T_2 and T_5) in control, 0.38 (T_6) to 0.48 (T_1, T_3 and T_5) in 1.0 kR, 0.38 (T_6) to 0.48 (T_1) in 1.5 kR, 0.35 (T_6) to 0.51 (T_8) in 2.0 kR, 0.31 (T_5) to 0.44 (T_1, T_2 and T_8) in 2.5 kR and 0.31 (T_5) to 0.41 (T_1, T_2 and T_4) in 3.0 kR (Table 13c).

d) Sugar : acid ratio

The sugar : acid ratio in vM_2 ranged from 20.22 (T_5) to 28.88 (T_6) in control, 21.89 (T_1) to 29.19 (T_6) in 1.0 kR, 22.31 (T_1) to 29.56 (T_6) in 1.5 kR, 22.71 (T_8) to 33.25 (T_6) in 2.0 kR, 24.92 (T_2) to 34.62 (T_6) in 2.5 kR and 25.77 (T_2) to 36.57 (T_6) in 3.0 kR (Table 13d). From

T_1 to T_7 sugar acid ratio increased with increase in dose of gamma ray exposures.

In VM_3 generation, it ranged from 19.49 (T_5) to 30.47 (T_7) in control, 21.14 (T_5) to 26.78 (T_6) in 1.0 kR, 23.48 (T_1) to 27.12 (T_6) in 1.5 kR, 23.70 (T_2) to 30.79 (T_6) in 2.0 kR, 24.06 (T_2) to 31.47 (T_6) in 2.5 kR and 26.49 (T_2) to 33.36 (T_6) in 3.0 kR (Table 13d). Increasing the dose of gamma rays, sugar : acid ratio increased in all the different sizes and age groups of suckers.

II. Induced mutagenesis in-vitro

Standardisation of culture media for shoot-tip culture of banana

In the present investigation semi-solid media described by Bower and Fraser (1982) and Swamy et al. (1983), and liquid medium described by Krikorian and Cronauer (1984) were tried. Among these, liquid medium of Krikorian and Cronauer was found to be more effective. Shoot tip cultures were exposed to 0.50, 0.75, 1.00, 1.25 and 1.50 kR gamma rays. Out of this 1.0, 1.25 and 1.5 kR do not come up well on field transplantation.

14. Growth characters (90 days after planting)

The growth characters, mainly plant height, number of leaves and girth of pseudostem 90 days after planting

as influenced by shoot-tip culture of banana and different doses of gamma exposures are depicted in Table 14.

a) Plant height

The control population recorded the maximum plant height on the third month of planting and attained a height of 67.50 cm. Gamma exposures affected the height of plantlets and height was decreased as the dose level increased. When 0.50 kR gamma exposure recorded a plant height of 65.60 cm, it was 62.90 cm under 0.75 kR gamma exposure.

b) Number of functional leaves per plant

When the control population recorded 9.00 leaves per plant, 0.50 and 0.75 kR gamma exposures recorded 8.50 and 8.00 respectively.

c) Girth of pseudostem

The girth of pseudostem was 8 cm in control population while it was 9.50 cm and 10.00 cm under 0.50 and 0.75 kR respectively.

15. Growth characters at the time of harvest

The mean plant height, number of leaves and girth of pseudostem at harvest as influenced by shoot-tip culture

Table 14. Growth characters 90 days after planting

Gamma exposures / Characters	Plant height (cm)	Number of leaves	Girth of pseudostem (cm)
C	67.50	9.00	8.00
0.50	65.60	8.50	9.50
0.75	62.90	8.00	10.00

Table 15. Growth characters at the time of harvest

Gamma exposures / Characters	Plant height (cm)	Number of leaves	Girth of pseudostem (cm)
C	301.50	13.00	50.00
0.50	291.00	12.50	52.00
0.75	288.00	12.00	54.00

of banana and different levels of gamma ray exposures are depicted in Table 15.

a) Plant height

The maximum plant height at harvest recorded by control population was 301.50 cm. On increasing the dose of gamma ray exposures from 0.50 kR to 0.75 kR plant height decreased from 291.00 to 288.00 cm.

b) Number of functional leaves per plant

The control population recorded 13.00 leaves at harvest when gamma exposures of 0.50 and 0.75 kR doses were given, 12.50 and 12.00 leaves per plant appeared respectively.

c) Girth of pseudostem

The control population recorded a girth of 50 cm at harvest. Plants subjected to gamma exposure of 0.50 and 0.75 kR showed 52 and 54 cm respectively.

16. Shooting characters

Effect of various exposures of gamma rays on shooting characters mainly days taken to shooting, days taken from shooting to bunch maturity and total duration as influenced by shoot-tip cultures of banana are depicted in Table 16.

Table 16. Shooting characters

Gamma exposures	Characters	Days taken to shooting	Days taken from shooting to bunch maturity	Total duration (days)
C		356	90	445
0.50		359	92	450
0.75		358	91	447

Table 17. Bunch characters

Gamma exposures	Characters	Weight of Bunch (kg)	Length of Bunch (cm)	Number of hands/bunch
C		5.00	24.00	4.00
0.50 kR		6.00	28.00	6.00
0.75 kR		5.75	26.00	5.00

a) Days taken to shooting

The days taken to shooting by control population were 356. The gamma exposure of 0.50 and 0.75 kR showed 359 and 358 days respectively.

b) Days taken from shooting to bunch maturity

The days taken from shooting to bunch maturity recorded by the control population was 90. Gamma exposure of 0.50 and 0.75 kR took 92 and 91 days respectively.

c) Total duration

The days taken to harvest from planting recorded by the control population was 445 days while it was 450 days and 447 days under 0.50 and 0.75 kR gamma ray exposures respectively.

17. Bunch characters

Effect of various exposures of gamma rays in bunch characters mainly weight of bunch, length of bunch, number of hands per bunch as influenced by shoot-tip culture of banana is elucidated in Table 17.

a) Weight of bunch

The control population recorded a bunch weight of 5.00 kg/plant, while it was 6.00 and 5.75 kg under 0.50

and 0.75 kR exposures of gamma rays respectively. Here the control population recorded the lowest bunch weight and the highest by 0.50 kR gamma exposure.

b) Length of bunch

The control population recorded a bunch length of 24 cm while 0.50 and 0.75 kR recorded a bunch length of 28 and 26 cm respectively.

c) Number of hands per bunch

The number of hands per bunch recorded by the control population was 4 whereas 0.50 and 0.75 kR gamma exposures recorded 6 and 5 hands per bunch respectively.

18. Fruit characters

Effect of various exposures of gamma rays on fruit characters mainly number of fingers per bunch and hand, length, girth and weight of fingers as influenced by shoot-tip culture of banana are presented in Table 18.

a) Number of fingers per bunch

Here the control population recorded 35 fingers per bunch while 0.50 and 0.75 kR gamma exposures recorded 48 and 47 respectively.

Table 18. Fruit characters

Gamma exposures / Characters	Number of fingers/ bunch	Number of fingers/ hand	Length of finger (cm)	Girth of finger (cm)	Weight of finger (gm)
C	35.0	8.0	20.0	15.0	141.4
0.50	48.0	10.0	19.0	16.0	170.7
0.75	47.0	9.5	18.0	16.5	180.2

Table 19. Fruit Quality Analysis

Gamma exposures / Characters	TSS (in %)	Total sugar (in %)	Acidity (in %)	Sugar: acid ratio
0	26.00	34.50	0.51	22.00
0.50	25.00	35.10	0.50	23.00
0.75	24.00	35.30	0.49	23.50

b) Number of fingers per hand

Here the control population recorded a mean of 8.00 fingers per hand whereas 0.50 and 0.75 kR gamma exposures recorded 10.00 and 9.50 fingers respectively.

c) Length of finger

The control population recorded a mean fruit length of 20 cm while 0.50 and 0.75 kR gamma exposures recorded 19 and 18 cm respectively. The control population recorded the highest finger length.

d) Girth of finger

The control population recorded the mean finger girth of 15.00 cm when 0.50 and 0.75 kR recorded 16.00 and 16.50 cm respectively.

e) Weight of finger

The control population recorded a mean finger weight of 141.40 gms, when it was 170.70 and 180.20 gm under 0.50 and 0.75 kR gamma ray exposures respectively. Here control recorded the minimum finger weight and maximum was recorded by 0.75 kR.

19. Fruit Quality Analysis

The data on fruit quality analysis of total soluble

solids, total sugar, acidity, sugar:acid ratio are shown in Table 19.

a) TSS

The control population recorded TSS of 26 per cent and 0.50 and 0.75 kR gamma exposures recorded 25 per cent and 24 per cent respectively.

b) Total sugar

The control population recorded a value of 34.5 per cent while it was 35.1 per cent and 35.3 per cent under 0.50 and 0.75 kR respectively.

c) Acidity

The control population recorded the highest acidity of 0.51 per cent whereas it was 0.50 per cent and 0.49 per cent under 0.50 and 0.75 kR respectively.

d) Sugar:Acid ratio

The control population recorded a sugar:acid ratio of 22.00. On increasing the dose of gamma ray exposure from 0.50 kR and 0.75 kR, sugar acid ratio increased from 23.00 to 23.50.

Plate 1. Chlorophyll deficient chimera in VM_1 generation (top to bottom)

a. 1 kR

b. 3 kR

a.

b.

Plate 2. Leaf size and shape variants induced in VM_1 generation (top to bottom)

a. Variants having leaves with tapering end

b. Variant having broad & short leaves

c. Variant with narrow, darker and thicker texture

a.

b.

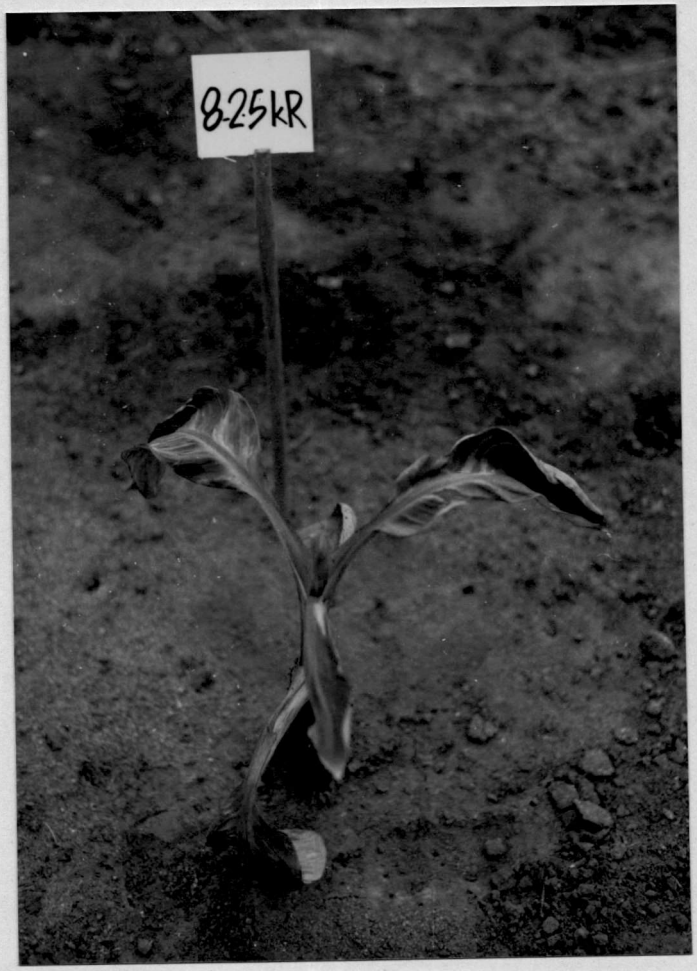
c.

Plate 3. Leaf variants induced in vM_1 generation

a. Leaves with yellow and white streaks
b. Leaves with split lamina
c. Stunted plant with crinkled leaf blades

a.

b.



c.

Plate 4. Dichotomy

a. Petiole dichotomy

b. Stem dichotomy

a.

b.

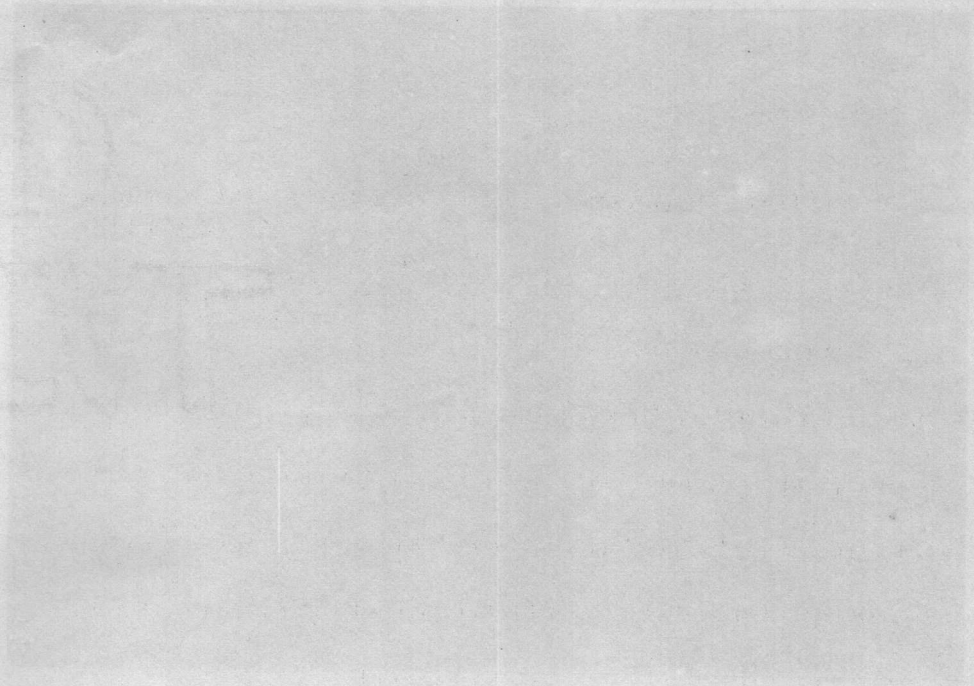


Plate 5. Morphological variants in petiole

a. Variant with twisted petiole

b. Variant having number of leaves with twisted petioles

a.

b.

Plate 6. Anthocyanin pigmentation of petiole

a. Control plant

b. Gamma ray exposed plant

a.

b.

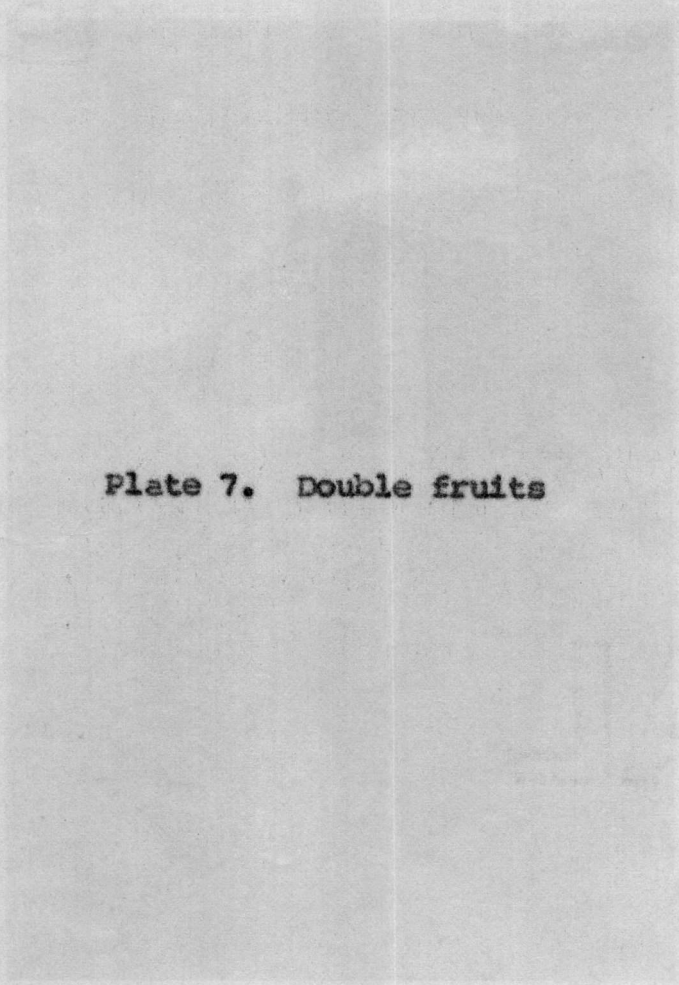


Plate 7. Double fruits

Plate 8. Early suckering

a. Control plant

b. Gamma ray exposed plant

a.

b.

Plate 9. *In-vitro* shoot tip culture

a. Shoot formation

b. Multiple shoot formation

a.

b.

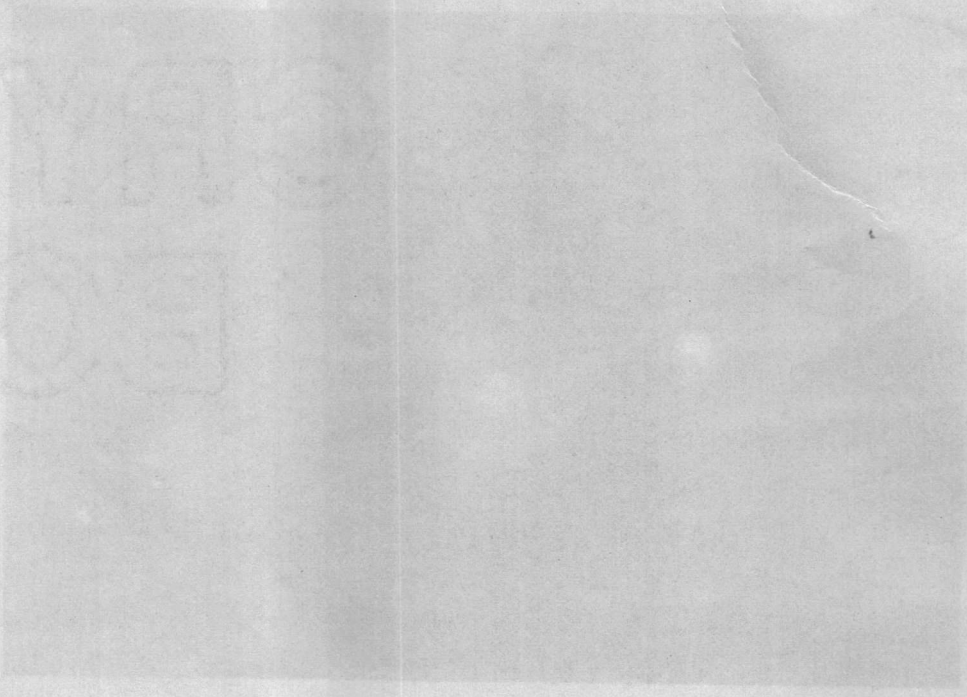


Plate 10. Induced *in-vitro* shoot tip culture

a. Root formation

b. Pot cultured plants

a.

b.

Plate 11. *Ex-vitro* plants showing

a. Field establishment

b. Stem dichotomy

a.

b.

Plate 12. *Ex-vitro* plants showing anthocyanin pigmentation

a. Control plant

b. *Ex-vitro* plant

a.

b.

DISCUSSION

DISCUSSION

The present investigation on "Induced mutations in banana variety nendran Musa paradisiaca L." was undertaken with a view to standardise the technique of mutagen treatment and to assess the extent of variability induced by gamma rays. Suckers of three age groups viz. one, two and three months old each in different sizes of pseudostem viz. 25, 50 and 75 per cent were as far as possible used as the material for irradiation. Exposures of gamma rays at 1.0, 1.5, 2.0, 2.5, 3.0 kR and control were used. The direct effect of the mutagen on growth and bunch characters in the vM_1 generation and the variations created in productive traits in the vM_2 and vM_3 generations were analysed in detail.

I. Direct effect of the mutagen

In the present investigation the different exposures of gamma rays produced a significant delay in sprouting in all the three age groups of banana suckers. The delay was found to increase with increase in levels of gamma ray exposures.

Similar results have been reported by Gregory (1955, 1968) in Pisum and Favret (1963) and Gaul (1967) in barley, Athwal (1963) in Cicer. Louis and Kadambavanasundaram

(1973a) and Shirshov and Shain (1966) in field beans, Sidorova et al. (1966), Maslov and Stepanova (1967), Narsinghani and Kumar (1976) and Bhojwani and Kaul (1976) in peas, Bajaj and Saettler (1970) in Phaseolus, Alikhan et al. (1973) in Cajanus cajan; Venkateswarlu et al. (1978) in pigeon pea, Majeid (1975) in tomato, Bohera and Patnaik (1979) in Amaranthus, Khanna and Maherchandani (1980) in gram and Nadarajan et al. (1985) in redgram.

The observed varied response on irradiation may be due to one of the following three reasons. It may be due to differences in the chromosome complements or due to the initiation of cell divisions in some of the treatments or thirdly due to greater time lapse between irradiation and planting. It has also been reported that it could be due to the destruction of auxins (Skoog, 1935). Smith and Kersten (1942), Gordon and Webber (1955) and Gordon (1957) suggested that it could be due to inhibition of auxin synthesis rather than destruction of synthesised auxins. Gross chromosomal breakage in Trifolium subterraneum subjected to X-rays and thermal neutrons were attributed to the cause of reduced germination by Brock (1965). Sinha and Godward (1972) working in Lens culinaris attributed it to physio-chemical disturbances or chromosomal aberrations.

Irrespective of the size of suckers, the mean percentage sprouting reduced with increase in gamma ray exposures. Panton and Menendez (1972) and Menendez (1973) obtained a 50 per cent sprouting in Musa acuminata by soaking seeds in EMS solution. Filippetti and Marzaro (1984) obtained mutants with gamma rays and EMS treatment in the X_1 of Vicia faba L., the percentage of emerged and surviving plants decreasing with increasing mutagen dose. Datta (1985) noted a reduction in sprouting and survival due to gamma irradiation and it increased with increase in dose in garden rose.

Post-germination mortality gives a good estimate of the direct effect of the mutagen. In the present investigation, the survival percentage in all the exposures was found to decrease with increase in the dose of gamma rays. This is in conformity with the observations of Shirshov and Shain (1966) in field bean and Teodoradze (1966) in french bean and soybean. Louis and Kadambavanasundaram (1973 b) noticed a significant reduction in the survival of cowpea with increase in dosage of gamma rays. A similar result was reported by Constantin et al. (1976) in soybean. About 50 per cent of survival reduction was observed in greengram caused by X-rays (Krishnaswami et al., 1977). Reddy et al. (1977) noted reduced survival percentage in groundnut by gamma irradiation. Constantain

and Love (1967) observed a reduction in survival in greengram with increase in dose of the same mutagen. Mujeeb and Greig (1972) in Phaseolus vulgaris observed a progressive reduction in survival with the increase in dose of gamma irradiation. The same trend was reported by Palaniswamy (1975), Alikhan et al. (1973) and Singh (1970) in rice, Gottschalk (1967), Ramulu (1974) in sorghum and Chaudhary (1978) in wheat.

The following cytological explanations are given for reduction in the survival with increased doses of irradiation. The reduction may be due to reduced cell growth resulting from cytological abnormalities or the decrease in the synthesis of auxins and other physiological changes as observed by Konzak et al. (1965). Mitotic abnormalities due to irradiation results in structural changes in the chromosomal complements which interfere with the normal growth and development of organs leading to decreased survival percentage with increasing doses. Others who have reported a mutagen dependent variation in survival are D'Amato et al. (1962) in wheat, Tomohira et al. (1964) in Capsicum and Datura and Sahib and Abraham (1970) in Capsicum.

Stotzky et al. (1964) reported a reduction in survival by gamma irradiation on seeds of wild diploid

Musa balbisiana and rhizomes of Musa sapientum cultivar Gros Michel. Dong et al. (1985) noted that in tea cultivar Fudingdabai, the survival rate was decreased by gamma irradiation.

In the present investigation a decrease in mean plant height 90 days after planting and at harvest was noticed with increasing doses of gamma ray exposures in comparison with the control. The same trend was noticed in all the different age groups and sizes of suckers in VM_1 generation.

A reduction in plant height as a result of mutagen treatment as was noted in the present investigation has been reported by several workers. Kwon and Im (1973) reported that plant height was retarded by 10 to 25 kR gamma ray treatments in soybean. Louis and Kadambavanasundaram (1973 a) reported a gradual reduction in the height of seedlings with increasing doses of gamma rays in cowpea. The same trend was reported by Constantain et al. (1976) in soybean and Khanna and Maherchandani (1980) in gram. Reduction in plant height following gamma irradiation was reported in rice (El. Aishy et al., 1976), ragi (Goud et al., 1969 and Raveendran, 1976) and wheat (Kapoor and Natarajan, 1970; Filev, 1972; Kozachenko, 1974; L'vova and Konorovkaya, 1974). Dwarfness with short stems was reported by Korah

(1959) in M_1 of rice.

In X_1 generation dwarf variants in cotton hybrids were obtained by Khan et al. (1981) by gamma irradiation. Akhund-Zade (1979) obtained dwarf mutants by gamma irradiation of cuttings, seeds and pollen of fig, pomegranate, feijoa, Pistachio and almond. In Rose variety 'Kiss of Fire' reduction in height was noted by gamma irradiation by Datta (1985).

It was noted in the present study that increasing the dose of gamma ray exposures, decreased the number of functional leaves produced per plant in comparison with control. The same trend was noticed in all age groups of suckers. This could be due to the upsetting of oxidation-reduction process cells, inactivation of vital enzymes especially those concerned with respiration and inhibition in the rate of assimilation and consequent changes in the nutrient levels of plant as reported by Ehrenberg (1955).

Periodical observations, 90 days after planting and at harvest of plant height, number of functional leaves and girth of pseudostem helped to determine the rate of growth. Increasing the dose of gamma ray exposure resulted in a significant reduction of plant height, number of functional leaves and girth of pseudostem. Increasing the dose of gamma ray exposure reduced the plant height, number

of functional leaves 90 days after planting and at harvest. The girth of pseudostem was also decreased in higher doses. This showed that rate of growth was reduced by mutagen treatment. Caldecott and Smith (1952) observed a reduction in growth of barley plants following seed irradiation with X-rays. Similar results were obtained by Konzak et al. (1961) in wheat and Woodstock and Justice (1967) in maize, wheat, sorghum and radish. Growth rate reduction could be due to auxin destruction as reported by Smith and Kersten (1942). Pele and Howard (1955) suggested that the possible interference of irradiation with synthesis of new DNA could be the cause, while Evans and Sparrow (1961) opined 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. Respiratory cycle is the main metabolic source of energy for growth. Ananthswamy et al. (1971) observed inhibition of seedling growth in gamma irradiated wheat seeds and suggested that the adverse effect of seedlings might be due to specific effects on certain respiratory system operating during crop growth. Sinha and Godward (1972) pointed out that growth inhibition at higher

doses may be due to chromosomal aberrations.

The role of DNA in reducing growth in the mutagen treated materials has been discussed by Sinha and Godward (1972). Pollard (1964) has postulated that irradiation stops DNA transcription and leads to a decrease in messenger RNA which should cause a decrease in protein synthesis and growth. Compact types in pear shoots, thicker than normal for their length or in other words, shoots with relatively short internodes but similar diameter to normal ones by mutagenic agents were reported by Devries et al., 1970. Dong et al. (1985) noted a decrease in growth rate by gamma irradiation in tea, cultivar Fudingdabai.

The flowering duration increased with increase in gamma ray exposures. Increasing the doses of gamma ray exposures of banana suckers resulted in an increase in the number of days taken to shooting, days taken from shooting to harvest and total duration increased. Plants with varying flowering habits such as early, intermediate and late flowering lines were obtained by Abrams and Fortuno (1962) in pigeon peas. Rudraswamy (1984) observed delayed flowering at higher doses of gamma rays in horse-gram. Louis and Kadambavanasundaram (1973 a) in cowpea and Khan (1984) in mungbean reported similar results.

Kerkadze and Kutateladze (1979) obtained early ripening mutants in citrus by gamma irradiation. Khaiwal et al. (1984) obtained 8 early maturing and high sugar content mutants by treating with gamma rays and EMS in sugarcane. Lapins (1975) obtained useful mutations altering the ripening time of fruit by Colichicine treatment in three diploid apricot cultivars.

In the present investigation, increasing the dose of gamma exposure resulted in decrease in bunch weight in all treatments except T_6 where 2 kR gamma exposure recorded the higheat bunch weight. A reduction in mean yield as a result of mutagen treatment has been reported by Papa et al. (1961) in soyabean, using physical mutagens. Vasudevan et al. (1969) observed increase in mean yield in barley at the highest exposure of X-rays. Matsuo and Onozawa (1961) concluded that mutations of polygenes could occur in plus as well as minus directions in the case of grain yield in rice after irradiation. Griffiths and Johnston (1962) showed that in oats seed irradiation caused mutations with regard to yield only in the minus direction. Rao and Siddiq (1977) induced variations for yield and its components in two varieties of rice and suggested that the changes in the mean value varied with the variety, character, mutagen and the generations. They opined that the

negative shift in the mean yield need not make breeders sceptical about the usefulness of mutation breeding for yield improvement. Kukimura and Kovyama (1982) obtained mutant clones in sweet potato Ipomea batatus (L) Lam with short and long stem,had decreased and increased tuber yield by treatment with gamma rays and EMS.

In the present study, increasing the dose reduced length of bunch and number of hands per bunch. A negative shift in mean panicle length following X-irradiation has been reported in rice by Sakai and Suzuki (1964). Nayar (1976) has also reported a similar reduction in mean panicle length in rice. Sakai and Suzuki (1964) reported a decrease in mean expression of polygenic characters like number of panicles after X-irradiation in rice. Tanaka (1968) found that the distribution of variants for certain quantitative characters was skewed and therefore stated that mutations for polygenes occurred mostly in a negative direction.

Number of fingers per bunch and per hand, length, girth and weight of finger decreased with increasing the dose of gamma exposure. This might be due to the delay in the initiation of flowering, inhibition of growth and reduction in fertility. Similar reports have been made by Louis and Kadambavanasundaram (1973 a) and Narsinghani and Kumar (1976) in cowpea and Swarup and Gill (1968) in

french bean. Virupakshappa et al. (1980) reported that the mean values for the number of pods per plant and seed weight in mutagen treated population were lesser than that in untreated populations.

Yashvir (1977) in Abelmoschus esculentus obtained a decrease in fruit length in M_1 by X-ray and EMS treatment. Conformation with the results obtained in the present investigation, where the finger length decreased with increasing the dose of gamma exposure.

A reduction in mean values as was noted in the present investigation, has been noted by Bhatia and Swaminathan (1962) and Borojevic and Borojevic (1969) in wheat, Brock (1967) in Arabdiopsis and Gaul (1965, 1967) in barley. In extensive studies performed by Scossiroli (1966 a, b) and Scossiroli et al. (1966) on wheat, this effect was shown in the same population for a large number of characters. Miah and Yamaguchi (1965) assumed that following gamma ray treatment in rice, mutations for most of the quantitative characters occurred symmetrically in plus as well as minus direction. Gaul (1965) found that induced micro and macro mutations in barley do not follow any particular direction and that they are at random. Aastveit (1966) also opined the same for rye following irradiation.

In the present investigation, fruit quality analysis showed that total soluble solids and acidity decreased with increase in dose of gamma ray exposures in vM_1. Total sugar content and sugar : acid ratio increased with increasing dose of gamma ray exposures. Decrease in acid content and increase in sugar : acid ratio are found to increase the quality of banana fruit. Though the size of the fruit has been decreased a significant increase in quality has resulted in the present study. This is a very useful result.

Chlorophyll deficient plants

In the present investigation, chlorophyll deficiency was noticed at lower doses in certain plants due to gamma irradiation. The different types of chlorophyll deficient plants observed include Striata and Chlorina. The striata type was found in greater frequency than the other type (Plate 1).

Chlorophyll disorganisation is one of the many effects of irradiation (Gustafsson, 1947). An increase in the frequency of chlorophyll mutation with increasing doses of radiations was reported by several investigators in rice. Matsuo et al. (1958) and Masima and Kawai (1959) reported that mutation frequency reached a maximum at

moderate doses of X-rays and gamma rays and decreased at higher doses. Louis and Kadambavanasundaram (1973 b) reported the occurrence of albino, xantha, and viridis mutants in cowpea following gamma irradiation. A wide spectrum of chlorophyll mutations in Lathyrus sativus was obtained by gamma irradiation (Chekalin, 1977).

In the present investigation, chlorophyll deficient patches were observed on the leaves in higher doses of gamma ray exposures. Similar results have been obtained by Ojomo and Chheda (1971) and Appa Rao and Jana (1979) in cowpea.

Morphological variations

a) Leaves

In the present investigation, a few plants were found to possess leaves with altered size and shape due to radiation treatment (Plate 2). The leaves were relatively narrow with darker and thicker texture. Modifications in leaf size and shape have been reported on similar lines in many plant genera as a consequence of mutagen treatments. Singh et al. (1939) reported variation in shape and size of leaves of Gossypium hirsutum following irradiation. Patel and Datta (1960) observed narrow leaves following X-ray treatment in Corchorus capsularis. In the present study,

the leaves were noted with yellow and white streaks (Plate 3) as well as stunted and crinked leaf blades. Plants with split lamina were also noticed consequent to gamma irradiation.

Narrow leaves were also reported in chillies following X-ray treatment by Sahib and Abraham (1970). Raghuvanshi and Singh (1974) observed crumpled leaves and dissected margins in Trigonella foenumgraceum following gamma ray treatment. Koshy and Abraham (1978) noticed progressive reduction in size, distorted shape, irregular lobing and change in texture of leaves in Abelmoschus esculentus following gamma ray treatments.

Irvine (1940) held the view that abnormalities observed in leaves after irradiation could be due to the disturbances of phytochromes as a result of irradiation. Meiselman et al. (1961) stated that the irradiation induced abnormalities such as reduction in the number and size or deformation of leaves might be due to chromosomal aberrations. Moh (1962) attributed activity from the centre to the flanks of the apex of the leaves.

Soriano (1971, 1972) by gamma irradiation obtained aberrant leaf characters in sweet potato. Miu (1973) and Miu et al. (1973) obtained plants with darker leaves after

treatment with 5.0 kR of gamma rays in sweet potato. Fortuno and Maldonado (1972) obtained mutants with drastic leaf aberrations in rhizomes of banana cultivar Gros Michel by gamma ray treatment. Rao and Giriraj (1975) obtained irradiated plants having thicker and darker leaves in bhindi by X-ray and gamma irradiation. Aleeva (1981) in sourcherry reported semidwarf plants with smaller and thicker leaves by gamma and X-irradiation in M_1 generation.

b) Dichotomy

Petiole and stem dichotomy (Plate 4) was observed in the irradiated population. As a result of dichotomy, bifurcation of the organ occurs. It is well known that this results from the death of the apical cells in irradiated materials and regeneration of two apices. Nettancourt and Contant (1966) observed the occurrence of fasciation and bifurcation of stem in tomato as a regular feature following chronic gamma irradiation. Singh and Mitra (1967) obtained bifurcation in Hibiscus with X-ray treatment. Stem dichotomy in apple and peaches was caused by gamma irradiation (Lapins et al., 1969). Bifurcation of stem could be explained on the basis of regeneration of affected meristem in Barley (Mackey, 1951). Bishop and Aalders (1955) attributed it to the delayed expression of

some chromosomal effect. Kuehnert (1962) explained that it may be due to enlargement of the central cells of tunica along a vertical axis followed by, periclinal divisions of the cells. This results in the displacement of activity from the centre to the flanks of the apex. As a result, two new apical meristems could develop. In the case of leaves also bifurcation of petiole and appearance of two leaflets at the same node have been reported by Raghuvanshi and Singh (1974), in Trigonella foenum-graceum. The cause of this may be the same as for the occurrence of stem dichotomy.

In some of the irradiated plants twisting of petiole was seen (Plate 5). In one variant a number of leaves with twisted petioles were produced from one sucker.

Induced polygenic mutation in vM_2 and vM_3 generations

The gamma ray induced variations in the vM_2 and vM_3 generations were analysed in various growth parameters for yield and other yield attributing characters. A decrease in mean plant height 90 days after planting and at harvest was noticed with increasing doses of gamma ray exposures. The same trend was noticed in all the different age groups and sizes of suckers both in vM_2 and vM_3 generations. Mutants showing dwarfness with short stems were reported

by Tedin and Hagberg (1952) in M_3 of Lupinus luteum, Hackbarth (1955) in M_2 of irradiated Lupinus albus, Korah (1959) M_2 of Oryza. Sakai and Suzuki (1964), after X-irradiation in rice, reported that mutation of polygenes responsible for quantitative characters like plant height occurs in most cases unidirectionally in minus direction. Sree Rangasamy et al. (1973) observed that greengram plants treated with gamma rays were shorter than the parents. Nayar (1976) found significant reduction in mean values in M_2 and M_3 generations of six polygenic characters including plant height in rice following gamma ray treatments. Manju and Mercy (1982) also obtained plants with reduced height in horsegram by gamma irradiation. Vasudevan et al. (1984) obtained erect mutants showing reduction in plant height in M_3 and M_4 generations of Vigna unguiculata.

In peas a reduction in seedling height by gamma irradiation was noted by Narsinghani and Kumar (1976), Kerkadze and Kutateladze (1979) in citrus obtained dwarf mutants in M_2 generation by gamma irradiation. Dwarf mutants were obtained by Khan et al. (1981) in M_1 and M_2 generations by gamma irradiation of cotton hybrids. Similar results have been reported by Louis and Kadambavanasundaram (1973 a) in cowpea and by Khan (1984) in mungbean.

The gamma ray exposed materials showed a reduction in mean leaf number. Increasing the dose of gamma ray exposures the mean leaf number 90 days after planting and at harvest was reduced in vM_2 and vM_3 generations. The mean girth of pseudostem in vM_2 generation decreased with increasing dose of gamma exposures. In vM_3 generation also increasing the dose of gamma exposures, girth of pseudostem decreased progressively from control to 3.0 kR.

In the present study, a delay was noted in the flowering and harvesting of bunches in vM_2 and vM_3 generations on increasing the dose of gamma exposures.

Increase in the dose of gamma ray exposures resulted in decrease in the bunch character values such as bunch weight, bunch length and number of hands per bunch. Matsuo et al. (1964) who observed significant differences between M_6 mutants and control with respect to weight of panicle in rice reported that mutation in polygenes could occur in positive as well as negative directions. This might be due to the delay in the initiation of flowering, inhibition of growth and reduction of fertility.

In the present investigation increasing the dose of gamma exposures resulted in decrease in the following fruit characters viz. number of fingers per bunch and hand, finger girth and finger weight. Similar reports have been

made by Louis and Kadambavanasundaram (1973 a) and Narsinghani and Kumar (1976) in cowpea and Swarup and Gill (1968) in frenchbean. Virupakshappa et al. (1980) reported that the mean values for the number of pods per plant and seed weight in mutagen treated populations of cowpea were lesser than that in untreated populations. The negative shift in the means of the treated population from the mean of the control agrees with this finding. Higher doses of gamma exposures reduced the fruit length. Significant differences in the mean values of panicle length among treated and between treated and control plants were observed by Matsuo et al. (1964) in M_6 generation of rice.

Variability created in vM_3 generation in the present study was higher than vM_2 generation. This is in agreement with the result obtained by Sakai and Suzuki (1964) in X-irradiated paddy. Patel and Swaminathan (1961) reported a wide range of variability in M_2, M_3 and M_4 generations of irradiated tobacco.

Nayar and Ninan (1978) observed that gamma ray exposures resulted in a significant reduction in mean weight of panicle in M_2 and M_3 generations of rice compared to control. A similar result was obtained by Lekha Rani (1985) in chillies in M_2 generation.

The number of fruits per plant and fruit length recorded a decrease with increase in doses of gamma rays. This might be due to the delay in the initiation of flowering, inhibition of growth and reduction of fertility. Similar reports have been made by Louis and Kadambavanasundaram (1973 a) and Narsinghani and Kumar (1976) in cowpea and Swarup and Gill (1968) in frenchbean. Virupakshappa et al. (1980) reported that the mean values for the number of pods per plant and seed weight in mutagen treated population of cowpea were less than that in untreated populations. Yashvir (1977) *in* Abelmoschus esculentus obtained variations in fruit length when low doses of X-ray and EMS were used.

Fruit quality analysis in the present study showed that total soluble solids and acidity values decreased with increase in dose of gamma rays in vM_2 and vM_3 generation. Total sugar content and sugar:acid ratio increased with increasing doses of gamma exposures in vM_2 and vM_3 generations.

Kukimura and Takemata (1975) reported that mutants with increased as well as reduced sugar content were obtained after treatment of shoots, dormant root tubers and seeds of sweet potato with gamma rays and ethylene imine.

Lacey (1977) studied the mutation spectrum of apple variety Cox's orange Pippin irradiated with 7 kR gamma rays found some mutations for dwarf type. Majority of the mutants did not produce enough good quality fruits to become commercial but it has been suggested that acceptable compact forms with desirable fruit quality can be found when sufficient mutants are produced.

Khairwal et al. (1984) obtained by treatment of gamma rays and EMS, high sugar mutants and mutants with increase for most quality characters over the control in sugarcane. Sharma et al. (1983) in mango reported that by gamma irradiation fruit quality was improved. Kukimura and Kovyama (1982) obtained a few mutant clones superior in total sugar content in sweet potato.

Morphological variations

The morphological variants noted in the present investigation in vM_2 and vM_3 generations were dichotomy (Plate 4) and anthocyanin pigmentation of petiole of leaf (Plate 6). Fortuno and Maldonado (1972) obtained one mutant with more intense pigmentation by gamma irradiation.

Fingers

Double fingers were produced in certain plants (Plate 7) which is a very rare phenomenon in Nendran variety.

Doubling tendency like double spikes, double peduncles and double kernels were observed by Sethi and Gill (1969) in barley following gamma ray treatments. Koshy and Abraham (1978) noticed twin fruits in the M_1 generation of bhindi.

In the present study, it has also been observed that some of the abnormalities are not heritable. The specific changes which lead to the initiation of such changes are still unknown but these could be due to physiological disturbances or hormonal imbalances, created due to the direct effect of the mutagen.

Suckering was early in gamma irradiated plant than control plants (Plate 8). This may be due to the early stimulation of suckers initials by irradiation.

B. In-vitro induced mutagenesis

The present investigation also attempted to standardise in-vitro techniques in relation to induced mutagenesis in banana variety Nendran (Musa paradisiaca L.) using shoot-tip culture. The main objectives envisaged include standardisation of shoot-tip culture technique for mutagen treatments and analysis of the extent of created variability for all the productive traits. The results that have emanated out of the investigation are discussed below.

1. Standardisation of culture media for shoot-tip culture of banana

In the present investigation the MS medium modified by three different workers was tested. Tested media include semi solid media described by Bower and Fraser (1982) and Swamy et al. (1983), and liquid medium described by Krikorian and Cronauer (1984). On comparative analysis it was seen that the medium described by Krikorian and Cronauer gave a better growth and an early tissue differentiation. Standardisation was done with shoot-tips isolated from three month old suckers (Plate 9 and 10).

The various results obtained by using Krikorian and Cronauer medium for shoot-tip culture isolation and different levels of gamma exposures are discussed below.

Mean plant height 90 days after planting and at harvest recorded by control population was the highest. In treated population as the dose of gamma exposures increased plant height decreased.

A similar observation has been reported by several workers. Yang and Lee (1980) reported that in banana variety 'Hsien-jen-chiao' dwarf mutants were obtained by EMS and diethyl sulphate treatment in which shooting height

was 50 cm less than in the original cultivar by EMS and diethyl sulphate treatment. Dwarfness was reported in shoot apex isolates of banana variety, 'Hsien-jen-chiao' and 'Pei-chiao' exposed to gamma rays by Huang and Kao (1979). Sunnino et al. (1986) obtained dwarf type mutants in potato variety 'Desiree' by gamma irradiation.

The number of functional leaves per plant 90 days after transferring to field was highest in control population. On increasing the dose of gamma exposure, number of functional leaves decreased. The number of functional leaves at harvest was also higher in the control population. Increasing the dose of gamma exposure, the number of leaves was reduced. The minimum number of leaves was recorded by 0.75 kR exposure.

The girth of pseudostem 90 days after planting was highest in the 0.75 kR exposures and lowest in the control population. The 0.50 and 0.75 kR exposures recorded highest girth of pseudostem than control population. The same trend was noticed in the girth of pseudostem at harvest. De Guzman et al. (1980) noticed a reduction in girth of pseudostem in banana variety 'Bungulan' at 2.5 kR gamma irradiation of shoot tip explants. When, in-vitro derived plants were established in the field, those derived from irradiated explants were similar to or sometimes better

than those from unirradiated explants with respect to girth of pseudostem.

In this study, the days taken to shooting was decreased, when the dose of gamma exposure was increased from 0.5 kR to 0.75 kR. The same trend was observed in days taken from shooting to bunch maturity and total duration. In all these characters the control population recorded, the minimum number of days and 0.50 kR gamma exposure recorded the maximum. The early growing of suckers as a result of higher exposure of gamma rays noted in the present investigation has also been reported by Huang and Kao (1979). They obtained early growing of suckers in shoot apex isolates of banana variety 'Hsien-jen-chiao' and 'Pei-chiao' exposed to gamma rays.

In the present study, on increasing the dose of gamma exposure from 0.50 to 0.75 kR, the bunch weight was decreased, though the 0.50 and 0.75 kR gamma exposures recorded higher bunch weight than control population. A similar trend was reported by Huang and Kao (1979). They reported high yield in shoot apex isolates of 'Hsien-jen-chiao' and 'Pei-chiao' banana varieties exposed to gamma rays.

The length of bunch recorded by control population was lower compared to gamma ray treated materials. On

increasing the dose of gamma exposures, a decrease in bunch length was also observed.

The bunch characters such as number of hands per bunch, number of fingers per hand and bunch in the control population recorded a lower value compared to treated materials. When the dose of gamma exposure was increased the number of hands and fingers decreased. The increase in number of hands and number of fingers compared to control noted in the present investigation was in conformity with the findings of De Guzman et al. (1980). In the banana variety 'Bungulan' she found that shoot tip explants derived from gamma irradiation were similar to or sometimes better than control population with respect to number of hands per bunch and fingers per bunch.

The 0.50 kR and 0.75 kR gamma exposures recorded higher finger weight and girth than control population and finger weight and girth was higher in the higher dose.

Fruit quality

Total sugar and sugar : acid ratio increased from control to 0.75 kR, TSS and acidity decreased from control to 0.75 kR.

Chlorophyll deficient plants

In the present investigation chlorophyll deficiency

was noticed at higher doses of gamma ray exposures, probably due to chlorophyll disorganisation. Silayoi et al. (1985) obtained plants showing chlorosis and necrosis by gamma irradiation of shoot tip segments of banana clone 'Kluai Hom Thong' (AAA). Espino et al. (1985) obtained chlorophyll streaking in Philippine fruit crops by gamma irradiation of shoot tissues, seedlings and plantlets.

Morphological variations

Stem dichotomy was observed in the irradiated population of shoot-tip culture (Plate 11). As a result of dichotomy bifurcation of organ occurs. This results from the death of the apical cells in irradiated materials and regeneration of two apices. Huang and Kao (1979) obtained early double suckering in shoot apex isolates of 'Hsien-jen-chiao' and 'Pei-chiao' exposed to gamma rays. They also found leaves with red mid-ribs also. Anthocyamin pigmentation for the petiole was found in the present study (Plate 12).

Sunnino et al. (1984) obtained a range of colour and morphological traits in buds of potato cultivar, Desiree by gamma irradiation. In 'Bangulan' variety of banana, several morphological aberrations were reported by De Guzman et al. (1980) in the shoot-tip explants with 1.0 kR irradiation.

SUMMARY

SUMMARY

The present investigation was carried out in the artment of Agricultural Botany, College of Agriculture, Layani during 1985-'88 and in the plant tissue culture oratory attached to the Department of Plantation Crops, lege of Horticulture, Vellanikkara, Thrissur during 5-'88. The project was taken up to standardise the hniques for induced mutagenesis *in-vivo* and *in-vitro* banana (*Musa paradisiaca* L.) var. Nendran and also to lyse the direct effect of ^{60}Co gamma rays on growth and ch characters in the vM_1 generation and variations ated in productive traits in the vM_2 and vM_3 generations. , two and three months old suckers of various sizes removing 25 to 75 per cent of the pseudostem) were psed to 1.0, 1.5, 2.0, 2.5 and 3.0 kR gamma rays. Five kers each were exposed under each treatment per repli- ion. Observations on sprouting characters including vival and biometric observation on various growth rices were taken in vM_1, vM_2 and vM_3 generations. prophyll deficient plants and morphological variants e also scored in the vM_1 generation. The fruit quality lysis was also carried out in all the three generations.

In *in-vitro* mutagenesis isolated shoot tips were osed to 0.50, 0.75, 1.00, 1.25 and 1.50 kR gamma rays.

Ex-vitro analysis of five plants per treatment per exposure was done in the vM_1 generation for various growth, bunch and fruit characters. The data were analysed statistically and the direct effect of different exposures of gamma rays on various sizes of suckers under different maturity was assessed.

The gamma ray exposures showed a significant delay in sprouting in all the three age groups. The delay in sprouting was found to increase with increase in levels of gamma ray exposures. Irrespective of the size of suckers, the mean percentage sprouting and the survival percentage in all the exposures were found to decrease with increase in the dose of gamma rays. A decrease was noticed in mean plant height, number of leaves and girth of pseudostem, 90 days after planting and at harvest with increasing doses of gamma rays in all the different age groups and sizes of suckers in vM_1 generation. With the increase in the dose days taken to shooting, from shooting to harvest and total duration increased in all the different sizes of suckers exposed to gamma rays. Increasing the dose of gamma exposure resulted in decrease in bunch weight, bunch length and number of hands per bunch. Number of fingers per bunch and fingers per hand, length, girth and weight of finger also decreased with increasing the dose of gamma exposure.

Fruit quality analysis showed that total soluble solids and acidity decreased with increase in dose of gamma ray exposures in vM_1. Total sugar content and sugar : acid ratio increased with increasing dose of the mutagen.

Chlorophyll deficient plants observed include striata and chlorina types. In higher doses exposures of gamma rays, chlorophyll deficient patches were observed in leaves. Variations in morphological traits on leaves, stem and petiole were also observed in vM_1 generation.

Induced polygenic variation in the vM_2 and vM_3 generations were analysed in banana for various growth parameters including yield and other yield attributes. Gamma rays at higher exposures reduced plant height, number of leaves, girth of pseudostem and delayed harvesting. Bunch weight, bunch length, number of hands per bunch, number of fingers per bunch and hand and length, girth, weight of finger, total soluble solids and acidity also showed a negative shift in mean values. Total sugars and sugar : acid ratio increased with increase in dose of gamma ray exposures.

On comparative analysis of the modifications of MS medium tried, viz., Bower and Fraser (1982), Swamy et al. (1983) (semi solid media) and Krikorian and Cronauer (1984)

(liquid medium), it was seen that the medium described by Krikorian and Cronauer gave a better growth and early tissue differentiation in shoot tip culture of banana.

In ex-vitro analysis plant height and number of leaves 90 days after planting and at harvest, were highest in control population. On increasing the dose of gamma ray exposures plant height and number of leaves decreased. The girth of pseudostem 90 days after planting and at harvest was lowest in control population and it increased as the dose of gamma ray exposure was increased. The days taken to shooting, from shooting to bunch maturity and total duration decreased when the dose of gamma exposure was increased from 0.5 kR to 0.75 kR. Increasing the dose of gamma exposure resulted in a decrease in bunch weight, bunch length, number of hands per bunch, number of fingers per hand and bunch, total soluble solids andacidity though it is higher than control in irradiated population. Weight and girth of finger, total sugar and sugar : acid ratio increased with increase in dose of gamma exposures.

The gamma ray exposures showed a significant delay in sprouting and this delay was found to increase with increase in levels of gamma ray exposures. The mean percentage sprouting, the survival percentage, mean plant height, number of leaves, girth of pseudostem 90 days after planting

and at harvest, bunch weight, bunch length, number of hands per bunch, number of fingers per hand and bunch, length, girth and weight of finger, total soluble solids and acidity decreased with increase in dose of gamma ray exposures in vM_1 generation. With increase in dose days taken to shooting, from shooting to harvest, total duration, total sugar content, sugar acid ratio increased in all the different age groups and sizes of suckers exposed to gamma rays. Chlorophyll deficient plants observed include striata and chlorina types. Variations on morphological traits on leaves, stem and petiole were observed in vM_1 generation. Induced polygenic variations in the vM_2 and vM_3 generation reduced plant height, number of leaves, girth of pseudostem, bunch weight, bunch length, number of hands per bunch, number of fingers per hand and bunch, length, girth and weight of finger, total soluble solids and acidity showed a negative shift in mean values. With increase in dose of gamma rays days taken to shooting, from shooting to harvest, total duration, total sugar content and sugar acid ratio increased in all treatments. On comparative analysis of the three modifications of MS medium tried, liquid medium described by Krikorian and Cronauer (1984) gave a better growth and early tissue differentiation in shoot-tip culture of banana. In ex-vitro analysis plant height, number of leaves, the days taken to shooting, from

shooting to bunch maturity total duration, bunch length, bunch weight, number of hands per bunch, number of fingers per hand and bunch, total soluble solids andacidity decreased with increasing dose of gamma rays. Girth of pseudostem 90 days after planting andat harvest, finger weight, finger girth, total sugar and sugar acid ratio increased with increase in dose of gamma ray exposures.

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*Original not seen

INDUCED MUTATIONS IN BANANA var. NENDRAN

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ABSTRACT OF THE THESIS
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ABSTRACT

The present investigation was carried out in the Department of Agricultural Botany, College of Agriculture, Vellayani during 1985-'88 and in the plant tissue culture Laboratory attached to the Department of Plantation Crops, College of Horticulture, Vellanikkara, Thrissur during 1986-'88. The project was taken up to standardise the techniques for induced mutagenesis *in-vivo* and *in-vitro* in banana (*Musa paradisiaca* L.) var. nendran and also to analyse the direct effect of ^{60}Co gamma rays on growth and bunch characters in the vM_1 generation and variations created in productive traits in the vM_2 and vM_3 generations. One, two and three months old suckers of various sizes (after removal of 25 to 75 per cent of the pseudostem) were exposed to 1.0, 1.5, 2.0, 2.5 and 3.0 kR gamma rays. For *in-vitro* mutagenesis, isolated shoot tips were exposed to 0.50, 0.75, 1.00, 1.25 and 1.50 kR gamma rays. *Ex-vitro* analysis of five plants per treatment per exposure was done in the vM_1 generation for various growth, bunch and fruit characters.

The gamma ray exposures showed a significant delay in sprouting in all the three age groups. The delay in sprouting was found to increase with increase in levels of gamma ray exposures. Irrespective of the size of

suckers, the mean percentage sprouting and the survival percentage in all the exposures were found to decrease with increase in the dose of gamma rays. A decrease was noticed in mean plant height, number of leaves and girth of pseudostem, 90 days after planting and at harvest with increasing doses of gamma rays in all the different age groups and sizes of suckers in vM_1 generation. With increase in the irradiation dose, days taken to shooting, from shooting to harvest and total duration increased in all the different sizes of suckers exposed to gamma rays. Increasing the dose of gamma exposure resulted in decrease in bunch weight, bunch length and number of hands per bunch. Number of fingers per hand and per bunch and length, girth and weight of finger also decreased with increase in the dose of gamma irradiation.

Fruit quality analysis showed that total soluble solids and acidity decreased with increase in dose of gamma ray exposures in vM_1. Total sugar content and sugar : acid ratio increased with increasing dose of the mutagen.

Chlorophyll deficient plants and morphological variants of leaves, stem and petiole were also observed in vM_1 generation.

In VM_2 and VM_3 generation gamma rays at higher exposures reduced plant height, number of leaves, girth of pseudostem and delayed harvesting. Bunch and fruit characters showed a negative shift in mean values. Total sugars and sugar : acid ratio increased with increase in dose of gamma ray exposures.

On comparative analysis of the modifications of MS medium tried, viz., Bower and Fraser (1982), Swamy et al. (1983) (semi solid media) and Krikorian and Cronauer (1984) (liquid medium), it was seen that the medium described by Krikorian and Cronauer gave a better growth and early tissue differentiation in shoot tip culture of banana.

In ex-vitro analysis, plant height and number of leaves 90 days after planting and at harvest were highest in control population. On increasing the dose of gamma ray exposures plant height and number of leaves decreased. The girth of pseudostem 90 days after planting and at harvest was lowest in control population and it increased as the dose of gamma ray exposure was increased. The days taken to shooting, from shooting to bunch maturity and total duration decreased when the dose of gamma exposure was increased from 0.5 kR and 0.75 kR. Increasing the dose of gamma exposure resulted in a decrease in bunch weight, bunch length, number of hands per bunch, number of fingers

per hand and bunch, total soluble solids and acidity though it is higher than control in irradiated population. Weight and girth of finger, total sugar and sugar : acid ratio increased with increase in dose of gamma exposures.

To sum up, induced mutations, in banana variety 'Nendran' revealed that gamma irradiation can create variants with dwarf stature and altered bunch and fruit characters. A positive selection response was noticed in the later generations and helped to isolate out dwarf plants with high yielding ability. A medium for shoot-tip culture of nendran variety of banana was standardised for adopting induced mutagenesis. The ex-vitro plants were also analysed for various growth, bunch and fruit characters.